INTEGRATED NUTRIENT MANAGEMENT FOR SOIL FERTILITY AND CROP PRODUCTIVITY OF WATER ERODED LANDS AT DISTRICT SWAT

BY

MOHAMMAD NAEEM

A dissertation submitted to the NWFP Agricultural University, Peshawar in partial fulfilment of the requirements for the Degree of

DOCTOR OF PHILOSOPHY IN AGRICULTURE
(SOIL AND ENVIRONMENTAL SCIENCE)

DEPARTMENT OF SOIL AND ENVIRONMENTAL SCIENCES
FACULTY OF CROP PRODUCTION SCIENCES
NWFP AGRICULTURAL UNIVERSITY
PESHAWAR, PAKISTAN
AUGUST, 2009

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AUGUST 2009

Dedicated to

My sweet

&

Loving parents

VITA

The author was born on June 12th, 1978 at Mingora, Swat, NWFP, Pakistan. He completed his secondary education in 1994 from Government High School No. 1 Mingora, Swat, and then higher secondary from Govt. Jehanzeb Post Graduate College Said-u-Sharif, Swat in 1996. He obtained the degree of Bachelor of Science (Hons) in Agriculture with specialization in Soil & Environmental Sciences in 2001 and then Master of Science (Hons) in Agriculture with specialization in Soil & Environmental Sciences from NWFP Agricultural University, Peshawar in 2003. The author also obtained a formal training for a period of six months in 2008 at the University of Wales, Bangor, United Kingdom under the supervision of Dr. David Leonard Jones as a beneficiary of HEC Scheme “International Research Support Initiative Program”.

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(Muhammad Naeem)

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(Muhammad Naeem)

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INTEGRATED NUTRIENT MANAGEMENT FOR SOIL FERTILITY AND CROP PRODUCTIVITY OF WATER ERODED LANDS AT DISTRICT SWAT

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ABSTRACT

Eroded lands have very poor soil fertility and crop productivity due to the loss of top fertile soil during soil erosion. In order to meet the food requirements of increasing population such lands need to be restored. To achieve this objective, experiments were conducted at three sites i.e., Guljaba (slightly eroded), Gado (moderately eroded) and Kotlai (severely eroded), District Swat, North West Frontier Province (NWFP) of Pakistan from 2006 to 2008. The experiments were carried out to study the efficacy of combined application of organic and inorganic sources of plant nutrients and mungbean residues on soil fertility and crop productivity under wheat-mungbean-wheat cropping system. Mungbean was grown and a basal dose of 25-60-0 kg N-P_2O_5-K_2O ha^{-1} was applied. After mungbean harvest, three residues management practices, i.e., R+ (mungbean residues incorporated into soil), R- (mungbean residues removed) and F (fallow) were performed. After mungbean, wheat was grown and fertilizer treatments for wheat crop consisted of T1 (control), T2 (120 kg N ha^{-1}), T3 (120-90-0 kg N-P_2O_5-K_2O ha^{-1}), T4 (120-90-60 kg N-P_2O_5-K_2O ha^{-1}), T5 (90-90-60 kg N-P_2O_5-K_2O ha^{-1} + 10 t FYM ha^{-1}) and T6 (60-90-60 kg N-P_2O_5-K_2O ha^{-1} + 20 t FYM ha^{-1}). Experiments were laid out in RCBD split plot arrangement with residues management practices in the main plots and fertilizer treatments in the subplots. Three replications were used in the experiments. The results showed that soil properties were improved with T6 (application of 20 t FYM ha^{-1} and reducing commercial inorganic N fertilizer to 60 kg N ha^{-1}) and incorporation of mungbean residues (R+) both at surface soil (0-20 cm soil depth) and sub-surface (20-45 cm soil depth). Soil pH and bulk density were decreased, while AWHC, soil organic matter, available K and P, mineral N, total N and microbial properties (microbial activity, microbial biomass C and N and mineralizable C and N) were improved with T6 and R+ at the three sites. Analysis of the data combined over both

seasons and sites showed that all soil characteristics differed significantly among the sites Guljaba, Gado and Kotlai, as well as among seasons, both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). The deleterious effect of erosion on soil properties was more prominent in severely eroded soil as compared to moderately and slightly eroded soils. Soil properties were improved over time from their initial values during Kharif 2006 at all the three sites due to residual or cumulative effect through addition of inorganic fertilizers, farmyard manure and mungbean residues management, which implies the restoration of soil fertility over time. T6 increased the biological yield of wheat significantly over the other treatments with an increase of 34, 44 and 47% compared with the control at Guljaba, Gado and Kotlai respectively. Similarly, R+ increased biological yield of wheat by 10, 12.9 and 13% compared with the Fallow at Guljaba, Gado and Kotlai respectively. Similar trends were observed for grain yield, straw yield, 1000-grain weight and harvest index of wheat. T6 increased N and P uptake by wheat significantly over the other treatments and increased N concentration in wheat plant with an increase of 19, 22 and 22.5% compared with the control at Guljaba, Gado and Kotlai respectively. Similarly R+ increased N concentration in wheat plant with an increase of 11.7, 12.9 and 12.7% compared with the control at Guljaba, Gado and Kotlai respectively. Similar trends were observed for Plant P, grain N and grain P concentrations of wheat, except that effect of residues management practices on P concentration in both plant and grain was non-significant ($p>0.05$). Economic analysis of fertilizer treatments and residue management practices revealed that application of 20 t FYM ha^{-1} and reducing commercial inorganic N fertilizer to 60 kg N ha^{-1} (T6) and R- (mungbean residues removed) gave the highest relative increase in income (RII). It can be concluded from this study that application of balanced rate of fertilizers in combination with farmyard manure (FYM) would improve soil physical, chemical and biological properties and restore crop productivity under wheat-mungbean-wheat cropping system on sustainable basis. Mungbean is a very useful crop, as its pods can be picked and the crop biomass can be incorporated to improve the fertility of soil. Keeping in view the importance of legumes in cereal legume rotation, wheat-mungbean-wheat cropping system and application of 20 t FYM ha^{-1} and reducing commercial inorganic N fertilizer to 60 kg N ha^{-1} for wheat crop is recommended for restoring crop productivity on eroded lands.

1. INTRODUCTION

Soil erosion is displacement of soil particles from its original place through some agency such as rainfall, wind, gravity, etc., and deposition at some other place. Soil erosion is a normal geological process resulting in fertile soils around the world, which becomes destructive when accelerated by some factors such as cultivation on sloping lands. Accelerated erosion depletes soil fertility, degrades soil structure and decreases soil depth resulting in the destruction of the most basic of all natural resources (Olson, 1981; Eckholm, 1976; Lal, 2003).

Today scientists agree that soil resources are endangered by erosion globally (Wilkinson and McElroy, 2007; Montgomery, 2007; Van Oost *et al.*, 2007). Total land area affected by water erosion is 1094 Mha, of which 751 Mha is severely affected (Oldeman, 1994; Lal, 2003). Global rate of soil erosion is 75 billion Mg yr^{-1} (Pimentel *et al.*, 1995). Around the world there are some regional hot spots of erosion including the Himalayan-Tibetan ecosystem in South Asia, the sub-humid and semiarid regions of sub-Saharan Africa, highlands of Central America, the Loess Plateau in China, Haiti, the Andean region and the Caribbean (Scherr and Yadav, 1996). Worldwide 430 Mha of cropland (30% of the world cropland base) has been lost due to soil erosion (Lal, 1990).

Soil erosion degrades soil quality and affects all soil properties, e.g., topsoil depth, soil texture and structure, soil organic matter and nutrients content, bulk density, available water holding capacity (AWHC) and water transmission characteristics that determine soil fertility and crop productivity (Lal, 1988; Pimentel *et al.*, 1995). Soil erosion causes loss of plant nutrients such as N, P and K, and low cation exchange capacity (Kaihura *et al.*, 1999) decreases soil organic carbon (SOC) content (Rhoton and Tyler, 1990; Jacinthe *et al.*, 2002), available water holding capacity (AWHC) (Nizeyimana and Olson, 1988), trace elements (Zn, S), microbial biomass carbon and activity of soil macrofauna (Lal, 1991), while, increases soil bulk density (Kaihura *et al.*, 1999; Frye *et al.*, 1982).

Soil erosion generally causes a decline in crop productivity due to degraded soil physical, chemical and biological properties (Arriaga and Lowery, 2003; Larney *et al.*, 1995; Caravaca *et al.*, 1999). Soil loss negatively affects characteristics associated with crop productivity including soil nutrients, soil organic matter, soil bulk density and water holding capacity (Murdock and Frye, 1983). The loss of available water holding capacity (AWHC) is a primary effect leading to productivity loss (Andraski and Lowery, 1992; Kort *et al.*, 1998).

Erosion is a complex problem and its control is possible only to the extent that the impact of factors accelerating the erosion could be minimized. Strategies must be adopted for minimizing soil erosion on the farmer's field. Farmers have several options for correcting or compensating for soil erosion and restoring productivity of eroded soils. Using large amounts of commercial inorganic fertilizer may not improve crop yields to the level of non-eroded soil (Tanaka and Aase, 1989; Mahli *et al.*, 1994). This is especially true on calcareous soils where phosphorus fertilizer is precipitated as insoluble calcium phosphate (Lewis and Racz, 1969; Afif *et al.*, 1993) rendering it unavailable for crop uptake (Larney *et al.*, 1995).

Among the most promising soil nutrient management practices for restoration of eroded lands are: composts, animal manures, incorporation of crop residues, intercropping of legumes and dual purpose legumes and improved fallows or natural fallowing.

Recently the utilization of organic materials as fertilizers for crop production has received due consideration for sustainable cropping systems. Addition of farmyad manure to a degraded soil is a restorative option (Frye *et al.*, 1985; Dormaar *et al.*, 1988; Larney and Janzen, 1996) but only where it is available on-farm or within a short hauling distance (Freeze *et al.*, 1993).

Application of farmyard manure (FYM) or other organic manure to soil decreased bulk density, total soil porosity and improved soil moisture (Jadoon *et al.*, 2003; Celik *et al.*, 2004; Hati *et al.*, 2006a; Hati *et al.*, 2006b), available water holding capacity (AWHC) (Barzegar *et al.*, 2002), organic matter (Jadoon *et al.*, 2003), soil organic carbon (SOC) (Manna *et al.*, 2005; Dong *et al.*, 2006), soil organic carbon (SOC), TSN, available P, K^+ and Mg^{+2}. (Kaihura *et al.*, 1999), soil respiration and soil microbial biomass-C (Tejada *et al.*, 2006; Tejada *et al.*, 2009).

Another strategy for managing soil erosion is the incorporation or use of crop residues. Residues refer to the remains of plant components which may include dispersed straw, standing stubble, living vegetation or mulch after the removal of basic component (for example grains). Farmyard manure (FYM) refer to animal excrement and waste products mixed with organic left overs, while the process, in which the decayed plant products are cut into pieces and ploughed in where they stand, is termed as green manuring.

The application of crop residues has a positive effect on soil physical, chemical and biological properties, which protect the soil against erosion and contribute to its restoration (Tejada *et al.*, 2009) and has the potential to reverse the adverse effects of accelerated erosion on soil fertility (Kaihura *et al.*, 1999). This effect occurs for a number of reasons, application of crop residues conserve soil moisture (Ortega *et al.*, 2002) by reducing runoff and evaporation losses (Bennie and Hensley, 2001) and improves soil structure, saturated hydraulic conductivity, soil porosity, and bulk density (Wong *et al.*, 1999; Celik *et al.*, 2004), lowers soil temperature, increases availability of plant nutrients and organic mater and reduces soil pH (Rasmussen, 1999; Blair *et al.*, 2006; Anatoliy and Thelen, 2007), increases cation exchange capacity (Walker and Bernal, 2008), total organic N (Malhi *et al.*, 2006), plant available N (Anatoliy and Thelen, 2007), plant available P and K (Malhi *et al.*, 2006; Gangwar *et al.*, 2006; Blair *et al.*, 2006), total N mineralization (Kumar and Goh, 2002; Blair *et al.*, 2006), soil microbial biomass C and the enzymatic activities (Tejada *et al.*, 2009), microbial activity (Bezdicek *et al.*. 2003) and improves overall soil fertility (Ortega *et al.*, 2002) and crop productivity (Blair *et al.*, 2006; Anatoliy and Thelen, 2007).

Generally, incorporation of manures and crop residues into soil increases crops yield (Anatoliy and Thelen, 2007). Higher yield can be achieved when green manuring crops or residues are incorporated into the soil (Aulakh *et al.*, 2001). Leguminous or non-leguminous residue retention increases total soil N mineralization (Kumar and Goh, 2002).

Crop-fallow systems have been a popular practice for weed control and conserving soil moisture. However, due to the lack of cover for longer periods, the problem of erosion increases in fallow systems. Annual cropping decreases soil erosion by providing vegetative cover for longer periods during the year. Another alternative to crop-fallow is to grow a cover crop for soil protection and reduce runoff and improve water infiltration.

Meelu *et al.*, (1992) recommended green manuring with Sesbania to save fertilizer N in the rice-wheat cropping system. However, due to lack of direct monetary returns green manuring is not popular among the farmers. Mungbean crop can be grown as a dual purpose pulse crop and as well as has manurial value when, after picking the pods, its residues can be incorporated into the soil for soil fertility improvement (Sharma *et al.*, 1995; Sharma and Prasad, 1999). Tejada *et al.,* (2008) reported that incorporation of green manures into soil improved soil biological properties as well as nutrition, production and quality of the maize crop obtained.

Integrated plant nutrient management features the idea of sustainable agriculture by putting together the use of all natural and synthetic sources of plant nutrients. It maintains that natural resources should be used to produce increased output and incomes, without depleting natural resources, so that crop productivity increases in an efficient and environmentally safe manner, without sacrificing crop productivity for future generations. INM concept acknowledges the need for both organic and mineral inputs to sustain soil health and crop productivity due to positive interactions between them (Buresh *et al.*, 1997; Vanlauwe *et al.*, 2002).

Swat District is situated in the north-eastern part of NWFP, Pakistan. Swat is mainly a mountainous area. Its elevation ranges from about 600 to more than 6000 metres above sea level. There are great altitudinal variations within short distances giving rise to steep slopes. The climatic zones recognized in the area are: (1) Subhumid Subtropical zone (2) Humid Subtropical zone (3) Subhumid temperate zone (4) Humid temperate zone and (5) Subhumid boreal zone (Soil survey of Pakistan, 1976).

Some major landforms of the area are: (1) residual and colluvial slopes (2) loess plains and (3) alluvial plains. Precipitation over the Swat Catchment is the only source of moisture in the study area. Average annual rainfall ranges from 800 to 1200 mm. A part of precipitation moisture is conserved by the soil and helps to grow plants. Some water is also diverted from streams for irrigation at suitable locations. The major crops grown in the area are wheat, potatoes, fodder and maize (Soil survey of Pakistan, 1976).

Farming is the major source of income for the local population and cultivation on sloping land is a common practice, which has resulted in more runoff and soil losses, deteriorating soil fertility and crop productivity of the area. The present research was initiated to formulate measures for the restoration of soil fertility and crop productivity of the eroded area. No study has been done in the past in this part of the country in an integrated sense, where the effect of different sources of plant nutrients both organic (plant and animal origin) and inorganic could be analyzed for the restoration of soil fertility and crop productivity. Keeping in view the importance of balanced application of fertilizers and integrated plant nutrient management, experiments were conducted during 2006-2008 on the eroded lands at District Swat to study the effect of inorganic fertilizers alone and in combination with farmyard manure (FYM) and mungbean residues under wheat-mungbean-wheat cropping system for restoring soil fertility and crop productivity of these eroded lands on sustainable basis.

OBJECTIVES:

General:

- To formulate measures for the restoration of soil fertility and crop productivity of the eroded lands at District Swat.

Specific:

1. To study the effect of combined application of organic and inorganic sources of plant nutrients on soil fertility and crop productivity of the soil.

2. To study the effect of Mungbean residues on wheat yield and soil properties and to evaluate its effect on land improvement

3. To formulate strategies for restoring soil fertility and crop productivity for sustainable production in the study area.

2. REVIEW OF LITERATURE

2.1. Soil erosion

Soil erosion is displacement of soil particles from the place of its origin through some agency (e.g., rainfall, wind, gravity, etc.) and deposition at another place (Lal, 2003). Normal erosion is a constructive process resulting in fertile soils around the world, while, accelerated soil erosion is a destructive process. Accelerated erosion depletes soil fertility, degrades soil structure and decreases soil depth resulting in the destruction of the most basic of all natural resources (Olson, 1981; Eckholm, 1976; Lal, 2003).

The world community has recognized the importance of protecting and restoring this precious resource (Barford *et al.*, 2001; Lal, 2001). Sustainable management of soil was strongly advised at the Rio summit in 1992 (UNCED, 1992), UN Framework Convention on Climate Change (UNFCCC, 1992), the Kyoto Protocol (UNFCC, 1997) and the 1994 UN Framework Convention to Combat Desertification (UNFCD, 1996). Eroded soils remain unproductive unless appropriate soil amendments are applied (Larney and Janzen, 1997). Recent reports agree that erosion continues to endanger global soil resources (Montgomery, 2007; Van Oost *et al.*, 2007; Wilkinson and McElroy, 2007). Climate change, with its effects on temperature, timing and amounts of precipitation, and soil moisture, may increase erosion risk on agricultural land (Soil and Water Conservation Society, 2003; Zhang and Nearing, 2005). To adequately assess the effects of soil erosion on agricultural production, an understanding of the response of crop productivity to soil erosion is essential (Bakker *et al.*, 2004).

Lal (1998) reported that soil erosion is a global issue due to its severe adverse economic and environmental impacts. Economic impacts on productivity may be due to direct effects on crops/plants on-site and off-site, and environmental consequences are primarily off-site due either to pollution of natural waters or adverse effects on air quality due to dust and emissions of radioactive gases. Off-site economic effects of erosion are related to the damage to civil structure, siltation of water ways and reservoirs, and additional costs involved in water treatment. There are numerous reports regarding the on-site effects of erosion on productivity. However, a vast majority of these are from the U.S., Canada, Australia, and Europe, and only a few from soils of the tropics and subtropics.

On-site effects of erosion on agronomic productivity are assessed with a wide range of methods, which can be broadly grouped into three categories: agronomic/soil quality evaluation, economic assessment, and knowledge surveys. Agronomic methods involve greenhouse and field experiments to assess erosion-induced changes in soil quality in relation to productivity. A widely used technique is to establish field plots on the same soil series but with different severity of past erosion. Different erosional phases must be located on the same landscape position. Impact of past erosion on productivity can also be assessed by relating plant growth to the depth of a root-restrictive horizon. Impact of current erosion rate on productivity can be assessed using field runoff plots or paired watersheds, and that of future erosion using topsoil removal and addition technique. Economic evaluation of the on-site impact involves assessment of the losses of plant available water and nutrients and other additional inputs needed due to erosion. Knowledge surveys are conducted as a qualitative substitute for locations where quantitative data are not available. Results obtained from these different techniques are not comparable, and there is a need to standardize the methods and develop scaling procedures to extrapolate the data from plot or soil level to regional and global scale. There is also a need to assess on-site impact of erosion in relation to soil loss tolerance, soil life, soil resilience or ease of restoration, and soil management options for sustainable use of soil and water resources.

Restoration of degraded soils is a high global priority. If about 1.5 × 109 ha of soils in the world prone to erosion can be managed to effectively control soil erosion, it would improve air and water quality, sequester C in the pedosphere at the rate of about 1.5 Pg yr^{-1}, and increase food production. The risks of global annual loss of food production due to accelerated erosion may be as high as 190 × 106 Mg of cereals, 6 × 106 Mg of soybeans, 3 × 106 Mg of pulses, and 73 × 106 Mg of roots and tubers. The actual loss may depend on weather conditions during the growing season, farming systems, soil management, and soil ameliorative input used. Erosion-caused losses of food production are most severe in Asia, Sub-Saharan Africa, and elsewhere in the tropics rather than in other regions.

2.2. Global extent of soil erosion

Accelerated soil erosion has tormented mankind ever since the dawn of settled agriculture. UNEP (1986) estimated that 2 billion ha of land that was once biologically productive has been irreversibly degraded since 1000 AD. Rozanov *et al.* (1990) reported that more productive soil may have been irreversibly lost in the past 10,000 years than is currently under agricultural production (estimated at about 1500 Mha). The most widely used statistics on soil erosion is that by Oldeman (1994). Total land area affected by water erosion is 1094 Mha, of which 751 Mha is severely affected. There are also regional hot spots of erosion including the Himalayan-Tibetan ecosystem in South Asia, highlands of Central America, the Loess Plateau in China, the sub-humid and semiarid regions of sub-Saharan Africa, the Andean region, Haiti and the Caribbean (Scherr and Yadav, 1996).

Soil erosion is the most widespread form of soil degradation. Land area globally affected by erosion is 1094 million ha (Mha) by water erosion, of which 751 Mha is severely affected and 549 Mha by wind erosion, of which 296 Mha is severely affected. Whereas the effects of erosion on productivity and non-point source pollution are widely recognized, those on the C dynamics and attendant emission of greenhouse gases (GHGs) are not. Despite its global significance, erosion-induced carbon (C) emission into the atmosphere remains misunderstood and an unquantified component of the global carbon budget.

Soil erosion is a four-stage process involving detachment, breakdown, transport/redistribution and deposition of sediments. The soil organic carbon (SOC) pool is influenced during all four stages. Being a selective process, erosion preferentially removes the light organic fraction of a low density of <1.8 Mg m^{-3}. A combination of mineralization and C export by erosion causes a severe depletion of the SOC pool on eroded compared with uneroded or slightly eroded soils. In addition, the SOC redistributed over the landscape or deposited in depressional sites may be prone to mineralization because of breakdown of aggregates leading to exposure of hitherto encapsulated C to microbial processes among other reasons. Depending on the delivery ratio or the fraction of the sediment delivered to the river system, gross erosion by water may be 75 billion Mg, of which 15-20 billion Mg are transported by the rivers into the aquatic ecosystems and eventually into the ocean. The amount of total C displaced by erosion on the earth, assuming a delivery ratio of 10% and SOC content of 2-3%, may be 4.0-6.0 Pg year^{-1}. With 20% emission due to mineralization of the displaced C, erosion-induced emission may be 0.8-1.2 Pg C year^{-1} on the earth. Thus, soil erosion has a strong impact on the global C cycle and this component must be considered while assessing the global C budget. Adoption of conservation-effective measures may reduce the risks of C emission and sequester C in soil and biota (Lal, 2003).

Estimates of global rates of soil erosion have been made at 75 billion Mg yr^{-1} by Pimentel *et al.* (1995), assuming an average erosion rate of 100 Mg ha^{-1} on 751 Mha of area affected by severe erosion. Miliman and Syvitski (1992) estimated that the annual sediment transport to the ocean is about 20 billion Mg, but the mass of sediment in motion is about 30 billion Mg yr^{-1}. The annual sediment transport into the ocean by the world's rivers is 15-20 billion Mg (Walling and Webb, 1996). Soil erosion is a major threat to sustainable use of soil and water resources (Lal, 1998). Erosion influences several soil properties, e.g., topsoil depth (TSD), soil texture and structure, bulk density (Frye *et al.*, 1982), soil organic carbon (SOC) (Rhoton and Tyler, 1990), nutrient status, available water holding capacity (AWHC) (Nizeyimana and Olson, 1988) and water transmission characteristics that regulate soil quality and determine crop yield. Lal (1988) indicated that low levels of N, P, K, and low cation exchange capacity (CEC) are among the most important chemical and nutritional constraints affected by soil erosion.

With 5, 10 and 20 cm removal of topsoil depth (TSD), the corresponding maize yield reductions were 95%, 95% and 100% on Ultisols, 31%, 74%, 94% on an Alfisol, respectively (Mbagwu *et al.*, 1984). Experiments relating effects of natural erosion on crop yield have indicated that the effects are even more severe than that of artificial topsoil removal. Lal (1981) observed that over a five-year period, the grain yield of maize and cowpeas (Vigna unguiculata L. Walp.) decreased at the rate of 9 and 0.7 kg Mg^{-1} of soil loss, respectively. In another experiment, Lal (1985) observed that maize yield was reduced 16 times more due to topsoil loss from natural erosion compared to mechanical topsoil removal. In some cases, soil quality degraded by erosion can be improved by judicious use of inputs and improved soil management practices. Gajri *et al.* (1994) observed that application of farmyard manure (FYM) improved available water holding capacity (AWHC) and root growth in soil with unstable structure and low soil organic carbon (SOC) content.

World-wide soil erosion is the most widespread form of soil degradation. Globally land area affected by erosion is 1094 million ha (Mha) by water erosion, of which 751 Mha is severely affected, and 549 Mha by wind erosion, of which 296 Mha is severely affected (Lal, 2003). Soil erosion by water is serious global problem. In Africa, each year about 5 Mg ha^{-1} of productive topsoil is lost to oceans and lakes (Angima *et al.*, 2003).

2.3. Soil degredation

Soil is one of the most important natural resources and a major factor in global food production. Soil erosion is widely considered the most serious form of soil degradation, posing a significant threat to world's food production capacity and global food security (den Biggelaar *et al.*, 2003). Soil erosion continues to be a primary cause for soil degradation and the loss of soil quality throughout the world (Basic et al. 2004).

Soil degradation is a major threat to agricultural sustainability because it decreases actual and potential soil productivity (Lal, 1998). Consequently, improving the productive capacity of degraded soils is particularly important to sustainable agriculture. It has been recognized that soils have ability to restore their fertility after disturbance to a new state under a given set of favorable ecological and land use conditions (Blum, 1994; Lal, 1997; Zhao, 1995). There are several factors affecting restoration of soil fertility (Lal, 1994; Seybold *et al.*, 1999), comprised of intrinsic soil properties and endogenous factors (Carpenter *et al.*, 2001; Demkina and Anan'eva, 1998; Glazovskaya, 1999; Lal, 1997; Maul *et al.*, 1999; Seybold *et al.*, 1999; Tobias *et al.*, 2001). Management is an important external factor, because some soil constraints can be alleviated by judicious land use and various inputs, e.g., low pH can be modified by liming, nutrient deficiency can be overcome with addition of fertilizers. Because of great differences in agricultural inputs, land use may affect soil fertility restoration.

Inappropriate technologies have resulted in soil quality deterioration, leading to soil organic matter losses and structure degradation, affecting water, air and nutrients flows, and consequently plant growth (Golchin *et al.*, 1995; Tejada *et al.*, 2006).

2.4. Erosion and soil fertility

Soil erosion results in the loss of basic plant nutrients from the soil such as N, P, K^+ and Ca^{+2} and that water erosion selectively removes the fine organic particles leaving large particles and stones on the surface (Pimentel *et al.*, 1995). Water erosion leads to the mobilization and depletion of soil organic carbon (SOC) (Jacinthe *et al.*, 2002).

Lal (1998) pointed out that soil erosion increases the degree of soil-related constraints to production. The constraints can be physical, chemical or biological. Among important physical constraints are reduced topsoil depth (TSD) and loss of available water holding capacity (AWHC). Soil chemical constraints and nutritional disorders related to erosion include low cation exchange capacity (CEC), deficiency of plant nutrients (N, P, K and Zn), nutrient toxicity (Al, Mn) and high soil acidity (Lal, 1981, 1998). On the other hand biological constraints include low microbial biomass carbon and low microbial activity of soil macrofauna (Lal, 1991). Jacinthe et al. (2002) reported that Water erosion results in the mobilization and depletion of soil organic carbon (SOC).

Organic matter content of the soils is significantly correlated with soil erosion. Yields of till-derived soils decreased more with increasing degree of erosion than loess-derived soils (Fenton *et al.* 2005). Soil pH increased with the severity of erosion. Accelerated erosion was also associated with increase in exchangeable calcium (Ca^{+2}) and magnecium (Mg^{+2}) contents. Erosion exposes the sub-surface material containing bases that also increases soil pH. Increase in soil pH with severity of erosion was reported by Cihacek and Swan (1994), where soil erosion exposed the $CaCO_3$ rich material that increased soil pH (Kaihura *et al.*, 1999).

Kaihura et al. (1999) reported that soil erosion can adversely influence soil quality, especially in tropical soils. Plant nutrient content was generally lowest on severely eroded and the highest on least eroded soil classes. Soil pH decreased with increasing severity of erosion on soils with higher content of Ca^{+2} in the sub-surface. In general, there occurred a decline in soil organic carbon (SOC) and P with the decrease in TSD. The SOC content decreased on severely eroded soil class by 0.16%, 0.39% and 0.13% at Misufini 1, Mlingano 1 and Kirima Boro, respectively, compared to slightly or least eroded soil class. Corresponding decline in available P at these sites was 41%, 62% and 61%, respectively. Application of FYM significantly increased soil pH at some sites. Soil content of SOC, N, P, K and Mg were significantly increased by FYM application. Significant effects of N and P fertilizers on SOC and P were observed at most sites. In comparison with farmer's practice, FYM application increased SOC by 0.55%, N by 0.03%, P by six-fold and K by two-fold. Nitrogen and phosphorus fertilizers had comparable effects for SOC and P only at some sites. They further indicated that FYM is a better soil input than N and P fertilizers in improving soil quality. It was shown that SOC, N and P are most adversely affected with accelerated erosion and that FYM fertilizer applications have the potential to improve fertility of eroded soils. Photon and Tyler (1990) reported increase in bulk density with erosion and associated this with decrease in topsoil depth (TSD) to fragipan and decline in soil organic carbon (SOC) content.

Soil organic carbon (SOC) stock is an important component of the global carbon (C) cycle, which has the potential to influence global climate. Polyakov and Lal (2004) showed an overview of soil organic matter (SOM) models in the context of soil erosion and discussed basic processes driving erosion-induced SOC loss. Erosion influences SOC in two ways: redistribution of C within the watershed or ecosystem, and loss of C to the atmosphere. Erosion disperses soil, altering its microbiological activity as well as water, air and nutrient regimes. This, along with sediment enrichment, has an impact on greenhouse gas emission from soil. For most of agricultural settings, field studies suggest that cultivation along with soil erosion are the primary reasons for SOC loss. Tracing the fate of eroded C is a challenging task.

Modeling is the approach taken most often. In this paper we discuss approaches used in various SOC models to assess erosion-induced C loss from soil in agricultural ecosystems. An example with Century model applied to meadow and corn-soybean rotation under chisel-till demonstrated the model's ability to respond well to different erosion scenarios. It was estimated that at soil loss rate of 10 t ha^{-1} $year^{-1}$ (value often considered a threshold for maintaining productivity) 19% of the total SOC loss would be attributed to erosion after 90 years of cultivation.

2.5. Erosion and crop productivity

Soil erosion, which is a widespread problem in semiarid areas, may lead to a decline in soil productivity since the finest and most fertile soil particles are those which are generally removed (Caravaca et al. 1999). Effects of past erosion on crop yields differ significantly by crop, continent and soil type. However, aggregated across soils on the continental level, differences in crop productivity declines Mg^{-1} of soil erosion are quite low. However, depending on the specific crop and soil, relative yield losses Mg^{-1} or cm^{-1} of soil erosion were two to six times lower in Europe and North America and than in Asia, Africa, Australia and Latin America. The higher losses in the latter continents are due primarily to much lower average yields, so that with similar degrees of erosion, relative yields decrease more rapidly. Studies using management practices as their experimental method to determine effects of present erosion revealed much higher crop yield losses, which may be due to the combined effect of erosion and management practices. Comparing the results of present and past and erosion studies shows that unsuitable soil management practices may intensify the effect of erosion on productivity loss by several times. Proper soil management practices for an effective erosion control and maintaining crop productivity, therefore, is imperative to meet the requirements of increasing population (den Biggelaar *et al.*, 2003).

Soil erosion has both on-farm and off-farm impacts. Reduction of soil depth can impair the land's productivity, and the transport of sediments can degrade streams, lakes, and estuaries (Uri and Lewis, 1998). Soil erosion generally causes low crop productivity due to degraded soil physical, chemical and biological properties. Arriaga and Lowery, (2003) reported that corn was grown from 1985 to 1999 with minor differences in grain yield among erosion levels, but with a long-term trend of declining yield with severity of erosion. Respective average yields for slight, moderate and severe erosion levels were 10.7, 10.3 and 10.3 Mg ha^{-1}. Soil erosion, which is a prevalent problem of semiarid areas, may lead to a general decline in crop productivity due to the removal of finest and most fertile soil particles during the process of soil erosion (Caravaca *et al.*, 1999). Fenton *et al.*, (2005) pointed out that organic matter content of the soils was significantly correlated with soil erosion. Yields of till-derived soils decreased more with increasing severity of erosion than loess-derived soils. Izaurralde *et al.*, (1998) concluded that wheat yields were affected by the degree of simulated erosion and the rates of fertilizers applied. Average crop yields on the 20 cm cut decreased to less than half than those obtained on 0 cm cut (no erosion). Physical and chemical properties of eroded soil affected crop yields adversely (Malhi *et al.*, 1994; Larney *et al.*, 1995).

Arriaga and Lowery (2003) in a long-term study investigated the effects of past soil erosion on corn (Zea mays L.) production. They argued that soil erosion generally causes reduced crop productivity because of degraded soil physical and chemical properties. Average yields were 10.7, 10.3 and 10.3 Mg ha^{-1} for slight, moderate and severe erosion levels, respectively. Based on the 15 years of research it appears differences in grain yields among erosion levels can be attributed mainly to soil water availability. When rainfall was below the 15-year average, grain yield was 12.8, 12.9 and 15.2% less than that of the 15-year average for slight, moderate and severe erosion levels, respectively. Soil water storage increased as erosion severity increased, however more stored water was needed to produce comparable yields with increasing erosion level. den Biggelaar et al. (2003) estimated average production loss of 0.3% yr^{-1} at the global level, which corresponded to an estimated economic value of $523.1 million yr^{-1}. Reducing these production losses by limiting soil erosion is necessary to attain food security, especially in the developing countries of the tropics and subtropics.

den Biggelaar et al. (2003) estimated the impact of soil erosion on productivity by collating, synthesizing and comparing the results from published site-specific soil erosion-productivity experiments at a global scale. Using crop yield as a proxy measure for soil productivity, this analysis uses the data from 179 plot-level studies from 37 countries identified in the soil science literature to calculate absolute and relative yield losses per Mg or cm of soil erosion for various crops, aggregated by continent and soil order. The results show that effects of past erosion on yields differ greatly by crop, continent and soil order. However, aggregated across soils on the continental level, absolute differences in productivity declines Mg^{-1} of soil erosion are fairly small. However, depending on the specific crop and soil, relative erosion-induced yield losses Mg^{-1} or cm^{-1} of soil erosion were two to six times smaller in North America and Europe than in Africa, Asia, Australia and Latin America. The higher losses in the latter continents are due primarily to much lower average yields, so that with identical amounts of erosion, yields decline more rapidly in relative terms.

Studies using management practices as their experimental method to determine effects of present erosion showed much greater absolute and relative yield losses, which may be an artefact of the combined effect of erosion and variable management practices. Comparing the results of past and present erosion studies indicates that inappropriate soil management may amplify the effect of erosion on productivity by one or several orders of magnitude. Good soil management for effective erosion control and maintaining productivity, therefore, is imperative to meet the needs of the world's present and future population.

Izaurralde et al. (1998) conducted a field experiment to determine the influence of simulated erosion (artificial topsoil removal) on loss in yield of wheat and to determine to which extent fertilizers N and P will restore the lost crop productivity of two artificially-eroded soils. There were three depths of topsoil removal (0, 10, and 20 cm) as main plot treatments, and a factorial combination of four levels of N (0, 50, 100, and 150 kg N ha^{-1}) and three levels of P (0, 9, and 18 kg P ha^{-1}) as sub-plot treatments. Wheat yields at both sites were markedly reduced by increasing depth of topsoil removal. The erosion effects were more pronounced at Site 2 where average yield on the 20 cm cut decreased to less than half of that obtained under non-eroded conditions. At both sites, additions of fertilizer N and P to eroded soil increased wheat yield, but the yields did not match those obtained in non-eroded soil under the same fertilizer treatment. Plants growing on eroded soil responded differently to application of fertilizers N and P, not only in terms of yield but also in N and P concentration and uptake. The implication of these findings is that fertilization programs for fields with varying degree of erosion would require optimization of rates so as to restore yield and, at the same time, minimize nutrient losses (e.g., N leaching) and improve soil tilth.

Globally soil erosion has contributed to the loss of 430 million ha of cropland (30% of the world cropland base) (Lal, 1990). Soil loss negatively upsets soil characteristics associated with crop productivity including water holding capacity (AWHC), soil nutrients, soil organic matter, soil bulk density, and others (Murdock and Frye, 1983). In addition, sediments removed during water erosion accumulate in rivers, lakes and reservoirs resulting in future economic losses. The loss of available water holding capacity (AWHC) is a primary effect leading to the loss of crop productivity.

Slightly eroded soil held 14% more water in the top 1 m than severely eroded soil and, when plant-extractable water fell to 55±60% of available water holding capacity under moisture stress conditions, corn on slightly eroded soil had significantly higher evapotranspiration levels (Kort *et al.*, 1998; Andraski and Lowery, 1992). Erosion reduces the long-term productivity of soils. The actual effect varies considerably due to differences in topsoil depth (TSD), subsoil composition and depth, the crop being produced and other variables (Stone *et al.*, 1985; Daniels *et al.*, 1989). The long-term productivity loss due to erosion of a Minnesota soil was calculated to be 5%, but was greater on soils with >6% slope (Pierce *et al.*, 1983). Some soils exhibit steady crop productivity declines with progressive soil degradation, while others undergo no loss until some critical point in one (or more) yield-determining factor is reached at which yield reductions become obvious (Hoag, 1998). However, for simplicity of analysis and data comparison, den Biggelaar *et al.* (2001, 2004) assumed that relationship between soil degradation and crop productivity was linear, although they pointed out that in reality, linear relationships may not always best describe the relationships.

2.6. Erosion control

Soil erosion on agricultural land and its detrimental environmental and economical effects has aroused increased interest among both the research and policy-making communities. The call for erosion control measures adapted to local farming practices is high, especially in Europe where farmers are reluctant to adopt soil conservation techniques (Gyssels *et al.*, 2007). Erosion is a complex problem and its control is possible only to the extent that the impact of factors accelerating the erosion could be minimized. Strategies for minimizing erosion on the farmer's field are summarized below.

2.7. Fertility restoration

Farmers have several options for correcting or compensating for soil erosion and restoring productivity of eroded soils. The commonest approach is to apply additional chemical fertilizer to eroded areas to improve crop growth and reduce the potential of further erosion. However, large quantities of commercial fertilizer may not improve yields to the level of non-eroded soil (Olson, 1977; Mbagwu *et al.*, 1984; Tanaka and Aase, 1989; Mahli *et al.*, 1994). This is especially true on calcareous soils where fertilizer P is precipitated as insoluble Ca-P (Lewis and Racz, 1969; Afif *et al.*, 1993) rendering it unavailable for plant uptake (Larney *et al.*, 1995).

Recent interst in sustainable cropping systems has focused renewed attention on the use of organic materials as fertilizers. Livestiock manure is a restorative option (Frye *et al.*, 1985; Dormaar *et al.*, 1988; Larney and Janzen, 1996) but only where it is available on-farm or within a short hauling distance (Freeze *et al.*, 1993). However, there is a scarcity of information on the rates of manure necessary to restore productivity to eroded soils, especially in arid and semi-arid areas (Parr *et al.*, 1989). Because application rate governs the volume of manure to be transported and hence the economics of the operation, it needs to be examined for various levels of erosion. Fertilization programs for fields with varying degree of erosion would require optimization of rates so as to restore yield and, at the same time, minimize nutrient losses (e.g., N leaching) and improve soil tilth (Izaurralde *et al.*, 1998).

Zhang and Xu (2005) conducted an experiment to ameliorate degraded soils and restore their productivity. The result suggested that organic matter, total N, available N, and water-stable aggregates were the main characteristics for fertility restoration of the eroded red soil. Soil fertility was most rapidly restored where the soil had been used as vegetable land, and least restored when left as wasteland. The results indicated that land use strongly affected the fertility restoration of eroded red soils because of its effect on the input of nutrients and energy, thus determining the speed and direction of soil fertility evolution.

2.8. Integrated nutrient management

INM paradigm acknowledges the need for both organic and mineral inputs to sustain soil health and crop production due to positive interactions and complementarities between them (Buresh *et al.*, 1997; Vanlauwe *et al.*, 2002). Among the most promising organically based soil nutrient practices are: composts, animal manures, incorporation of crop residues, natural fallowing, improved fallows, relay or intercropping of legumes (and dual purpose legumes), and biomass transfer.

Initially, organic resources were merely seen as sources of nutrients, mainly nitrogen. A substantial amount of research was done on quantifying the availability of N from organic resources as influenced by their resource quality and the physical environment (Palm *et al.,* 2001). More recently, other contributions of organics extending beyond fertilizer substitution have been emphasized in research, such as the provision of other macro and micro-nutrients, reduction of phosphorus sorption capacity, increase in carbon/organic matter, reduction of soil borne pest and disease spectra in rotations, and improvement of soil moisture status (Vanlauwe *et al.*, 2002).

Hegde (1996) reported the possibility of substituting 50% of the N requirement for sorghum by farmyard manure (FYM) without adverse effect on productivity. Substitution of N fertilizer by wheat straw and green manure generally reduced yields of both sorghum and wheat. Integrated nutrient supply increased soil organic carbon and available N compared to application of all nutrients through fertilizers. It had a variable effect on available P status and reduced the decline in available K. Available soil S, Mn, and Fe increased, while available Cu and Zn remained unaffected. Because the integrated nutrient supply increased soil fertility, it is suggested for use in an irrigated sorghum-wheat system in order to maintain productivity.

It has been acknowledged that organic and mineral inputs cannot be substituted entirely by one another and are both required for sustainable crop production (Buresh *et al.*, 1997; Vanlauwe *et al.*, 2002). This is due to (1) practical reasons- fertilizers or organic resources alone may not provide sufficient amounts or may be unsuitable for alleviating specific constraints to crop growth (Sanchez and Jama, 2002), (2) the potential for added benefits created through positive interactions between organic and mineral inputs in the short-term and (3) the various roles each of these inputs play in the longer term. One key complementarity is that organic resources enhance the soil organic matter status and the functions it supports, while mineral inputs can be targeted to key limiting nutrients. Several attempts to quantify the size of added benefits and the mechanisms creating those have been made. Vanlauwe *et al.* (2002) reported positive interactions between urea and use of stover and other organic applications while Nhamo (2001) observed added benefits from manure and ammonium nitrate combinations.

2.8.1. Soil fertility restoration through fertilizers

Application of fertilizers has major effects on soil properties and farmers use huge quatities of commercial fertilizers to restore soil fertility for short-term benefits.

2.8.1.1. Soil physico-chemical properties

Increase in soil organic carbon (SOC) content under complete dose of inorganic NPK fertilizers as compared to unfertilized control has also been reported by Swarup and Wanjari (2000). Most of the researchers specifically emphasized upon soil organic carbon (SOC) and its pool fractions (active, slow and passive pools) which lead to improved soil fertility, sustainability and environmental quality (Carter, 2002).These results are supported by the work of other scientists (Patra *et al.*, 2000; Yadav *et al.*, 2000; Swarup, 2001; Chand *et al.*, 2006).

Zorita (2000) reported that fertilization changed soil bulk density from 1.05 to 1.33 Mg m^{-3}. (Hati *et al.* 2006) observed the lowest bulk density in the surface soil in NPK+FYM treatment (Jadoon *et al.*, 2003; Hati *et al.*, 2006). Hudson (1994) reported that soils high in organic matter have greater available water holding capacity (AWHC) than the soils of similar texture with less organic matter (Barzegar *et al.*, 2002). Increase in total soil porosity with farmyard manure (FYM) treatment as well as mungbean-wheat plots could be attributed to higher organic matter content, better soil particles aggregation and change in pore size distribution (Aggelides and Londra, 2000). Celik *et al.* (2004) and Hati *et al.* (2006) also found that soil porosity increases with the addition of organic manures. Yadav *et al.* (2000) found that combined use of organic manures plus inorganic fertilizers increased soil organic carbon (SOC) overtime at locations where soils were initially low in SOC content.

Manna *et al.* (2005) found that NPK+FYM either maintained or improved it over initial OC content. However, they suggested that application of 100 % NPK is adequate for maintaining soil organic carbon (SOC). On the other hand, Dong *et al.* (2006) reported that over 20 years with farmyard manure (FYM), soil organic matter increased by 80 % compared to only 10 % with NPK, which explained yield increases. Moreover, they suggested that if manure is to be applied, it would be best applied to the wheat crop, which showed a better response than maize. Hati *et al.* (2006) concluded from their long-term experiments that application of balanced application of fertilizers in combination with organic manures could sequester soil organic carbon in the surface layer, improve the soil physical environment and sustain higher crop productivity under intensive cropping system of soybean-wheat-maize (fodder). Patra *et al.* (2000) indicated that combined application of inorganic fertilizers with organics helps in increasing the availability of nutrients and crop yield and provides a significant effect on the succeeding crop. Yadav *et al.* (2000) also reported that available P content increased with P additions through fertilizers or manures.

2.8.1.2. Plant nutrients

Nitrogen fertilization has been reported to increase total N (203%) in soil (Habtegebrial *et al.*, 2007) increase 18% to 34% residual soil N (Yang *et al.*, 2007), increase soil NO_3-N (Malhi *et al.*, 2006), and increase organic N mineralization by 4.0 to 9.4% (Li *et al.*, 2003). Westfall (1996) reported that soil-plant system have buffer capacity, which prevents inorganic N accumulation at N fertilizer rates that exceed optimal crop N requirements in the dry land.

Application of N and P fertilizers also increase soil organic carbon (SOC) content. Adverse effects of severe erosion on soil quality and crop yield can be mitigated through application of farmyard manure (FYM) and judicious use of chemical fertilizers (Kaihura *et al.*, 1999).

In agricultural ecosystem soil organic matter and total N are important indicators in assessing the soil C stock, fertility and quality (Huang *et al.*, 2007), which are further influenced by the addition of fertilizer (Sainju *et al.*, 2006), and other relative proportion of the plant nutrients (Rasool *et al.*, 2007) and other farm management practices like incorporation of crop residue and crop rotation (Huang *et al.*, 2007). Fertilization is done for a number of reasons, e.g. to enhance crop production and quality, so improving farmers' livelihood, to sustain the fertility of soil, and as an option for compensating for the N fertility decline under continuous winter cereal cropping.

Improving soil fertility, harmonizing with maximum crop production and utilizing low inputs of fertilizer nitrogen, to avoid watercourse pollution (Semenov *et al.*, 2007) is a major current focus. Water contamination by nitrates has increased international awareness and it is widely accepted that over application of fertilizer is the principal factor responsible for water contamination by nitrates (Abril, *et al.*, 2007). Thus improvement of soil fertility and productivity along with reduction of global warming and water course pollution necessitates the maintaining and/or conserving of organic C and N concentrations in the soil by means of management practices (Malhi *et al.*, 2006) and reducing their loss through mineralization and erosion (Sainju *et al.*, 2002). In achieving these specific objectives, environmental factors play an important role (López-Bellido *et al.*, 1998; López-Bellido and López-Bellido 2001). Significant microbial (15%) and soluble N (40%) losses at the end of the crop cycle have occurred, due to leaching by high precipitation (250 mm) (Abril, *et al.*, 2007). Post harvest soil NO_3–N levels in the 150-cm profile varied with nitrogen fertilizer rate, but in wetter condition some of NO_3–N leached down below root zone (Halvorson *et al.*, 2001a). Both soil moisture and temperature have key roles in N loss via N_2O emission (Meng *et al.*, 2005).

The physical fertility of the soil, which creates a suitable environment for the availability and uptake of nutrients, is generally ignored (Rasool *et al.*, 2007) and cereal producers are under pressure to increase yields and maintain profitability against a background of environmental constraints and high fertilizer costs (Semenov *et al.*, 2007). Thus need for appropriate cultural practices for enhancing crop yields and maintaining soil fertility with low inputs in a varied climate is essential (Iqbal *et al.*, 2005).

Published data has showed the benefits of adding nitrogen fertilizers in terms of improving various soil and plant attributes, for example improvement in soil residual N (López-Bellido *et al.*, 2005), N uptake and C removed in wheat (Malhi *et al.*, 2006), total grain N in wheat (Halvorson *et al.*, 2001b), grain yield, high amount of stored N (Melaj *et al.*, 2003).

P-supplying power played a lesser role than N in the restoration of soil productivity. Even when applied at very high rates, there was sufficient evidence in yield responses and soil extractable P data to suggest that fertilizer P was immobilized by the carbonate-rich surfaces on the moderately and severely eroded treatments (Larney and Janzen, 1997).

Fertilization, either with N or with other macronutrients has major effects on the soil. However, applied FN is subject to loss by volatilization, immobilization, denitrification and leaching (Malhi *et al.*, 2001), and its efficiency of use depends upon soil and climatic factors, fertilizer material, and soil, crop and fertilizer management practices. Nitrogen fertilization rate (Malhi *et al.*, 2006) and timing (Gooding *et al.*, 2007) have key roles in the improving soil attributes. Increasing FN application is a potential treat for watercourse pollution (Abril *et al.*, 2007), increases losses in the form of N2O (Malhi *et al.*, 2006), leads to high cost of fertilization (Ailincai, 1997), and has other detrimental impacts on the environment. To minimize losses, the FN should be applied nearest to the time it is needed by the crop i.e. several weeks after emergence (Olson and Kurtz, 1982; Aldrich, 1984; Fox *et al.*, 1986), as timing of FN application affects the soil mineral N (Gooding *et al.*, 2007) contents. Application of N and P fertilizers had no effects on soil pH (Kaihura *et al.*, 1999). The application of K fertilizer increased available K (Zhang and Xu, 2005).

Nitrogen fertilization has been shown to enhance soil total N (203%) and C/N ratio (Habtegebrial *et al.*, 2007) give an increase of 18% to 34% in residual soil N (Yang *et al.*, 2007), increase soil NO3-N (Malhi *et al.*, 2006),and increase organic N mineralization by 4.0 to 9.4% (Li *et al.*, 2003) etc. Increasing rate of FN application enhanced residual soil N (Yang *et al.*, 2007), and concentration of NO3-N (Malhi *et al.*, 2006). Westfall (1996) reported that soil-plant system have buffer capacity, which prevents inorganic N accumulation at FN rates that exceed optimal crop N requirements in the dry land.

Alvarez (2005) reported that N fertilization had positive effects on C sequestration but was climatic responsive. It had no effects in tropical regions, but in temperate climates appeared to promote net carbon sequestration. In N limited condition more C assimilation than N (Triboi *et al.*, 2006) was observed. In contrast, Dolan *et al.*, (2006) concluded that N fertilization generally have no effects on SOC in sandy soil (0-45cm depths), when compared to control at Rosemount, MN US.

Nitrogen fertilization affected the soil properties like change in bulk density from 1.05 to 1.33 $Mg\ m^{-3}$ (Zorita 2000). It increased pH by application of ammonium form of N (Li *et al.*, 2003), which in return has large effects on soil organic matter turnover during mineralization of N (Kemmitt *et al.*, 2006)

Soil bulk density decreased during the experimental period as a result of dilution of the denser soil mineral fratction and soil aeration increases because of the increase in soil porosity accompanying structural stability. This decrease was more significant in the soils amended with composted plant residues with higher humic acid concentration. These results are in agreement with Kay and VandenBygaart (2002) and Tejada *et al.* (2006).

Application of N and P fertilizers also increase SOC content. Adverse effects of severe erosion on soil quality and crop yield can be mitigated through application of FYM and judicious use of chemical fertilizers (Kaihura *et al.*, 1999).

2.8.1.3. Microbiological properties

Li et al. (2008) studied the relationship between soil quality and soil microbial properties such as soil microbial biomass and soil enzyme activities in order to illustrate the function of soil microbial properties as bio-indicators of soil health. In this study, microbial biomass C and N contents (Cmic & Nmic). soil enzyme activities, and soil fertility with different fertilizer regimes were carried out based on a 15-year long-term fertilizer experiment in a wheat-maize rotation receiving either no fertilizer (CK), mineral fertilizers (NPK), mineral fertilizers with wheat straw incorporated (NPKW+), mineral fertilizers with incremental wheat straw incorporated (NPKW+), mineral fertilizers plus swine manure (NPKM), mineral fertilizers plus incremental swine manure (NPKM+) or mineral fertilizers with maize straw incorporated (NPKS). In different fertilization treatments Cmic changed from 96.49 to 500.12 mg kg-1, and Nmic changed from 35.89 to 101.82 mg kg-1. Compared with CK, the other treatments increased Cmic & Nmic, Cmic/Corg (organic C) ratios, Cmic/Nmic, urease activity, soil organic matter (SOM). soil total nitrogen (STN), and soil total phosphorus (STP). All these properties in treatment with fertilizers input NPKM+ were the highest. Meantime, long-term combined application of mineral fertilizers with organic manure or crop straw could significantly decrease the soil pH. Some of soil microbial properties (Cmic/Nmic. urease activity) were positively correlated with soil nutrients. Cmic/Nmic was significantly correlated with SOM and STN contents. The correlation between catalase activity and soil nutrients was not significant. In addition, except of catalase activity, the soil pH in this experiment was negatively correlated with soil microbial properties. In conclusion, soil microbial properties reflect changes of soil quality and thus can be used as bio-indicators of soil health.

Soil respiration and soil microbial biomass-C increased progressively during the experimental period with compost addition (Tejada *et al.*, 2009). The general increase in biomass-C and soil respiration can be attributed to the incorporation of easily degradable materials, which stimulate the zymogeneous microbial activity of the soil, and to the incorporation of exogenous microorganisms (Blagodatsky *et al.*, 2000; Schaffers, 2000). Tejada *et al.* (2006) found an increase in soil microbial biomass carbon and soil respiration after the application to the soil of diverse organic wastes such as contton gin compost, beet vinasse composted with a crushed cotton gin compost and poultry manure. It has been suggested that the improvement in the physical properties of soil, particularly structural stability and porosity, may affect its biological and biochemical activities (Giusquiani *et al.*, 1995; Tejada *et al.*, 2006).

Several studies have indicated that soil microbial processes are directly and indirectly influenced by soil structure. The presence of small pores reduces accessibility of organic materials to decomposers, leading to physical protection of C and a reduction in N mineralization (Van Veen and Kuikman, 1990; Tejada *et al.*, 2006). Soil respiration and soil microbial biomass-C depends on the quality of organic inputs as well as on the quantity. The fact that soil microbial biomass and soil respiration were higher in the soils amended with composted plant residues with a higher fulvic acid concentration may be due to a greater labile fraction of organic matter in these residues. The labile fraction of organic matter is the most degradable and therefore the most susceptible to mineralization, acting as an immediate energy source for microorganisms (Tejada *et al.*, 2009; Cook and Allan, 1992). The application of composted plant residues had a positive effect on soil physical, chemical and biological properties, and also favors the appearance of spontaneous vegetation, which will protect the soil against erosion and will contribute to its restoration. Therefore the addition of this type of organic waste may be considered a good strategy for recovering semiarid areas (Tejada *et al.* 2009).

2.8.1.4. Fertilizers and crop productivity

General erosion-productivity relationships have been defined using landscape analysis (De Jong *et al.*, 1983), artificial erosion methods (Dormaar *et al.*, 1986; Ives and Shaykewich, 1987; Morrison and Shyakewick, 1987; Larney *et al.*, 1995) and simulation modeling (Grier *et al.*, 1991; Izaurralde *et al.*, 1994). Lost productivity can be partly restored by adding back topsoil, fertilizers, and manure (Dormaar *et al.*, 1986; Ives and Shaykewich, 1987; Larney *et al.*, 1991; Malhi *et al.*, 1994; Izaurralde *et al.*, 1994). Manure is an excellent amendment to restore productivity but its wide use is constrained by its availability and trucking costs (Izaurralde *et al.*, 1998). Addition of fertilizer N and P to eroded soil improved wheat yield, but these yields did not reach the levels obtained in non-eroded soil under the same fertilizer treatment (Izaurralde *et al.*, 1998).

Organic manure improved moisture conservation and organic matter in the soil (More, 1994; Reeves, 1997; NFDC, 1998; Swarup, 2001; Jadoon *et al.*, 2003; Manna *et al.*, 2005; Dong *et al.*, 2006). Bhatti *et al.* (1995) compared the low and high rates of NPK on wheat yield in farmer's fields in NWFP under irrigated as well as rainfed conditions and reported that the yields from high fertilizer rates were significantly higher than from low fertilizer rates.

Farmyard manure (FYM) in combination with NPK fertilizers increased the yield of maize and wheat (Bakhsh *et al.*, 2001; Jadoon *et al.*, 2003; Ghosh *et al.*, 2004 a; Bhatti, *et al.*, 2005). Bakhsh *et al.* (1994) reported the effect of balanced application of NPK on the yield of wheat under the conditions of Rod-Kohi area in D.I. Khan (Din, 2004). Similar results of balanced application of NPK on the yield of paddy have been reported by Gurmani *et al.* (1996). Balanced and integrated supply of nutrients increased crop yields (Yadav *et al.*, 2000; Ghosh *et al.*, 2004a; Manna *et al.*, 2005; Dong *et al.*, 2006; Hati *et al.*, 2006a; Manna *et al.*, 2006).

2.8.1.5. Yield and yield components

Wheat yield and yield attributes were significantly increased with increasing N application (Kibe *et al.*, 2006). Increased N fertilizer had increased grain yield by over 30% in wheat (Dang *et al.*, 2006). Zorita (2000) obtained a strong correlation between wheat grain yield and N fertilization. Patil *et al.*, (2006) obtained higher sorghum yield (18 and 23%) with the application of 25 and 50 kg N ha^{-1} when compared to control (produced 1393 kg ha^{-1} yield). Carryover effects of N applied to wheat increased chickpea yield (López-Bellido *et al.*, 2004). Applied (336 kg N ha−1) increased yield from 3.6 to 4.1 Mg ha−1 when compared to the lower application rates. Wheat grain yield was largely attributed to N uptake and remobilization after flowering (Kichey *et al.*, 2007). Addition of N with irrigation treatments increased grain yield, spikelets, grain $spike^{-1}$, and other yield components (Zhai and Xiu LI, 2006). Nitrogen fertilization at jointing stage increased grain yield, grain $spike^{-1}$ and 1000-grain weight (López-Bellido *et al.*, 1998). López-Bellido *et al.*, (2003) carried out correlation among yield components. Seed yield and number of seeds per pod were associated with higher 1000 seed weight, and harvest index rose with seeds per pod. Seed per pod and harvest index both decreased with increased pods m^{-2}.

Maize grain yield was significantly improved by application of farmyard manure (FYM) and fertilizer (Kaihura *et al.*, 1999).

2.8.1.6. Plant nutrients uptake

Plant N uptake is influenced by the N application levels, types (Iqbal *et al.,* 2005) and times. Fan *et al.,* 2005 reported that N fertilizer applications of more than 120 kg ha^{-1} for wheat increased crop N uptake and N balance (i.e. the difference in N fractions between harvest and sowing samples). Total wheat N uptake was in the range of 50 to 127 kg N ha^{-1} while seed N uptake fluctuated between 34 and 107 kg N ha^{-1} (López-Bellido *et al.*, 2003). On average 36.6–38.4% of applied N was recovered by wheat crop and 2.1–2.8% by the following crop, with recovery generally decreased in the subsequent three crops i.e. beans, maize and wheat (Dang *et al.,* 2006).

Grain-N concentration varied little with erosion and P levels but increased almost by 50% between the lowest and highest N rate used. The greatest changes in plant N uptake were observed with varying levels of simulated erosion and N rates applied. Grain-P concentrations changed little with P applications but were diluted with respect to controls as the levels of erosion and N increased (Izaurralde *et al.*, 1998).

2.8.2. Restoration through fallow management

Crop-fallow systems have been a common practice for replenishment of soil water and weed control. However, erosion problems have increased in many fallow systems due to the lack of cover for extended periods. Flexible or annual cropping decreases soil erosion by reducing or eliminating a fallow period, thus providing vegetative cover for longer periods during the year. Another alternative to crop-fallow is to grow a cover crop during fallow periods to provide soil protection and, in the long term, increase water infiltration and reduce runoff.

2.8.3. Farmyard manure and residue management

One of the most valuable tools for managing erosion involves the use of plant residues. Residues refers to any type of vegetative cover left remaining on the field and may include standing stublle, dispersed straw, living vegetation or mulch. Practices that maintain residues on the surface are less susceptible to soil erosion than practices that remove excess residues. As the amount of residue cover increases, soil loss via erosional processes decreases. This effect of residue cover on reducing soil loss occurs for a variety of reasons, they stabilize soil particles and soil moisture is conserved under residue management due to increased infiltration and decreased evaporation as a result of less wind and more canopy shading.

All composted plant residues had a positive effect on soil physical properties (soil structure stability and soil bulk density) and soil biological properties (biomass C and the enzymatic activities) (Tejada et al., 2009). In general, the higher surface residue maintained increased microbial activity, maintained higher surface residue, and reduced erosion in winter wheat, the vulnerable phase in the crop rotation for erosion (Bezdicek et al., 2003).

Residue application is considered as an alternative way of adding fertilizer to increase soil fertility and crop production in organic farming (Wong *et al.,* 1999). They also found that compost increased available water by 86%, and farmyard manure (FYM) by 56%, compared with no application. Retention of plant residues near soil surface resulted in lower evapo-transpiration, higher content of soil water, lower soil temperature, more nutrients and organic matter, less soil pH, more stable soil aggregates and better protection for erosion (Rasmussen, 1999). Organic amendments when coupled with fertilizer applications increased crop yields and soil organic matter and fertility (Blair *et al.*, 2006a), and are one of the most common rehabilitation practices to improve soil physiochemical properties (Celik *et al.,* 2004). Barton et al. (2004) reported that straw mulch was very effective in decreasing erosion rates. In 1993, 1994, 1995 and 1996, soil loss was 18, 66, 86 and 78% less than the conventionally tilled plots, respectively. Straw mulch maintained topsoil structure and encouraged infiltration, thus decreasing runoff and erosion rates. Conversely, erosion rates under conventional tillage were high. Erosion rates from the polythene mulch plots were similar to conventional tillage, as infiltration was effectively decreased, thereby concentrating runoff and channelling it towards exposed, inter-mulch areas. However, maize development and grain yields were consistently higher under the polythene mulch than the other treatments.

Supplementing the nutrient requirement of crops through organic manures plays a key role in sustaining soil fertility, and crop productivity and reducing use of fossil fuels. Patra et al. (2000) conducted field experiments to assess the herb and essential oil yields of Japanese mint (Mentha arvensis cv. Hy 77), and its nutrient accumulation under single and combined applications of organic manures and inorganic fertilizers (NPK). Changes in physical and chemical characteristics of the soils were also determined. Eight treatments comprising different combinations of NPK through inorganic fertilizers and farm yard manure (FYM) were compared. The distilled waste of mint after extraction of essential oil was recycled to soils in the plots to supplement the nutritional requirement of the succeeding mustard crop (Brassica juncea cv. Pusa Bold). Herb and essential oil yield of mint were significantly higher with combined application of organic and inorganic sources of nutrients as compared to single applications. Accumulation of N and P was at par under full inorganic and combined supply, whereas, K accumulation was higher with the former. Soil organic C and pH after harvest of mint did not significantly differ among the treatments, but the level of mineralizable N, Olsen-P and NH_4OAc extractable K were higher in soil with integrated supply of nutrients. Significant increase in soil water stable aggregates, organic C, available NPK and microbial biomass, and decrease in soil bulk density were observed with waste recycling over fertilizer application. These benefits were reflected in the seed and stubble yield of mustard which succeeded mint. This study indicates that combined application of inorganic fertilizers with organics helps in increasing the availability of nutrients and crop yield and provides a significant effect to the succeeding crop. Similarly, recycling crop residues reduces the need for fossil fuel based fertilizer, and helps in sustaining and restoring soil fertility in terms of available nutrients and major physical and chemical characteristics of the soil.

Residue decomposition depends on the temperature and nature of the material. A proportion of the organic N, and the NH_4-N pool, are rapidly converted to nitrate-N but other organic fractions are slowly mineralized. This reflects the degree of stabilization. Approximately 90% of the available N (60% of total applied N) was converted to nitrate-N and 30% resisted mineralization (Smith *et al.*, 1998), where as 10% was immobilized after 4000 °C (thermal time).

Soil and crop management practices including placement of plant residues may alter the quantity and quality of the soil C and N fractions (Sainju *et al.*, 2007). However, other researchers, for example Fisher *et al.*, (2002) observed no change in crop productivity due residue retentions. Resent research on soil conditioned with residue or manure has been summarized in Table 3. Residue or manure retention and incorporation into the soil effects on both soil physiochemical characteristics and plant growth are reported here in more detailed.

Arsenault and Bonn (2005) reported that crop residues are efficient in reducing erosion and surface water runoff on agricultural soils. Evaluating the crop residue cover fraction and its spatial distribution is important to scientists involved in the modelling of soil erosion and surface runoff, and also to authorities wishing to assess soil conservation adoption by farmers. Nyakatawa et al. (2007) evaluated long-term effects of conservation tillage with poultry litter application on soil erosion estimates in cotton plots under conventional tillage system with winter rye cover cropping declined by 36% from 8.0 Mg ha^{-1} $year^{-1}$ in 1997 to 5.1 Mg ha^{-1} $year^{-1}$ in 2004. This result was largely attributed to cumulative effect of surface residue cover which increased by 17%, from 20% in 1997 to 37% in 2004. In conventional tillage without winter rye cover cropping, soil erosion estimates were 11.0 Mg ha^{-1} $year^{-1}$ in 1997 and increased to 12.0 Mg ha^{-1} $year^{-1}$ in 2004. In no-till system, soil erosion estimates generally remained stable over the study period, averaging 0.5 and 1.3 Mg ha^{-1} $year^{-1}$ with and without winter rye cover cropping, respectively. This study shows that cover cropping is critical to reduce soil erosion and to increase the sustainability of cotton production in the southeast U.S. Application of N in the form of ammonium nitrate or poultry litter significantly increased cotton canopy cover and surface root biomass, which are desirable attributes for soil erosion reduction in cotton plots.

Whether it is traditional, modern or "sustainable" agriculture, soil organic matter plays a key role in sustaining crop production and in preventing land degradation. a field experiment was conducted to determine the effects of tillage, fertilisation and their interaction on soil organic carbon (SOC) (0-10 cm), crop performance and microbial activities. SOC was increased in the tillage treatments in 2000 by 35% but only with 18% in 2001 suggesting reduced carbon accumulation in the absence of organic and mineral restitution. Ploughing in maize straw under conditions of N deficiency led to a drastic decrease in SOC due microbial priming effect that, was not observed when ploughing in sheep dung. In no-till system, losses, organic amendment N concentration and the soil N status determined the impact on SOC and crop productivity. The negative effect on SOC in the tillage treatment with maize straw (4.1 g kg^{-1}) was less when maize straw was combined with urea (6.2 g kg^{-1}). It is concluded that in semi-arid West Africa, without both organic resource and N inputs, soil organic matter "pays" for crop N nutrition. Increasing SOC accumulation while improving crop yield may be conflicting under low-input agricultural systems in semi-arid West Africa. Therefore, optimum soil organic carbon and crop performance results from a judicious combination of organic resources and inorganic N mediated by microbial activity (Ouédraogo et al., 2007).

2.8.3.1. Effect of residue and FYM on soil properties

Residue incorporation has major positive effects on soil fertility enhancement through addition of organic matter, labile C, and improving other soil properties. Increased available P and K (Gangwar *et al.*, 2006), and other macronutrients (N, Mg, Na, and Ca) and micronutrients (Cu, Zn and Mn) resulting from compost or residue application (Wong *et al.*, 1999) are valuable additions to enhance soil fertility. farmyard manure (FYM) produced a surplus of 19 kg P ha^{-1} yr^{-1} and 99 kg K ha^{-1} yr^{-1} in a silty sand soil applied at the rate of 15 t ha^{-1} yr^{-1} (Ellmer *et al.*, 2000) compared to the control (without FYM).

2.8.3.2. Soil physical properties

Considerable improvements in soil physical properties (25% more porosity, 16 times more water holding capacity and increased infiltration rate) due to residue or manure applications have been reported (Gangwar *et al.,* 2006). Decrease in soil temperature, and increased soil moisture by the addition of wheat residue to corn was also recorded (Anatoliy and Thelen, 2007). Manured plots have greater porosity, improved saturated hydraulic conductivity and reduced bulk density (Wong *et al.,* 1999; Celik *et al.,* 2004). Soil organic amendment did not affect soil electrical conductivity, but have more cation exchange capacity when compared to non-amended soil (Walker and Bernal, 2008). Crop residue (>6 t ha^{-1}) has decreased runoff, and evaporation losses (Bennie and Hensley, 2001). Ortega *et al* (2002) declared crop residue as a best source of conservation soil water and to control soil erosion.

2.8.3.3. Soil organic matter and plant nutrients

Substantial positive effects of residue or manure application have been observed on organic matter and C. Total organic C and total soil C, fine fraction and organic matter, were generally greater when straw residue was incorporated than when it was not (Malhi *et al.,* 2006). Manure addition has increased all C fractions, particularly the labile C and the structural stability of soil (Blair *et al.,* 2006a). Rasool *et al.,* (2007) obtained 44% more organic matter, 2.5 times more total C, and 5 times more labile C in manured (35 t FYM ha^{-1} $year^{-1}$) plots. Blair *et al.,* (2006b) obtained increased concentrations of labile C (173%) as compared to non-labile C (80%) in 200 t FYM ha^{-1} $year^{-1}$ applied plots. Residue incorporation plays a key role in improving global carbon budgets (Sullivan *et al.,* 2007).

Soil organic matter (SOM) is understood today as the non-living product of the decomposition of plant and animal substances. Because it is now recognised that SOM tightly controls many soil properties and major biogeochemical cycles its status is often taken as a strong indicator of fertility and land degradation. Nonetheless the building of the SOM concept has not been easy. A reason for this is that the SOM concept is the product of interdisciplinary cognitive production as well as of a cultural moving context (Manlay et al., 2007).

Historically, three periods involving SOM in relation to cropping sustainability can be distinguished. (1) Until 1840, some still believed that plant dry matter was mainly derived from uptake of matter supplied by SOM, which was termed humus at that time. Agriculturists who believed this based the management of cropping systems fertility on the management of humus, i.e. through organic inputs. In 1809 Thaër proposed a "Humus Theory" that remained very influential for 30 years, as well as a quantified assessment of the agro-ecological and economic sustainability of farming systems. (2) From the 1840s to the 1940s, Liebig's "mineral nutrition theory", progressive abandonment of recycling of nutrients between cities and country, and breakthroughs in the processes of fertilizer industry paved the way for intensive mineral fertilization as a substitute for organic practices. Although understanding of SOM and soil biological functioning was improving it had little impact on the rise of new mineral-based cropping patterns. (3) Since the 1940s, SOM has been gaining recognition as a complex bio-organo-mineral system, and as a pivotal indicator for soil quality and agro-ecosystems fertility. This has resulted from: (a) methodological and conceptual breakthroughs in its study, leading to significant scientific developments in characterising the role of humus as an ecosystem component; (b) a growing societal demand for the assessment of the environmental cost of intensification in modern agricultural practices, which has led to growing interest in organic farming, agroforestry, conservation tillage, and the use of plant cover; (c) investigation of the potential of SOM as a sink for greenhouse gas carbon in response to concerns about global climate change. In summary the interest in SOM over time, both from the viewpoint of scientific concept and that of field practices, can be described by a sine curve. Its definition and the recognition of its functions have gained both much from the combination of holistic and reductionist approaches and from the progressive amplification of the scale at which it has been considered (Manlay et al., 2007).

Organic C at surface soil (0-45cm) was increased by straw returned when compared to harvest (Dolan *et al.,* 2006; Gangwar *et al.,* 2006). Higher residue inputs in legume based systems, increased C stocks in a mixture of oat (*Avena sativa* L.) and maize when combined with N fertilizer and C stocks remained steady over a long period (Diekow *et al.,* 2005). Despite having a higher C/N ratio than rice residue, wheat residue additions to flooded rice resulted in greater C sequestration in soil than did either rice residue or 40 Mg ha^{-1} green manure application. Mixing crop residues with urea enhanced incorporation of new organic matter in the coarse fraction and reduced soil C mineralization from the fine fraction (Ouédraogo *et al.,* 2006). In contrast, other researchers for example Liu *et al.,* (2006) reported that manure or crop residue alone may not be adequate to maintain soil organic C levels, but the combinations of inorganic fertilizers with farmyard manure in appropriate ratio are supposed to increase soil organic C content.

Organic N of soil is directly influenced by tillage, residue application and N fertilization management and was found to increase with retention of residues (Dolan *et al.,* 2006). Total organic N was generally greater with straw residues retention (Malhi *et al.,* 2006). More plant N becomes available to corn (Anatoliy and Thelen, 2007) with addition of N fertilizer and wheat straw incorporation. Fertilizer additions have positive effects on total N mineralization from farmyard manure (FYM) (Blair *et al.,* 2006).

Leguminous residue retention increased total soil N mineralization, and was significantly correlated with the C/N ratio of the residues (Kumar and Goh, 2002). Higher residue inputs in legume-based systems, along with N fertilizer application increased N stocks of oats and maize (Diekow *et al.*, 2005). Net mineralized N was approximately 18 kg N ha^{-1} in red clover residues, compared with insignificant amounts from pea and wheat residues (Soon *et al.*, 2001). Kumar and Goh, (2002) obtained 56 kg N ha^{-1} N mineralization in red clover higher than field pea (51kg N ha^{-1}), which was greater than wheat (34 kg N ha^{-1}). Nitrogen release from residue ranged from 6 to 9 kg ha^{-1} during the wheat season and the immobilization of N fertilizer decreased when residue was allowed to decompose for 10 days or longer (Singh *et al.,* 2004). Nitrogen balance was positive either in wheat or peas, when the N input (tops + roots) were considered, but if only the tops were incorporated or the residue was burnt, then the N balance was lower or even negative (Kumar and Goh, 2002).

2.8.3.4. Mirobiological properties

Microbial activity, microbial biomass-C and-N increased significantly with balanced application of fertilizer and combined application of farmyard manure (FYM) and inorganic fertilizers (Hopkins and Shiel, 1996; Mahmood *et al.*, 1997;

Kandeler *et al.*, 1999; Malewar *et al.*, 1999; Kaur *et al.*, 2005; Goyal *et al.*, 2006; Manna *et al.*, 2006; Masto *et al.*, 2006 and Prakash *et al.*, 2007). The readily metabolizable-C and -N in organic manures in addition to increasing root biomass and root exudates due to enhanced crop growth are the most influential factors contributing to the biomass increase. Kaur *et al.* (2005) have also observed that in general, microbial biomass-C tends to be lower in unfertilized soils or those fertilized with chemical fertilizers compared to organic manures.

Continuous application of farmyard manure (FYM) with inorganic fertilizers increased the mineralizable-C and -N and mineral -N significantly due to the reason that continuous application of farmyard manure (FYM) increased the organic matter and more root biomass production due to greater crop growth (Masto *et al.*, 2006). Prakash *et al.* (2007) reported build-up of total soil organic-C in soybean-wheat rotation. Similar crop effects on microbial activity were reported by Manjaiah *et al.* (2000), cropping systems with legumes showed relatively higher microbial activities than other systems.

2.8.3.5. Effect of residue and FYM on crop productivity

Incorporation of crop residue either alone (Anatoliy and Thelen, 2007) or in combination with inorganic N fertilizer (Aulakh *et al.*, 2001) has been reported to have positive effects on crop growth and production. Using cover crops and animal manure-based systems as substitute nutrient management strategies increased farm cost-effectiveness (Gareau, 2004).

Generally, incorporation of manure and residues in soil, increases yield in crops. For example Singh *et al.*, (2004) recorded 0.18-0.39 t ha^{-1} more yield in wheat and rice, and increment have been found in corn (Anatoliy and Thelen, 2007), in rice (Aulakh *et al.*, 2001). More dry weight yields of corn and Chinese mustard (*Brassica chinensis*) in soils receiving manure compost amendment were obtained (Wong *et al.*, 1999). Higher yield would be better achieved when green manure crops and/or residue will soil incorporated (Aulakh *et al.*, 2001). Wheat dry weight was higher and other crops (total of eight crops) were also taller in soil irrigated with lagoon slurry (received manure since, 1968), than the soil irrigated with normal water, and they concluded that slurry from the lagoon was not detrimental to early growth of eight crops (Zhu and Kirkham, 2003).

Prakash *et al.,* (2004) reported that poultry manure (100 t ha^{-1}) followed by sewage sludge increased yield of Citronella Oil (Java Type) (*Cymbopogon winterianus Jowitt*). Addition of wheat residue increased emergence, population and plant height in the early developmental stages but grain moisture and test weight of corn grain at harvest decreased (Anatoliy and Thelen, 2007). On contrary, researchers for example Aulakh *et al.,* (2001) reported that wheat or rice residue incorporation reduce the maize emergence and population. Fisher *et al* (2002) reported no change in wheat yield by straw residue retention. The gradual N release from manure and compost with time appeared to benefit weeds more than winter wheat (Blackshaw *et al.*, 2005), but is source dependent.

2.8.3.6. Organic manures

Unsuitable agricultural practices together with adverse environmental condition have led to degradation of soil. One method for recovering degraded soil in semiarid regions is to add organic matter in order to improve soil characteristics, thereby enhancing biogeochemical nutrient cycles (Ros *et al.,* 2003). soil organic carbon (SOC), N and P were mostly adversely affected with accelerated erosion and that farmyard manure (FYM) fertilizer application has the potential to improve fertility of eroded soils (Kaihura *et al.*, 1999). Organic matter acts as a cementing factor, necessary for flocculating soil particles to form stable aggregates (Puget *et al.,* 2000; Spaccini *et al.,* 2004; Tejada *et al.,* 2006). Martens (2000) indicated that the aggregate binding effect of labile soil organic carbon is rapid but transient while slower decomposing soil organic carbon has subtler effects on aggregation, but the effects may be longer lived.

Soil contents of soil organic carbon (SOC), TSN, available P, K and Mg were significantly increased by farmyard manure (FYM) application. In contrast, application of farmyard manure (FYM) decreased bulk density (Kaihura *et al.*, 1999). Increase in soil chemical quality with farmyard manure (FYM) application can be explained by its potential to release CO_2, NH_4^+, NO_3^-, PO_3^- and undecomposed humic products to the soil through mineralization (Stevenson, 1994). Meelu (1981) reported that application of 12 Mg ha^{-1} FYM produced a residual effect equivalent to 30 kg of N and 13 kg of P to the succeeding crop. Johnson (1986) attributed some effects of farmyard manure (FYM) to improvements in available water holding capacity (AWHC) and availability of N in ways that cannot be mimicked by application of N fertilizers. Application of farmyard manure (FYM) increased soil pH, soil organic carbon (SOC), and plant available nutrients, and enhanced soil quality (Kaihura *et al.*, 1999). Adverse effects of severe erosion on soil quality and crop yield can be mitigated through application of farmyard manure (FYM) and judicious use of chemical fertilizers (Kaihura *et al.*, 1999). The application of high rates of manure compensated for the loss of topsoil (Larney and Janzen, 1997). Manure-derived NO_3-N was less mobile in the moderatedly and severely eroded surfaces created by topsoil removal. This implies that eroded soils may accommodate high rates of manure without an associated NO_3-N leaching problem, because of the absence of a network of macropores (Larney and Janzen, 1997).

The application of green manure to soil is considered a good management practice in any agricultural production system because it can increase cropping system sustainability by reducing soil erosion and ameliorating soil physical properties (MacRae and Mehuys, 1985; Smith *et al.*, 1987), by increasing soil organic matter and fertility levels (Doran and Smith, 1987; Power, 1990), by increasing nutrient retention (Drinkwater *et al.*, 1995; Dinnes *et al.*, 2002), and by reducing global warming potential (Robertson *et al.*, 2000).

Soil microbial biomass respond much more quickly to the changes in soil management practices as compared to total soil organic matter (Goyal *et al.*, 1999; Garcia *et al.*, 2000). Application of organic wastes with a high organic matter content, such as fresh and composted urban wastes (Ros *et al.*, 2003), decayed and composted plant materials derived from municipal wastes (Walker, 2003), and cotton gin compost and poultry manures (Tejada *et al.*, 2006) to semiarid soils has become a common environmental exercise for soil restoration, maintaining soil organic matter, reclaiming degraded soils, and supplying plant nutrients (Tejada *et al.*, 2008).

The application of green manures to soil is considered a good management practice in any agricultural production system because stimulate soil microbial growth and activity, with subsequent mineralization of plant nutrients (Eriksen, 2005), and therefore increase soil fertility and quality (Doran *et al.*, 1988). Leguminous and non-leguminous plants are used as green manures. Leguminous green manures can fix large quantity of atmospheric N_2 and can provide useful amounts of organic matter on soil. Non-leguminous green manures only can increase the organic matter in soil and do not fix atmospheric N_2 (Tejada *et al.*, 2008).

2.8.3.7. C:N ratio

Nitrogen fertilization has been shown to enhance soil total N (203%) and C/N ratio (Habtegebrial *et al.*, 2007). The lowest soil C/N ratio values were observed for control soil as compared to composted residues amended soils as mineralization prevails over immobilization in residues amended soil (Tejada *et al.*, 2009). Tejada and Gonzalez (2006) observed a high degree of mineralization of a crushed cotton gin compost after its application to soil, the soil C/N ratio presenting values around 10-12.

Leguminous residue retention increased total soil N mineralization during the growing period of first wheat crop, and was significantly correlated with the C/N ratio of the residues (Kumar and Goh, 2002).

Also, green manure decomposition and subsequent nutrients release depend largely on soil physical (moisture, temperature, texture, mineralogy and acidity), chemical (C/N ratio, presence of nutrients) and biological (biological activity) (Myers *et al.*, 1994). Of all these parameters, possibly the soil C/N ratio is the parameter that better controls the mineralization of the organic matter after ists incorporation to the soil. In this respect, Tejada and Gonzalez (2006) studying the effect of a crushed cotton gin compost with and without N on a rice crop, found that the soil C/N ratio is the soil parameter most significant for controlling nutrient release. Also, decomposition rates of incorporated green manure differed less between seasons and locations than for mulched green manure. Incorporated residues are in a generally more favorable environment for microbial decomposition (e.g., close soil contact, adequate soil moisture, etc) (Wilson and Hargrove, 1986).

According to Hadas and Portnoy (1994) and Tejada and Gonzalez (2006), the C/N ratio of the organic wastes will largely determine the balance between mineralization and immobilization. The C/N ratio was the best predicting parameter for the potential amount of N that can mineralize from a crop residue (Chaves *et al.*, 2004). In this respect, Maiksteniene and Arlauskiene (2004) found a higher mineralization of clover and Lucerne green manures after the application of soil (C/N ratio 12 and 10, respectively) that vetch and oat mixture (C/N ratio 31) and straw wheat (C/N ratio 55).

2.8.3.8. Legumes mungbean

Harnessing N through biological N_2-fixation and appropriate residue management can be an effective method of sustaining soil fertility if conditions for N_2-fixation are optimized (McDonagh *et al.*, 1997). There has also been a research focus on combining these organic resources with low rates of mineral N fertilizers, to improve synchrony and N use efficiency (Palm *et al.*, 1997). The application of different green manures to soil increased microbial biomass-C and soil respiration rapidly (Tejada *et al.*, 2008; Goyal *et al.*, 1999; Fontaine *et al.*, 2003; Stark *et al.*, 2007).

Inclusion of mungbean in crop rotation with wheat improved the yield of wheat as well as soil organic fertility (Shah *et al.*, 2003). Crop residues after harvest of legumes represent a poetentially valuable source of N for improving soil N pools of poor soils (Peoples and Craswell, 1992). The application of different green manures to soil increased microbial biomass-C and soil respiration rapidly (Goyal *et al.*, 1999; Fontaine *et al.*, 2003; Stark *et al.*, 2007; Tejada *et al.*, 2008). The application of green manures to the soil produced an improvement in the soil biological properties as well as in the nutrition, production and quality of the obtained maize (Tejada *et al.*, 2008).

Green manuring increased rice yields over no summer crop by 0.6-1.0 t ha^{-1} y^{-1} and the succeeding wheat yield by 0.2-0.3 t ha^{-1} y^{-1}, whereas, mungbean residue incorporation significantly increased rice yield over fallow by 0.6-0.8 t ha^{-1} y^{-1} and wheat yield by 0.5 t ha^{-1} y^{-1}. Mungbean without residue incorporation was no better than no summer crop (Sharma and Prasad, 1999). Green manuring or incorporation of mungbean residue resulted in recycling of 77-113 kg N ha^{-1} and increased productivity of the rice-wheat cropping system by 0.5-1.3 t ha^{-1} y^{-1} and plant-N uptake by 12-35 kg ha^{-1} y^{-1} over no summer crop. The productivity and plant-N uptake of the rice-wheat cropping system, without nitrogen application to rice after Sesbania green manuring or incorporation of mungbean residue, were similar to those obtained with 120 kg N ha^{-1} application to rice after no summer crop. Mungbean residue incorporation had the advantage of producing 0.5 t ha^{-1} y^{-1} of protein-rich pulse grain and was more useful for increasing the productivity of a rice-wheat cropping system (Sharma and Prasad, 1999). Morris *et al.* (1986) and John *et al.* (1989, 1992) reported that a short-duration green manure crop accumulated 62-74 kg N ha^{-1}. Mungbean produced 0.5-0.6 t ha^{-1} y^{-1} grain and 3-3.4 t ha- y^{-1} residue and accumulated 92-96 kg N ha^{-1}, 20% of which was in the grain. Thus, incorporation of mungbean residue resulted in recycling of about 77 kg N ha^{-1} y^{-1} (Sharma and Prasad, 1999).

Growing summer mungbean prior to rice, picking its pods for grain and incorporating its residues for green manuring is highly advantageous to a rice-wheat cropping system as it increases both the productivity as well as plant-N uptake in a similar manner to Sesbania green manuring besides producing 0.5 t ha^{-1} pulse grain, and, hence, it is strongly recommended to farmers (Sharma and Prasad, 1999).

Mungbean produced 0.5-0.6 t ha^{-1} y^{-1} grain and 3-3.4 t ha- y^{-1} residue and accumulated 92-96 kg N ha^{-1}, 20% of which was in the grain. Thus, incorporation of mungbean residue resulted in recycling of about 77 kg N ha^{-1} y^{-1} (Sharma and Prasad, 1999).

Mungbean residue incorporation significantly increased straw yields of rice and wheat. Mungbean without residue incorporation gave significantly higher straw yields of wheat than no summer crop (Sharma and Prasad, 1999). Incorporation of mungbean residue was effective for plant-N uptake by the rice-wheat cropping system, the increase over no summer crop being 17-30 kg N ha^{-1} y^{-1} (Sharma and Prasad, 1999) producing 0.5 t ha^{-1} y^{-1} of protein-rich pulse grain and was more useful for increasing the productivity of a rice-wheat cropping system (Sharma and Prasad, 1999). Morris *et al.*

(1986) and John *et al.* (1989, 1992) reported that a short-duration green manure crop accumulated 62-74 kg N ha^{-1}.

Jiang et al. (2006) studied the dynamics of the soil organic carbon pool and soil fertility in soils with different number of growing years of alfalfa (Medicago sativa L.) in the semiarid Loess Plateau of China. The soil water content and soil water potential decreased and the depth of desiccated layers grew with the number of growing years of alfalfa. The soil organic C (SOC) cannot be enhanced on short timescales in these unfertilized and mowed-alfalfa grasslands in the topsoil, but the light fraction of organic C (LFOC), soil microbial biomass C (MBC) and microbial biomass N (MBN) all increased with the number of growing years. When alfalfa had been growing for more than 13 yr, the soil MBC increased slowly, suggesting that the MBC value is likely to reach a constant level. SOC, soil total P (STP), available P (AvaiP) and the ratio of SOC to soil total N (C/N) all decreased monotonically with the growing years of alfalfa up to 13 yr and then increased. SOC was significantly positively correlated with STP, AvaiP, soil total C (STC) and soil total N (STN). MBC and LFOC were significantly positively correlated with the number of growing years of alfalfa, and LFOC was more sensitive to vegetation components, degree of cover and landform than to the number of years of growth. SOC showed a significant negative correlation with LFOC/SOC and MBC/SOC. A significant positive correlation exists between MBC and soil inorganic C (SIC). LFOC, MBC, LFOC/SOC and MBC/SOC were all significantly positively correlated with each other. Therefore, practices that involve water-harvesting technologies and add residues and phosphate fertilizer to soils should be promoted to improve soil nutrients and hydration and to postpone the degradation of alfalfa grasslands under long-term alfalfa production.

Researchers have explored a number of ways of incorporating N_2-fixing grain legumes into cropping systems (Mpepereki *et al.*, 1996, 2000; Mapfumo, 2000), organic resources such as cattle manure and agroforestry tree prunnings (Mafongoya *et al.*, 1997; Murwira, 1994), and “rainfall responsive” use of limited available mineral fertilizers (Piha, 1993), to increase availability of N to cereal crops.

Shah *et al.* (2003) reported the results of mungbean residue incorporation under similar conditions that grain yield benefits of residues were 13 % for mungbean, and 8 % for wheat and lentil. They attributed increase in yield due to improvement of N economy of the cropping system due to retention of residues. Ghosh *et al.* (2004a) also found that soybean as preceding crop recorded the highest seed yield of wheat as compared with intercropping or sole cereal (Ghosh *et al.*, 2004b). Jain and Jain (1993) reported that wheat performed better after legume with respect to grain yield than that of cereals.

Shah *et al.* (2003) reported that grain yield benefits of crop residues were 13 % for mungbean as compared with 8 % for wheat and lentil. They attributed this effect to the retention of residues which improve N economy of the cropping system and enhance crop productivity through the additional N and other soil effects. It has been also reported by NFDC (1998) that green manuring of mungbean substantially retained moisture content (Bhatti and Khan, 2000). Nuruzzaman *et al.* (2004) found that faba bean was the best species in promoting subsequent wheat growth, and therefore it appears to be a suitable P-solubilizing legume crop for use in rotations with wheat (Godo and Reisenauer, 1980; Shen *et al.*, 2002).

Summer green manuring with Sesbania has been recommended to save fertilizer N in the rice-wheat cropping system in India (Meelu *et al.*, 1992). Higher N-fixation by S. rostrata as compared to S. aculeate has been reported (Palaniappan, 1997). However, green manuring has not found favor with the farmers due to lack of immediate monetary returns. A dual purpose mungbean yields additional grain and has manorial value when, after picking the manure pods, its residue is incorporated in the soil (Sharma and Prasad, 1999, Sharma *et al.*, 1995).

The application of green manures to the soil produced an improvement in the soil biological properties as well as in the nutrition, production and quality of the obtained maize (Tejada *et al.*, 2008).

The benefits of growing pulses in cropping systems are well established. They can fix substantial amounts of atmospheric N2, which allows them to be grown in poor soils without N fertilizers. Though legumes play an important role in the national economy, they have benn neglected by most pulses-growing countries and are usually considered minor crops. They are usually grown on degraded soil with poor management. Summer legumes have great potential on eroded lands as they need less water and can give good plant cover during summer rains.

The decomposition of green manures is complex, and is controlled by numerous factors such as availability of carbon and nitrogen, the biochemical nature of the plant residue, contact between soil and compost and soil and climatic factors, etc. According to Hadas and Portnoy (1994) and Tejada and Gonzalez (2006), the C/N ratio of the organic wastes will largely determine the balance between mineralization and immobilization. The C/N ratio was the best predicting parameter for the potential amount of N that can mineralize from a crop residue (Chaves *et al.*, 2004). In this respect, Maiksteniene and Arlauskiene (2004) found a higher mineralization of clover and Lucerne green manures after the application of soil (C/N ratio 12 and 10, respectively) that vetch and oat mixture (C/N ratio 31) and straw wheat (C/N ratio 55).

This increase in soil microbial biomass carbon and soil respiration can be attributed to the incorporation of easily degradable materials, which stimulate the autochthonous microbial activity and to the incorporation of exogenous microorganisms (Blagodatsky *et al.*, 2000; Tejada *et al.*, 2006). Soil microbial respiration, measured through CO2 production is a direct indicator of microbial activity, and indirectly reflects the availability of organic material (Gomez *et al.*, 2001; Tejada and Gonzalez, 2003; Tejada *et al.*, 2006).

3. MATERIALS AND METHODS

3.1. Selection of sites

Field experiments were conducted at Tehsil Kabal District Swat of North West Frontier Province, Pakistan to study integrated nutrient management for soil fertility and crop productivity of water eroded lands at District Swat. A survey was made for the selection of three eroded sites at District Swat during 2006, based on the past history of soil erosion. Three eroded lands as shown below were selected using soil survey report (1976),

- Slightly eroded (Guljaba)
- Moderately eroded (Gado)
- Severely eroded (Kotlai)

The locations of the selected sites are given in Table 1.

Table 1: Locations of experimental sites

Site	Geo-Position	Elevation	Vernacular – Position
Guljaba	34^0-45′-51″ N 72^0-14′-57″ E	923 m	1 km from Kabal on Kabal road
Gado	34^0-45′-51″ N 72^0-14′-56″ E	919 m	8 km from Kabal on Shamozai road
Kotlai	34^0-46′-59″ N 72^0-14′-51″ E	1005 m	7 km from Kabal on Shamozai Kotlai road

3.2. Criteria for measuring degree of erosion

Criteria for measuring degree of erosion are given in Table 2. Selected soils were characterized for the degree of erosion based on some of their physical and chemical properties.

Table 2: Criteria for measuring degree of erosion

S.No	Erosion Class	Criteria
1	No Apparent Erosion	Nearly all the original topsoil remains & there is no apparent evidence of erosion.
2	Moderate Erosion	Top 6 or 7 inches is mostly original topsoil, while occasional subsoil spots are exposed on the field.
3	Severe Erosion	Top 6 or 7 inches is mixed topsoil and subsoil, numerous subsoil spots are exposed on the field.

Source: (Bosworth and Albert, 1982)

Table 3 gives the details of the survey results. The three sites were classified following USDA soil classification system (USDA, 1998). Site Guljaba was in Pirsabak soil series and was categorized as slightly eroded following Bosworth and Albert (1982) criteria for measuring degree of erosion, site Gado was in Missa soil series and categorized as moderately eroded, while Kotlai was in Missa gullied soil series and it was categorized as severely eroded soil.

Table 3: Soil series and USDA taxonomic classes of the three sites.

Locations	Soil series	Taxonomic class	Degree of Erosion
Guljaba	Pirsabak	Coarse silty, mixed, thermic, Typic Eutrudepts	Slightly eroded
Gado	Missa	Coarse silty, mixed, thermic, Typic Eutrudepts	Moderately eroded
Kotlai	Missa gullied	Coarse silty, mixed, thermic, Typic Eutrudepts	Severely eroded

3.3. Soil analysis before the experiments

Before the experiment triplicate soil samples were taken both from 0-20 cm and 20-45 cm soil depths from each site and analyzed at the laboratory of Soil and Environmental Sciences, NWFP Agricultural University, Peshawar. The details of the laboratory analysis are given in Table 4. It is evident from Table 4 that organic matter and most plant nutrients in the soils were either deficient or marginal as the soils were eroded.

Table 4: Soil analysis of experimental sites before the experiment

Site	**-----Guljaba-----**		**-------Gado-------**		**-------Kotlai------**	
Soil depth (cm)	**0-20**	**20-45**	**0-20**	**20-45**	**0-20**	**20-45**
$pH_{(1:5)}$	7.38	7.27	7.65	7.59	7.93	8.05
$EC_{(1:5)}$ (dS m^{-1})	0.85	0.89	0.99	0.93	0.89	1.07
Lime (g kg^{-1})	68.3	60	162	174	145	193
O.M (g kg^{-1})	11.93	11.77	9.37	9.27	8.4	7.67
ABDTPA Extractable (mg kg^{-1} soil)						
P	1.39	1.32	1.17	1.2	0.98	0.97
K	60.6	61.17	67.47	67.6	60.3	59.8

3.4. Characteristics of soil amendments

Table 5 gives the details of the characteristics of the soil amendments used in the experiment. Soil amendments included mungbean residues and farmyard manure. Dry weight of mungbean residues and farmyard manure (FYM) was 31.3% and 40.6%, total organic C was 180 and 163.8 g kg^{-1} DM, total N was 32.8 and 12.9 g kg^{-1} DM, while C/N ratio was 5.51 and 12.7 respectively.

Table 5: Characteristics of the soil amendments used in the experiment

Property of amendment	Mungbean residues	FYM
Dry weight (%)	31.3	40.6
Total organic C (g kg^{-1} DM)	180.7	163.8
Total N (g kg^{-1} DM)	32.8	12.9
C/N ratio	5.51	12.7

3.5. Field experiments

Field experiments were started at each site during July 2006 for four seasons on mungbean and wheat crops. The experimental design was 2 factors RCBD split-plot. Main-plot factor was residue management practices, which included 3 residue management practices, i.e., F (fallow), R– (Mungbean residues removed) and R+ (Mungbean residues incorporated). Sub-plot factor consisted of six fertilizers treatments, i.e., T1 (Control), T2 (120 kg N ha^{-1}), T3 (120-90-0 kg N-P_2O_5-K_2O ha^{-1}), T4 (120-90-60 kg N-P_2O_5-K_2O ha^{-1}), T5 (90-90-60 kg N-P_2O_5-K_2O ha^{-1} + 10 t FYM ha^{-1}), and T6 (60-90-60 kg N-P_2O_5-K_2O ha^{-1} + 20 t FYM ha^{-1}).

In July 2006 during kharif, mungbean variety Swat 97 was first sown in two of the three main-plots, while the third main-plot was left fallow. After about 60 days of growth, 1 m^2 area was harvested in each treatment plot of mungbean and data were recorded on biomass yield, grain yield (kg ha^{-1}) and 1000-grain weight (g). Mungbean crop was harvested in October 2006. Immediately after harvesting, aboveground residues of Mungbean crop were either completely removed (R-) or incorporated with the help of cultivator (R+) into respective plots.

In November 2006 during winter wheat variety Tatara was sown in all the plots. Sub-plot size was 5 m x 4 m. All the fertilizer treatments were applied to their respective plots. All the fertilizers were applied at the time of sowing of wheat crop and were incorporated into the soil. In case of NPK treatments, half N plus all P, and K were applied at sowing and the remaining half N after about one month. Farmyard manure was applied @10 Mg ha^{-1} to T5 and 20 Mg ha^{-1} to T6 plots about one month before sowing of wheat crop during the two winter seansons. Wheat crop was harvested from a net area of 1 m^2 in duplicate from each treatment plot in June and threshed after sun drying in the field. The following crop parameters were recorded.

Biological yield

After harvesting, the wheat crop was sun dried in the field. Weight of the bundle was taken at two days interval until there was no considerable change in dry weight of the crop. The weight was recorded in kg ha^{-1}.

Grain yield

The bundle in each plot was threshed by micro-plot thresher. The grains were thoroughly cleaned and weighed with top loader balance and data recorded in kg ha^{-1}.

1000-grain weight

1000 normal grains from each plot were taken at random and weighed with the help of electric balance (g).

Harvest index

Harvest index was calculated by using the following formula:

$$Harvest\ index\ (\%) = \frac{grain\ yield}{biological\ yield} \times 100$$

3.6. Experimental layout

Three main- plots were maintained at the experimental site of each site. Each main-plot was divided into six sub-plots. Residue management practices were done in main-plots while fertilizer treatments were applied to sub-plots.

Following is an outline of the residues management practices and fertilizers treatments.

LAYOUT OF THE EXPERIMENT

Residues Management Practices

R1

R+	T2	T4	T1	T6	T3	T5
R-	T4	T2	T6	T3	T5	T1
F	T3	T1	T5	T4	T2	T6

R2

R+	T2	T4	T3	T5	T1	T6
R-	T4	T6	T5	T1	T2	T3
F	T4	T2	T6	T3	T1	T5

R3

R+	T5	T1	T6	T4	T3	T2
R-	T1	T4	T3	T6	T5	T2
F	T3	T6	T5	T2	T4	T1

Design: RCBD Split-plot

Replications (R): Three

Duration: Two years (2006-2008)

Residues management practice (main-plot factor)

1. F (Fallow plots)
2. R- (Mungbean residues removed)
3. R+ (Mungbean residues incorporated into plots)

Fertilizer treatments (sub-plot factor)

1. T1 (Control)
2. T2 (120 kg N ha^{-1})
3. T3 (120-90-0 kg N-P_2O_5-K_2O ha^{-1})
4. T4 (120-90-60 kg N-P_2O_5-K_2O ha^{-1})
5. T5 (90-90-60 kg N-P_2O_5-K_2O ha^{-1} + 10 t FYM ha^{-1})
6. T6 (60-90-60 kg N-P_2O_5-K_2O ha^{-1} + 20 t FYM ha^{-1})

3.7. Laboratory procedures

After harvesting of each crop at each site, soil and plant samples were collected from each treatment plot and brought to the laboratory of Departemt of Soil & Environmental Sciences, NWFP Agricultural University, Peshawar. Soil samples were dried, ground and sieved through 2 mm sieve, which were stored in the clean, dry and labelled plastic bottles for further analysis. All shoot and grain samples were oven dried at 80 $^{\circ}$C to a constant mass, weighed, then finely ground (<0.1 mm) and stored in plastic bags. The soil and plant samples were analysed for the following physical, chemical and biological properties.

Bulk density of the soil was determined by core method (Blake and Hartage, 1984). Organic matter content of the soil was determined by wet digestion method of Walkley and Black (Nelson and Sommers, 1982), Electrical conductivity was measured in 1:5 soil water suspension following 30 minutes of stirring and read on EC meter as reported by (Rhodes, 1996). Soil pH was measured in 1:5 soil water suspension following 30 minutes of stirring and read on pH meter (Model German Type B-124 using glass and calomel electrodes) (Mclean, 1982). AB-DTPA extractable P and K were determined by the procedure described by (Soltanpour and Schwab, 1997). 10 g soil was added to 20 ml AB-DTPA solution shaking for 30 minutes and then filtered. For phosphorus in 1 ml of aliquot, 4 ml distilled water 5 ml ascorbic acid mixed reagent added and volume made up to 25 ml.

3.7.1. Determination of mineral N in soil

Mineral N in the soil sample was determined by the steam distillation method of Mulvaney (1996). In this method, 20 g soil sample was extracted with 100 ml of 1 M KCl for 1 h and then filtered. With pipette an aliquot of 20 ml of filtrate was distelled with 0.2 g MgO + 0.2 g Devarda's alloy to recover both NH_4 and NO_3 into 5 ml boric acid mixed indicator solution. Distillate was titrated against 0.005 M HCl till permanent faint pink color and the amount of mineral N was calculated as follows,

$$\mathrm{N}\ (\%) = \frac{(\text{ml of HCl used in sample} - \text{ml of HCl used in blank}) \times 0.014\ \times \mathrm{N}}{\text{weight of sample (g)}} \times 100$$

3.7.2. Determination of organic C in soil

Total organic carbon in the soil was determined by the Walkely-Black procedure (Nelson and Sommers, 1982). In this procedure 1 g soil was treated with 10 ml of 0.1 M $K_2Cr_2O_7$ and 20 ml concentrated H_2SO_4 to completely oxidize organic C. After a gentle swirling of the reactants for 15 min, 200 ml distilled water was added and kept to cool for 30 min. After filtering, the un-utilized $K_2Cr_2O_7$ was determined by back titration against 0.5 N $FeSO_4$ solution in the presence of o-phenonthroline indicator.

3.7.3. Determination of total N in soil and plant samples

Total N in soil and plant samples was determined by the Kjeldhal method of Bremmer (1996). 1 g of the finely ground soil or in case of grain/FYM, 0.2 g sample was digested with 3 ml of concentrated H_2SO_4 in the presence of digestion mixture containing K_2SO_4, $CuSO_4$ and Se (100:10:1) on block digester for about 4-5 hours. After cooling, the digest was distilled with 20 ml of 40% NaOH solution into 5.0 ml boric acid mixed indicator solution. The distillate was titrated against standard 0.1 N HCl and the amount of N calculated in sample.

$$\mathrm{N}\ (\%) = \frac{(\text{ml of HCl used in sample} - \text{ml of HCl used in blank}) \times 0.014 \times \mathrm{N}}{\text{weight of sample (g)}} \times 100$$

3.7.4. Determination of total phosphorus in plant samples and farmyard manure (FYM)

Total P in plant samples was determined by the perchloric acid-nitric acid digestion method as described by Kue (1996). In this method, 1.0 g sample was digested with 10 ml concentrated HNO_3 (overnight treatment) and 4.0 ml perchloric acid at 100 to 350 $^{\circ}$C for about 1 ½ hr. After cooling the digest was filtered and diluted to 50 ml (Solution A). 1.0 ml of solution A was treated with 5.0 ml ascorbic acid and diluted to 25 ml and then read for phosphorus on spectrophotometer at 880nm.

3.7.5. Determination of total potassium in plant samples and farmyard manure (FYM)

The plant samples for K determination were digested by the perchloric acid-nitric acid digestion method as described by Kue (1996). In brief, 1.0 g sample was digested with 10 ml concentrated HNO_3 (overnight treatment) and 4.0 ml perchloric acid at

100 to 350 °C for about 1 ½ hr. After cooling the digest was filtered and diluted to 50 ml (Solution A). 1.0 ml of solution A was treated with 5.0 ml ascorbic acid and diluted to 25 ml and then read for potassium on flame photometer.

3.7.6. Determination of available water holding capacity (AWHC)

Available water holding capacity was determined by the method as described by (Raza *et al.*, 2003). Soil samples were taken in rubber rings arranged on pressure plates, saturated with water for 24 hours and kept in pressure membrane apparatus to determine water contents at different pressures. The pressures of 0.1, 0.3, 0.5 and 1 bars were used. After recording moisture content at each pressure, a relationship was established between matric suction and gravimetric water content using the following expression:

Equation 1: $\Psi = a\omega^b$

Where (Ψ = matric suction (MPa), ω = gravimeteric water content (g g^{-1}) and a, b = constants which depend upon the soil texture). Equation 1 was linearized by taking logarithm of both the sides as follows:

Equation 2: $\log \Psi = \log a + b \log \omega$

Equation 2 was used to determine water content at field capacity (0.03 MPa) and permanent wilting point (1.5 MPa). Available water holding capacity (AWHC) was determined using the following equation:

Equation 3: $$AWHC\ (\%) = \frac{\omega fc - \omega pwp}{\text{dry weight of soil (g)}} \times 100$$

Where (ω_{fc} = water content at field capacity ($cm^3\ cm^{-3}$) and ω_{pwp} = water content at permanent wilting point ($cm^3\ cm^{-3}$)).

3.7.7. Determination of soil microbiological properties

3.7.7.1. Microbial biomass-C and N

Microbial biomass carbon (C) and nitrogen (N) were determined by using $CHCl_3$ fumigation-extraction method of Vance *et al.* (1987) and Brookes *et al.* (1985). In this method, soil samples were fumigated with chloroform to kill all microbes in the soil samples by keeping 20 g moist soil samples in a 50 ml beaker inside desiccator shut to air tight by lining with moist tissues. The desiccator was connected to a vacuum pump and samples were evacuated three times, each time for about one minute after boiling the chloroform. After the last evacuation, the samples were kept in the dark under vacuum for 24 hours. The non-fumigated samples were also kept in the desiccator (without vacuum) in the dark for a day. After one day, the chloroform was removed from the desiccator and then carefully evacuated three times, each time for two minutes to make sure that all chloroform has been evacuated. The fumigated soil samples were then inoculated with 1.0 g of non-fumigated same soil sample and incubated in the presence of NaOH solution. The CO_2 evolved was trapped in 0.3 M NaOH solution suspended in incubated flasks containing soil samples. After adding 10 ml of 1 M $BaCl_2$ solution and 4-5 drops of phenolphthalein, the solution was titrated against 0.1 N HCl until the pink color disappeared. The CO_2 evolution was also measured in the non-fumigated soil incubated in a similar way.

3.7.7.2. Measurement of CO_2 evolution

Both fumigated and non-fumigated samples were transferred to individual 500 ml conical flasks. A vial containing 5 ml of 0.3 M NaOH was suspended in each flask. Flasks were properly shut to air tight using rubber bungs, and incubated at 25°C for 2, 5, 10 and 15 days. At each incubation period, the NaOH solution of the vial was transferred to a 250 ml conical flask. After adding 10 ml of 1 M $BaCl_2$ solution and 4-5 drops of phenolphthalein, the solution was titrated against 0.1 N HCl until the pink colour disappeared. The vial was re-filled with fresh NaOH (same strength and amount) and suspended in same flask. The flasks were re-incubated and the same process was repeated for 5^{th}, 10^{th} and 15^{th} days of incubation period. After measuring CO_2 evolution at day 10, both fumigated and non-fumigated samples were analyzed for mineral N.

Calculation of soil microbial biomass-C

Soil microbial biomass-C (MBC) was calculated from the CO_2-C respired from fumigated and non-fumigated samples using the equation of Jenkinson and Ladd (1981).

Microbial biomass-C $= (F_c - U_{fc}) / K_c$

Where (F_c = CO_2 flush from fumigated soil, U_{fc} = CO_2 produced from non-fumigated soil and $K_c = 0.45$).

Calculation of soil microbial biomass-N

Soil microbial biomass-N (MBN) was calculated from the amount of mineral N produced in fumigated and non-fumigated samples using the equation of Jenkinson (1988):

Microbial biomass-N $= (F_n - U_{fn}) / K_n$

Where (F_n = The flush of total mineral-N from fumigated soil after 10 days of incubation, U_{fn} = The total mineral-N during 10 days of incubation from non-fumigated soil and $K_n = 0.54$)

Mineralizable-C and -N

Mineralizable-C was estimated from the total amount of CO_2 produced from an non-fumigated soil sample during 10 days of incubation. The amount of mineralizable C was calculated as 44 g of CO_2 contains 12 g of C. Mineralizable-N was determined in same sample run for measuring mineralizable-C as follows:

The sample was analyzed for mineral-N before incubation (day 0) and after incubation (day 10). The amount of mineralizable-N was calculated by difference as follows:

Mineralizable N = Mineral-N at day 10 – Mineral-N at day 0

3.8. Statistical analysis

The collected data on different soil properties and crop yields was analysed statistically using two Factors RCBD Split-plot with 3 replications using MS Excel and statistical package MStatC. Treatments were compared using LSD test of significance at $p<0.05$ according to Gomez and Gomez (1984). For economic analysis, after considering the cost of fertilizer N, P, K and organic materials application, the incomes from wheat and mungbean yield were used for economic analysis (CIMMYT, 1988) using the following formulae:

i. Gross Income = value of grain yield + value of straw yield

ii. Gross Income over control = treatment gross income – control gross income

iii. Net Income over control = gross income over control – total expenditure

iv. Relative increase in income (RII) = (net income over control / control gross income) × 100

The incomes in Rupees were converted into US$ based on the prevailing currency rate (year 2006–2007 equivalency US$ 1 = Rs. 65).

4. RESULTS AND DISCUSSIONS

4.1. Effect of fertilizer treatments and residues management on soil physical, chemical and biological properties

Following is an account of the effect of organic and inorganic fertilizer treatments and mungbean residues management practices on soil physical, chemical and biological properties of three sites under different degrees of erosion (slightly, moderately and severely eroded).

4.1.1. Guljaba (slightly eroded soil)

4.1.1.1. Soil pH

Data in Table 6 show that effect of fertilizer treatments on soil pH at surface soil (0-20 cm soil depth) was statistically significant ($p<0.05$) only during Rabi 2008 (Appendix 4), while non-significant ($p>0.05$) during the rest of the seasons (Appendix 1-3). During Rabi 2008 control plots had the highest soil pH, while T6 had the lowest soil pH. At sub-surface soil (20-45 cm soil depth) effect of fertilizer treatments on soil pH was statistically non-significant ($p>0.05$) during Kharif 2006 and Rabi 2007 (Appendix 6 and 7), while it was significant during Kharif 2007 and Rabi 2008 (Appendix 8 and 9). During Kharif 2007 and Rabi 2008, T6 had the lowest soil pH followed by T4, while rest of the treatments had higher soil pH (Fig. 1). Combined analysis of soil pH over seasons (Appendix 5 and 10) showed that treatments effect at sub-surface soil was very highly significant ($p<0.001$). T6 had the lowest soil pH, while T2 and T3 had the highest soil pH and were at par with each other. T6 decreased soil pH by 1.1% at surface and 1.3% at sub-surface soil.

It is evident from Table 6 that effect of management practices on soil pH at surface soil (0-20 cm soil depth) was statistically significant ($p<0.05$) during Kharif 2007 and Rabi 2008 (Appendix 3 and 4), while it was non-significant ($p>0.05$) during Kharif 2006 and Rabi 2007 (Appendix 1 and 2). During Kharif 2007 R+ had the lowest soil pH as compared to R- and fallow plots (Fig. 2). At sub-surface soil (20-45 cm soil depth) effect of management practices on soil pH was statistically non-significant ($p>0.05$) during all the four seasons (Appendix 6-9). Combined analysis of soil pH over seasons showed that residues management effect at surface soil

(Appendix 5) was very highly significant (p<0.001). R+ had the lowest soil pH, followed by fallow, while R- had the highest. R+ decreased soil pH by 1.13% compared with the fallow.

Table 6: Effect of fertilizer treatments and residues management practices on soil $pH_{(1:5)}$ at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)[d]
Soil depth = 0-20 cm						
T1[a]	7.38	7.32	7.32	7.30 a[c]	7.33	…
T2	7.35	7.30	7.27	7.27 ab	7.30	-0.40
T3	7.33	7.33	7.30	7.26 ab	7.30	-0.32
T4	7.30	7.28	7.27	7.25 ab	7.27	-0.73
T5	7.36	7.29	7.24	7.17 bc	7.26	-0.87
T6	7.37	7.29	7.21	7.12 c	7.25	-1.10
$LSD_{(0.05)}$	ns	ns	ns	0.119	ns	
F[b]	7.33	7.30	7.29 ab	7.26 a	7.30 b	…
R-	7.38	7.35	7.34 a	7.31 a	7.35 a	0.71
R+	7.32	7.25	7.17 b	7.11 b	7.21 c	-1.13
$LSD_{(0.05)}$	ns	ns	0.131	0.146	0.043	
Soil depth = 20-45 cm						
T1	7.30	7.26	7.26 a	7.23 ab	7.27 b	…
T2	7.38	7.36	7.34 a	7.31 a	7.35 a	1.12
T3	7.33	7.33	7.34 a	7.34 a	7.33 a	0.95
T4	7.31	7.27	7.25 ab	7.23 ab	7.26 b	0.00
T5	7.33	7.29	7.26 a	7.18 bc	7.26 b	-0.04
T6	7.32	7.21	7.14 b	7.07 c	7.18 c	-1.13
$LSD_{(0.05)}$	ns	ns	0.118	0.114	0.053	
F	7.32	7.28	7.27	7.25	7.28	…
R-	7.29	7.27	7.28	7.25	7.27	-0.09
R+	7.36	7.31	7.25	7.18	7.28	-0.05
$LSD_{(0.05)}$	ns	ns	ns	ns	ns	

[a] Treatments: T1=NPK (0-0-0), T2=NPK (120-0-0), T3=NPK (120-90-0), T4=NPK (120-90-60), T5=NPK (90-90-60) + 10 t FYM ha^{-1}) and T6=NPK (60-90-60) + 20 t FYM ha^{-1}). All NPK rates were in kg $N\text{-}P_2O_5\text{-}K_2O$ ha^{-1}. Data has been pooled from 3 management practices and 3 replications.

[b] Residues management Practices: F (fallow), R- (mungbean residues removed) and R+ (mungbean residues incorporated into soil). Data has been pooled from 6 fertilizer treatments and 3 replications.

[c] Means followed by similar letter(s) in a column under each category are statistically non-significant using least significant difference (LSD) test at 5% level of probability. ns= Not significant at (p<0.05).

[d] Percent increase over control.

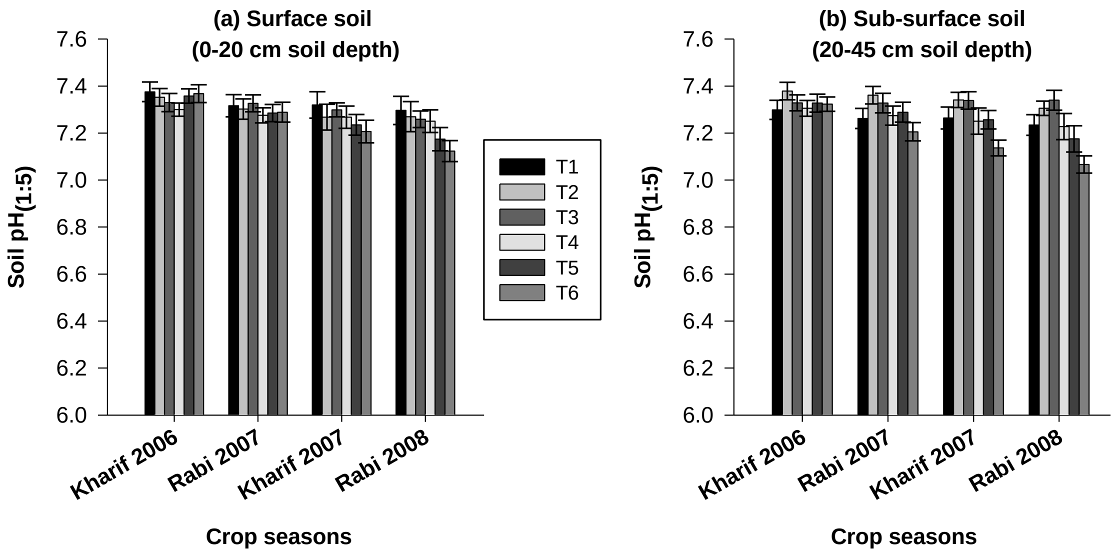

Fig. 1 Effect of fertilizer treatments on soil $pH_{(1:5)}$ at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons. Error bars show standard errors of means.

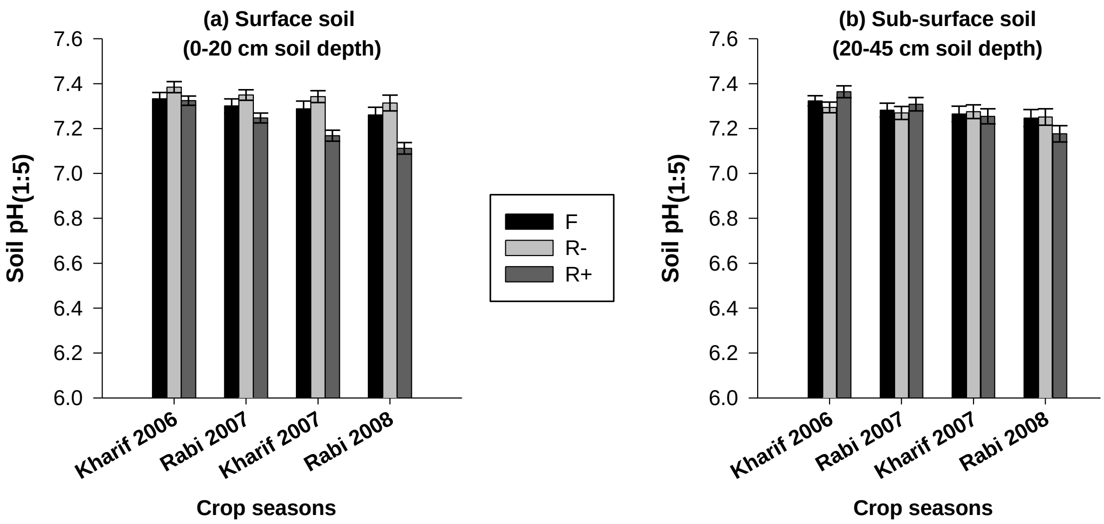

Fig. 2 Effect of residues management practices on soil $pH_{(1:5)}$ at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

4.1.1.2. Soil electrical conductivity

Data in Table 7 show that effect of fertilizer treatments on soil electrical conductivity at both surface (0-20 cm soil depth) and sub-surface soil (20-45 cm soil depth) was statistically non-significant (Appendix 11-19) during all the seasons (Fig. 3). Analysis of the data combined over seasons showed that effect of fertilizer treatement was statistically significant ($p<0.05$) at sub-surface and very highly significant ($p<0.001$) at surface soil (Appendix 15 and 20). At the surface soil (0-20 cm soil depth), T4 had the highest EC (0.89 dS m^{-1}) with an increase of 27%

compared with the control (T1). T1 had the lowest EC (0.85 dS m^{-1}).

Effect of management practices on soil electrical conductivity at both surface (0-20 cm soil depth) and sub-surface soil (20-45 cm soil depth) was statistically non-significant (Appendix 11-19) during all the four seasons (Table 7 and Fig. 4). Analysis of the data combined over seasons (Appendix 15) showed that effect of residues management practices at surface soil (0-20 cm soil depth) was very highly significant ($p<0.001$). R- had the highest EC (1.01 dS m^{-1}) with an increase of 10.3% compared with the fallow (F).

Table 7: Effect of fertilizer treatments and residues management practices on soil $EC_{(1:5)}$ (dS m^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(dS m^{-1})……………………………….					
Soil depth = 0-20 cm						
T1	0.85	0.85	0.84	0.87	0.85 d	…
T2	0.97	0.99	0.97	0.99	0.98 b	15.13
T3	0.93	0.93	0.92	0.96	0.93 bc	9.37
T4	1.07	1.07	1.08	1.11	1.08 a	27.01
T5	0.92	0.92	0.91	0.93	0.92 bcd	7.88
T6	0.90	0.89	0.88	0.89	0.89 cd	4.10
$LSD_{(0.05)}$	ns	ns	ns	ns	0.077	
F	0.92	0.92	0.91	0.93	0.91 b	…
R-	1.00	1.01	1.01	1.04	1.01 a	10.31
R+	0.91	0.90	0.89	0.91	0.90 b	-2.09
$LSD_{(0.05)}$	ns	ns	ns	ns	0.042	
Soil depth = 20-45 cm						
T1	1.07	1.08	1.07	1.06	1.07 a	…
T2	0.99	0.98	0.98	0.97	0.98 abc	-8.24
T3	1.01	1.00	0.99	0.99	1.00 abc	-6.65
T4	0.96	0.95	0.94	0.94	0.95 bc	-11.43
T5	0.93	0.91	0.90	0.90	0.91 c	-14.99
T6	1.07	1.05	1.03	1.03	1.04 ab	-2.29
$LSD_{(0.05)}$	ns	ns	ns	ns	0.101	
F	0.99	0.98	0.98	0.97	0.98	…
R-	1.01	1.01	1.00	1.01	1.01	2.77
R+	1.02	0.99	0.97	0.97	0.99	0.84
$LSD_{(0.05)}$	ns	ns	ns	ns	ns	

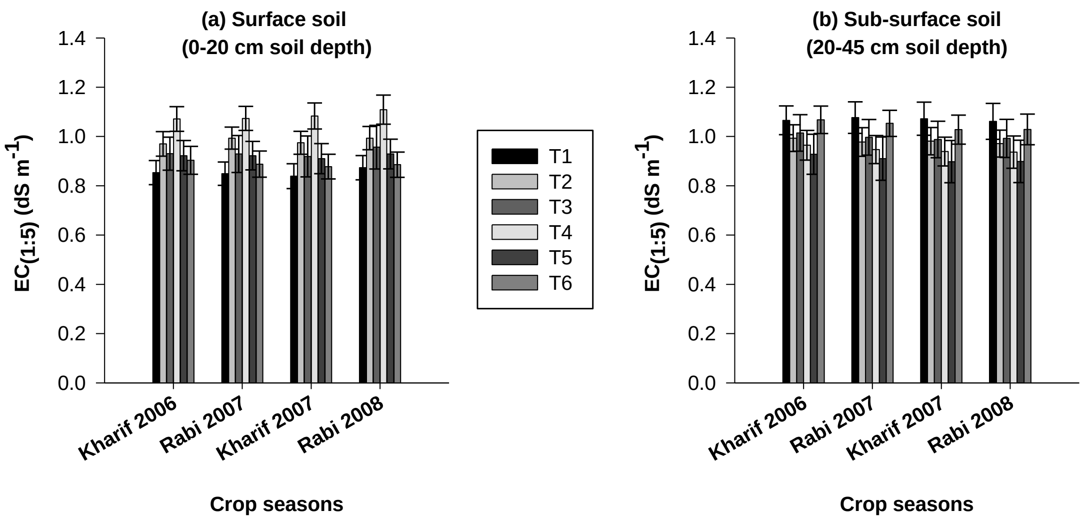

Fig. 3 **Effect of fertilizer treatments on soil $EC_{(1:5)}$ (dS m^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

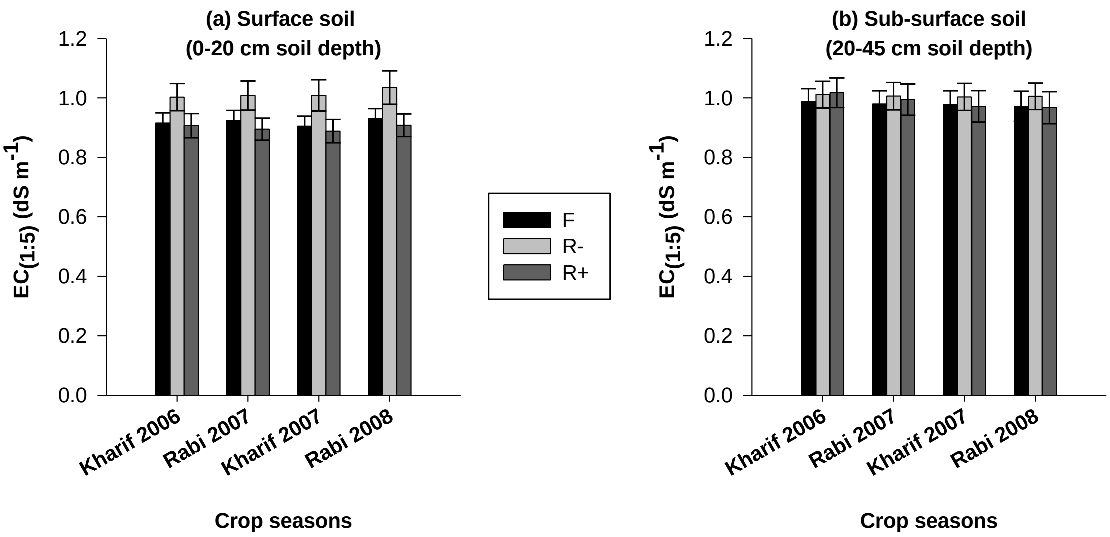

Fig. 4 **Effect of residues management practices on soil $EC_{(1:5)}$ (dS m^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

4.1.1.3. Soil organic matter

Effect of fertilizer treatments on soil organic matter was non-significant ($p>0.05$) both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during Kharif 2006, while during rest of the seasons it was very highly significant ($p<0.001$) (Appendix 21 and 29). Treatment T6 had the highest organic matter (Table 8) followed by T5 at both surface and sub-surface soils during all the seasons except Kharif 2006 (Fig. 5). Analysis of data combined over seasons (Appendix 25 and 30) revealed that highest organic matter was found in T6 followed by T5 at both surface and sub-surface soils. The respective increase in organic matter of T5 and T6 was 8.15% and 17% at surface soil and 3.76 and 12.35% at sub-surface soil

Table 8: Effect of fertilizer treatments and residues management practices on soil organic matter (g kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(g kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	12.56	12.14 c	13.34 c	14.56 c	13.15 c	…
T2	12.32	11.67 c	13.00 c	14.26 c	12.81 de	-2.58
T3	12.17	11.67 c	12.90 c	14.08 c	12.70 e	-3.40
T4	12.39	11.91 c	13.20 c	14.38 c	12.97 cd	-1.37
T5	12.62	13.48 b	14.73 b	16.06 b	14.22 b	8.15
T6	12.61	15.11 a	16.31 a	17.51 a	15.39 a	17.00
$LSD_{(0.05)}$	ns	0.512	0.514	0.492	0.241	
F	11.66 b	10.31 c	11.60 c	12.79 c	11.59 c	…
R-	12.94 a	13.29 b	14.48 b	15.69 b	14.10 b	21.67
R+	12.73 a	14.39 a	15.67 a	16.94 a	14.93 a	28.85
$LSD_{(0.05)}$	0.691	0.595	0.595	0.581	0.236	
Soil depth = 20-45 cm						
T1	12.33	12.38 b	12.84 c	13.00 c	12.64 c	…
T2	12.44	12.51 b	12.81 c	12.83 c	12.65 c	0.09
T3	12.31	12.48 b	12.90 c	12.94 c	12.66 c	0.15
T4	12.33	12.47 b	13.01 c	13.16 c	12.74 c	0.81
T5	11.99	12.59 b	13.59 b	14.29 b	13.11 b	3.76
T6	12.29	13.44 a	14.93 a	16.13 a	14.20 a	12.35
$LSD_{(0.05)}$	ns	0.465	0.497	0.514	0.235	
F	11.56 b	11.72 c	11.94 c	12.13 c	11.83 c	…
R-	12.53 a	12.76 b	13.48 b	13.71 b	13.12 b	10.87
R+	12.76 a	13.46 a	14.62 a	15.34 a	14.05 a	18.68
$LSD_{(0.05)}$	0.265	0.322	0.298	0.326	0.116	

Data in Table 8 shows that residue management practices had very highly significant ($p<0.001$) effect on soil organic matter at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during the four seasons (Appendix 21-29). R+ resulted in highest organic matter followed by R-, while fallow plots had the lowest organic matter. Combined analysis of the data over seasons also showed similar effect on soil organic matter (Fig. 6 and Appendix 25 and 30). The respective increases of R- and R+ over fallow were 21.7% and 28.9% at surface soil and 10.9 and 18.7% at sub-surface soil.

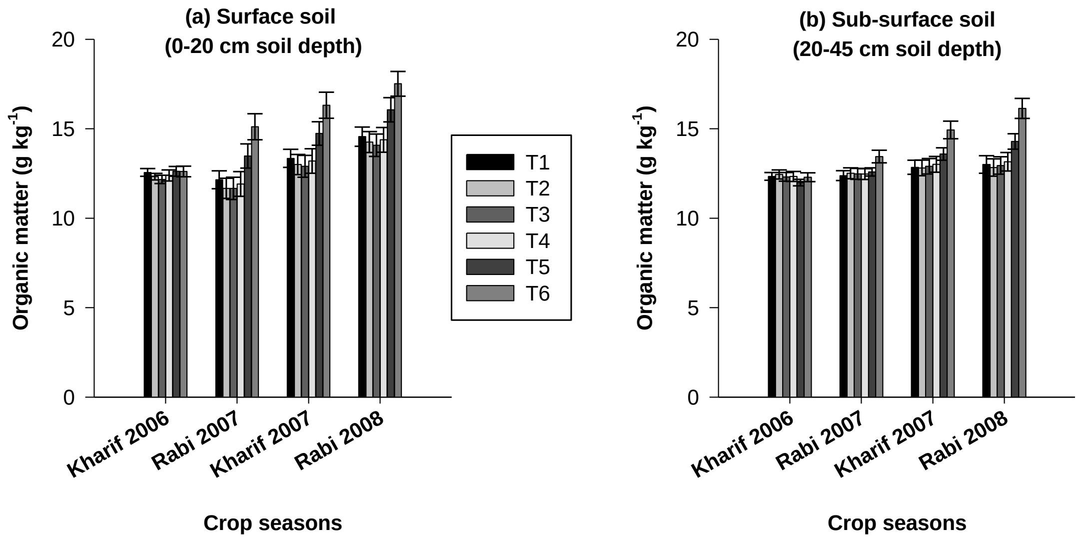

Fig. 5 **Effect of fertilizer treatments on soil organic matter (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

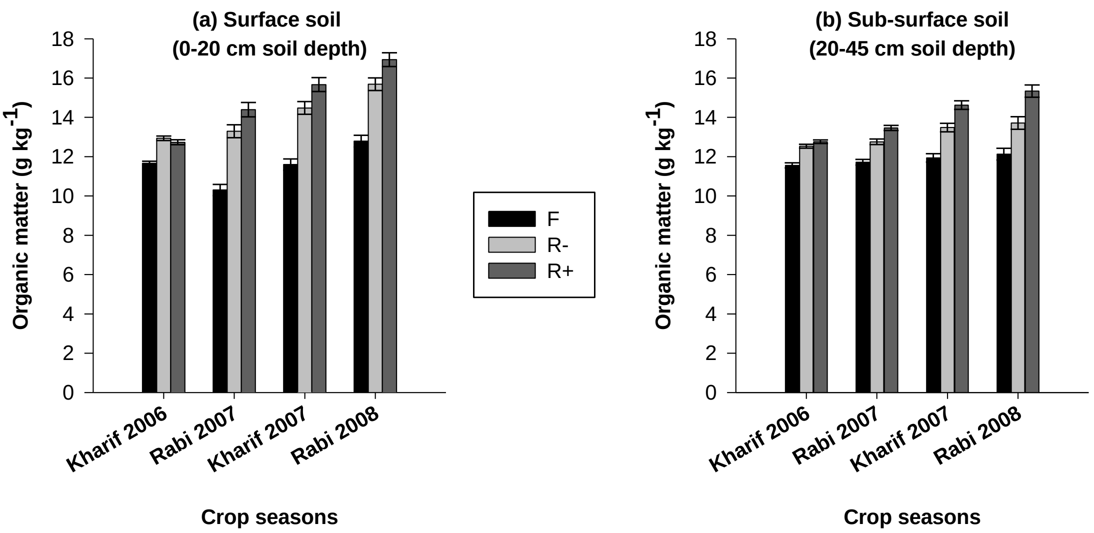

Fig. 6 **Effect of residues management practices on soil organic matter (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

4.1.1.4. AB-DTPA extractable potassium

Effect of fertilizer treatments on extractable potassium was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the seasons except Kharif 2006 (Appendix 31-39). Treatment T6 had the highest potassium followed by T5 which was at par with T4 at both surface and sub-surface soils, while control had the lowest potassium content (Table 9 and Fig. 7). Analysis of data combined over seasons showed that fertilizer treatments had similar effect on AB-DTPA extractable potassium (Appendix 35 and 40). The respective increases in potassium contents of T6, T5 and T4 were 16.0, 10.7 and 10.1% at surface soil and 9.8, 4.9 and 7.8% at sub-surface soil.

Table 9: Effect of fertilizer treatments and residues management practices on AB-DTPA extractable K (mg kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(mg kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	62.60	63.7 b	65.0 b	65.2 c	64.13 c	…
T2	62.60	64.1 b	65.3 b	66.3 c	64.56 c	0.68
T3	62.50	64.2 b	65.4 b	66.6 c	64.68 c	0.87
T4	61.10	70.8 a	72.0 a	78.5 b	70.58 b	10.07
T5	62.00	71.6 a	72.9 a	77.5 b	70.99 b	10.70
T6	61.60	75.2 a	76.5 a	84.3 a	74.39 a	16.01
LSD$_{(0.05)}$	ns	5.06	5.09	5.06	2.400	
F	60.60	65.7	67.00	70.10	65.86 b	…
R-	63.90	68.7	70.00	72.40	68.76 a	4.40
R+	61.60	70.3	71.50	76.80	70.05 a	6.37
LSD$_{(0.05)}$	ns	ns	ns	ns	2.016	
Soil depth = 20-45 cm						
T1	64.10	64.7 ab	66.0 c	67.1 c	65.50 c	…
T2	62.50	63.6 ab	65.9 c	66.7 c	64.71 c	-1.21
T3	60.30	61.7 b	63.6 c	63.4 c	62.23 d	-5.00
T4	62.70	67.8 a	73.3 ab	78.5 b	70.58 ab	7.75
T5	61.30	66.4 a	71.1 b	76.2 b	68.75 b	4.97
T6	60.50	67.5 a	75.6 a	83.9 a	71.89 a	9.77
LSD$_{(0.05)}$	ns	4.23	4.38	4.29	2.025	
F	61.10	64.10	67.40	70.00	65.66 b	…
R-	62.60	64.80	67.60	70.40	66.36 b	1.06
R+	62.00	67.00	72.70	77.50	69.80 a	6.30
LSD$_{(0.05)}$	ns	ns	ns	ns	2.657	

Data in Table 9 shows that residue management practices had non-significant ($p>0.05$) effect on soil potassium at both surface and sub-surface soils (Appendix 31-39) during the four seasons (Fig. 8), while combined analysis of the data over seasons showed significant effect of residues management practices on potassium content at both surface and sub-surface soils (Appendix 35 and 40). The respective increases of R- and R+ over fallow were 4.4 and 6.4% at surface soil and 1.1 and 6.3% at sub-surface soil.

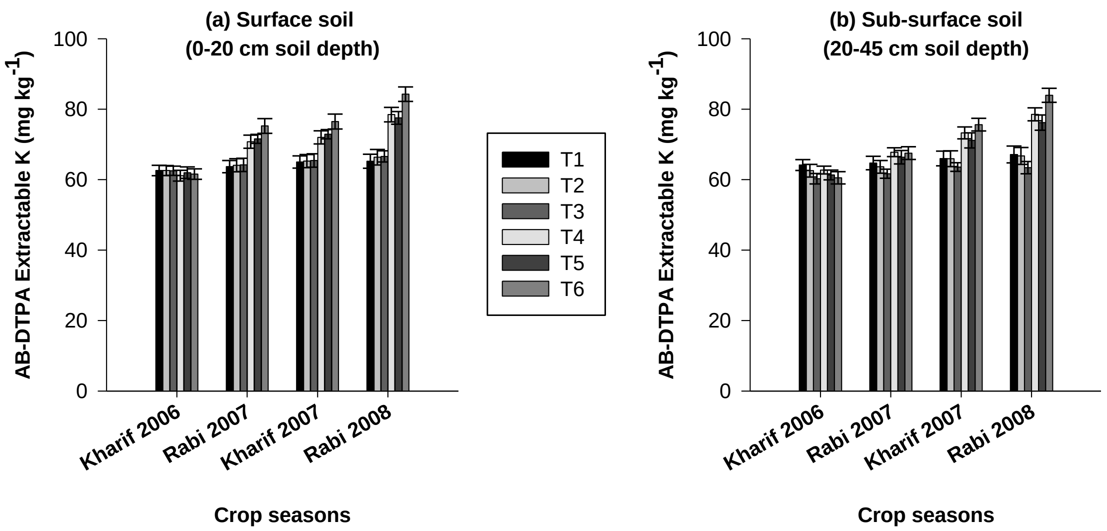

Fig. 7 **Effect of fertilizer treatments on AB-DTPA extractable K (mg kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

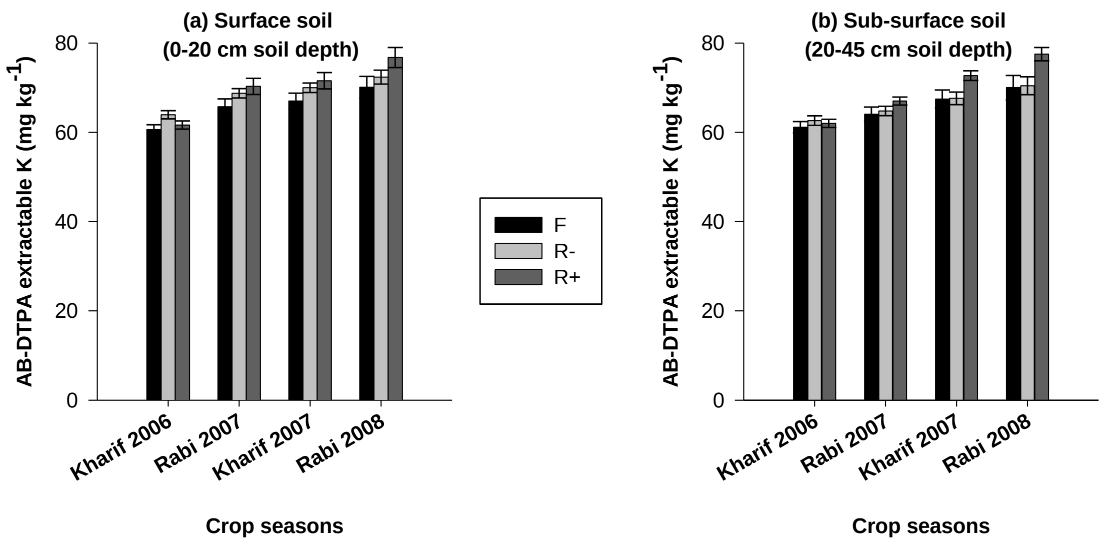

Fig. 8 **Effect of residues management practices on AB-DTPA extractable K (mg kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

4.1.1.5. AB-DTPA extractable phosphorus

Effect of fertilizer treatments on extractable phosphorus was significant at both surface and sub-surface soils during all the season except Kharif 2006 (Appendix 41-49). Treatment T6 had the highest phosphorus followed by T5 and then by T3 and T4, while T1 had the lowest phosphorus at both surface and sub-surface soils (Fig. 9). Analysis of data combined over seasons showed that treatments had similar effect on AB-DTPA extractable phosphorus (Appendix 45 and 50). The respective increases in phosphorus contents of T6, T5, T4 and T3 were 21.8, 18.5, 10.9 and 9.2% at surface soil and 21.9, 19.1, 13.0 and 9.1% at sub-surface soil (Table 10).

Table 10: Effect of fertilizer treatments and residues management practices on AB-DTPA extractable P (mg kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(mg kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	1.36	1.38 c	1.45 d	1.47 d	1.41 e	…
T2	1.43	1.44 bc	1.51 d	1.52 d	1.48 d	4.32
T3	1.35	1.48 b	1.61 c	1.74 c	1.54 c	9.16
T4	1.37	1.50 b	1.63 c	1.77 c	1.57 c	10.90
T5	1.40	1.58 a	1.76 b	1.96 b	1.68 b	18.51
T6	1.34	1.59 a	1.85 a	2.10 a	1.72 a	21.75
$LSD_{(0.05)}$	ns	0.068	0.072	0.080	0.033	
F	1.38	1.48	1.59 b	1.71 b	1.54 b	…
R-	1.38	1.48	1.60 b	1.71 b	1.54 b	0.36
R+	1.36	1.53	1.71 a	1.87 a	1.62 a	4.99
$LSD_{(0.05)}$	ns	ns	0.072	0.069	0.027	
Soil depth = 20-45 cm						
T1	1.36	1.35 c	1.46 c	1.47 d	1.42 e	…
T2	1.35	1.39 bc	1.44 c	1.46 d	1.40 e	-0.12
T3	1.34	1.45 b	1.61 b	1.75 c	1.54 d	9.11
T4	1.42	1.45 b	1.68 b	1.82 c	1.62 c	13.03
T5	1.40	1.53 a	1.79 a	1.98 b	1.69 b	19.05
T6	1.35	1.55 a	1.86 a	2.11 a	1.73 a	21.87
$LSD_{(0.05)}$	ns	0.075	0.077	0.082	0.036	
F	1.35	1.44	1.58 b	1.69 b	1.52 b	…
R-	1.37	1.44	1.60 b	1.71 b	1.54 b	1.02
R+	1.38	1.48	1.74 a	1.90 a	1.64 a	7.21
$LSD_{(0.05)}$	ns	ns	0.035	0.025	0.016	

Residue management practices also had significant effect on soil phosphorus at both surface and sub-surface soils during all the seasons except during Kharif 2006 and Rabi 2007 both at surface soil (0-20 cm soil depth) and sub-surface soil (20-45 cm soil depth) (Appendix 41-49). R+ had the highest AB-DTPA Extractable Phosphorus as compared to R- and fallow plots (Fig. 10). Combined analysis of the data over seasons also showed significant effect of residues management practices on phosphorus content at both surface and sub-surface soils (Appendix 45 and 50). The respective increases of R- and R+ over fallow were 0.4 and 5.0% at surface soil and 1.0 and 7.2% at sub-surface soil (Table 10).

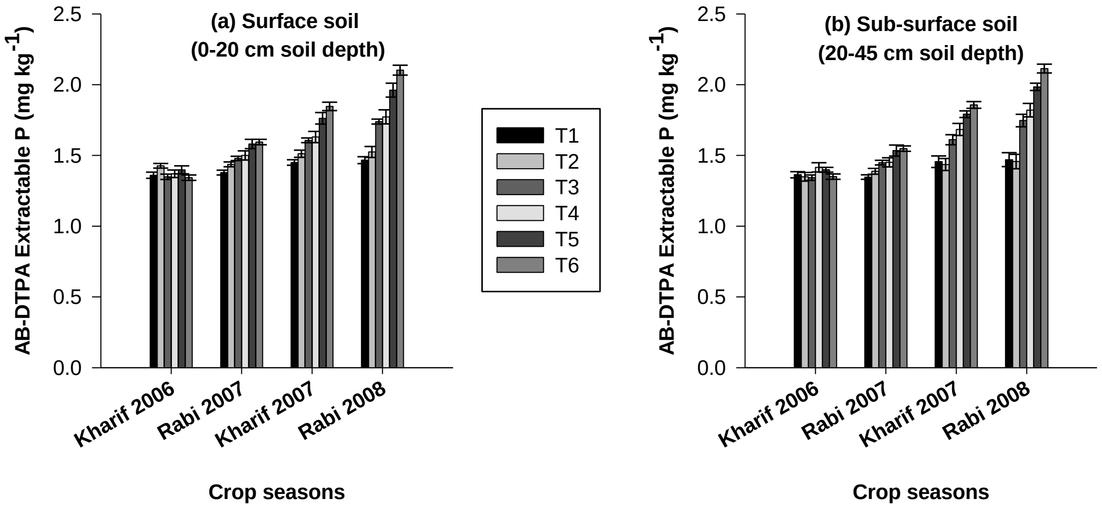

Fig. 9 **Effect of fertilizer treatments on AB-DTPA extractable P at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

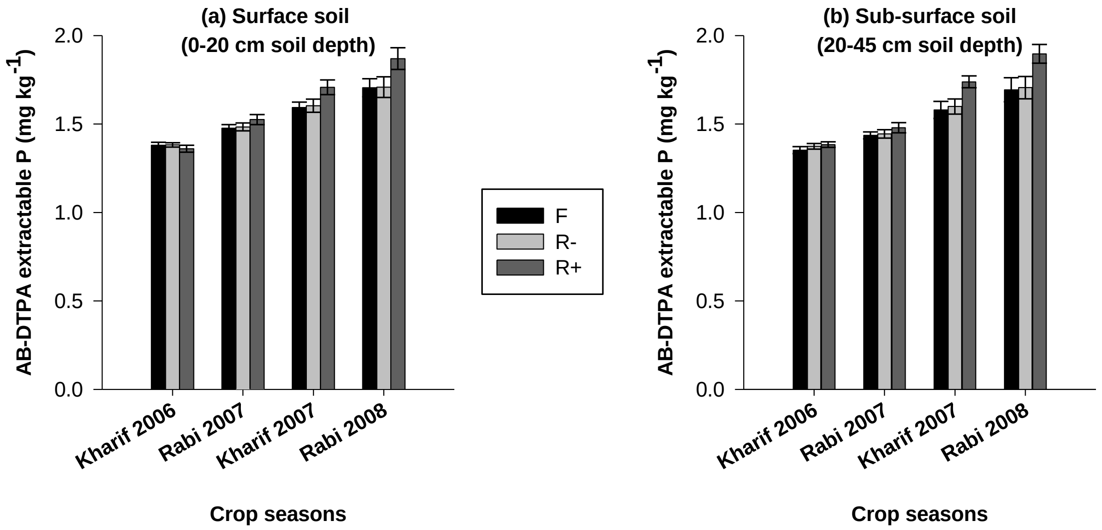

Fig. 10 **Effect of residues management practices on AB-DTPA extractable P (mg kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

4.1.1.6. Mineral nitrogen

Effect of fertilizer treatments on mineral nitrogen was significant at both surface and sub-surface soils during all the seasons except Kharif 2006 (Appendix 51-59). Compared to other treatments treatment T3 had the highest mineral nitrogen followed by T5 at both surface and sub-surface soils (Fig. 11). Analysis of data combined over seasons showed that treatments had the same effect on mineral nitrogen (Appendix 55 and 60). The respective increases in mineral nitrogen of T3, T4 and T5 over control were 12.7, 8.7 and 9.7% at surface soil and 14.4, 10.5 and 16.6% at sub-surface soil (Table 11).

Table 11: Effect of fertilizer treatments and residues management practices on soil mineral N (μg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(μg g^{-1} soil)………………………………					
Soil depth = 0-20 cm						
T1	13.9	13.9 bc	14.1 b	14.2 b	14.0 c	…
T2	13.1	14.4 ab	16.0 a	17.5 a	15.3 b	8.84
T3	13.6	15.0 a	16.5 a	18.1 a	15.8 a	12.71
T4	13.1	14.4 ab	16.0 a	17.5 a	15.2 b	8.70
T5	13.2	14.6 ab	16.1 a	17.6 a	15.4 ab	9.67
T6	12.6	13.2 c	14.1 b	15.0 b	13.7 c	-2.02
$LSD_{(0.05)}$	ns	1.09	1.12	1.20	0.54	
F	13.0	14.0	15.0	16.0 b	14.5 c	…
R-	13.4	14.4	15.4	16.3 b	14.9 b	2.80
R+	13.3	14.3	16.0	17.7 a	15.3 a	5.80
$LSD_{(0.05)}$	ns	ns	ns	0.95	0.40	
Soil depth = 20-45 cm						
T1	13.7	13.7 d	13.6 d	13.9 e	13.7 d	…
T2	13.0	14.3 cd	15.6 b	17.0 c	15.0 b	9.09
T3	13.6	15.0 ab	16.3 ab	17.8 ab	15.7 a	14.36
T4	13.1	14.4 bc	15.8 b	17.3 bc	15.2 b	10.51
T5	13.9	15.3 a	16.6 a	18.1 a	16.0 a	16.55
T6	13.0	13.8 cd	14.4 c	15.3 d	14.1 c	2.97
$LSD_{(0.05)}$	ns	0.73	0.72	0.73	0.36	
F	13.5	14.6	15.6	16.5	15.1 a	…
R-	13.3	14.3	15.2	16.2	14.7 b	-2.11
R+	13.3	14.3	15.3	17.0	15.0 ab	-0.44
$LSD_{(0.05)}$	ns	ns	ns	ns	0.26	

Effect of residue management practices on soil mineral nitrogen at both surface and sub-surface soils was non-significant during all the seasons except during Rabi 2008 at surface soil (0-20 cm soil depth) which was statistically significant ($p<0.05$) (Appendix 51-59) and R+ had the highest mineral nitrogen as compared to R- and fallow plots (Fig. 12). Combined analysis of the data over seasons also showed significant effect of residues management practices on mineral nitrogen at both surface and sub-surface soils (Appendix 55 and 60). The respective increases in soil mineral nitrogen of R- and R+ over fallow were 2.8 and 5.8% at surface soil, while at sub-surface soil there was decrease of 2.1 and 0.4% in R- and R+ respectively (Table 11).

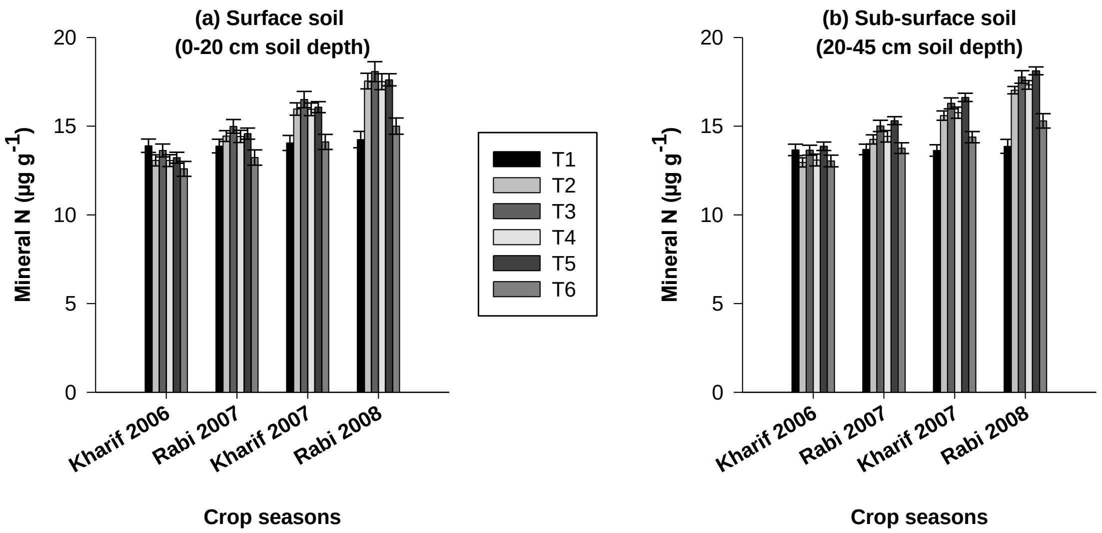

Fig. 11 **Effect of fertilizer treatments on soil mineral N (µg g^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

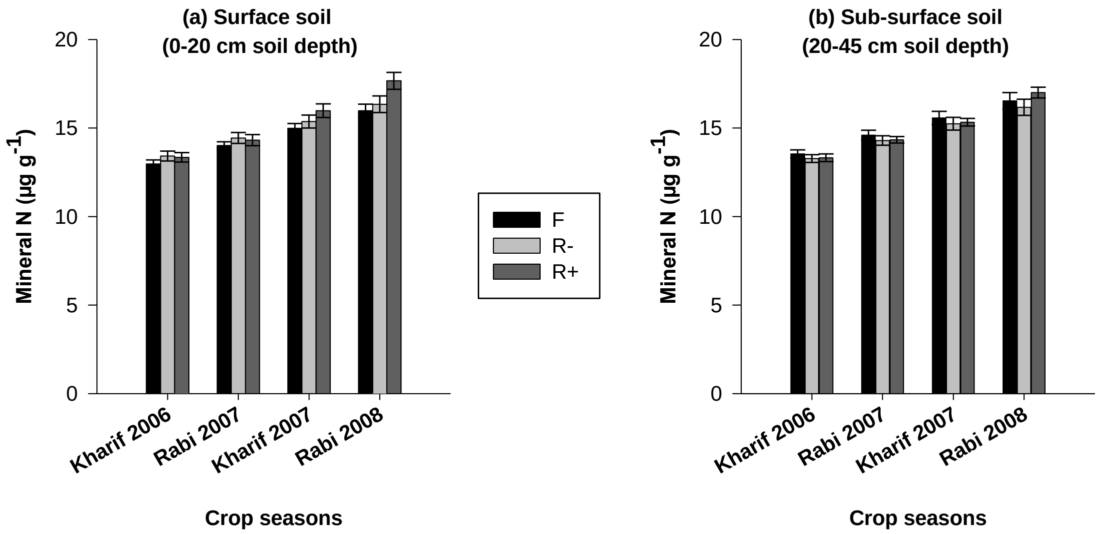

Fig. 12 **Effect of residues management practices on soil mineral N (µg g^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

4.1.1.7. Soil bulk density

Effect of fertilizer treatments on soil bulk density was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the season except during Kharif 2006 (Appendix 61-69). Treatment T6 had the lowest bulk density followed by T5 at both surface and sub-surface soils, while control plots had the highest soil bulk density (Fig. 13). Analysis of the data combined over seasons showed that treatments had the same effect on soil bulk density (Appendix 65 and 70). The respective decreases in bulk density of T6 and T5 over control were 5.2 and 2.9% at surface soil and 5.1and 1.5% at sub-surface soil (Table 12).

Table 12: Effect of fertilizer treatments and residues management practices on soil bulk density (Mg m^{-3}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(Mg m^{-3})………………………………					
Soil depth = 0-20 cm						
T1	1.40	1.38 a	1.34 a	1.32 a	1.36 a	…
T2	1.38	1.37 a	1.33 a	1.31 a	1.35 a	-0.74
T3	1.38	1.37 a	1.33 a	1.31 a	1.35 a	-0.74
T4	1.39	1.37 a	1.34 a	1.32 a	1.35 a	-0.74
T5	1.38	1.35 ab	1.29 b	1.26 b	1.32 b	-2.94
T6	1.37	1.32 b	1.26 c	1.21 c	1.29 c	-5.15
$LSD_{(0.05)}$	ns	0.033	0.034	0.042	0.015	
F	1.38	1.37 a	1.34 a	1.33 a	1.35 a	…
R-	1.39	1.37 a	1.32 a	1.29 b	1.34 a	-0.74
R+	1.38	1.34 b	1.28 b	1.24 c	1.31 b	-2.96
$LSD_{(0.05)}$	ns	0.029	0.025	0.026	0.011	
Soil depth = 20-45 cm						
T1	1.39	1.39 a	1.37 a	1.36 a	1.38 a	…
T2	1.39	1.38 a	1.35 a	1.34 ab	1.36 ab	-1.45
T3	1.37	1.36 ab	1.34 a	1.33 ab	1.35 b	-2.17
T4	1.37	1.36 ab	1.34 a	1.34 ab	1.35 b	-2.17
T5	1.40	1.38 a	1.34 a	1.31 b	1.36 b	-1.45
T6	1.38	1.34 b	1.29 b	1.25 c	1.31 c	-5.07
$LSD_{(0.05)}$	ns	0.032	0.033	0.036	0.015	
F	1.38	1.37	1.35 a	1.34 a	1.36 a	…
R-	1.39	1.37	1.34 a	1.33 a	1.36 a	0.00
R+	1.38	1.36	1.32 b	1.30 b	1.34 b	-1.47
$LSD_{(0.05)}$	ns	ns	0.019	0.012	0.007	

Residue management practices had also significant effect on soil bulk density at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during the four seasons except during Kharif 2006 at surface soil (0-20 cm soil depth) and during Kharif 2006 and Rabi 2007 at sub-surface soil (20-45 cm soil depth) (Appendix 61-69). R+ resulted in lowest bulk density, followed by R-, while fallow plots had the highest bulk density (Fig. 14). Combined analysis of the data over seasons showed significant effect of residues management practices on bulk density at both surface and sub-surface soils (Appendix 65 and 70). R+ decreased soil bulk density by 3.0% at surface and 1.5% at sub-surface soil (Table 12).

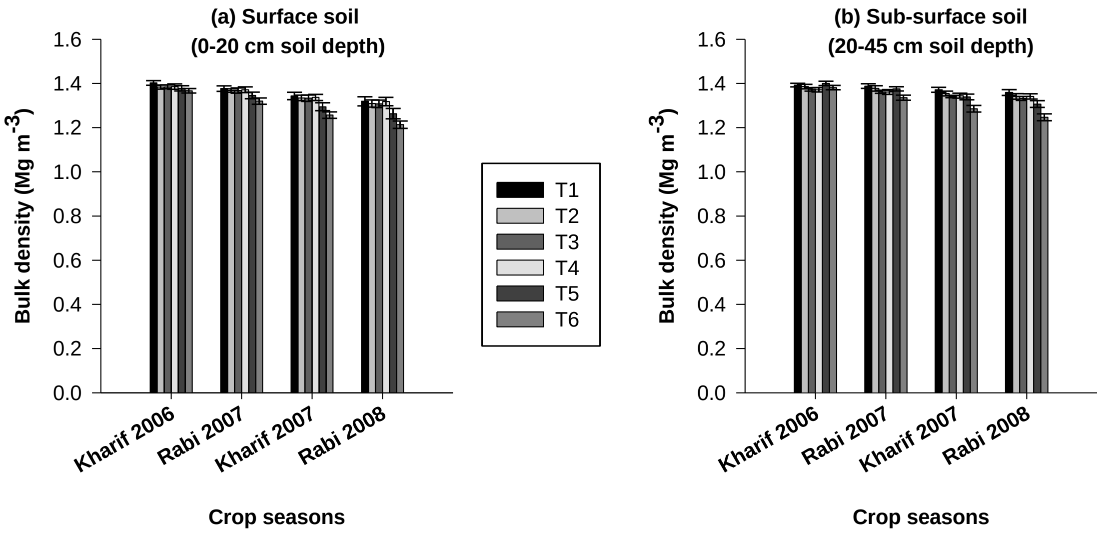

Fig. 13 **Effect of fertilizer treatments on soil bulk density (Mg m^{-3}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

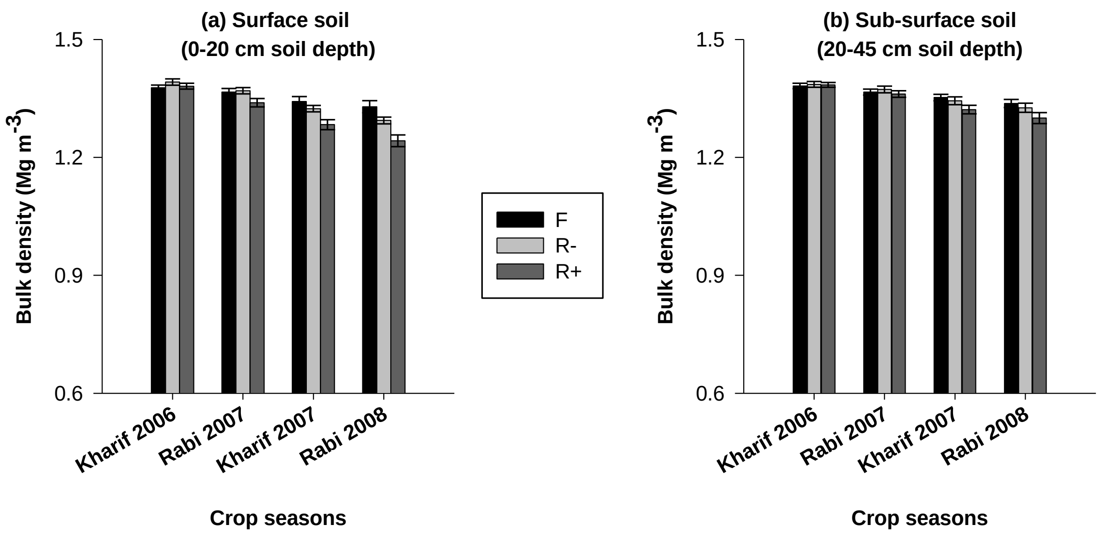

Fig. 14 **Effect of residues management practices on soil bulk density (Mg m^{-3}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

4.1.1.8. Available water holding capacity

Effect of fertilizer treatments on available water holding capacity was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the seasons except during Kharif 2006 (Appendix 71-79). Treatment T6 had the highest organic matter followed by T5 (Fig. 15). Analysis of data combined over seasons showed that treatments had similar effect on AWHC (Appendix 75 and 80). The respective increases in AWHC of T5 and T6 over control were 3.0 and 5.8% at surface soil and 1.7 and 5.4% at sub-surface soil (Table 13).

Table 13: Effect of fertilizer treatments and residues management practices on soil AWHC (g kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(g kg^{-1})……………………………….					
Soil depth = 0-20 cm						
T1	176.9	179.9 b	185.0 c	188.6 c	182.6 c	…
T2	179.6	181.5 b	185.4 c	190.3 bc	184.2 c	0.88
T3	178.9	181.3 b	186.1 c	190.2 bc	184.1 c	0.82
T4	179.0	181.0 b	185.4 c	189.1 c	183.6 c	0.55
T5	180.0	184.3 ab	191.6 b	196.6 b	188.1 b	3.01
T6	181.6	188.0 a	198.2 a	204.8 a	193.2 a	5.81
$LSD_{(0.05)}$	ns	4.613	5.31	6.59	2.53	
F	180.2	181.9 ab	184.7 c	187.6 c	183.6 b	…
R-	178.4	180.8 b	187.7 b	191.9 b	184.7 b	0.60
R+	179.5	185.4 a	193.5 a	200.3 a	189.7 a	3.32
$LSD_{(0.05)}$	ns	3.56	2.73	4.17	1.25	
Soil depth = 20-45 cm						
T1	177.9	178.2 c	180.9 b	182.4 c	179.9 c	…
T2	179.1	179.9 bc	183.2 b	185.1 bc	181.8 bc	1.06
T3	180.5	182.4 abc	184.9 b	186.3 bc	183.5 b	2.00
T4	180.6	182.6 ab	184.8 b	185.1 bc	183.3 b	1.89
T5	177.2	180.1 bc	185.0 b	189.7 b	183.0 b	1.72
T6	180.2	185.8 a	192.9 a	199.5 a	189.6 a	5.39
$LSD_{(0.05)}$	ns	4.31	4.85	5.61	2.25	
F	179.6	181.6 ab	183.3 b	185.7 c	182.6 b	…
R-	178.7	180.5 b	184.9 ab	187.1 b	182.8 b	0.11
R+	179.4	182.4 a	187.6 a	191.3 a	185.2 a	1.42
$LSD_{(0.05)}$	ns	1.833	2.81	1.432	0.49	

Residue management practices had also significant effect on available water holding capacity at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the seasons except during Kharif 2006 (Appendix 71-79). R+ resulted in highest available water holding capacity followed by R-, while fallow plots had the lowest available water holding capacity (Fig. 16). Combined analysis of data over seasons showed that residues management practices had similar effect on AWHC at both surface and sub-surface soils (Appendix 75 and 80). R+ increased AWHC by 3.3% at surface and 1.4% at sub-surface soil (Table 13).

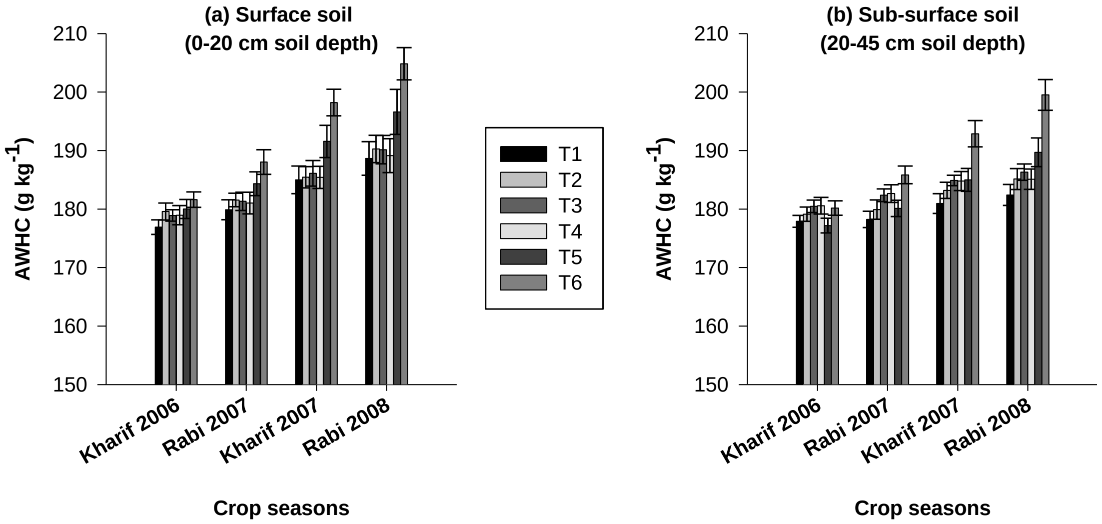

Fig. 15 Effect of fertilizer treatments on soil AWHC (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

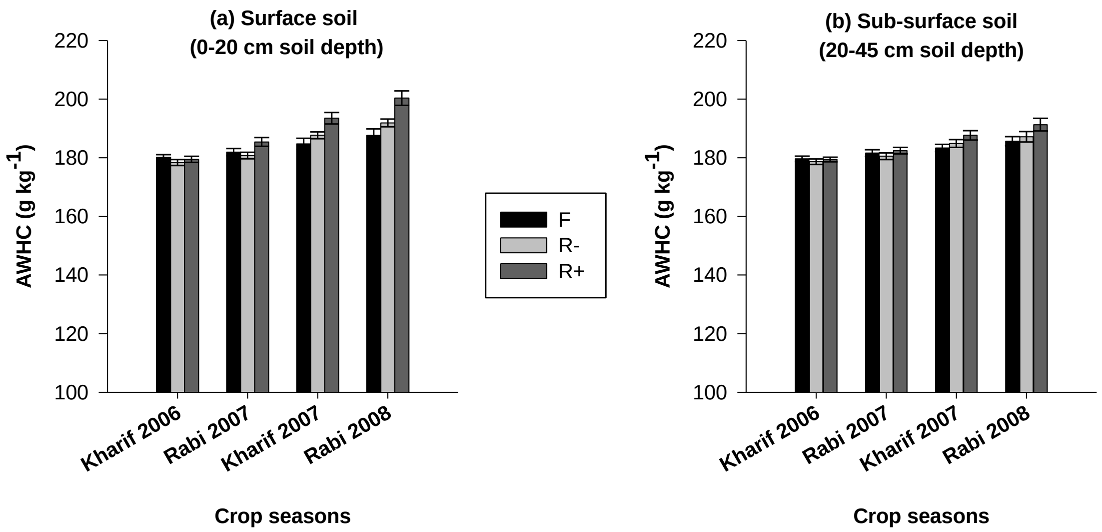

Fig. 16 Effect of residues management practices on soil AWHC (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

4.1.1.9. Total nitrogen

Effect of fertilizer treatments on soil total nitrogen was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the seasons except during Kharif 2006 (Appendix 81-89). Treatment T6 had the highest total nitrogen followed by T5 (Fig. 17). Analysis of the data combined over seasons showed that treatments had similar effect on total nitrogen (Appendix 85 and 90). The respective increases in total nitrogen of T5 and T6 over control were 8.2 and 17.0% at surface soil and 2.9 and 9.9% at sub-surface soil (Table 14).

Table 14: Effect of fertilizer treatments and residues management practices on soil total N (g kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(g kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	0.733	0.712 cd	0.780 c	0.855 c	0.770 c	…
T2	0.739	0.704 cd	0.749 c	0.840 c	0.758 cd	-1.56
T3	0.725	0.686 d	0.760 c	0.827 c	0.750 d	-2.60
T4	0.725	0.719 c	0.789 c	0.841 c	0.768 c	-0.26
T5	0.748	0.774 b	0.873 b	0.936 b	0.833 b	8.18
T6	0.744	0.890 a	0.957 a	1.013 a	0.901 a	17.01
$LSD_{(0.05)}$	ns	0.0304	0.0527	0.0431	0.0148	
F	0.699 b	0.614 c	0.691 c	0.753 c	0.689 c	…
R-	0.759 a	0.781 b	0.848 b	0.917 b	0.826 b	19.88
R+	0.750 a	0.847 a	0.915 a	0.985 a	0.874 a	26.85
$LSD_{(0.05)}$	0.0414	0.0414	0.0293	0.0414	0.0158	
Soil depth = 20-45 cm						
T1	0.730	0.726 b	0.776 bc	0.766 c	0.749 c	…
T2	0.721	0.742 b	0.744 c	0.753 c	0.740 c	-1.20
T3	0.718	0.728 b	0.761 bc	0.761 c	0.742 c	-0.93
T4	0.737	0.737 b	0.756 c	0.781 c	0.753 c	0.53
T5	0.705	0.746 b	0.801 b	0.831 b	0.771 b	2.94
T6	0.712	0.784 a	0.874 a	0.921 a	0.823 a	9.88
$LSD_{(0.05)}$	ns	0.0304	0.0431	0.0319	0.0147	
F	0.686 c	0.691 c	0.704 c	0.713 c	0.699 c	…
R-	0.727 b	0.751 b	0.794 b	0.796 b	0.767 b	9.73
R+	0.749 a	0.789 a	0.858 a	0.897 a	0.823 a	17.74
$LSD_{(0.05)}$	0.0174	0.0293	0.0292	0.0105	0.0112	

Residue management practices had significant effect on soil total nitrogen at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the four seasons (Appendix 81-89). R+ resulted in highest soil total nitrogen followed by R-, while fallow plots had the lowest soil total nitrogen (Fig. 18). Combined analysis of the data over seasons showed that residues management practices had similar effect on total nitrogen both at surface and sub-surface soils (Appendix 85 and 90). The respective increases in total nitrogen of R- and R+ over fallow were 19.9 and 26.9% at surface soil and 9.7 and 17.7% at sub-surface soil (Table 14).

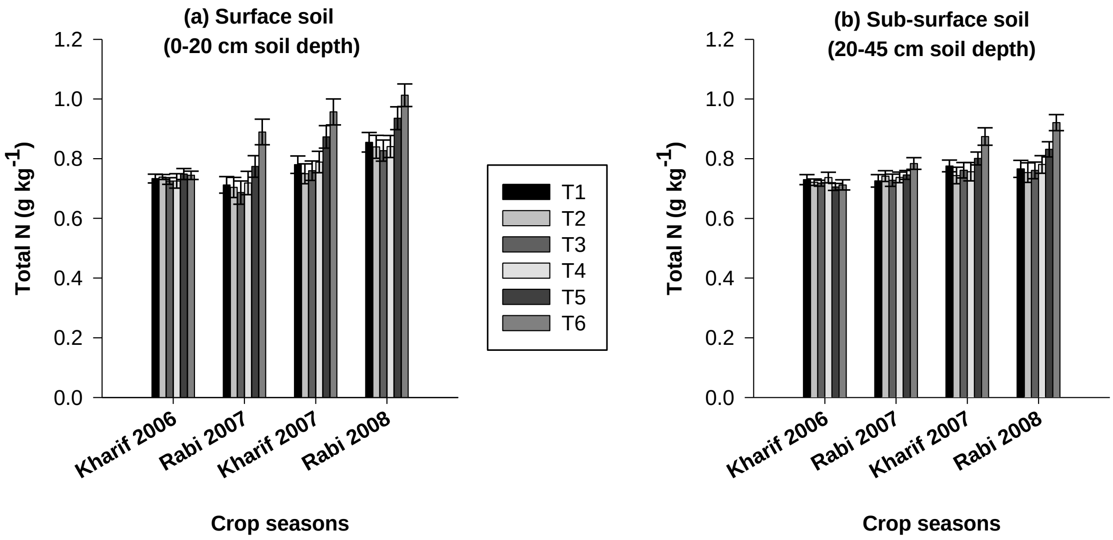

Fig. 17 **Effect of fertilizer treatments on soil total N (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

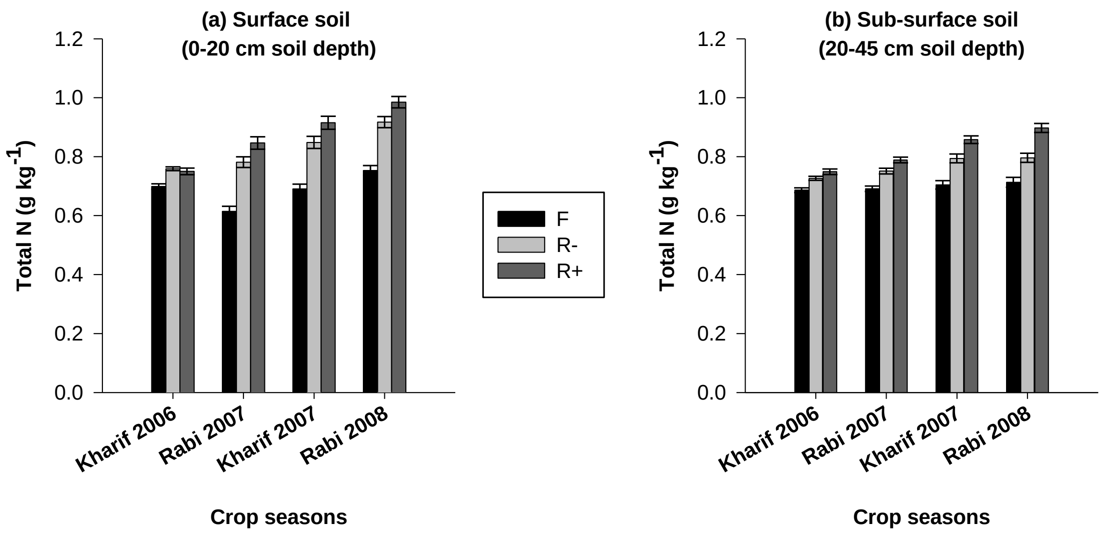

Fig. 18 **Effect of residues management practices on soil total N (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba over seasons**

4.1.1.10. Soil biological properties

4.1.1.10.1. Soil respiration

Data in Table 15 shows that effect of fertilizer treatments on cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 91-98). Treatment T6 had the highest soil respiration followed by T5 (Fig. 19).

Table 15: Effect of fertilizer treatments and residues management practices on cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba

Treatment	2 Days	5 Days	10 Days	15 Days
	……………………..……($\mu g\ CO_2\ g^{-1}$)………………………………			
Soil depth = 0-20 cm				
T1	126.3 f	242.2 f	345.8 f	384.4 f
T2	141.2 e	261.4 e	360.6 e	409.8 e
T3	156.5 d	283.8 d	396.5 d	431.3 d
T4	174.0 c	310.1 c	410.5 c	458.6 c
T5	194.4 b	328.4 b	442.1 b	486.9 b
T6	209.8 a	350.9 a	468.6 a	515.0 a
$LSD_{(0.05)}$	5.39	8.72	9.04	9.53
F	143.7 c	255.1 c	363.0 c	405.6 c
R-	164.2 b	295.7 b	408.4 b	449.9 b
R+	193.2 a	337.6 a	440.7 a	487.4 a
$LSD_{(0.05)}$	11.31	9.39	11.48	12.45
Soil depth = 20-45 cm				
T1	101.0 f	219.2 f	321.4 f	357.4 f
T2	117.9 e	241.0 e	349.4 e	385.1 e
T3	135.2 d	263.5 d	374.6 d	411.2 d
T4	152.1 c	290.8 c	392.5 c	434.4 c
T5	172.3 b	301.9 b	415.8 b	459.1 b
T6	187.5 a	329.9 a	446.0 a	485.9 a
$LSD_{(0.05)}$	8.15	8.36	10.95	9.84
F	118.0 c	236.1 c	344.8 c	383.4 c
R-	144.4 b	274.4 b	384.9 b	419.1 b
R+	170.6 a	312.7 a	420.2 a	464.0 a
$LSD_{(0.05)}$	6.29	5.58	4.45	8.04

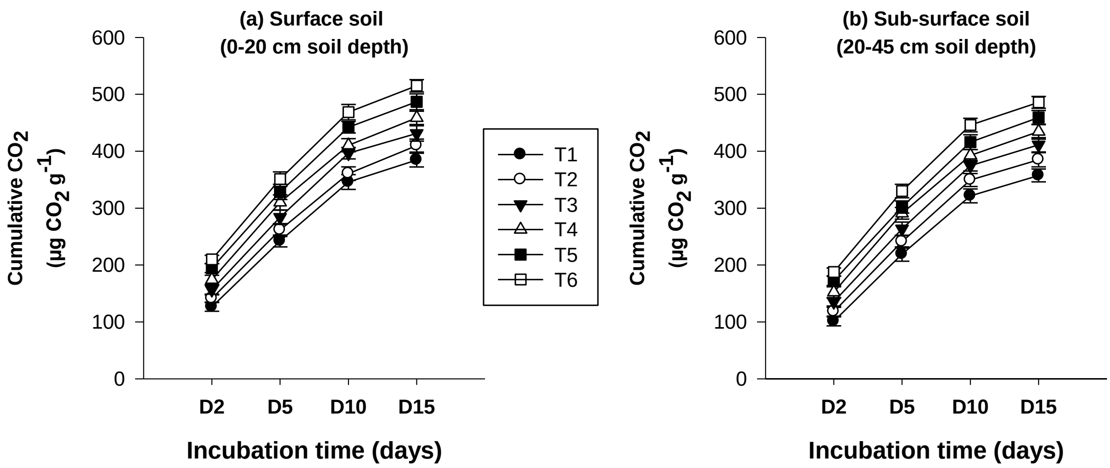

Fig. 19 Effect of fertilizer treatments on cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba

Residue management practices had also significant effect on cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 91-98). R+ resulted in highest soil respiration followed by R-, while fallow plots had the lowest soil respiration (Table 15 and Fig. 20).

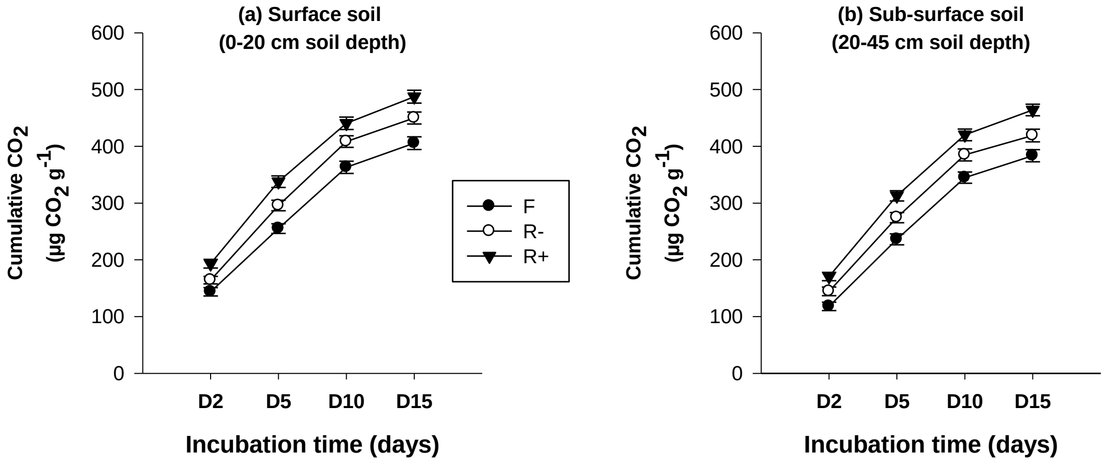

Fig. 20 Effect of residues management practices on cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Guljaba

4.1.1.10.2. Microbial biomass carbon

Effect of fertilizer treatments on microbial biomass carbon was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 99 and 100). Treatment T6 had the highest microbial biomass carbon followed by T5 (Table 16 and Fig. 21a).

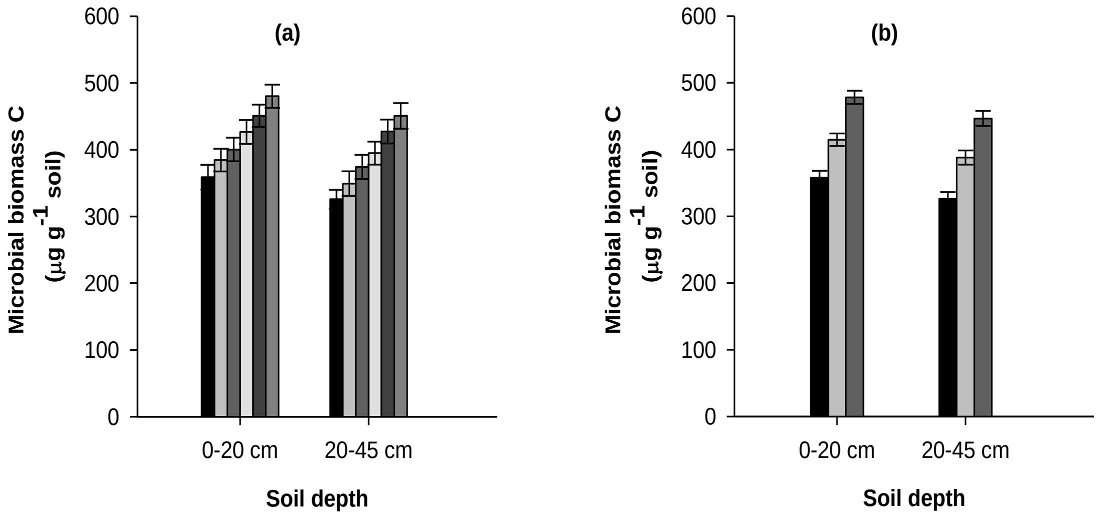

Fig. 21 Effect of (a) fertilizer treatments and (b) residues management practices on microbial biomass C at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba

Residue management practices had significant effect on microbial biomass carbon at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 99 and 100). R+ resulted in highest microbial biomass carbon followed by R-, while fallow plots had the lowest microbial biomass carbon (Table 16 and Fig. 21b).

Table 16: Effect of fertilizer treatments and residues management practices on microbial biomass C and N and mineralizable C and N at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba

Treatment	MBC	MBN	Cmin	Nmin
	………………………..……($\mu g\ g^{-1}$)………………………………			
Soil depth = 0-20 cm				
T1	358.8 f	11.7 f	94.3 f	16.1 f
T2	384.5 e	15.4 e	98.3 e	19.3 e
T3	400.3 d	19.2 d	108.1 d	22.8 d
T4	426.5 c	23.9 c	111.9 c	26.5 c
T5	450.8 b	27.0 b	120.6 b	30.3 b
T6	480.2 a	30.9 a	127.8 a	33.9 a
$LSD_{(0.05)}$	7.51	0.75	2.46	0.82
F	357.7 c	17.3 c	99.0 c	21.4 c
R-	414.6 b	21.2 b	111.4 b	24.9 b
R+	478.2 a	25.5 a	120.2 a	28.3 a
$LSD_{(0.05)}$	6.70	0.68	3.13	0.95
Soil depth = 20-45 cm				
T1	325.7 f	8.8 f	87.7 f	14.1 f
T2	349.2 e	13.5 e	95.3 e	17.4 e
T3	374.2 d	17.2 d	102.2 d	21.0 d
T4	394.9 c	21.2 c	107.0 c	24.8 c
T5	427.4 b	25.4 b	113.4 b	27.7 b
T6	450.7 a	29.7 a	121.6 a	31.6 a
$LSD_{(0.05)}$	7.98	0.68	2.99	0.75
F	326.4 c	15.3 c	94.0 c	19.2 c
R-	388.1 b	19.4 b	105.0 b	23.0 b
R+	446.6 a	23.1 a	114.6 a	26.0 a
$LSD_{(0.05)}$	2.89	1.08	1.21	1.22

MBC = Microbial biomass C ($\mu g\ g^{-1}$ soil), MBN = Microbial biomass N ($\mu g\ g^{-1}$ soil), C_{min} = mineralizable C ($\mu g\ C\ g^{-1}$ soil), and N_{min} = mineralizable N ($\mu g\ N\ g^{-1}$ soil)

4.1.1.10.3. Microbial biomass nitrogen

Effect of fertilizer treatments on microbial biomass nitrogen was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 101 and 102). Treatment T6 had the highest microbial biomass nitrogen followed by T5 (Table 16 and Fig. 22a).

Residue management practices had significant effect on microbial biomass nitrogen at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 101 and 102). R+ resulted in highest microbial biomass nitrogen followed by R-, while fallow plots had the lowest microbial biomass nitrogen (Table 16 and Fig. 22b).

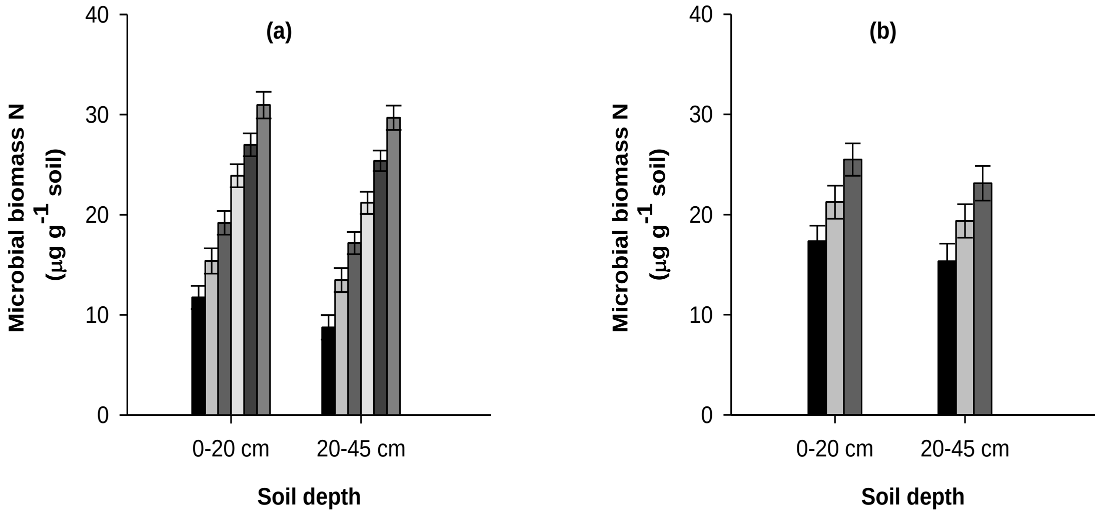

Fig. 22 Effect of (a) fertilizer treatments and (b) residues management practices on microbial biomass N at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba

4.1.1.10.4. Mineralizable C

Effect of fertilizer treatments on Mineralizable C was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 103 and 104). Treatment T6 had the highest Mineralizable C followed by T5 (Table 16 and Fig. 23a).

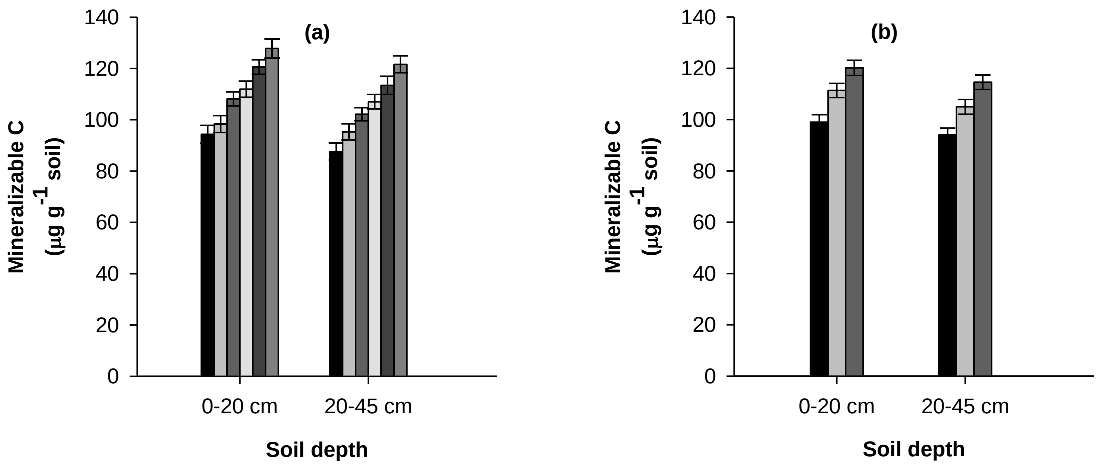

Fig. 23 Effect of (a) fertilizer treatments and (b) residues management practices on mineralizable C at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba

Residue management practices had significant effect on Mineralizable C at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 103 and 104). R+ resulted in highest Mineralizable C followed by R-, while fallow plots had the lowest Mineralizable C (Table 16 and Fig. 23b).

4.1.1.10.5. Mineralizable N

Effect of fertilizer treatments on Mineralizable N was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 105 and 106). Treatment T6 had the highest Mineralizable N followed by T5 (Table 16 and Fig. 24a).

Residue management practices had significant effect on Mineralizable N at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 105 and 106). R+ resulted in highest Mineralizable N followed by R-, while fallow plots had the lowest Mineralizable N (Table 16 and Fig. 24b).

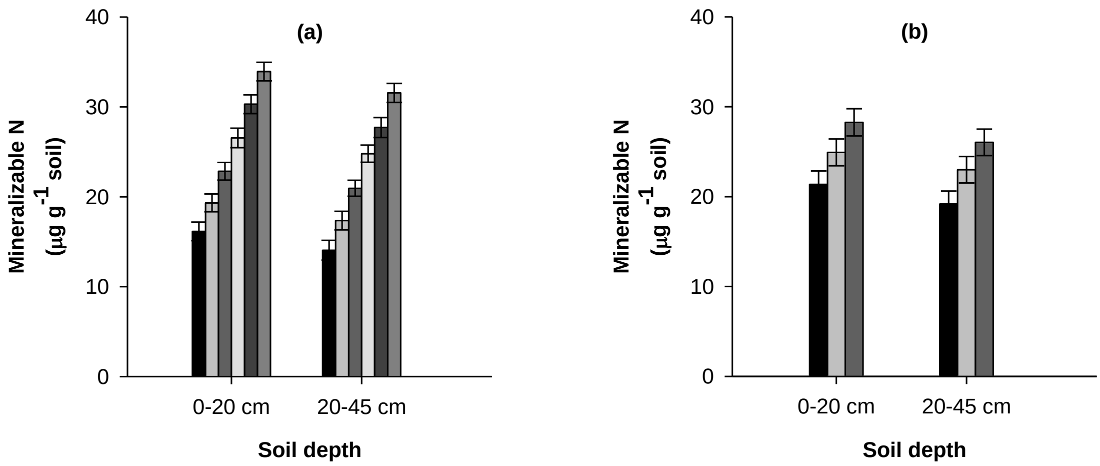

Fig. 24 Effect of (a) fertilizer treatments and (b) residues management practices on mineralizable N at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Guljaba

4.1.2. Gado (moderately eroded soil)

4.1.2.1. Soil pH

Data in Table- show that effect of fertilizer treatments on soil pH both at surface soil (0-20 cm soil depth) and sub-surface soil (20-45 cm soil depth) was statistically significant only during Kharif 2007 and Rabi 2008, while non-significant ($p>0.05$) during the rest of the seasons (Appendix 107-115). During Kharif 2007 and Rabi 2008 control plots had the highest soil pH, while T6 had the lowest soil pH (Fig. 25). Combined analysis of the data over seasons showed that treatments effect was significant both at surface and sub-surface soils (Appendix 111 and 116). T6 had the lowest soil followed by T5. T6 decreased soil pH by 1.6% at surface and 0.7% at surface soil (Table 17).

Table 17: Effect of fertilizer treatments and residues management practices on soil pH at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
Soil depth = 0-20 cm						
T1	7.66	7.64	7.62 ab	7.64 a	7.64 a	…
T2	7.63	7.63	7.62 ab	7.60 ab	7.62 ab	-0.25
T3	7.64	7.63	7.61 ab	7.60 ab	7.62 ab	-0.27
T4	7.65	7.67	7.65 a	7.65 a	7.65 a	0.18
T5	7.66	7.59	7.57 b	7.53 b	7.59 b	-0.69
T6	7.65	7.57	7.46 c	7.39 c	7.52 c	-1.60
$LSD_{(0.05)}$	ns	ns	0.081	0.096	0.039	
F	7.66	7.64	7.63	7.62	7.64 a	…
R-	7.65	7.63	7.60	7.59	7.62 a	-0.26
R+	7.65	7.60	7.54	7.49	7.57 b	-0.89
$LSD_{(0.05)}$	ns	ns	ns	ns	0.043	
Soil depth = 20-45 cm						
T1	7.59	7.59	7.52 cd	7.51 bc	7.56 c	…
T2	7.64	7.64	7.59 abc	7.58 abc	7.61 ab	0.65
T3	7.65	7.65	7.62 ab	7.60 ab	7.63 a	0.94
T4	7.67	7.67	7.63 a	7.64 a	7.64 a	1.10
T5	7.66	7.66	7.54 bc	7.49 c	7.57 bc	0.15
T6	7.65	7.65	7.44 d	7.34 d	7.51 d	-0.68
$LSD_{(0.05)}$	ns	ns	0.089	0.094	0.039	
F	7.66	7.66	7.61	7.59	7.62 a	…
R-	7.62	7.62	7.52	7.52	7.57 b	-0.76
R+	7.66	7.66	7.55	7.47	7.57 b	-0.71
$LSD_{(0.05)}$	ns	ns	ns	ns	0.029	

Effect of management practices on soil pH at both surface soil (0-20 cm soil depth) and sub-surface soil (20-45 cm soil depth) was statistically non-significant ($p>0.05$) during all the seasons (Fig. 26) (Appendix 107-115). Combined analysis of soil pH over seasons showed that residues management practices effect was significant both at surface and sub-surface soils (Appendix 111 and 116). R+ had the lowest soil pH, followed by T5. R+ decreased soil pH by 0.9% at surface and 0.7% at sub-surface soil (Table 17).

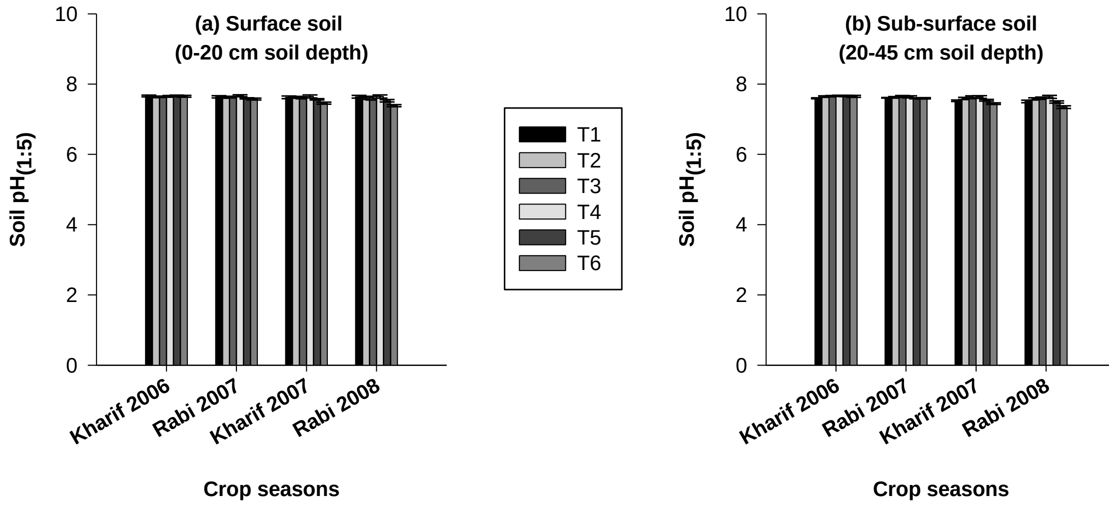

Fig. 25 **Effect of fertilizer treatments on soil pH at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons**

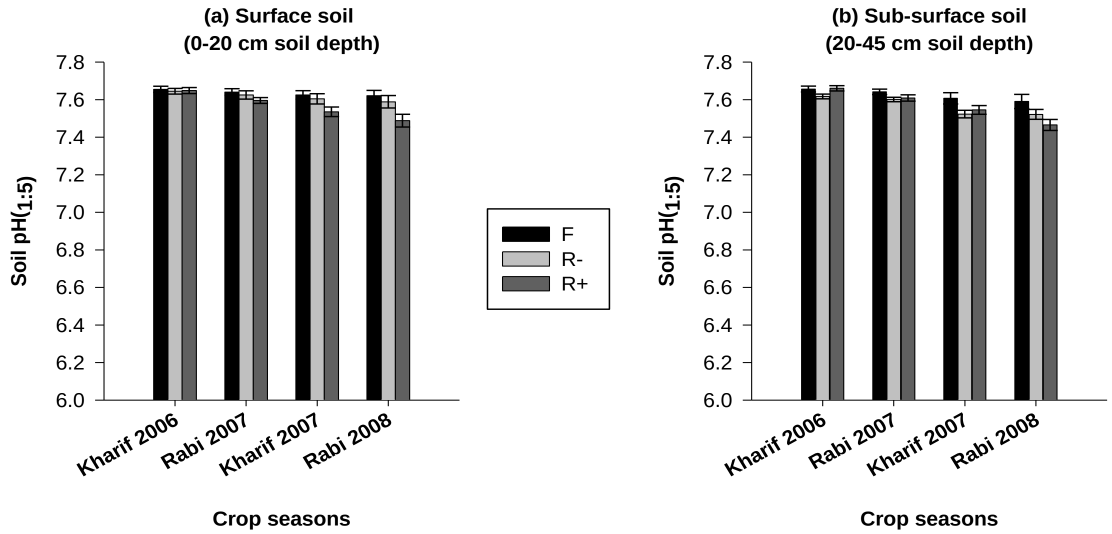

Fig. 26 **Effect of residues management practices on soil pH at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons**

4.1.2.2. Soil electrical conductivity

Data in Table 18 show that effect of fertilizer treatments on soil electrical conductivity both at surface (0-20 cm soil depth) and sub-surface soil (20-45 cm soil depth) was statistically non-significant ($p>0.05$) during all the seasons (Fig. 27) (Appendix 117-126).

Effect of residues management practices on soil electrical conductivity both at surface (0-20 cm soil depth) and sub-surface soil (20-45 cm soil depth) was also statistically non-significant (Appendix 117-126) during all the four seasons (Table 18 and Fig. 28).

Table 18: Effect of fertilizer treatments and residues management practices on soil $EC_{(1:5)}$ (dS m^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	………………………..……(dS m^{-1})………………………………					
Soil depth = 0-20 cm						
T1	1.06	1.06	1.07	1.06	1.06 ab	…
T2	1.00	0.99	0.98	0.98	0.99 bc	-6.83
T3	1.05	1.04	1.04	1.04	1.04 ab	-1.81
T4	0.94	0.95	0.94	0.94	0.94 c	-11.36
T5	0.91	0.92	0.93	0.92	0.92 c	-13.40
T6	1.10	1.08	1.07	1.05	1.08 a	1.36
$LSD_{(0.05)}$	ns	ns	ns	ns	0.074	
F	1.03	1.04	1.04	1.03	1.04 a	…
R-	1.01	1.00	0.99	1.00	1.00 ab	-3.48
R+	0.99	0.98	0.98	0.96	0.98 b	-5.92
$LSD_{(0.05)}$	ns	ns	ns	ns	0.047	
Soil depth = 20-45 cm						
T1	1.08	1.07	1.09	1.07	1.08 ab	…
T2	1.03	1.00	0.99	0.98	1.00 bc	-6.84
T3	1.02	1.01	0.99	0.99	1.00 bc	-6.74
T4	1.03	1.01	1.02	1.00	1.02 b	-5.50
T5	0.91	0.91	0.91	0.90	0.91 c	-15.56
T6	1.17	1.17	1.16	1.16	1.16 a	8.21
$LSD_{(0.05)}$	ns	ns	ns	ns	0.097	
F	1.00	1.00	0.99	0.99	1.00 b	…
R-	1.10	1.09	1.08	1.08	1.09 a	9.12
R+	1.02	1.00	1.01	0.99	1.01 b	0.95
$LSD_{(0.05)}$	ns	ns	ns	ns	0.069	

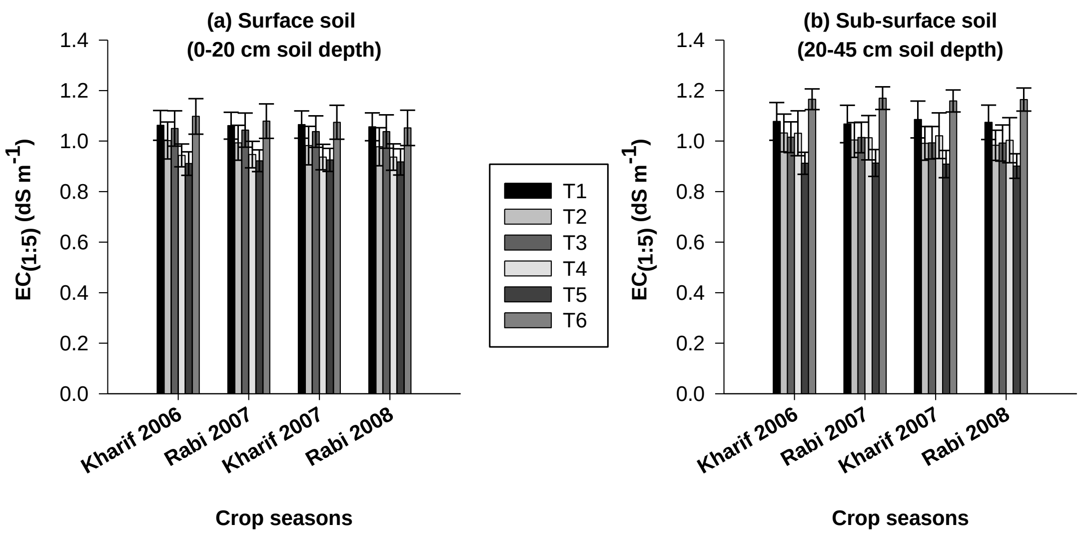

Fig. 27 Effect of fertilizer treatments on soil $EC_{(1:5)}$ (dS m^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons

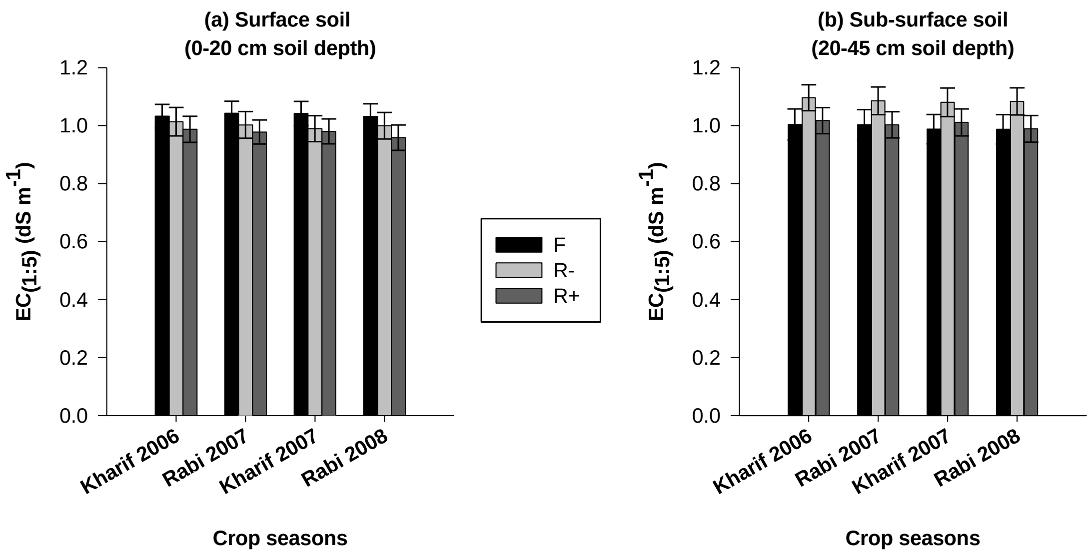

Fig. 28 **Effect of residues management practices on soil $EC_{(1:5)}$ (dS m^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons**

4.1.2.3. Soil organic matter

Effect of fertilizer treatments on soil organic matter was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the seasons except during Kharif 2006 (Appendix 127-135)and T6 had the highest organic matter followed by T5 (Fig. 29). Analysis of the data combined over seasons revealed similar results (Appendix 131 and 136). The respective increases in organic matter of T5 and T6 were 3.7 and 9.3% at surface soil and 4.1 and 10.4% at sub-surface soil (Table 19).

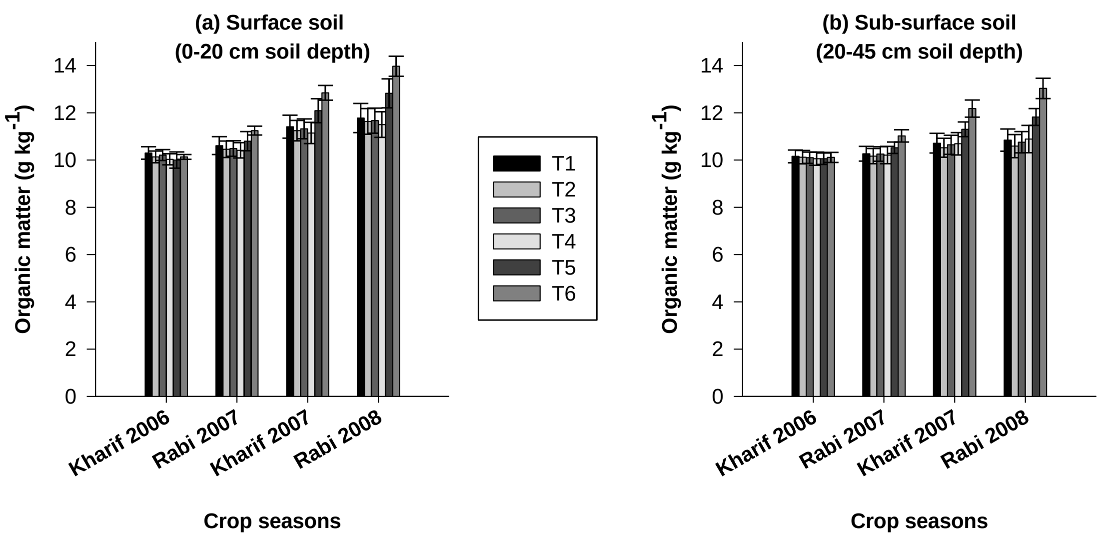

Fig. 29 **Effect of fertilizer treatments on soil organic matter (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons**

Residue management practices had also significant effect on soil organic matter at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during the all the seasons (Appendix 127-135). R+ resulted in highest organic matter followed by R-, while fallow plots had the lowest organic matter (Fig. 30). Combined analysis of the data over seasons also showed similar effect on soil organic matter (Appendix 131 and 136). The respective increases of R- and R+ over fallow were 17.2 and 23.4% at surface soil and 14.6 and 22.4% at sub-surface soil (Table 19).

Table 19: Effect of fertilizer treatments and residues management practices on soil organic matter (g kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(g kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	10.30	10.61 b	11.41 c	11.78 c	11.03 c	…
T2	10.13	10.46 b	11.24 c	11.63 c	10.87 cd	-1.44
T3	10.21	10.49 b	11.32 c	11.67 c	10.92 cd	-0.93
T4	10.03	10.41 b	11.14 c	11.50 c	10.77 d	-2.29
T5	10.00	10.80 ab	12.09 b	12.82 b	11.43 b	3.65
T6	10.13	11.24 a	12.84 a	13.97 a	12.05 a	9.27
LSD$_{(0.05)}$	ns	0.482	0.509	0.513	0.237	
F	9.39 b	9.56 b	10.16 c	10.27 c	9.84 c	…
R-	10.50 a	11.02 a	12.03 b	12.61 b	11.54 b	17.23
R+	10.51 a	11.43 a	12.84 a	13.80 a	12.15 a	23.38
LSD$_{(0.05)}$	0.417	0.495	0.608	0.622	0.209	
Soil depth = 20-45 cm						
T1	10.16	10.27 b	10.71 c	10.84 c	10.49 c	…
T2	10.12	10.17 b	10.52 c	10.59 c	10.35 c	-1.38
T3	10.10	10.26 b	10.64 c	10.76 c	10.44 c	-0.53
T4	10.06	10.21 b	10.69 c	10.89 c	10.46 c	-0.32
T5	10.06	10.52 b	11.30 b	11.82 b	10.93 b	4.10
T6	10.11	11.02 a	12.18 a	13.03 a	11.59 a	10.40
LSD$_{(0.05)}$	ns	0.492	0.507	0.525	0.243	
F	9.28 b	9.41 c	9.67 c	9.78 c	9.53 c	…
R-	10.47 a	10.64 b	11.19 b	11.41 b	10.93 b	14.61
R+	10.55 a	11.17 a	12.17 a	12.78 a	11.67 a	22.35
LSD$_{(0.05)}$	0.436	0.440	0.460	0.469	0.172	

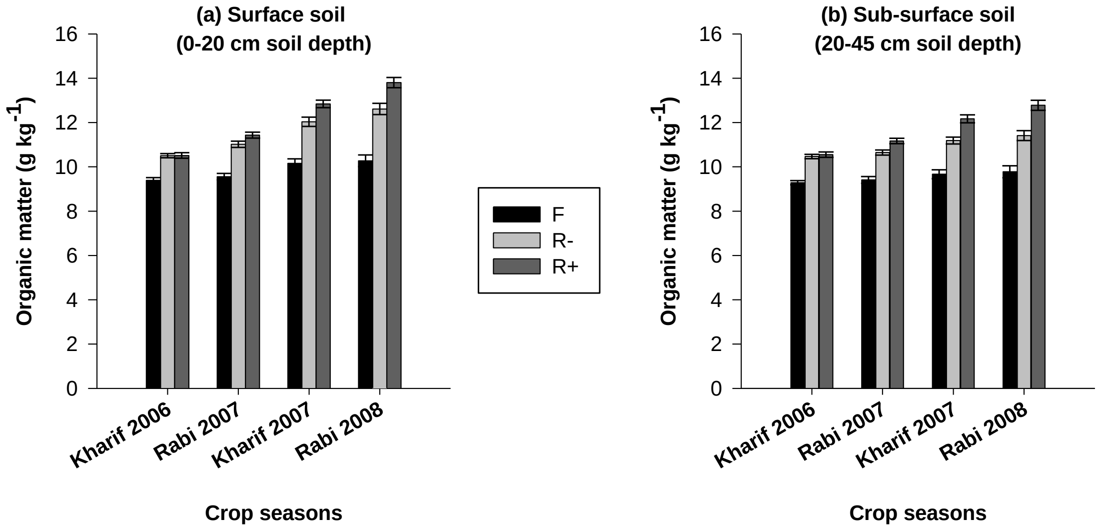

Fig. 30 Effect of residues management practices on soil organic matter (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons

4.1.2.4. AB-DTPA extractable potassium

Effect of fertilizer treatments on extractable potassium was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the seasons except Kharif 2006 (Appendix 137-145). Treatment T6 had the highest potassium followed by T4 and T5 at both surface and sub-surface soils (Fig. 31). Analysis of the data combined over seasons showed that treatments had similar effect on AB-DTPA extractable potassium (Appendix 141 and 146). The respective increases in potassium contents of T4, T5 and T6 over control were 11.7, 7.8 and 18.5% at surface soil and 7.8, 11.9 and 16.8% at sub-surface soil (Table 20).

Residue management practices had non-significant ($p>0.05$) effect on soil potassium at both surface and sub-surface soils during all the seasons except during Rabi 2008 at surface soil (Fig. 32) (Appendix 137-145). Combined analysis of the data over seasons showed significant effect of residues management practices on potassium content at both surface and sub-surface soils (Appendix 141 and 146). At surface soil R- and R+ increased K content by 3.1 and 7.4% respectively, while at sub-surface soil R+ increased K content by 6.2% (Table 20).

Table 20: Effect of fertilizer treatments and residues management practices on AB-DTPA Extractable K (mg kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(mg kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	66.0	67.8 cd	70.4 c	71.3 c	68.9 d	…
T2	63.0	64.0 de	63.8 d	64.2 d	63.7 e	-7.43
T3	62.1	62.2 e	63.5 d	63.2 d	62.8 e	-8.83
T4	67.2	73.7 ab	80.1 b	86.5 b	76.9 b	11.66
T5	64.4	71.4 bc	77.4 b	83.7 b	74.2 c	7.79
T6	67.3	77.3 a	86.4 a	95.4 a	81.6 a	18.47
$LSD_{(0.05)}$	ns	5.27	5.38	5.29	2.52	
F	64.7	67.0	70.6	73.3 b	68.9 c	…
R-	65.4	69.5	73.5	76.0 b	71.1 b	3.13
R+	65.0	71.7	76.7	82.8 a	74.0 a	7.42
$LSD_{(0.05)}$	ns	ns	ns	6.5	1.82	
Soil depth = 20-45 cm						
T1	64.9	65.6 bc	67.0 c	66.5 c	66.0 c	…
T2	64.0	63.9 bc	65.0 c	63.7 c	64.2 cd	-2.81
T3	61.1	61.2 c	61.9 c	61.6 c	61.5 d	-6.89
T4	60.3	68.3 ab	75.1 b	80.8 b	71.1 b	7.75
T5	64.5	71.2 a	76.9 ab	82.8 ab	73.8 b	11.85
T6	64.0	73.1 a	82.0 a	89.2 a	77.1 a	16.78
$LSD_{(0.05)}$	ns	5.43	6.20	7.05	2.92	
F	63.9	66.8	70.3	71.2	68.1 b	…
R-	61.9	65.2	68.4	70.4	66.5 b	-2.34
R+	63.6	69.7	75.2	80.8	72.3 a	6.23
$LSD_{(0.05)}$	ns	ns	ns	ns	3.73	

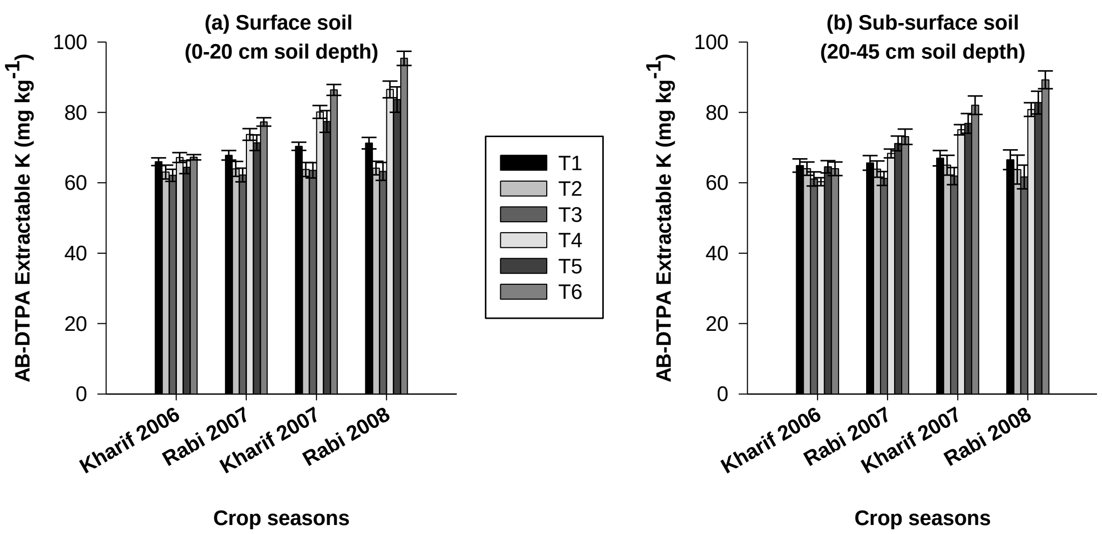

Fig. 31 Effect of fertilizer treatments on AB-DTPA Extractable K (mg kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons

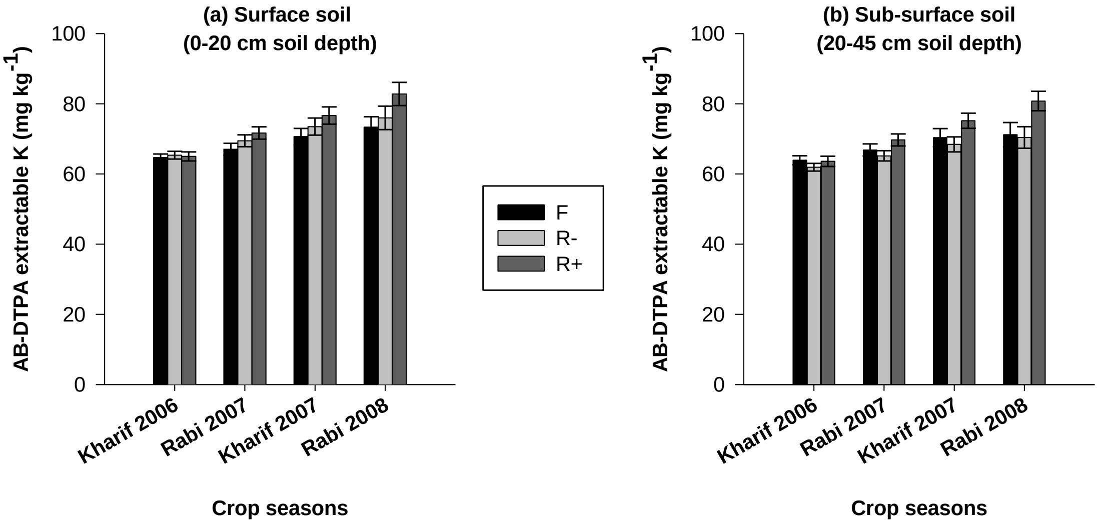

Fig. 32 **Effect of residues management practices on AB-DTPA Extractable K (mg kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons**

4.1.2.5. AB-DTPA extractable phosphorus

Effect of fertilizer treatments on extractable phosphorus was significant at both surface and sub-surface soils during all the seasons except Kharif 2006 (Appendix 147-155). Treatment T6 had the highest phosphorus followed by T5, while T1 had the lowest phosphorus at both surface and sub-surface soils (Fig. 33). Analysis of data combined over seasons showed that treatments had similar effect on AB-DTPA extractable phosphorus (Appendix 151 and 156). The respective increases in phosphorus contents of T3, T4, T5 and T6 over control were 13.2, 12.1, 19.2 and 21.9% at surface soil and 10.9, 10.3, 19.5 and 24.9% at sub-surface soil (Table 21).

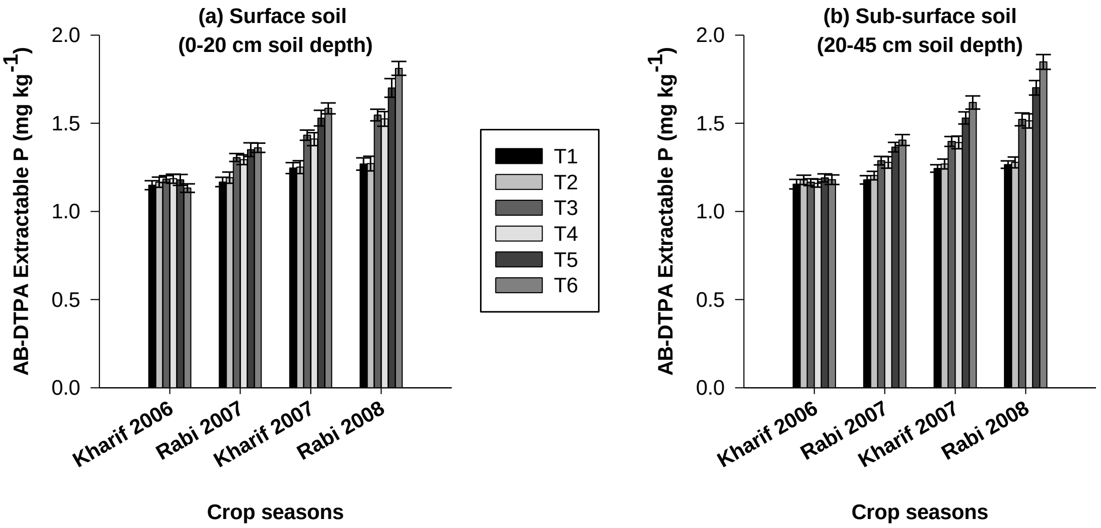

Fig. 33 **Effect of fertilizer treatments on AB-DTPA Extractable P (mg kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons**

Table 21: Effect of fertilizer treatments and residues management practices on AB-DTPA Extractable P (mg kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(mg kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	1.15	1.17 b	1.25 c	1.27 d	1.21 c	…
T2	1.17	1.19 b	1.25 c	1.27 d	1.22 c	1.01
T3	1.18	1.31 a	1.43 b	1.55 c	1.37 b	13.20
T4	1.19	1.29 a	1.41 b	1.52 c	1.35 b	12.08
T5	1.18	1.35 a	1.53 a	1.70 b	1.44 a	19.21
T6	1.13	1.36 a	1.58 a	1.81 a	1.47 a	21.92
LSD$_{(0.05)}$	ns	0.084	0.085	0.088	0.042	
F	1.17	1.26 b	1.37 b	1.46 b	1.31 b	…
R-	1.15	1.24 a	1.36 b	1.46 b	1.30 b	-1.07
R+	1.18	1.33 a	1.50 a	1.64 a	1.41 a	7.53
LSD$_{(0.05)}$	ns	0.049	0.052	0.047	0.019	
Soil depth = 20-45 cm						
T1	1.15	1.18 d	1.24 d	1.27 d	1.21 d	…
T2	1.18	1.20 cd	1.27 d	1.28 d	1.23 d	1.79
T3	1.17	1.29 b	1.40 c	1.52 c	1.34 c	10.95
T4	1.16	1.28 bc	1.39 c	1.51 c	1.34 c	10.33
T5	1.19	1.36 a	1.53 b	1.70 b	1.45 b	19.48
T6	1.18	1.40 a	1.62 a	1.85 a	1.51 a	24.94
LSD$_{(0.05)}$	ns	0.076	0.081	0.081	0.039	
F	1.18	1.28	1.40	1.49 b	1.34 b	…
R-	1.16	1.26	1.36	1.46 b	1.31 b	-2.00
R+	1.17	1.32	1.47	1.61 a	1.39 a	4.25
LSD$_{(0.05)}$	ns	ns	ns	0.097	0.034	

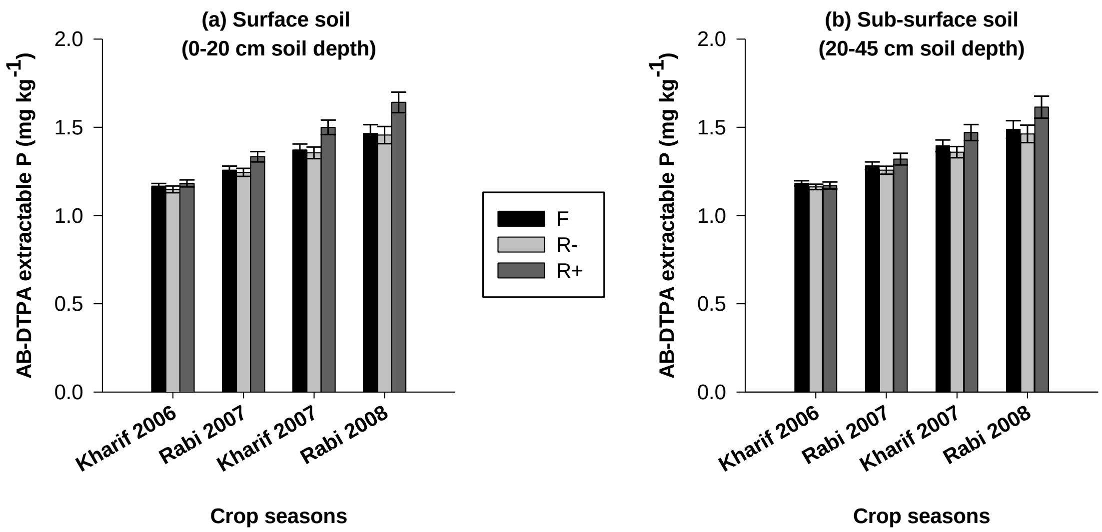

Fig. 34 Effect of residues management practices on AB-DTPA Extractable P (mg kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Residue management practices had significant effect on soil phosphorus during all the seasons except Kharif 2006 at surface soil, while it was significant only during Rabi 2008 at sub-surface soils (Fig. 34) (Appendix 147-155). Combined analysis of the data over seasons also revealed similar results (Appendix 151 and 156). R+ increased P content by 7.5% at surface soil and 4.3% at sub-surface soil (Table 21).

4.1.2.6. Mineral nitrogen

Effect of fertilizer treatments on mineral nitrogen was significant at both surface and sub-surface soils during all the seasons except during Kharif 2006 (Appendix 157-165). T5 had the highest mineral nitrogen followed by T2 and T4 at surface soil, while at sub-surface soil T4 had the highest mineral nitrogen followed by T2 and T3 (Fig. 35). Analysis of data combined over seasons showed similar effect (Appendix 161 and 166).

Table 22: Effect of fertilizer treatments and residues management practices on soil mineral N (μg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	………………………(μg g^{-1} soil)…………………………					
Soil depth = 0-20 cm						
T1	11.0	10.6	11.2 c	11.4 c	11.2 d	…
T2	10.6	12.9	13.5 a	15.1 a	12.8 ab	17.76
T3	10.2	12.5	13.1 ab	14.6 a	12.4 b	13.87
T4	10.5	12.8	13.4 a	15.0 a	12.7 ab	16.57
T5	10.8	13.1	13.7 a	15.3 a	13.0 a	19.24
T6	10.7	11.5	12.1 bc	13.1 b	11.8 c	6.94
$LSD_{(0.05)}$	ns	12.2	1.01	1.05	0.49	
F	10.6	12.0	12.6	13.6	12.1 b	…
R-	10.8	12.2	12.8	13.8	12.3 ab	1.88
R+	10.5	12.5	13.1	14.8	12.5 a	4.53
$LSD_{(0.05)}$	ns	12.2	ns	ns	0.41	
Soil depth = 20-45 cm						
T1	10.4	10.4 d	10.4 d	10.7 d	10.5 d	…
T2	10.5	11.8 ab	13.2 ab	14.8 ab	12.6 b	19.91
T3	10.2	11.5 bc	12.9 ab	14.4 b	12.2 b	16.96
T4	11.2	12.5 a	13.8 a	15.4 a	13.2 a	26.14
T5	10.2	11.5 bc	12.8 b	14.4 b	12.2 b	16.97
T6	10.1	10.8 cd	11.5 c	12.3 c	11.2 c	6.81
$LSD_{(0.05)}$	ns	0.92	0.92	0.92	0.45	
F	10.1	11.1	12.2	13.1 b	11.6 c	…
R-	10.5	11.5	12.5	13.5 b	12.0 b	2.82
R+	10.7	11.6	12.7	14.4 a	12.3 a	6.02
$LSD_{(0.05)}$	ns	ns	ns	0.8	0.28	

The respective increases in mineral nitrogen of T2, T3, T4 and T5 over control were 17.8, 13.9, 16.6 and 19.2% at surface soil and 19.9, 16.9, 26.1 and 16.9% at sub-surface soil (Table 22).

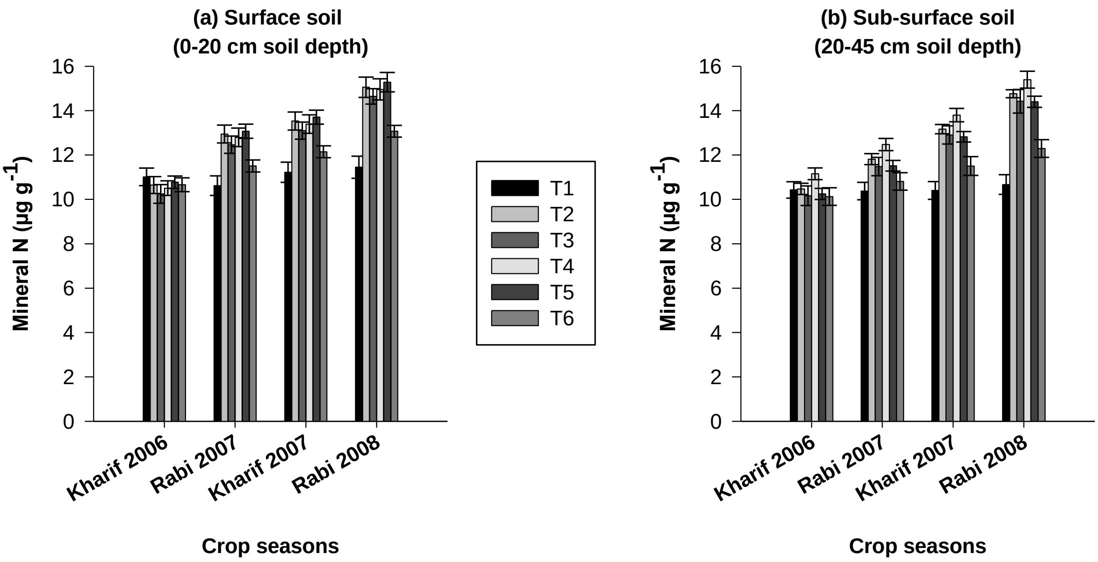

Fig. 35 Effect of fertilizer treatments on soil mineral N (µg g^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons

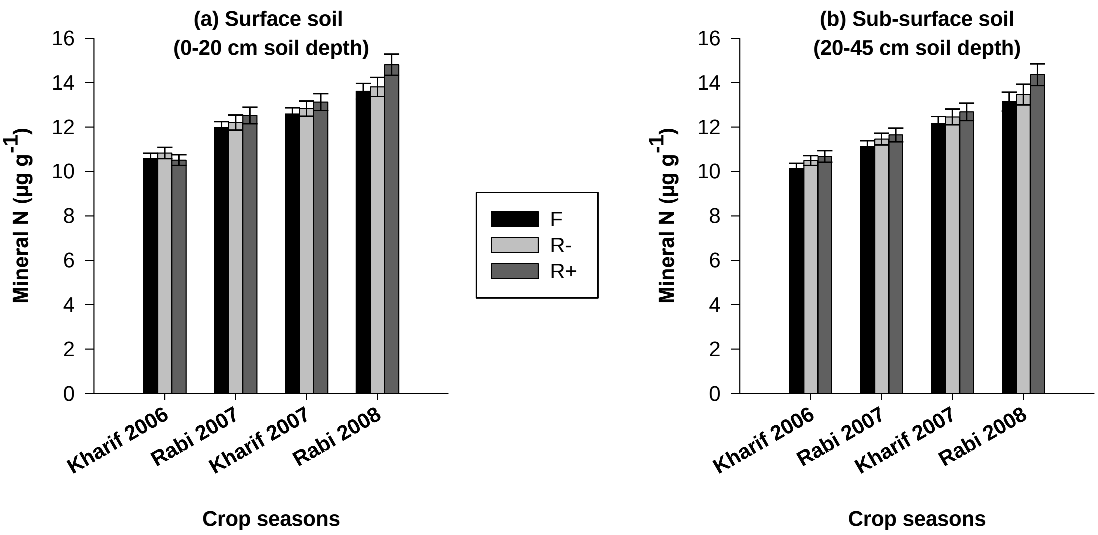

Fig. 36 Effect of residues management practices on soil mineral N (µg g^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Effect of residues management practices on soil mineral nitrogen at both surface and sub-surface soils was non-significant ($p>0.05$) during all the seasons except during Rabi 2008 (Appendix 157-165) at surface soil (0-20 cm soil depth) which was statistically significant and R+ had the highest mineral nitrogen as compared to R- and fallow plots (Fig. 36). Combined analysis of the data over seasons also showed significant effect of residues management practices on mineral nitrogen at both surface and sub-surface soils (Appendix 161 and 166). The respective increases in soil mineral nitrogen of R- and R+ over fallow were 1.9 and 4.5% at surface and 2.8 and 6.0% at sub-surface soil (Table 22).

4.1.2.7. Soil bulk density

Effect of fertilizer treatments on soil bulk density was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the season except during Kharif 2006 (Appendix 167-175). Treatment T6 had the lowest bulk density followed by T5 at both surface and sub-surface soils, while control plots had the highest soil bulk density (Fig. 37).

Table 23: Effect of fertilizer treatments and residues management practices on soil bulk density (Mg m^{-3}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(Mg m^{-3})………………………………					
Soil depth = 0-20 cm						
T1	1.42	1.41 ab	1.38 ab	1.35 ab	1.39 bc	…
T2	1.43	1.41 ab	1.36 b	1.34 ab	1.38 cd	-0.72
T3	1.43	1.41 ab	1.38 ab	1.37 a	1.40 ab	0.72
T4	1.45	1.43 a	1.40 a	1.37 a	1.41 a	1.44
T5	1.43	1.40 bc	1.35 bc	1.32 b	1.37 d	-1.44
T6	1.41	1.37 c	1.32 c	1.26 c	1.34 e	-3.60
$LSD_{(0.05)}$	ns	0.031	0.034	0.036	0.015	
F	1.42	1.41	1.38 a	1.36 a	1.39 a	…
R-	1.43	1.41	1.37 a	1.34 a	1.39 a	0.00
R+	1.44	1.40	1.34 b	1.30 b	1.37 b	-1.44
$LSD_{(0.05)}$	ns	ns	0.024	0.024	0.011	
Soil depth = 20-45 cm						
T1	1.43	1.42 a	1.40 ab	1.38 b	1.41 b	…
T2	1.43	1.43 a	1.41 ab	1.40 ab	1.42 b	0.71
T3	1.44	1.43 a	1.41 ab	1.40 ab	1.42 ab	0.71
T4	1.45	1.44 a	1.43 a	1.42 a	1.43 a	1.42
T5	1.44	1.42 a	1.39 b	1.37 b	1.41 b	0.00
T6	1.42	1.38 b	1.33 c	1.30 c	1.36 c	-3.55
$LSD_{(0.05)}$	ns	0.030	0.031	0.033	0.015	
F	1.44	1.43	1.42 a	1.41 a	1.42 a	…
R-	1.43	1.42	1.39 b	1.38 b	1.41 b	-0.70
R+	1.44	1.41	1.37 c	1.34 c	1.39 c	-2.11
$LSD_{(0.05)}$	ns	ns	0.012	0.009	0.007	

Analysis of the data combined over seasons showed similar effect on soil bulk density (Appendix 171 and 176). The respective decreases in bulk density of T5 and T6 over control were 1.4 and 3.6% at surface and 0.7 and 2.1% at sub-surface soil (Table 23).

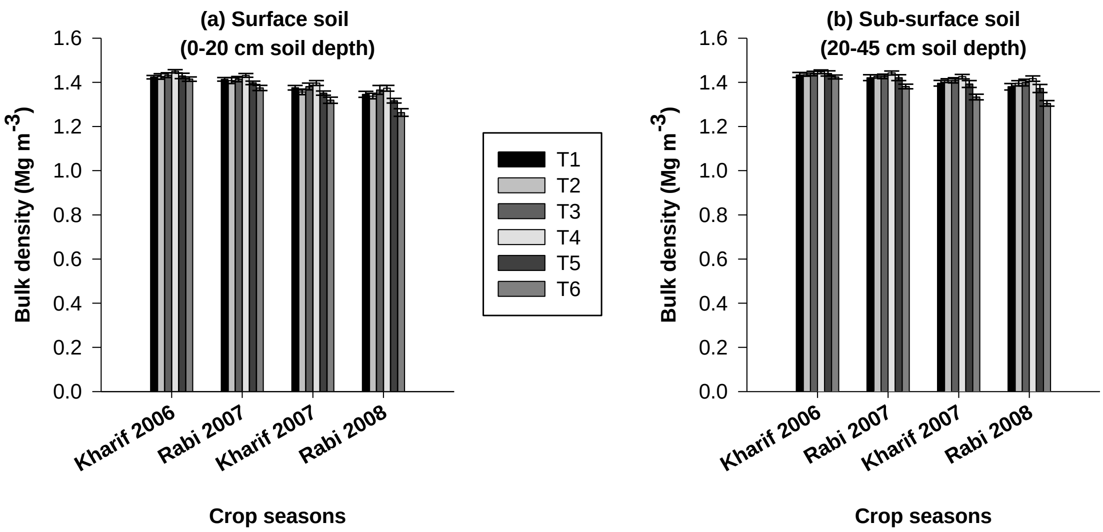

Fig. 37 Effect of fertilizer treatments on soil bulk density (Mg m^{-3}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons

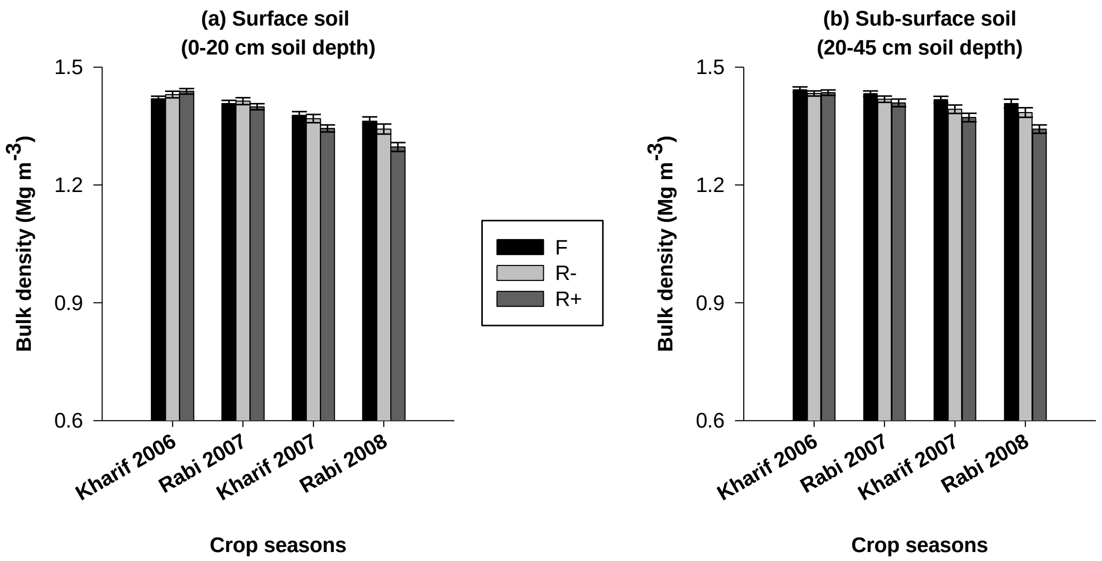

Fig. 38 Effect of residues management practices on soil bulk density (Mg m^{-3}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Residue management practices had also significant effect on soil bulk density at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during the season3 and 4 (Appendix 167-175). R+ decreased soil bulk density (Fig. 38). Combined analysis of the data over seasons showed significant effect of residues management practices on bulk density at both surface and sub-surface soils (Appendix 171 and 176). As compared to fallow, R+ decreased soil bulk density by 1.4% at surface and 2.1% at sub-surface soil (Table 23).

4.1.2.8. Available water holding capacity

Effect of fertilizer treatments on available water holding capacity was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the seasons except during Kharif 2006 (Appendix 177-185). Treatment T6 had the highest AWHC followed by T5 (Fig. 39). Analysis of data combined over seasons showed that treatments had similar effect on AWHC (Appendix 181 and 186). The respective increases in AWHC of T5 and T6 over control were 0.9 and 3.6% at surface soil and 1.2 and 2.6% at sub-surface soil (Table 24).

Table 24: Effect of fertilizer treatments and residues management practices on soil AWHC (g kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(g kg^{-1})……………………………….					
Soil depth = 0-20 cm						
T1	174.6	175.9 bc	180.6 bc	184.6 bc	178.9 bc	…
T2	173.4	175.9 bc	183.0 c	185.3 bc	179.4 bc	0.28
T3	173.4	175.5 bc	179.4 bc	181.5 c	177.4 cd	-0.84
T4	170.8	172.5 c	177.5 c	180.9 c	175.4 d	-1.96
T5	174.0	177.0 ab	182.7 b	188.2 b	180.5 b	0.89
T6	175.5	180.6 a	188.8 a	196.7 a	185.4 a	3.63
LSD$_{(0.05)}$	ns	3.98	4.71	4.89	2.12	
F	175.0	176.0	180.1 b	182.1 c	178.3 b	…
R-	173.3	175.1	181.2 b	185.0 b	178.7 b	0.22
R+	172.4	177.5	184.7 a	191.5 a	181.6 a	1.85
LSD$_{(0.05)}$	ns	ns	3.41	2.73	1.13	
Soil depth = 20-45 cm						
T1	172.4	174.7 b	177.8 b	179.9 b	176.2 bc	…
T2	172.8	173.7 b	176.4 b	177.3 bc	175.1 bcd	-0.62
T3	172.1	173.7 b	175.5 b	177.0 bc	174.6 cd	-0.91
T4	171.2	171.9 b	174.3 b	175.4 c	173.2 d	-1.70
T5	172.4	175.0 b	178.0 b	181.1 b	176.6 b	0.23
T6	174.4	179.9 a	186.5 a	190.4 a	182.8 a	3.75
LSD$_{(0.05)}$	ns	3.68	4.13	4.20	1.89	
F	172.0	173.1	175.4	176.6 c	174.2 c	…
R-	173.1	174.9	177.9	179.3 b	176.3 b	1.21
R+	172.6	176.5	181.0	184.8 a	178.7 a	2.58
LSD$_{(0.05)}$	ns	ns	1.31	0.89	0.90	

Residue management practices had significant effect on available water holding capacity at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during during Kharif 2007 and Rabi 2008 (Appendix 177-185). R+ resulted in highest available water holding capacity followed by R-, while fallow plots had the lowest available water holding capacity (Fig. 40). Combined analysis of data over seasons showed that residues management practices had similar effect on AWHC at both surface and sub-surface soils (Appendix 181 and 186). R+ increased AWHC by 1.9% at surface and 2.6% at sub-surface soil (Table 24).

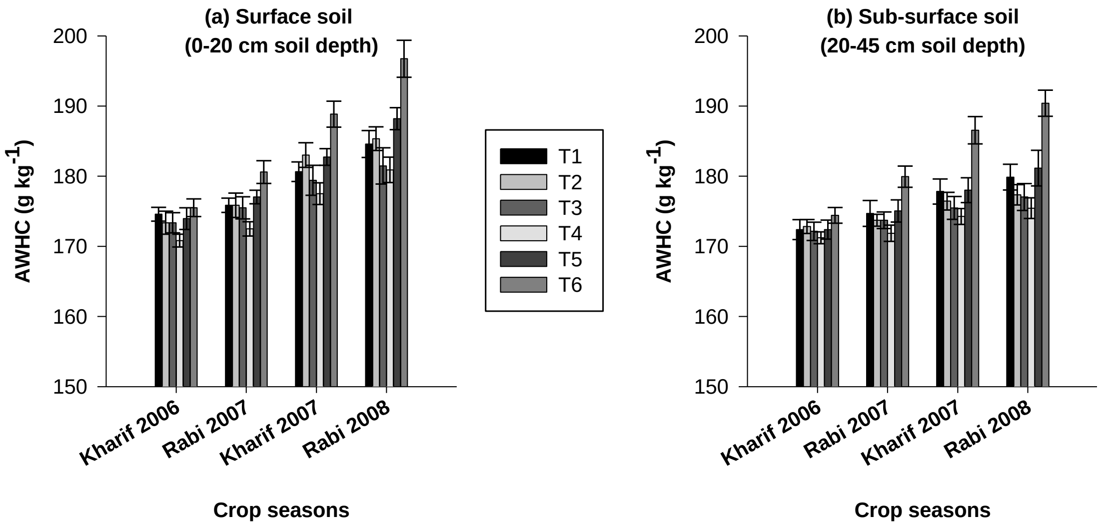

Fig. 39 **Effect of fertilizer treatments on soil AWHC (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons**

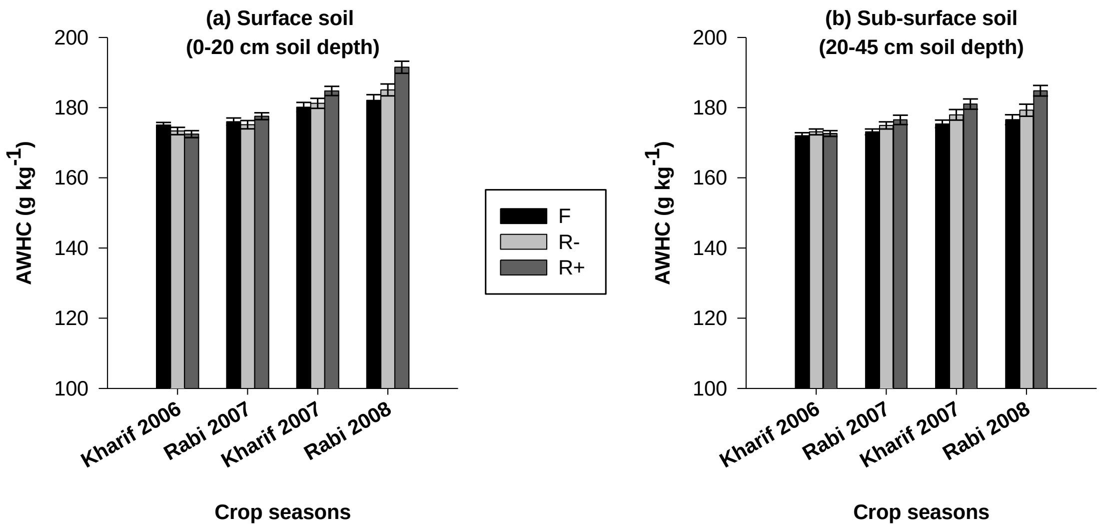

Fig. 40 **Effect of residues management practices on soil AWHC (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons**

4.1.2.9. Total nitrogen

Effect of fertilizer treatments on soil total nitrogen was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the seasons except during Kharif 2006 (Appendix 187-195). Treatment T6 had the highest total nitrogen followed by T5 (Fig. 41). Analysis of the data combined over seasons showed that treatments had similar effect on total nitrogen (Appendix 191 and 196). The respective increases in total nitrogen of T5 and T6 over control were 4.1 and 9.8% at surface soil and 3.7 and 8.9% at sub-surface soil (Table 25).

Table 25: Effect of fertilizer treatments and residues management practices on soil total N (g kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(g kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	0.615	0.634 bc	0.664 c	0.694 c	0.652 c	…
T2	0.610	0.628 bc	0.670 c	0.682 c	0.647 c	-0.77
T3	0.604	0.610 c	0.678 c	0.683 c	0.644 c	-1.23
T4	0.591	0.623 bc	0.667 c	0.696 c	0.644 c	-1.23
T5	0.606	0.643 ab	0.721 b	0.748 b	0.679 b	4.14
T6	0.602	0.672 a	0.766 a	0.825 a	0.716 a	9.82
$LSD_{(0.05)}$	ns	0.0304	0.0304	0.0431	0.0148	
F	0.561 b	0.573 b	0.609 b	0.611 c	0.588 c	…
R-	0.626 a	0.658 a	0.717 a	0.749 b	0.688 b	17.01
R+	0.627 a	0.674 a	0.757 a	0.803 a	0.715 a	21.60
$LSD_{(0.05)}$	0.0105	0.0293	0.0507	0.0414	0.0112	
Soil depth = 20-45 cm						
T1	0.614	0.619 ab	0.635 bc	0.650 c	0.629 c	…
T2	0.611	0.599 b	0.635 bc	0.634 c	0.620 c	-1.43
T3	0.605	0.612 ab	0.622 c	0.640 c	0.620 c	-1.43
T4	0.590	0.614 ab	0.635 bc	0.633 c	0.618 c	-1.75
T5	0.601	0.635 ab	0.671 b	0.701 b	0.652 b	3.66
T6	0.613	0.646 a	0.718 a	0.761 a	0.685 a	8.90
$LSD_{(0.05)}$	ns	0.0374	0.0431	0.0431	0.0209	
F	0.558 b	0.561 b	0.572 c	0.584 c	0.569 c	…
R-	0.631 a	0.641 a	0.666 b	0.672 b	0.652 b	14.59
R+	0.628 a	0.661 a	0.719 a	0.754 a	0.691 a	21.44
$LSD_{(0.05)}$	0.0293	0.0414	0.0293	0.0293	0.0158	

Residue management practices had significant effect on soil total nitrogen at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the four seasons (Appendix 187-195). R+ resulted in highest soil total nitrogen followed by R-, while fallow plots had the lowest soil total nitrogen (Fig. 42). Combined analysis of the data over seasons showed that residues management practices had similar effect on total nitrogen both at surface and sub-surface soils (Appendix 191 and 196). The respective increases in total nitrogen of R- and R+ over fallow were 17.0 and 21.6% at surface soil and 14.6 and 21.4% at sub-surface soil (Table 25).

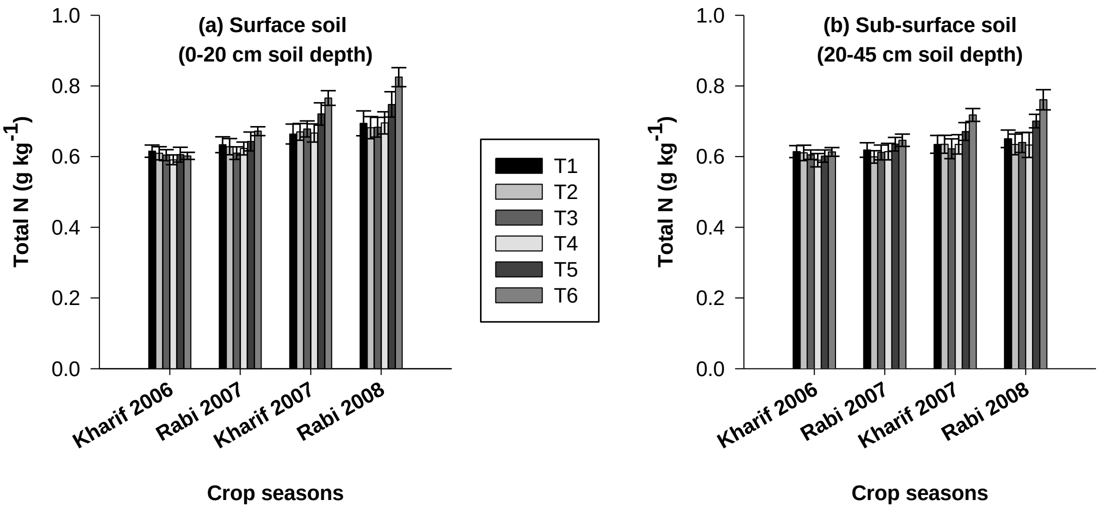

Fig. 41 Effect of fertilizer treatments on soil total N (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons

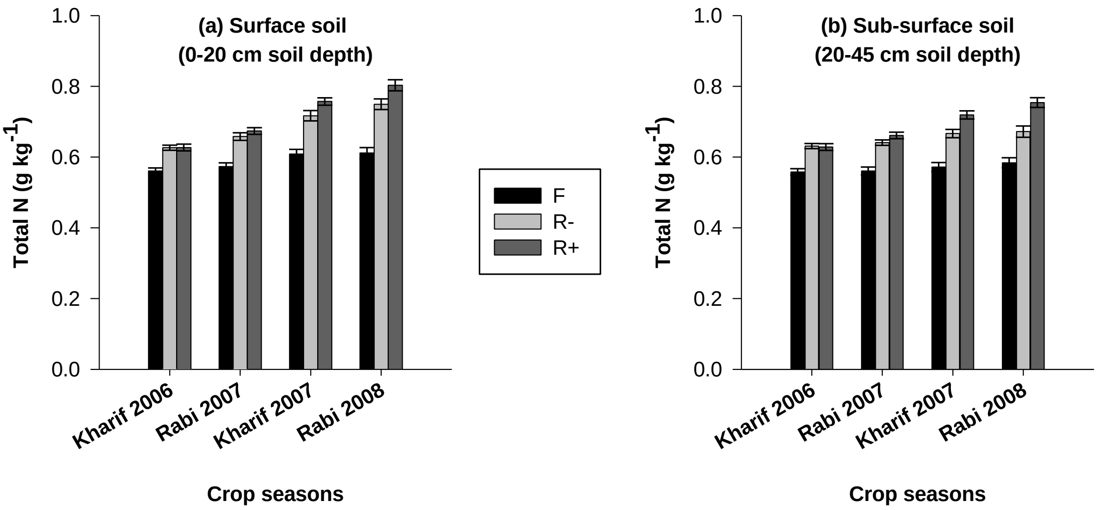

Fig. 42 Effect of residues management practices on soil total N (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado over seasons

4.1.2.10. Soil biological properties

4.1.2.10.1. Soil respiration

Effect of fertilizer treatments on cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 197-204). Treatment T6 had the highest soil respiration followed by T5, which included farmyard manure (FYM) additions (Table 26 and Fig. 43).

Table 26: Effect of fertilizer treatments and residues management practices on cumulative CO_2 (µg CO_2 g^{-1}) evolved during 2, 5, 10 and 15 days incubation at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado

Treatment	2 Days	5 Days	10 Days	15 Days
	……………………..……(µg CO_2 g^{-1})………………………………			
Soil depth = 0-20 cm				
T1	114.3 f	222.1 f	307.9 f	362.3 f
T2	129.0 e	241.9 e	347.7 e	385.2 e
T3	144.7 d	263.9 d	364.2 d	402.6 d
T4	165.6 c	285.4 c	394.2 c	425.6 c
T5	178.8 b	297.7 b	415.7 b	457.7 b
T6	192.8 a	318.7 a	430.0 a	480.1 a
$LSD_{(0.05)}$	6.77	8.37	9.13	8.29
F	129.5 c	234.5 c	336.8 c	381.2 c
R-	154.0 b	273.6 b	379.4 b	417.0 b
R+	179.1 a	306.7 a	413.6 a	458.6 a
$LSD_{(0.05)}$	9.52	7.25	6.25	13.63
Soil depth = 20-45 cm				
T1	93.2 f	199.7 f	292.6 f	327.9 f
T2	110.4 e	220.7 e	320.6 e	360.8 e
T3	127.0 d	242.5 d	339.6 d	385.7 d
T4	142.2 c	258.3 c	359.1 c	397.7 c
T5	158.8 b	283.6 b	390.5 b	432.1 b
T6	175.0 a	305.1 a	410.1 a	454.9 a
$LSD_{(0.05)}$	6.94	9.02	7.98	9.75
F	107.5 c	216.4 c	318.0 c	353.5 c
R-	136.7 b	253.9 b	347.4 b	393.0 b
R+	159.0 a	284.7 a	390.9 a	433.0 a
$LSD_{(0.05)}$	5.56	5.78	9.15	11.00

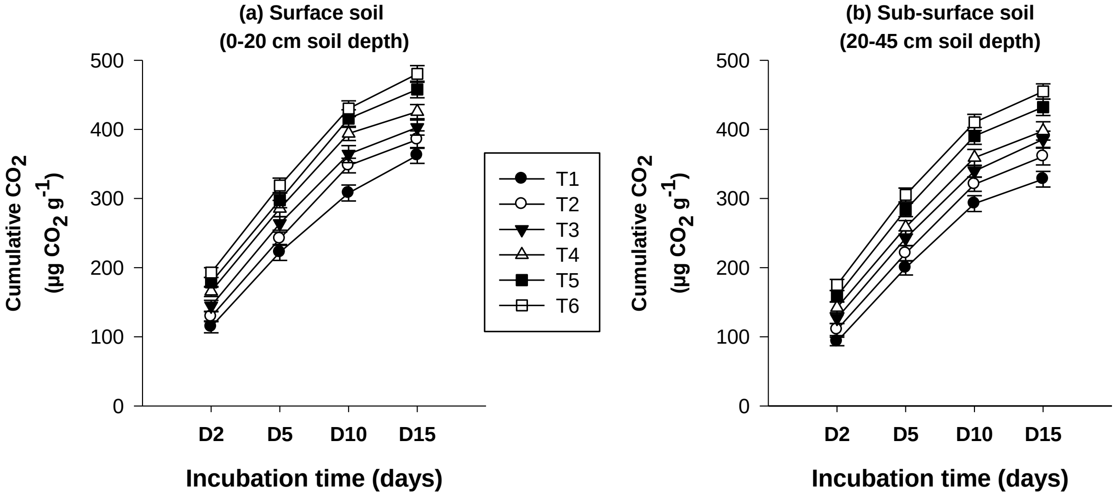

Fig. 43 Effect of fertilizer treatments on cumulative CO_2 (µg CO_2 g^{-1}) evolved during 2, 5, 10 and 15 days incubation at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado

Residue management practices had significant effect on cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 197-204). R+ resulted in highest soil respiration followed by R-, while fallow plots had the lowest soil respiration (Table 26 and Fig. 44).

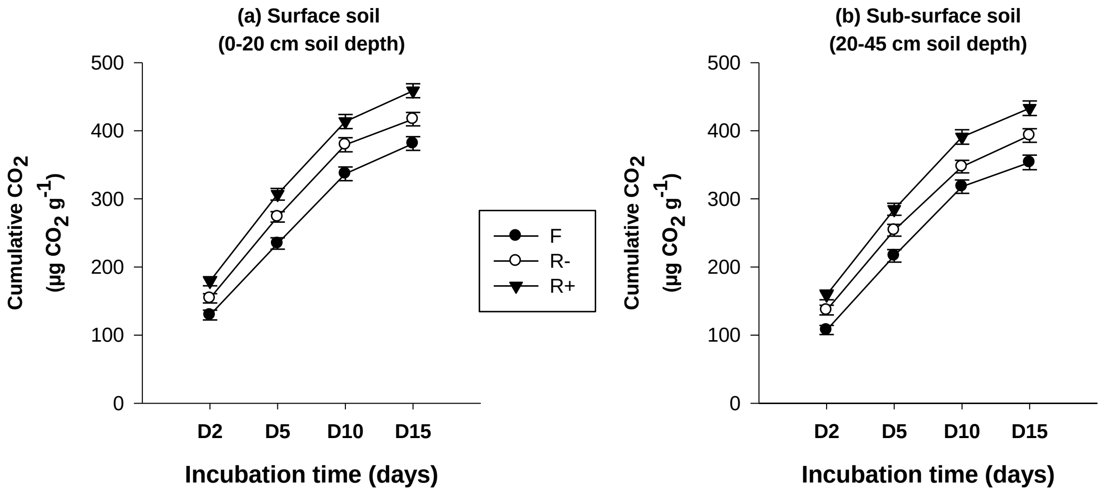

Fig. 44 Effect of residues management practices on cumulative CO_2 (µg CO_2 g^{-1}) evolved during 2, 5, 10 and 15 days incubation at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Gado

4.1.2.10.2. Microbial biomass carbon

Effect of fertilizer treatments on microbial biomass carbon was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 205 and 206). Treatment T6 had the highest MBC followed by T5, which included farmyard manure (FYM) additions (Table 27 and Fig. 45a).

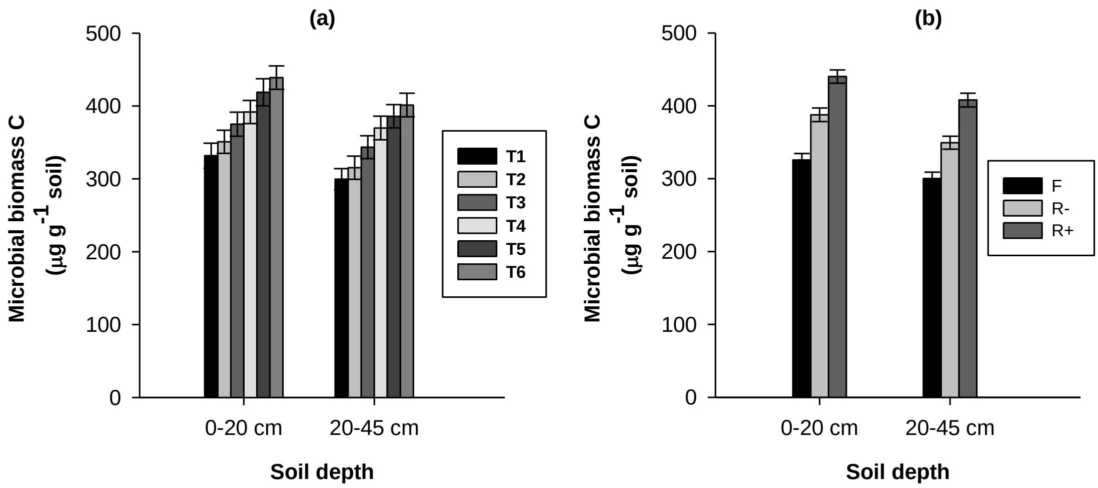

Fig. 45 Effect of (a) fertilizer treatments and (b) residues management practices on microbial biomass C (µg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado

Residue management practices had significant effect on microbial biomass carbon at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 205 and 206). R+ resulted in highest microbial biomass carbon followed by R-, while fallow plots had the lowest microbial biomass carbon (Table 27 and Fig. 45b).

Table 27: Effect of fertilizer treatments and residues management practices on microbial biomass C and N and mineralizable C and N (µg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado

Treatment	MBC	MBN	Cmin	Nmin
	……………………..……(µg g^{-1})………………………………			
Soil depth = 0-20 cm				
T1	331.8 f	8.2 f	84.0 f	13.5 f
T2	350.8 e	12.3 e	94.8 e	16.5 e
T3	375.0 d	16.3 d	99.3 d	20.4 d
T4	391.7 c	19.9 c	107.5 c	23.7 c
T5	418.8 b	23.8 b	113.4 b	26.4 b
T6	438.9 a	27.8 a	117.3 a	30.0 a
$LSD_{(0.05)}$	6.62	0.63	2.49	0.91
F	325.6 c	14.2 c	91.9 c	18.3 c
R-	387.8 b	18.2 b	103.5 b	21.9 b
R+	440.2 a	21.7 a	112.8 a	25.1 a
$LSD_{(0.05)}$	9.15	0.58	1.71	0.62
Soil depth = 20-45 cm				
T1	299.6 f	6.5 f	79.8 f	11.1 f
T2	315.3 e	10.4 e	87.4 e	14.5 e
T3	343.4 d	14.2 d	92.6 d	17.7 d
T4	369.7 c	18.0 c	97.9 c	20.8 c
T5	385.9 b	21.7 b	106.5 b	24.4 b
T6	401.3 a	25.4 a	111.8 a	27.4 a
$LSD_{(0.05)}$	6.78	0.78	2.18	0.85
F	300.3 c	12.5 c	86.7 c	16.0 c
R-	349.4 b	15.9 b	94.7 b	19.3 b
R+	407.9 a	19.7 a	106.6 a	22.6 a
$LSD_{(0.05)}$	10.11	0.74	2.49	0.39

MBC = Microbial biomass C (µg g^{-1} soil), MBN = Microbial biomass N (µg g^{-1} soil), C_{min} = mineralizable C (µg C g^{-1} soil), and N_{min} = mineralizable N (µg N g^{-1} soil)

4.1.2.10.3. Microbial biomass nitrogen

Effect of fertilizer treatments on microbial biomass nitrogen was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 207 and 208). Treatment T6 had the highest microbial biomass nitrogen followed by T5, which included farmyard manure (FYM) additions (Table 27 and Fig. 46a).

Residue management practices had significant effect on microbial biomass nitrogen at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 207 and 208). R+ resulted in highest microbial biomass nitrogen followed by R-, while fallow plots had the lowest microbial biomass nitrogen (Table 27 and Fig. 46b).

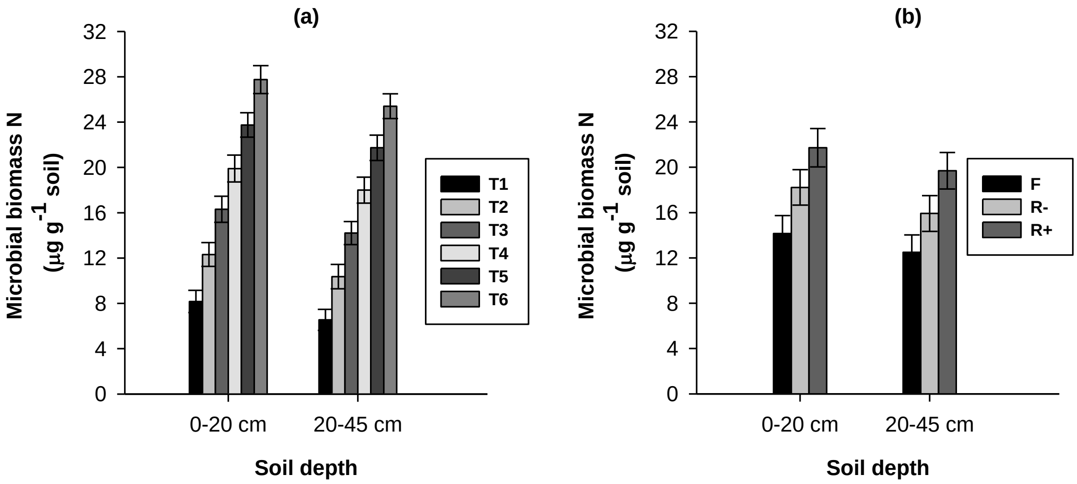

Fig. 46 Effect of (a) fertilizer treatments and (b) residues management practices on microbial biomass N (µg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado

4.1.2.10.4. Mineralizable C

Effect of fertilizer treatments on Mineralizable C was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 209 and 210). Treatment T6 had the highest Mineralizable C followed by T5, which included farmyard manure (FYM) additions (Table 27 and Fig. 47a).

Residue management practices had significant effect on Mineralizable C at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 209 and 210). R+ resulted in highest Mineralizable C followed by R-, while fallow plots had the lowest Mineralizable C (Table 27 and Fig. 47b).

4.1.2.10.5. Mineralizable N

Effect of fertilizer treatments on Mineralizable N was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 211 and 212). Treatment T6 had the highest Mineralizable N followed by T5, which included farmyard manure (FYM) additions (Table 27 and Fig. 48a).

Residue management practices had significant effect on Mineralizable N at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 211 and 212). R+ resulted in highest Mineralizable N followed by R-, while fallow plots had the lowest Mineralizable N (Table 27 and Fig. 48b).

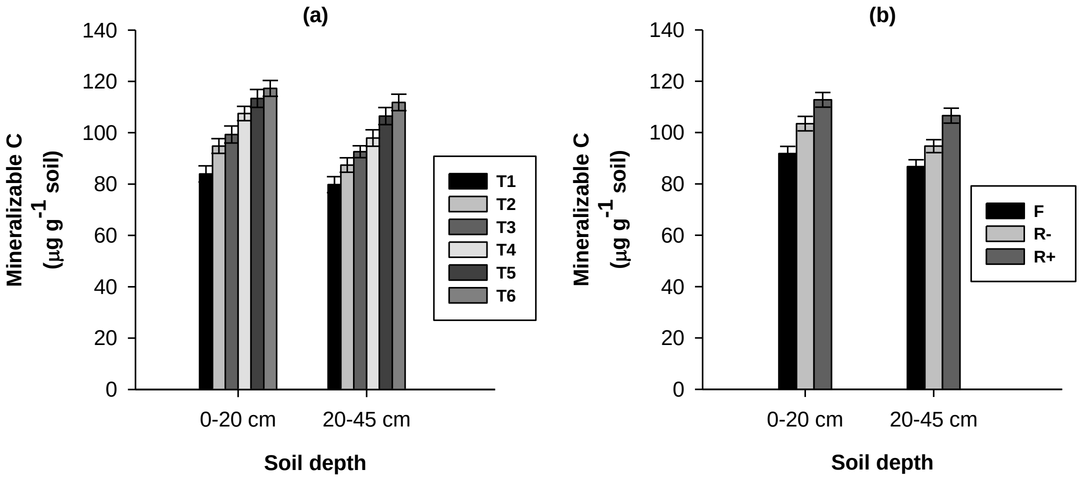

Fig. 47 **Effect of (a) fertilizer treatments and (b) residues management practices on mineralizable C (µg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado**

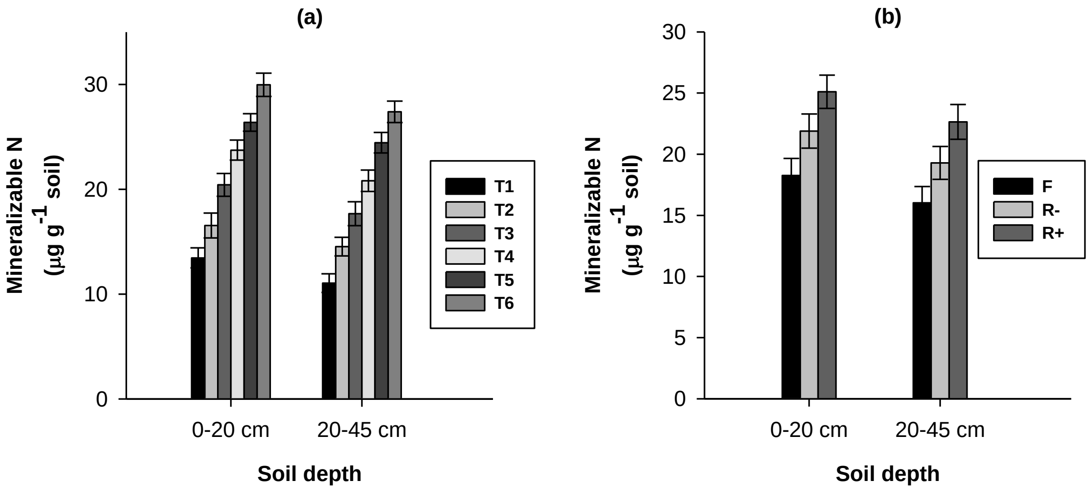

Fig. 48 **Effect of (a) fertilizer treatments and (b) residues management practices on mineralizable N (µg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Gado**

4.1.3. Kotlai (severely eroded soil)

4.1.3.1. Soil pH

Data in Table- show that effect of fertilizer treatments on soil pH at both surface soil (0-20 cm soil depth) and sub-surface soil (20-45 cm soil depth) was statistically significant during Kharif 2007 and Rabi 2008, while non-significant ($p>0.05$) during the rest of the seasons (Appendix 213-221). T6 had the lowest soil pH followed by T5 (Fig. 49). Combined analysis of the data over seasons showed similar effect on soil pH (Appendix 217 and 222). T5 and T6 decreased soil pH by 1.0 and 1.9% at surface and 0.1 and 0.4% respectively (Table 28).

Table 28: Effect of fertilizer treatments and residues management practices on soil pH at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
Soil depth = 0-20 cm						
T1	7.95	7.96	7.99 a	7.97 a	7.97 a	…
T2	7.99	7.97	7.94 ab	7.92 a	7.95 a	-0.17
T3	7.97	7.95	7.95 ab	7.91 a	7.94 a	-0.29
T4	8.00	7.98	7.98 a	7.98 a	7.99 a	0.24
T5	7.96	7.93	7.85 bc	7.79 b	7.88 b	-1.04
T6	7.95	7.86	7.76 c	7.68 c	7.81 c	-1.93
$LSD_{(0.05)}$	ns	ns	0.101	0.110	0.047	
F	7.98	7.96 a	7.94 a	7.92 a	7.95 a	…
R-	7.98	7.98 a	7.96 a	7.93 a	7.96 a	0.11
R+	7.96	7.89 b	7.84 b	7.78 b	7.87 b	-1.08
$LSD_{(0.05)}$	ns	0.060	0.081	0.075	0.025	
Soil depth = 20-45 cm						
T1	8.02	7.99	7.97 ab	7.94 ab	7.98 bc	…
T2	8.03	8.02	8.00 ab	8.00 a	8.01 ab	0.41
T3	8.05	8.05	8.03 a	8.03 a	8.04 a	0.77
T4	8.06	8.05	8.02 a	8.00 a	8.04 a	0.73
T5	8.04	7.97	7.92 bc	7.87 bc	7.95 cd	-0.34
T6	8.04	7.95	7.88 c	7.79 c	7.92 d	-0.78
$LSD_{(0.05)}$	ns	ns	0.083	0.096	0.042	
F	8.04	8.01	7.98 a	7.98 a	8.00 a	…
R-	8.04	8.02	7.99 a	7.94 b	8.00 a	-0.09
R+	8.04	7.99	7.94 b	7.90 c	7.97 b	-0.43
$LSD_{(0.05)}$	ns	ns	0.034	0.024	0.016	

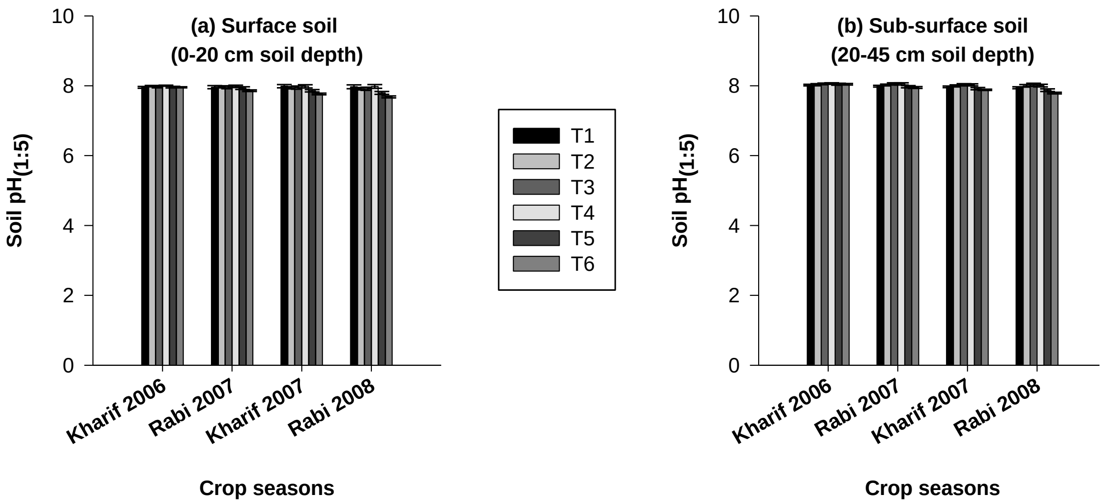

Fig. 49 Effect of fertilizer treatments on soil pH at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Effect of management practices on soil pH at surface soil (0-20 cm soil depth) was statistically significant during all the seasons except during Kharif 2006 at surface and Kharif 2006 and Rabi 2007 at sub-surface soil (Appendix 213-221). R+ had the lowest soil pH as compared to R- and fallow plots. Combined analysis of soil pH over seasons showed that residues management effect was significant both at surface and sub-surface soils (Appendix 217 and 222). R+ had the lowest soil pH (Fig. 50). As compared to fallow R+ decreased soil pH by 1.1% at surface and 0.4% at sub-surface soil (Table 28).

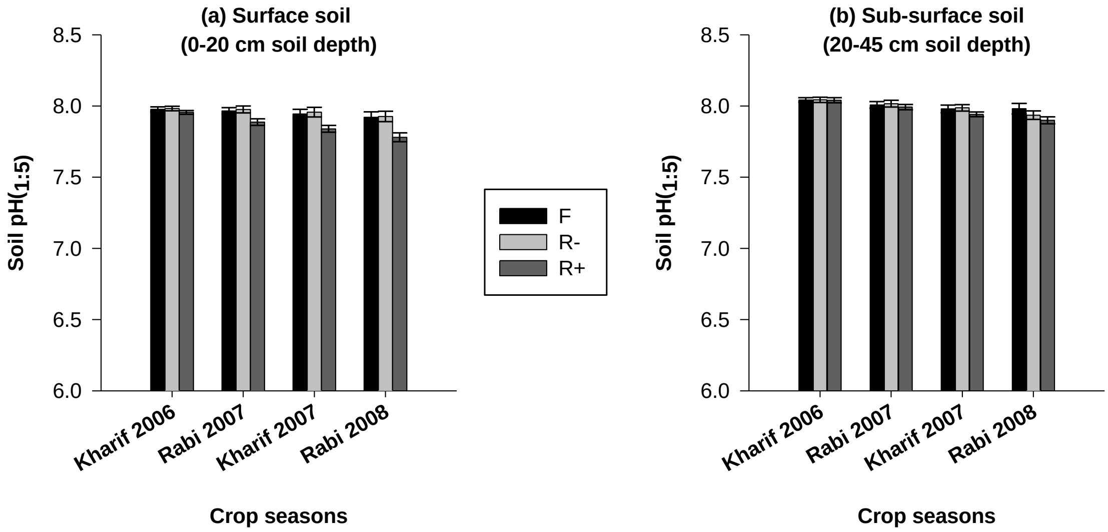

Fig. 50 Effect of residues management practices on soil pH at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

4.1.3.2. Soil electrical conductivity

Data in Table- show that effect of fertilizer treatments on soil electrical conductivity at both surface (0-20 cm soil depth) and sub-surface soil (20-45 cm soil depth) was statistically non-significant ($p>0.05$) during all the seasons (Fig. 51) (Appendix 223-231). Analysis of the data combined over season showed similar results (Table 29) (Appendix 227 and 232).

Effect of management practices on soil electrical conductivity at both surface (0-20 cm soil depth) and sub-surface soil (20-45 cm soil depth) was statistically non-significant ($p>0.05$) during all the four seasons (Fig. 52) (Appendix 223-231). Analysis of the data combined over season showed similar results (Table 29) (Appendix 227 and 232).

Table 29: Effect of fertilizer treatments and residues management practices on soil $EC_{(1:5)}$ (dS m^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(dS m^{-1})…………………………….					
Soil depth = 0-20 cm						
T1	1.01	1.04	0.99	1.01	1.01 a	…
T2	1.02	0.99	1.03	1.02	1.01 a	0.19
T3	1.05	0.97	0.98	0.94	0.99 a	-2.72
T4	0.88	0.90	0.84	0.83	0.86 b	-14.87
T5	1.01	1.03	0.92	0.88	0.96 ab	-5.19
T6	0.98	1.00	0.91	0.90	0.95 ab	-6.26
$LSD_{(0.05)}$	ns	ns	ns	ns	0.103	
F	1.00	0.99	0.96	0.95	0.97	…
R-	0.98	0.97	0.93	0.93	0.95	-2.28
R+	1.01	1.00	0.94	0.91	0.96	-1.11
$LSD_{(0.05)}$	ns	ns	ns	ns	ns	
Soil depth = 20-45 cm						
T1	1.07	1.09	1.02	1.03	1.05 a	…
T2	0.98	0.93	0.91	0.94	0.94 b	-10.69
T3	1.00	1.05	1.05	1.03	1.03 ab	-1.75
T4	0.95	0.95	0.93	0.90	0.93 b	-11.48
T5	1.13	1.13	1.11	1.17	1.13 a	7.88
T6	1.00	1.02	1.06	1.07	1.04 ab	-1.35
$LSD_{(0.05)}$	ns	ns	ns	ns	0.106	
F	0.96	0.99	0.99	1.00	0.98 b	…
R-	1.05	1.04	1.00	1.01	1.03 ab	4.35
R+	1.05	1.05	1.04	1.06	1.05 a	6.75
$LSD_{(0.05)}$	ns	ns	ns	ns	0.055	

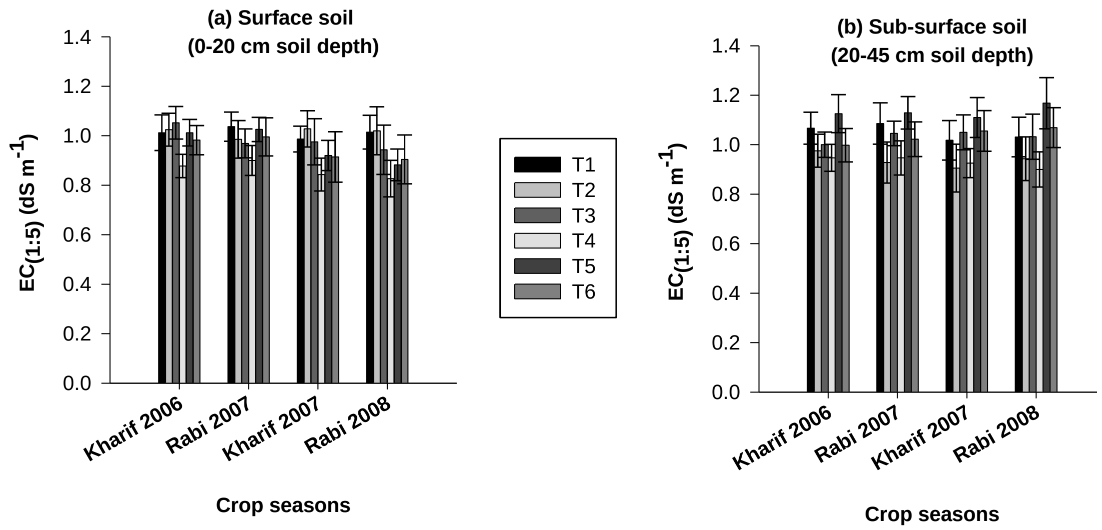

Fig. 51 Effect of fertilizer treatments on soil $EC_{(1:5)}$ (dS m^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

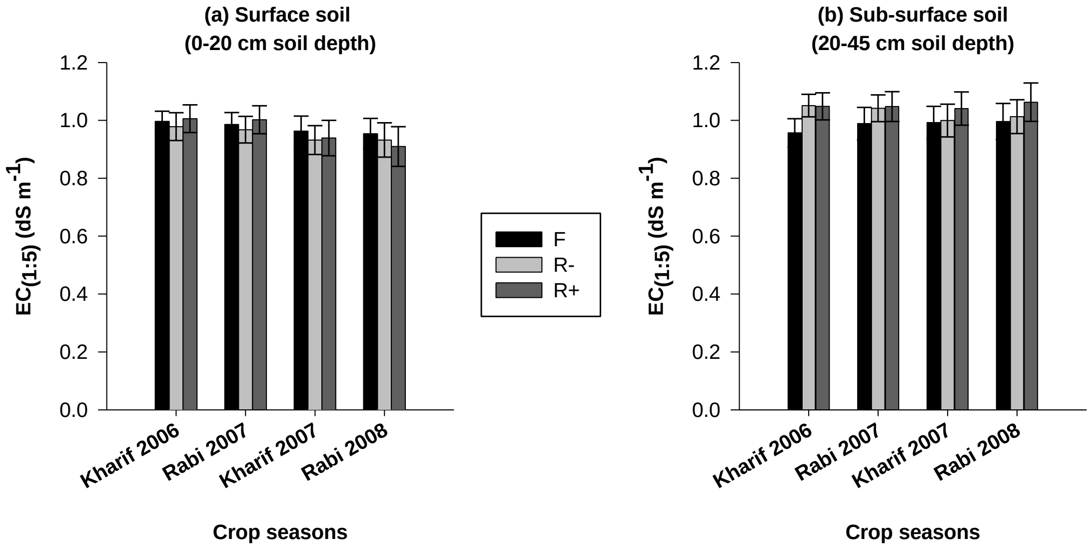

Fig. 52 **Effect of residues management practices on soil $EC_{(1:5)}$ (dS m^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons**

4.1.3.3. Soil organic matter

Effect of fertilizer treatments on soil organic matter was non-significant ($p>0.05$) at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during Kharif 2006 and Rabi 2007, while significant during rest of the seasons (Appendix 233-241). Treatment T6 had the highest organic matter followed by T5 at both surface and sub-surface soils (Fig. 53).

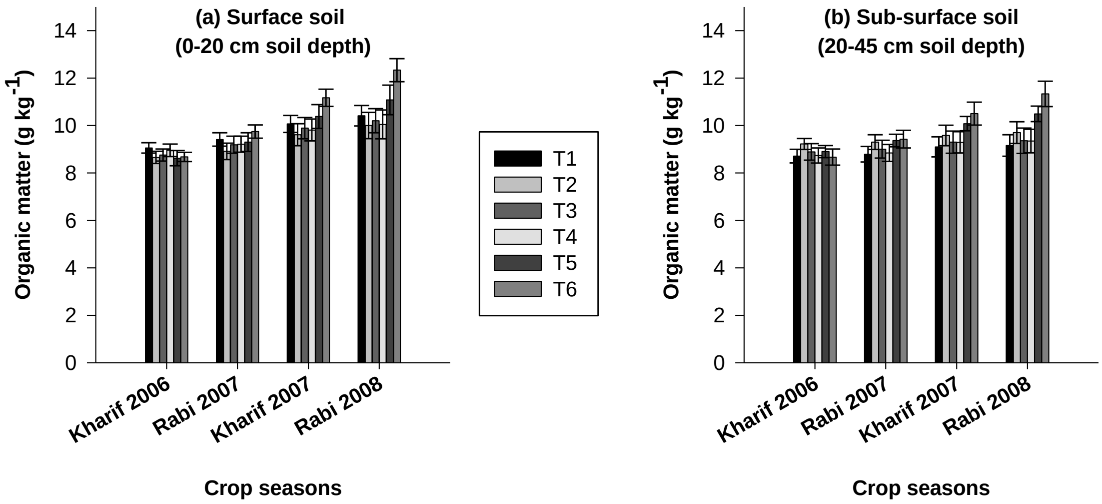

Fig. 53 **Effect of fertilizer treatments on soil organic matter (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons**

Analysis of data combined over seasons revealed that highest organic matter was found in T6 followed by T5 at both surface and sub-surface soils (Appendix 237 and 242). The respective increases in organic matter of T5 and T6 over control were

1.1 and 7.7% at surface soil and 8.6 and 11.7% at sub-surface soil (Table 30).

Residue management practices had significant effect on soil organic matter at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the seasons (Appendix 233-241). R+ resulted in highest organic matter followed by R-, while fallow plots had the lowest organic matter (Fig. 54). Combined analysis of the data over seasons also showed similar effect on soil organic matter (Appendix 237 and 242). The respective increases of R- and R+ over fallow were 22.0 and 26.9% at surface soil and 21.8 and 27.9% at sub-surface soil (Table 30).

Table 30: Effect of fertilizer treatments and residues management practices on soil organic matter (g kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(g kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	9.06	9.41	10.07 bc	10.41 c	9.74 bc	…
T2	8.66	8.91	9.61 c	10.00 c	9.29 d	-4.54
T3	8.76	9.19	9.89 bc	10.20 c	9.51 cd	-2.34
T4	8.96	9.21	9.81 c	10.04 c	9.51 cd	-2.37
T5	8.62	9.30	10.38 b	11.08 b	9.84 b	1.11
T6	8.68	9.74	11.17 a	12.33 a	10.48 a	7.65
$LSD_{(0.05)}$	ns	ns	0.541	0.538	0.248	
F	7.98 b	8.13 b	8.61 c	8.74 c	8.37 c	…
R-	9.26 a	9.78 a	10.62 b	11.18 b	10.21 b	22.03
R+	9.12 a	9.97 a	11.24 a	12.12 a	10.61 a	26.85
$LSD_{(0.05)}$	0.377	0.430	0.469	0.495	0.169	
Soil depth = 20-45 cm						
T1	8.71	8.79	9.10 c	9.16 c	8.94 d	…
T2	9.22	9.30	9.58 bc	9.70 c	9.45 c	5.72
T3	8.89	9.00	9.30 c	9.36 c	9.14 d	2.21
T4	8.73	8.84	9.29 c	9.34 c	9.05 d	1.27
T5	8.90	9.37	10.08 ab	10.49 b	9.71 b	8.61
T6	8.67	9.42	10.50 a	11.33 a	9.98 a	11.65
$LSD_{(0.05)}$	ns	ns	0.531	0.558	0.252	
F	7.83 b	7.97 b	8.12 c	8.26 c	8.04 c	…
R-	9.38 a	9.52 a	10.07 b	10.23 b	9.80 b	21.81
R+	9.36 a	9.87 a	10.74 a	11.21 a	10.29 a	27.97
$LSD_{(0.05)}$	0.474	0.721	0.550	0.638	0.230	

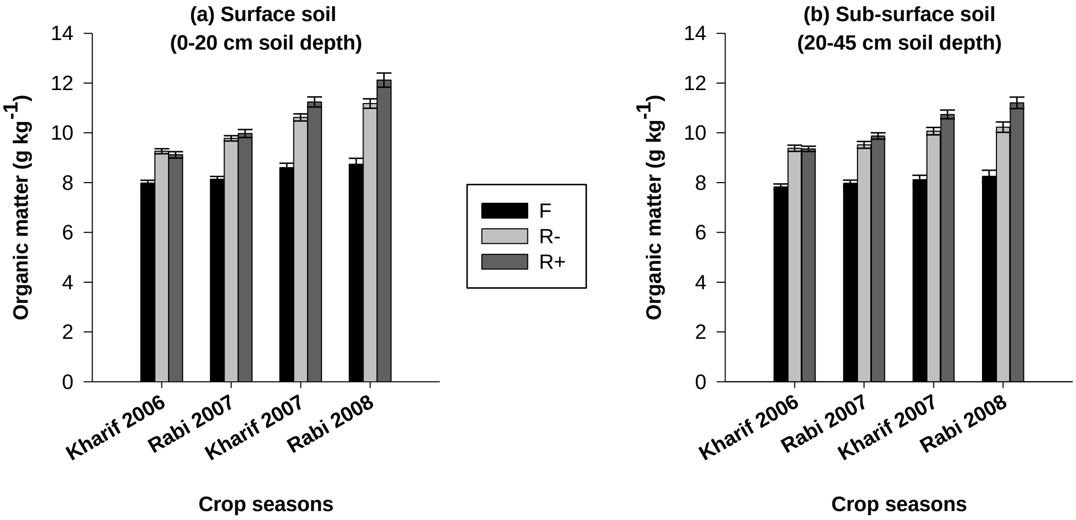

Fig. 54 **Effect of residues management practices on soil organic matter (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons**

4.1.3.4. AB-DTPA extractable potassium

Effect of fertilizer treatments on extractable potassium was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the seasons except Kharif 2006 (Appendix 243-251). Treatment T6 had the highest potassium which was at par with T4, followed by T5 at surface, while at sub-surface T6 had the highest K content followed by T5. Control had the lowest potassium content both at surface and sub-surface soils (Fig. 55). Analysis of data combined over seasons showed that treatments had similar effect on AB-DTPA extractable potassium (Appendix 247 and 252). The respective increases in potassium contents of T4, T5 and T6 were 13.8, 6.9 and 12.8% at surface soil and 10.2, 13.6 and 18.4% at sub-surface soil (Table 31).

Residue management practices had non-significant ($p>0.05$) effect on soil potassium at both surface and sub-surface soils during the all the seasons exept during Kharif 2007 and Rabi 2008 at surface soil (Fig. 56) (Appendix 243-251). Combined analysis of the data over seasons showed significant effect of residues management practices on potassium content at both surface and sub-surface soils (Appendix 247 and 252). As compared to fallow R+ increased K content by 12.1% at surface and 4.7% at sub-surface soil (Table 31).

Table 31: Effect of fertilizer treatments and residues management practices on AB-DTPA Extractable K (mg kg⁻¹) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(mg kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	62.2	63.4 cd	63.9 c	64.7 c	63.6 c	…
T2	60.0	60.2 d	62.1 c	62.2 c	61.1 d	-3.80
T3	63.3	65.1 bc	65.8 c	65.7 c	65.0 c	2.28
T4	63.4	70.0 a	75.3 a	80.4 a	72.3 a	13.78
T5	60.6	66.2 abc	70.6 b	74.6 b	68.0 b	6.96
T6	59.2	68.5 ab	76.2 a	82.9 a	71.7 a	12.81
$LSD_{(0.05)}$	ns	4.08	4.64	5.21	2.17	
F	60.3	62.7	65.8 b	68.0 b	64.2 b	…
R-	60.5	64.0	66.2 b	68.0 b	64.7 b	0.76
R+	63.6	70.1	75.0 a	79.2 a	72.0 a	12.11
$LSD_{(0.05)}$	ns	ns	6.57	7.20	2.59	
Soil depth = 20-45 cm						
T1	62.5	63.7 c	63.7 c	63.4 c	63.3 d	…
T2	64.8	66.6 bc	66.4 c	66.3 c	66.0 c	4.25
T3	62.0	63.8 c	63.9 c	63.1 c	63.2 d	-0.15
T4	60.3	67.4 abc	73.1 b	78.3 b	69.8 b	10.21
T5	62.8	69.4 ab	75.1 ab	80.2 b	71.9 b	13.55
T6	63.1	71.8 a	78.9 a	86.1 a	75.0 a	18.40
$LSD_{(0.05)}$	ns	4.43	4.87	5.38	2.28	
F	62.7	66.8	69.1	71.3	67.5 b	…
R-	62.2	65.7	67.9	69.7	66.4 b	-1.69
R+	62.8	68.9	73.6	77.5	70.7 a	4.74
$LSD_{(0.05)}$	ns	ns	ns	ns	2.20	

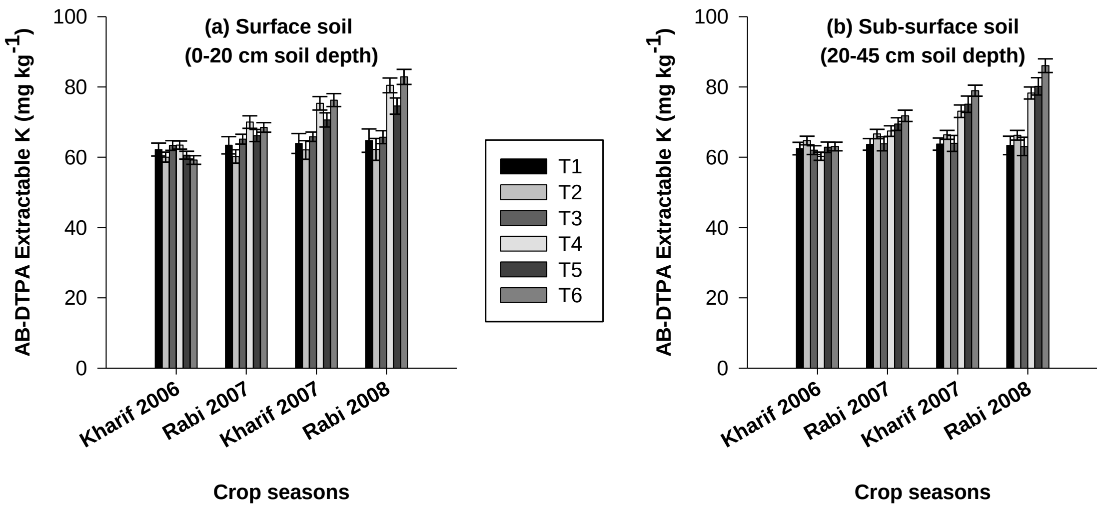

Fig. 55 Effect of fertilizer treatments on AB-DTPA Extractable K (mg kg⁻¹) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

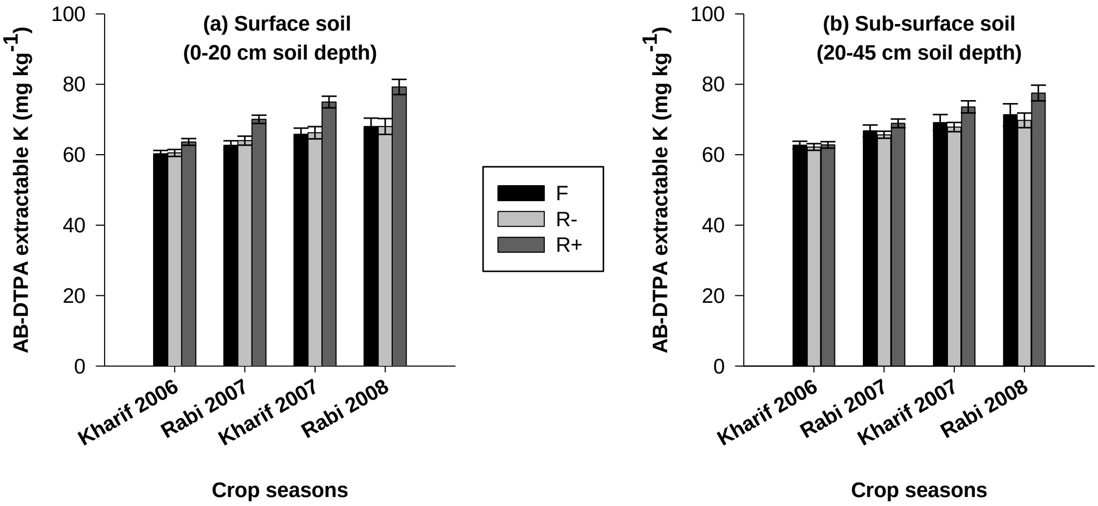

Fig. 56 **Effect of residues management practices on AB-DTPA Extractable K (mg kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons**

4.1.3.5. AB-DTPA extractable phosphorus

Effect of fertilizer treatments on extractable phosphorus was significant at both surface and sub-surface soils during all the seasons except during Kharif 2006 at sub-surface soils (Appendix 253-261). Treatment T6 had the highest phosphorus followed by T5, while T1 had the lowest phosphorus at both surface and sub-surface soils (Fig. 57). Analysis of data combined over seasons showed that treatments had similar effect on AB-DTPA extractable phosphorus (Appendix 257 and 262). The respective increases in phosphorus contents of T4, T5 and T6 over control were 16.8, 21.9 and 28.7% at surface soil and 14.5, 22.7 and 21.8% at sub-surface soil (Table 32).

Residue management practices also had significant effect on soil phosphorus at both surface and sub-surface soils during all the seasons except during Kharif 2006 and 2 both at surface soil (0-20 cm soil depth) and sub-surface soil (20-45 cm soil depth) (Appendix 253-261). R+ had the highest AB-DTPA Extractable Phosphorus as compared to R- and fallow plots (Fig. 58). Combined analysis of the data over seasons also showed significant effect of residues management practices on phosphorus content at both surface and sub-surface soils (Appendix 257 and 262). As compared to fallow R+ causes increase in P content by 5.5% at surface soil and 0.4% at sub-surface soil (Table 32).

Table 32: Effect of fertilizer treatments and residues management practices on AB-DTPA Extractable P (mg kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(mg kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	0.95 ab	0.96 b	1.03 e	1.05 e	1.00 f	…
T2	0.99 a	1.01 b	1.07 de	1.09 e	1.04 e	4.12
T3	0.90 b	1.03 b	1.13 d	1.24 d	1.08 d	7.91
T4	1.01 a	1.11 a	1.22 c	1.33 c	1.17 c	16.84
T5	0.97 ab	1.13 a	1.30 b	1.47 b	1.22 b	21.91
T6	0.98 a	1.18 a	1.39 a	1.59 a	1.28 a	28.67
LSD$_{(0.05)}$	0.027	0.070	0.074	0.080	0.036	
F	0.97	1.06	1.16 b	1.25 b	1.11 b	…
R-	0.96	1.05	1.16 b	1.25 b	1.10 b	-0.81
R+	0.97	1.10	1.25 a	1.38 a	1.17 a	5.51
LSD$_{(0.05)}$	ns	ns	0.064	0.079	0.027	
Soil depth = 20-45 cm						
T1	0.97	0.98 c	1.05 c	1.07 c	1.02 d	…
T2	0.94	0.95 c	1.03 c	1.05 c	0.99 d	-2.27
T3	0.96	1.07 b	1.19 b	1.30 b	1.13 c	11.00
T4	0.99	1.11 ab	1.22 b	1.34 b	1.16 b	14.52
T5	1.00	1.16 a	1.33 a	1.50 a	1.25 a	22.70
T6	0.93	1.13 ab	1.33 a	1.55 a	1.24 a	21.83
LSD$_{(0.05)}$	ns	0.066	0.068	0.070	0.033	
F	1.00	1.09	1.20 a	1.28 b	1.14 a	…
R-	0.96	1.05	1.15 b	1.25 b	1.10 b	-3.14
R+	0.93	1.06	1.22 a	1.36 a	1.15 a	0.40
LSD$_{(0.05)}$	ns	ns	0.038	0.047	0.019	

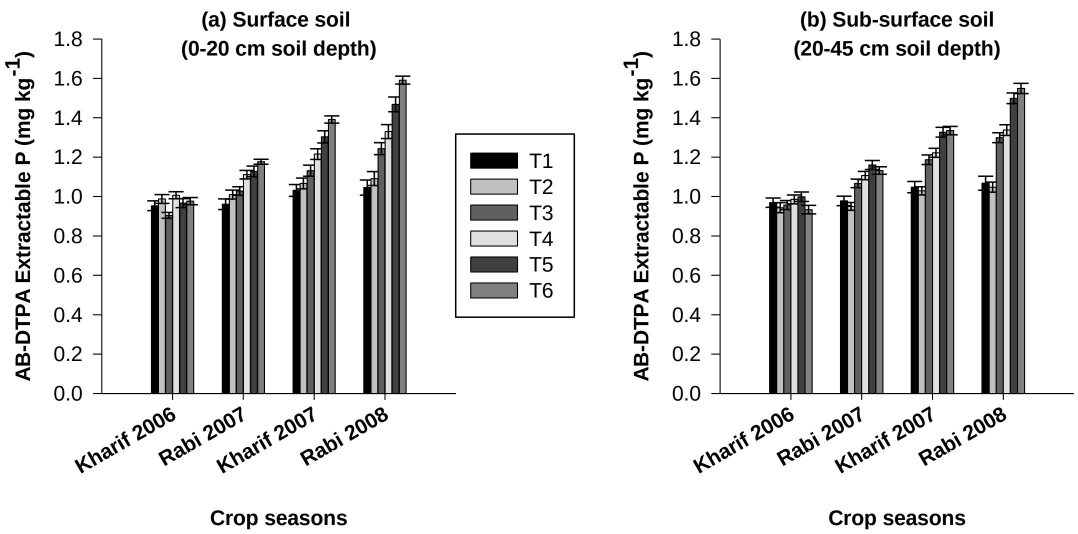

Fig. 57 Effect of fertilizer treatments on AB-DTPA Extractable P (mg kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

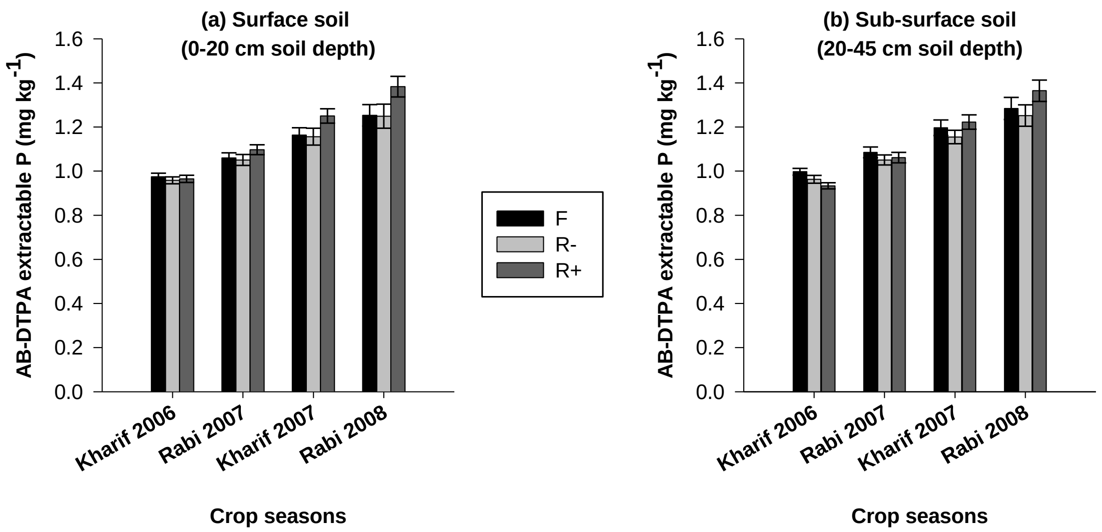

Fig. 58 **Effect of residues management practices on AB-DTPA Extractable P (mg kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons**

4.1.3.6. Mineral nitrogen

Effect of fertilizer treatments on mineral nitrogen was significant at both surface and sub-surface soils during all the seasons except Kharif 2006 (Appendix 263-271). Compared to other treatments T2 and T3 had the highest mineral nitrogen wich were at par with each other at both surface and sub-surface soils (Fig. 59). Analysis of data combined over seasons showed that treatments had similar effect on mineral nitrogen (Appendix 267 and 272). The respective increases in mineral nitrogen of T2, T3, T4 and T5 over control were 27.4, 25.6, 22.1 and 22.1% at surface soil and 32.9, 26.9, 23.0 and 28.0% at sub-surface soil (Table 33).

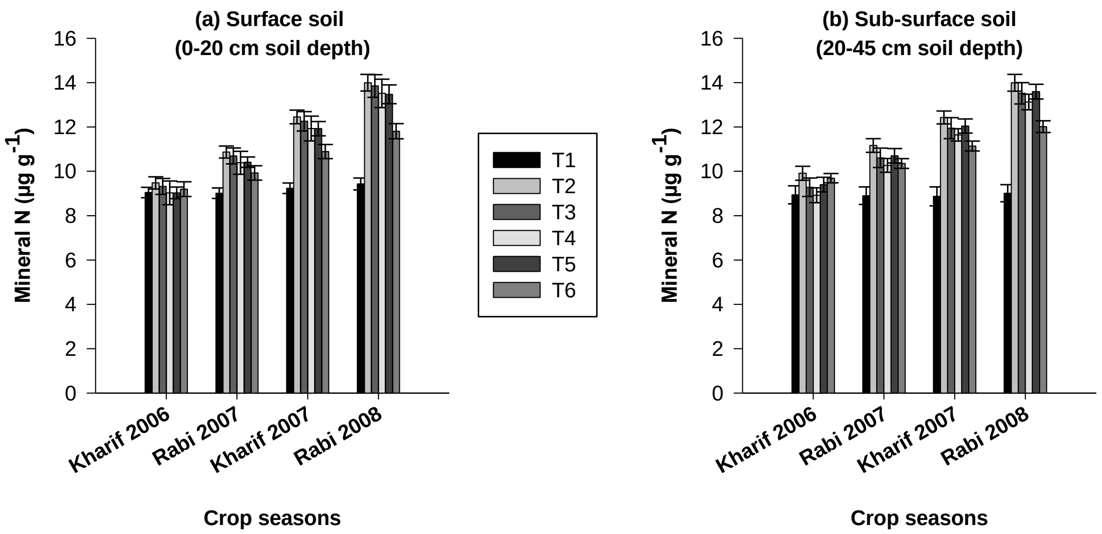

Fig. 59 **Effect of fertilizer treatments on soil mineral N (µg g^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons**

Table 33: Effect of fertilizer treatments and residues management practices on soil mineral N (µg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(µg g^{-1} soil)………………………………					
Soil depth = 0-20 cm						
T1	9.0	9.0 c	9.2 c	9.4 c	9.2 d	…
T2	9.5	10.9 a	12.5 a	14.0 a	11.7 a	27.41
T3	9.3	10.7 ab	12.3 a	13.8 a	11.5 ab	25.55
T4	9.0	10.4 ab	11.9 a	13.5 a	11.2 b	22.12
T5	9.0	10.4 ab	11.9 a	13.5 a	11.2 b	22.07
T6	9.2	9.9 b	10.9 b	11.8 b	10.5 c	13.87
$LSD_{(0.05)}$	ns	0.90	0.90	0.91	0.44	
F	8.7 b	9.7 b	10.8 c	11.8 c	10.3 c	…
R-	9.4 a	10.4 a	11.4 b	12.4 b	10.9 b	5.93
R+	9.4 a	10.5 a	12.2 a	13.9 a	11.5 a	12.23
$LSD_{(0.05)}$	0.50	0.47	0.42	0.40	0.17	
Soil depth = 20-45 cm						
T1	8.9	8.9 b	8.9 c	9.0 c	8.9 d	…
T2	9.9	11.2 a	12.4 a	14.0 a	11.9 a	32.96
T3	9.3	10.6 a	11.9 ab	13.5 a	11.3 b	26.95
T4	8.9	10.3 a	11.6 ab	13.1 a	11.0 bc	23.03
T5	9.4	10.7 a	12.0 ab	13.6 a	11.4 ab	28.03
T6	9.7	10.4 a	11.1 b	12.0 b	10.8 c	20.90
$LSD_{(0.05)}$	ns	1.00	1.01	1.01	0.49	
F	9.3	10.3	11.3	12.2	10.7	…
R-	9.4	10.4	11.4	12.4	10.9	1.51
R+	9.4	10.4	11.3	13.0	11.0	2.57
$LSD_{(0.05)}$	ns	ns	ns	ns	ns	

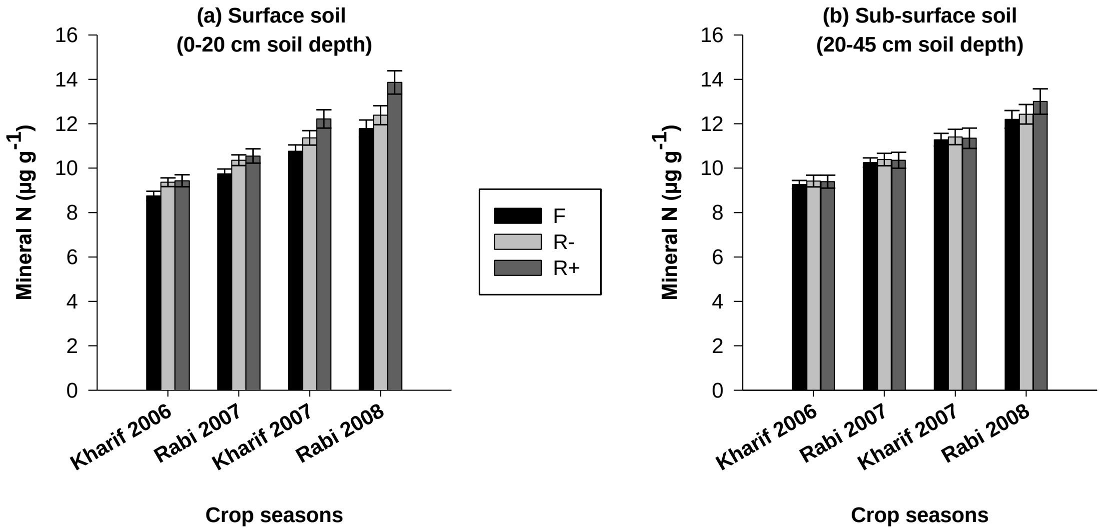

Fig. 60 Effect of residues management practices on soil mineral N (µg g^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Effect of residue management practices on soil mineral nitrogen was significant only at surface soil during all the seasons (Appendix 263-271). R+ had the highest mineral nitrogen as compared to R- and fallow plots (Fig. 60). Combined analysis of the data over seasons also showed significant effect of residues management practices on mineral nitrogen at surface soil (Appendix 267 and 272). The respective increases in soil mineral nitrogen of R- and R+ over fallow were 5.9 and 12.2% respectively (Table 33).

4.1.3.7. Soil bulk density

Effect of fertilizer treatments on soil bulk density was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the season except during Kharif 2006 (Appendix 273-281). Treatment T6 had the lowest bulk density followed by T5 at both surface and sub-surface soils, while control plots had the highest soil bulk density (Fig. 61). Analysis of the data combined over seasons showed that treatments had the same effect on soil bulk density (Appendix 277 and 282). The respective decreases in bulk density of T5 and T6 over control were 0.7 and 3.4% at surface soil and 2.0 and 2.0% at sub-surface soil (Table 34).

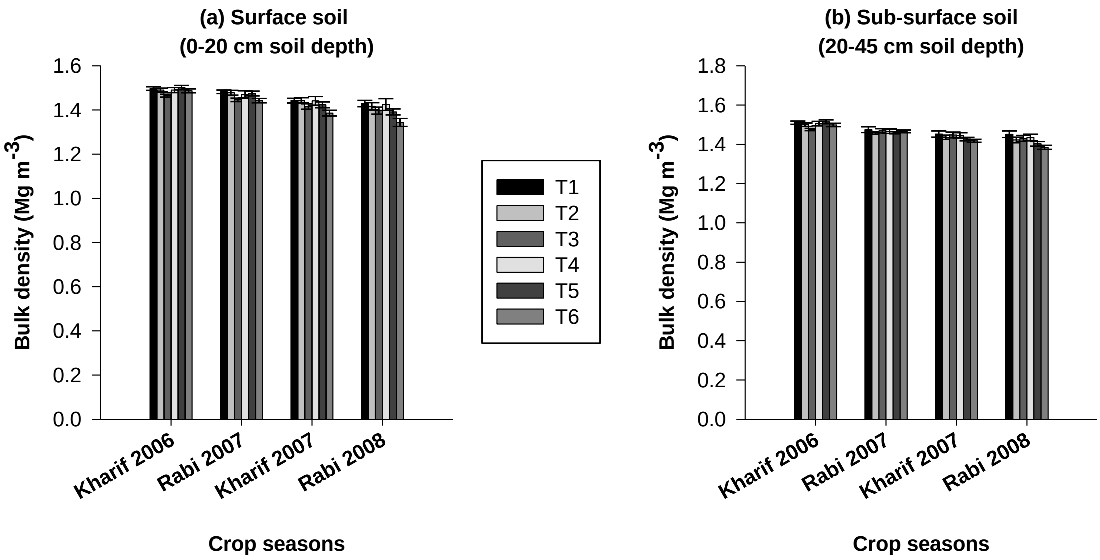

Fig. 61 Effect of fertilizer treatments on soil bulk density (Mg m^{-3}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Residue management practices had significant effect on soil bulk density during the four seasons except during Kharif 2006 at surface soil (0-20 cm soil depth) and only during Rabi 2008 at sub-surface soil (20-45 cm soil depth) (Appendix 273-281). R+ resulted in lowest bulk density, followed by R-, while fallow plots had the highest bulk density (Fig. 62).

Table 34: Effect of fertilizer treatments and residues management practices on soil bulk density (Mg m^{-3}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(Mg m^{-3})………………………………					
Soil depth = 0-20 cm						
T1	1.50	1.48 a	1.44 a	1.43 a	1.46 a	…
T2	1.49	1.48 a	1.44 a	1.42 ab	1.46 ab	0.00
T3	1.46	1.45 bc	1.42 ab	1.40 ab	1.43 c	-2.05
T4	1.49	1.47 abc	1.44 a	1.42 ab	1.46 ab	0.00
T5	1.50	1.47 ab	1.42 a	1.39 b	1.45 b	-0.68
T6	1.49	1.44 c	1.39 b	1.34 c	1.41 d	-3.42
$LSD_{(0.05)}$	ns	0.030	0.032	0.036	0.015	
F	1.49	1.48	1.45 a	1.45 a	1.47 a	…
R-	1.49	1.47	1.43 ab	1.40 b	1.45 b	-1.36
R+	1.49	1.45	1.39 b	1.35 c	1.42 c	-3.40
$LSD_{(0.05)}$	ns	ns	0.038	0.038	0.011	
Soil depth = 20-45 cm						
T1	1.51	1.47	1.45	1.45 a	1.47 a	…
T2	1.50	1.46	1.44	1.42 ab	1.45 bc	-1.36
T3	1.48	1.47	1.45	1.43 ab	1.46 ab	-0.68
T4	1.51	1.47	1.45	1.43 a	1.46 ab	-0.68
T5	1.51	1.46	1.43	1.40 bc	1.44 c	-2.04
T6	1.50	1.47	1.42	1.38 c	1.44 c	-2.04
$LSD_{(0.05)}$	ns	ns	ns	0.031	0.015	
F	1.50	1.47	1.46	1.44	1.46 a	…
R-	1.50	1.46	1.43	1.43	1.45 ab	-0.68
R+	1.50	1.47	1.42	1.39	1.44 b	-1.37
$LSD_{(0.05)}$	ns	ns	ns	ns	0.019	

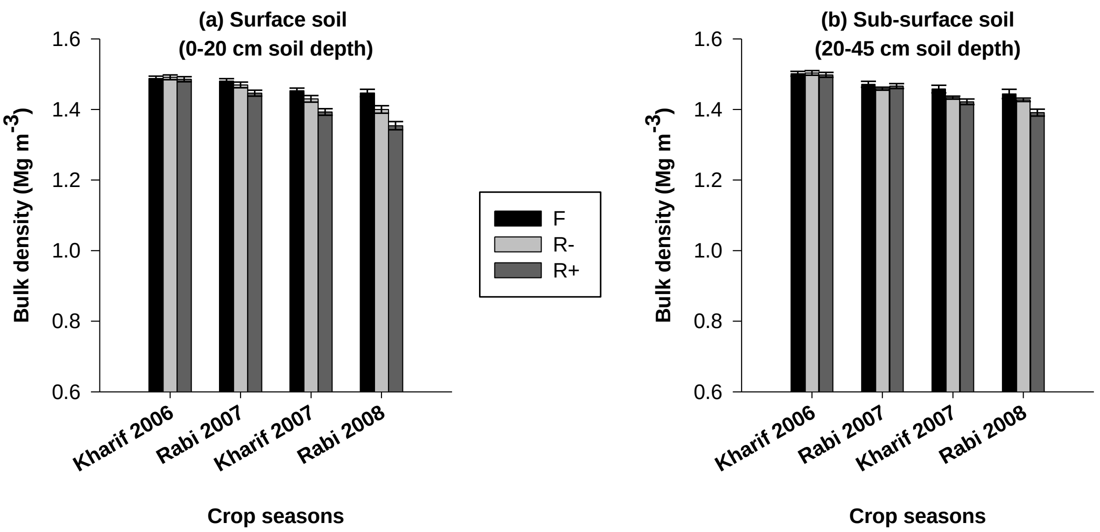

Fig. 62 Effect of residues management practices on soil bulk density (Mg m^{-3}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Combined analysis of the data over seasons showed significant effect of residues management practices on bulk density at both surface and sub-surface soils (Appendix 277 and 282). The respective decreases in soil bulk density of R- and R+ over fallow were 1.4 and 3.4% at surface and 0.7 and 1.4% at sub-surface soil (Table 34).

4.1.3.8. Available water holding capacity

Effect of fertilizer treatments on available water holding capacity was significant at surface (0-20 cm soil depth) during all the seasons except during Kharif 2006 and at sub-surface soils (20-45 cm soil depth) only during Rabi 2008 (Appendix 283-291). T6 had the highest organic matter followed by T5 (Fig. 63). Analysis of data combined over seasons showed that treatments had similar effect on AWHC (Appendix 287 and 292). The respective increases in AWHC of T5 and T6 over control were 1.1 and 3.6% at surface soil and 1.4 and 2.1% at sub-surface soil (Table 35).

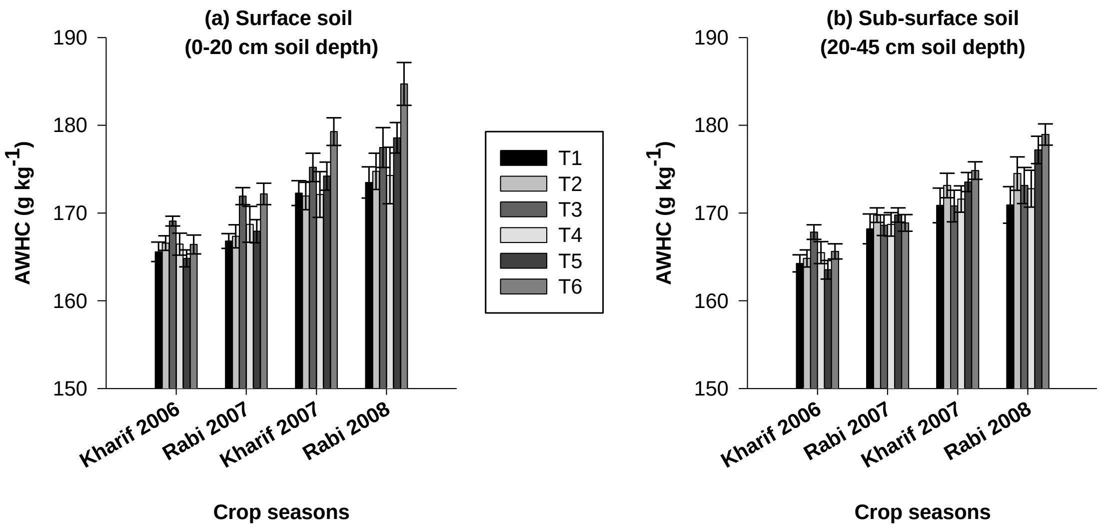

Fig. 63 Effect of fertilizer treatments on soil AWHC (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Residue management practices had significant effect on available water holding capacity only at surface (0-20 cm soil depth) during Kharif 2007 and Rabi 2008 (Appendix 283-291). R+ resulted in highest available water holding capacity followed by R-, while fallow plots had the lowest available water holding capacity (Fig. 64). Combined analysis of data over seasons showed that residues management practices had significant effect on AWHC at both surface and sub-surface soils (Appendix 287 and 292). The respective increases in AWHC of R- abd R+ over fallow were 1.5 and 3.6% at surface and 0.9 and 1.9% at sub-surface soil (Table 35).

Table 35: Effect of fertilizer treatments and residues management practices on soil AWHC (g kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	………………………..……(g kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	165.6	166.8 b	172.3 b	173.5 c	169.5 c	…
T2	166.6	167.3 b	171.9 b	174.8 bc	170.2 c	0.41
T3	169.1	171.9 a	175.2 ab	177.5 bc	173.4 b	2.30
T4	166.4	168.7 ab	172.1 b	174.3 bc	170.4 c	0.53
T5	164.8	167.9 b	174.2 b	178.6 b	171.4 c	1.12
T6	166.4	172.2 a	179.3 a	184.7 a	175.6 a	3.60
$LSD_{(0.05)}$	ns	3.55	4.41	4.52	1.90	
F	166.7	167.3	170.6 b	171.2 c	168.9 c	…
R-	166.1	168.6	173.6 b	177.2 b	171.4 b	1.48
R+	166.6	171.6	178.3 a	183.2 a	175.0 a	3.61
$LSD_{(0.05)}$	ns	ns	4.14	4.66	1.52	
Soil depth = 20-45 cm						
T1	164.3	168.2	170.9	170.9 c	168.6 c	…
T2	164.8	169.8	173.1	174.5 bc	170.6 ab	1.19
T3	167.8	168.6	170.8	173.1 c	170.1 bc	0.89
T4	165.5	168.7	171.6	172.8 c	169.6 bc	0.59
T5	163.5	169.8	173.5	177.2 ab	171.0 ab	1.42
T6	165.6	168.9	174.8	178.9 a	172.1 a	2.08
$LSD_{(0.05)}$	ns	ns	ns	3.79	1.58	
F	165.3	168.4	169.9	171.3	168.7 b	…
R-	164.9	169.7	173.0	173.7	170.3 ab	0.95
R+	165.5	168.9	174.5	178.7	171.9 a	1.90
$LSD_{(0.05)}$	ns	ns	ns	ns	2.25	

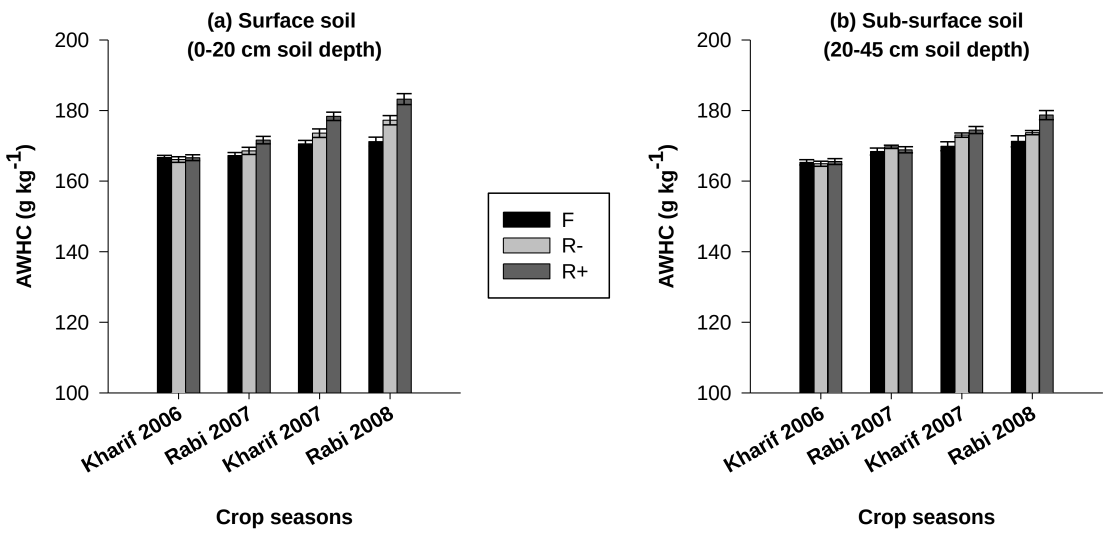

Fig. 64 Effect of residues management practices on soil AWHC (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

4.1.3.9. Total nitrogen

Effect of fertilizer treatments on soil total nitrogen was significant at surface soil (0-20 cm soil depth) during Kharif 2007 and Rabi 2008, while at sub-surface soil (20-45 cm soil depth) during all the seasons except during Kharif 2006 (Appendix 293-301). T6 had the highest total nitrogen followed by T5 (Fig. 65). Analysis of the data combined over seasons showed that treatments had significant effect on total nitrogen (Appendix 297 and 302). The respective increases in total nitrogen of T5 and T6 over control were 0.5 and 7.7% at surface soil and 7.8 and 10.4% at sub-surface soil (Table 36).

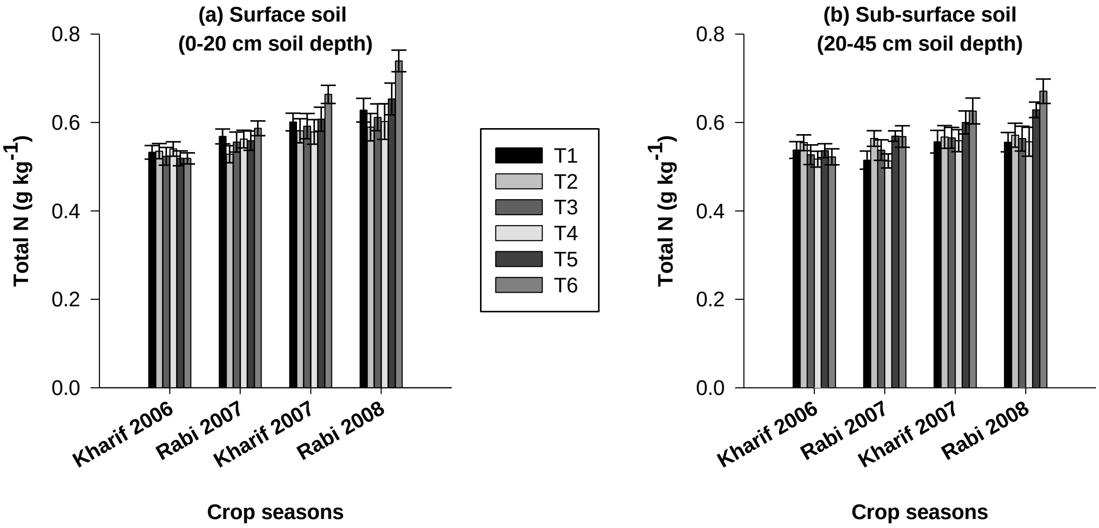

Fig. 65 Effect of fertilizer treatments on soil total N (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Residue management practices had significant effect on soil total nitrogen at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) during all the four seasons (Appendix 293-301). R+ resulted in highest soil total nitrogen followed by R-, while fallow plots had the lowest soil total nitrogen (Fig. 66). Combined analysis of the data over seasons showed that residues management practices had significant effect on total nitrogen both at surface and sub-surface soils (Appendix 297 and 302). The respective increases in total nitrogen of R- and R+ over fallow were 19.5 and 24.6% at surface soil and 19.3 and 25.8% at sub-surface soil (Table 36).

Table 36: Effect of fertilizer treatments and residues management practices on soil total N (g kg^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

Treatment	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Average	Increase (%)
	……………………..……(g kg^{-1})………………………………					
Soil depth = 0-20 cm						
T1	0.532	0.568	0.601 b	0.628 bc	0.582 b	…
T2	0.535	0.528	0.581 b	0.589 d	0.558 c	-4.12
T3	0.523	0.556	0.592 b	0.612 cd	0.571 bc	-1.89
T4	0.540	0.562	0.579 b	0.602 cd	0.571 bc	-1.89
T5	0.519	0.559	0.608 b	0.653 b	0.585 b	0.52
T6	0.519	0.587	0.664 a	0.739 a	0.627 a	7.73
$LSD_{(0.05)}$	ns	ns	0.0431	0.0358	0.0209	
F	0.482 b	0.505 b	0.520 b	0.524 c	0.508 c	…
R-	0.557 a	0.575 a	0.627 a	0.668 b	0.607 b	19.49
R+	0.546 a	0.601 a	0.665 a	0.719 a	0.633 a	24.61
$LSD_{(0.05)}$	0.0293	0.0293	0.0507	0.0145	0.0112	
Soil depth = 20-45 cm						
T1	0.538	0.515 c	0.556 c	0.555 c	0.541 c	…
T2	0.554	0.564 ab	0.567 bc	0.571 c	0.564 b	4.25
T3	0.527	0.537 bc	0.565 bc	0.563 c	0.548 c	1.29
T4	0.517	0.513 c	0.559 bc	0.556 c	0.536 c	-0.92
T5	0.536	0.569 a	0.600 ab	0.629 b	0.583 a	7.76
T6	0.522	0.568 a	0.626 a	0.671 a	0.597 a	10.35
$LSD_{(0.05)}$	ns	0.0304	0.0431	0.0304	0.0148	
F	0.472 b	0.485 b	0.491 c	0.505 c	0.488 c	…
R-	0.561 a	0.562 a	0.597 b	0.609 b	0.582 b	19.26
R+	0.564 a	0.586 a	0.648 a	0.659 a	0.614 a	25.82
$LSD_{(0.05)}$	0.0293	0.0414	0.0293	0.0293	0.0112	

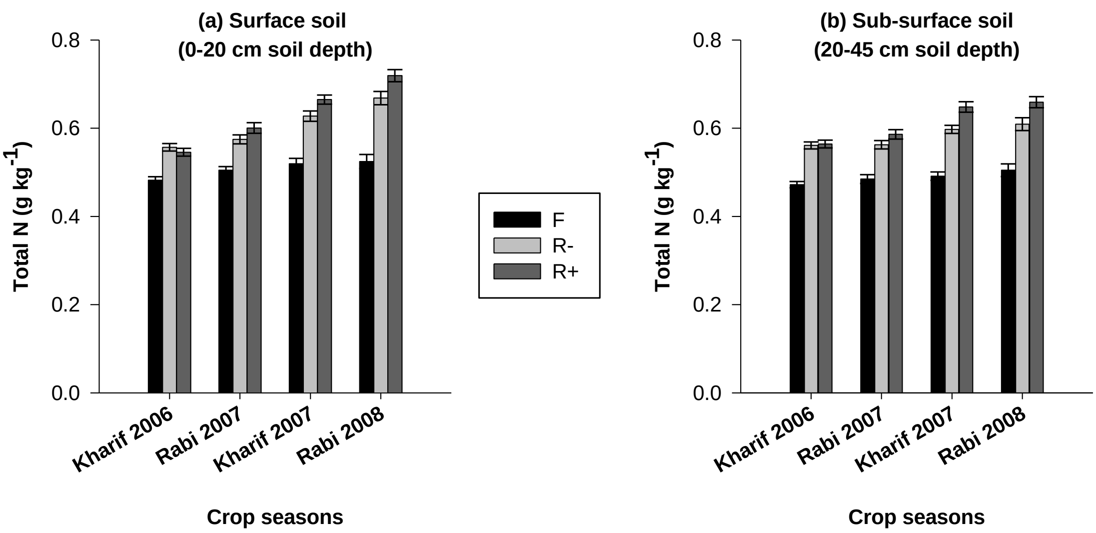

Fig. 66 Effect of residues management practices on soil total N (g kg^{-1}) at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai over seasons

4.1.3.10. Soil biological properties

4.1.3.10.1. Soil respiration

Effect of fertilizer treatments on cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 303-310). Treatment T6 had the highest soil respiration followed by T5, which included farmyard manure (FYM) additions (Table 37 and Fig. 67).

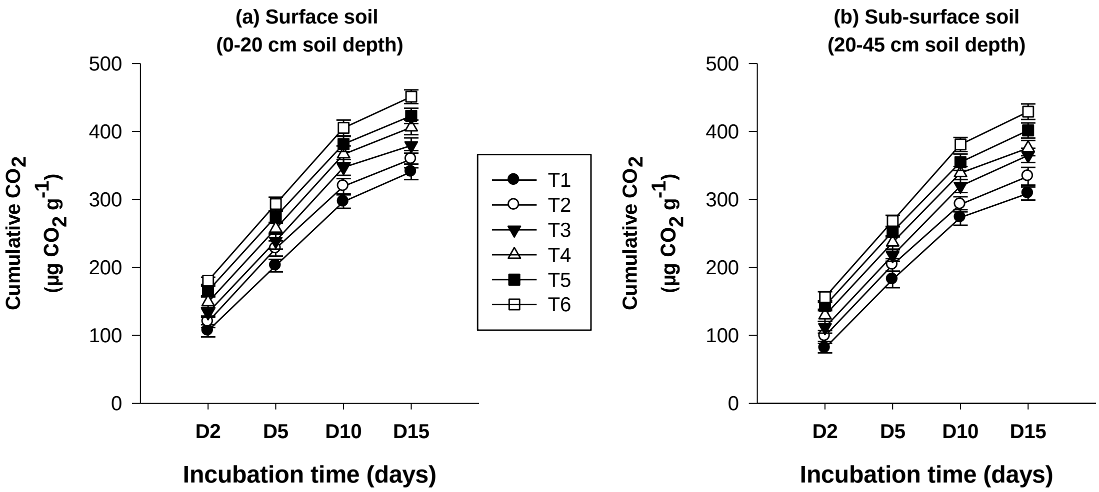

Fig. 67 Effect of fertilizer treatments on cumulative CO_2 (µg CO_2 g^{-1}) evolved during 2, 5, 10 and 15 days incubation at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai

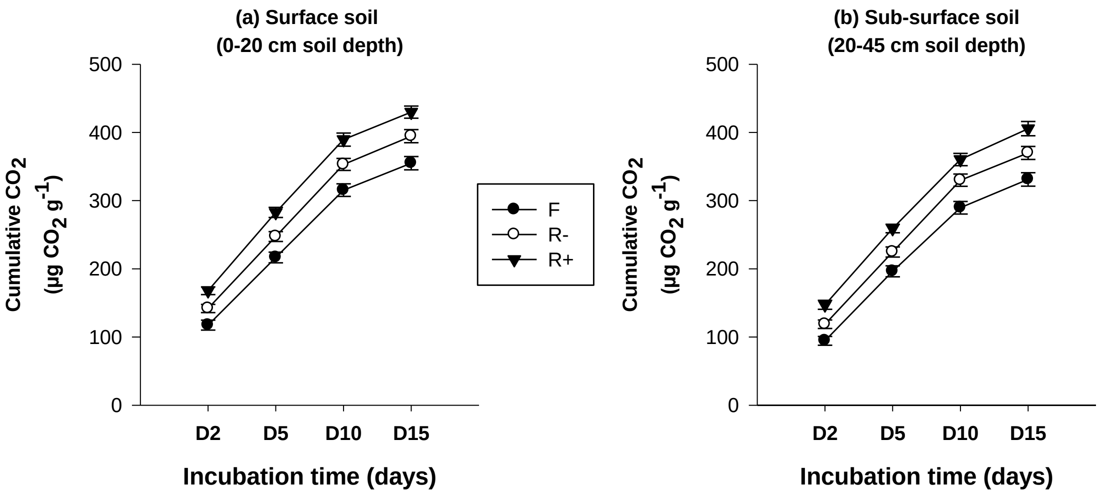

Fig. 68 Effect of residues management practices on cumulative CO_2 (µg CO_2 g^{-1}) evolved during 2, 5, 10 and 15 days incubation at (a) surface (0-20 cm soil depth) and (b) sub-surface soils (20-45 cm soil depth) of site Kotlai

Residue management practices had significant effect on cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 303-310). R+ resulted in highest soil respiration followed by R-, while fallow plots had the lowest soil respiration (Table 37 and Fig. 68).

Table 37: Effect of fertilizer treatments and residues management practices on cumulative CO_2 (µg CO_2 g^{-1}) evolved during 2, 5, 10 and 15 days incubation at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai

Treatment	2 Days	5 Days	10 Days	15 Days
	……………………………(µg CO_2 g^{-1})……………………………			
Soil depth = 0-20 cm				
T1	106.8 f	202.6 f	296.8 f	340.6 f
T2	119.9 e	227.7 e	319.4 e	359.1 e
T3	133.5 d	238.7 d	347.0 d	379.3 d
T4	148.8 c	256.8 c	366.4 c	405.9 c
T5	165.4 b	274.7 b	381.4 b	422.9 b
T6	180.2 a	293.1 a	405.1 a	451.0 a
$LSD_{(0.05)}$	5.51	8.03	10.64	9.51
F	117.5 c	216.7 c	315.4 c	354.9 c
R-	141.9 b	247.4 b	353.1 b	394.6 b
R+	167.9 a	282.7 a	389.5 a	429.9 a
$LSD_{(0.05)}$	5.73	3.58	10.56	9.70
Soil depth = 20-45 cm				
T1	81.3 f	182.1 f	273.4 f	308.7 f
T2	98.9 e	203.7 e	292.7 e	334.0 e
T3	111.7 d	217.5 d	319.5 d	364.7 d
T4	129.4 c	236.6 c	338.9 c	375.4 c
T5	143.5 b	252.5 b	354.6 b	401.4 b
T6	156.2 a	268.1 a	380.7 a	429.0 a
$LSD_{(0.05)}$	6.47	5.15	10.28	8.33
F	94.5 c	196.4 c	289.6 c	331.1 c
R-	118.8 b	224.7 b	330.0 b	369.9 b
R+	147.3 a	259.2 a	360.3 a	405.6 a
$LSD_{(0.05)}$	8.84	10.51	2.85	12.31

4.1.3.10.2. Microbial biomass carbon

Effect of fertilizer treatments on MBC was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 311 and 312). Treatment T6 had the highest microbial biomass carbon followed by T5, which included farmyard manure (FYM) additions (Table 38 and Fig. 69a).

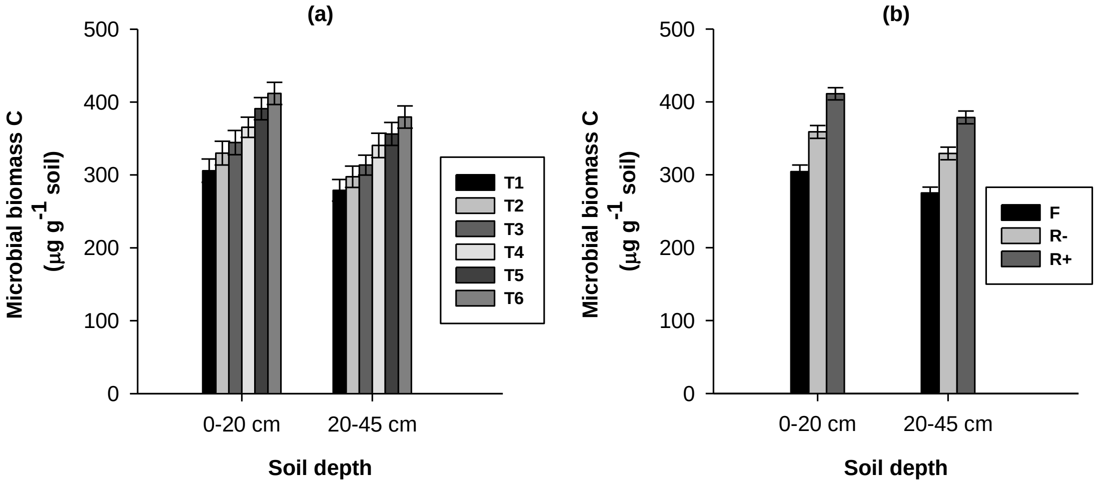

Fig. 69 **Effect of (a) fertilizer treatments and (b) residues management practices on microbial biomass C (µg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai**

Residue management practices had significant effect on microbial biomass carbon at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 311 and 312). R+ resulted in highest microbial biomass carbon followed by R-, while fallow plots had the lowest microbial biomass carbon (Table 38 and Fig. 69b).

4.1.3.10.3. Microbial biomass nitrogen

Effect of fertilizer treatments on microbial biomass nitrogen was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 313 and 314).

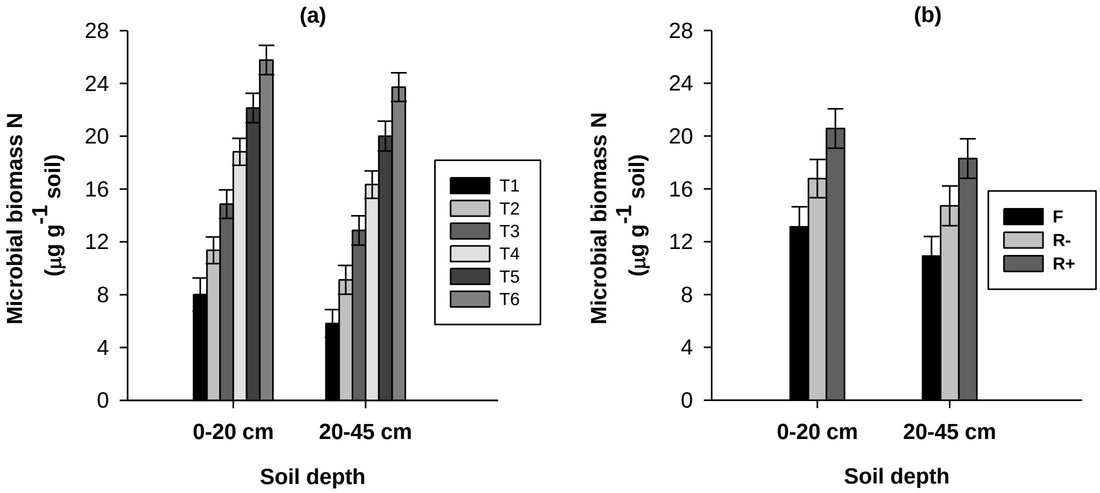

Fig. 70 **Effect of (a) fertilizer treatments and (b) residues management practices on microbial biomass N (µg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai**

Treatment T6 had the highest microbial biomass nitrogen followed by T5, which included farmyard manure (FYM) additions (Table 38 and Fig. 70a).

Residue management practices had significant effect on microbial biomass nitrogen at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 313 and 314). R+ resulted in highest microbial biomass nitrogen followed by R-, while fallow plots had the lowest microbial biomass nitrogen (Table 38 and Fig. 70b).

Table 38: Effect of fertilizer treatments and residues management practices on microbial biomass C and N and mineralizable C and N (µg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai

Treatment	MBC	MBN	Cmin	Nmin
	……………………..……(µg g^{-1})………………………………			
Soil depth = 0-20 cm				
T1	305.9 f	8.0 f	80.9 f	11.4 f
T2	329.9 e	11.4 e	87.1 e	15.0 e
T3	344.5 d	14.9 d	94.6 d	17.9 d
T4	365.4 c	18.8 c	99.9 c	20.7 c
T5	390.8 b	22.1 b	104.0 b	23.8 b
T6	411.8 a	25.8 a	110.5 a	27.2 a
$LSD_{(0.05)}$	6.31	0.73	2.90	0.66
F	304.2 c	13.1 c	86.0 c	16.2 c
R-	358.8 b	16.8 b	96.3 b	19.4 b
R+	411.1 a	20.6 a	106.2 a	22.4 a
$LSD_{(0.05)}$	8.40	0.73	2.88	0.88
Soil depth = 20-45 cm				
T1	278.9 f	5.8 f	74.6 f	9.0 f
T2	297.5 e	9.1 e	79.8 e	12.4 e
T3	313.5 d	12.9 d	87.1 d	15.8 d
T4	340.6 c	16.3 c	92.4 c	19.0 c
T5	356.2 b	20.0 b	96.7 b	21.5 b
T6	379.4 a	23.7 a	103.8 a	24.7 a
$LSD_{(0.05)}$	6.50	0.61	2.81	0.80
F	275.0 c	10.9 c	79.0 c	14.0 c
R-	329.3 b	14.7 b	90.0 b	17.1 b
R+	378.7 a	18.3 a	98.3 a	20.1 a
$LSD_{(0.05)}$	7.26	0.37	0.78	0.96

MBC = Microbial biomass C (µg g^{-1}), MBN = Microbial biomass N (µg g^{-1}), C_{min} = mineralizable C (µg g^{-1}), and N_{min} = mineralizable N (µg g^{-1})

4.1.3.10.4. Mineralizable C

Effect of fertilizer treatments on Mineralizable C was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix

315 and 316). Treatment T6 had the highest Mineralizable C followed by T5, which included farmyard manure (FYM) additions (Table 38 and Fig. 71a).

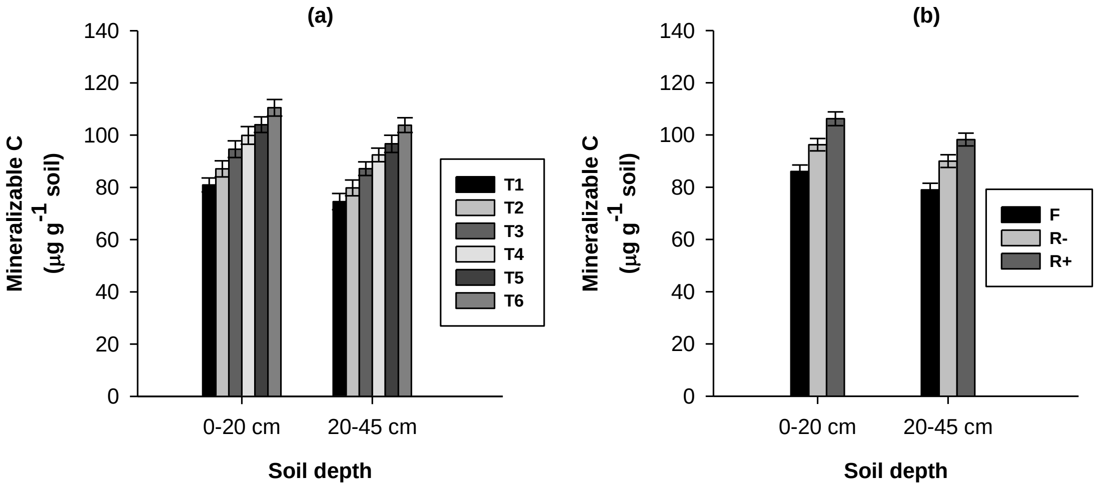

Fig. 71 Effect of (a) fertilizer treatments and (b) residues management practices on mineralizable C (µg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai

Residue management practices had significant effect on Mineralizable C at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 315 and 316). R+ resulted in highest Mineralizable C followed by R-, while fallow plots had the lowest Mineralizable C (Table 38 and Fig. 71b).

4.1.3.10.5. Mineralizable N

Effect of fertilizer treatments on Mineralizable N was significant at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 317 and 318). Treatment T6 had the highest Mineralizable N followed by T5, which included farmyard manure (FYM) additions (Table 38 and Fig. 72a).

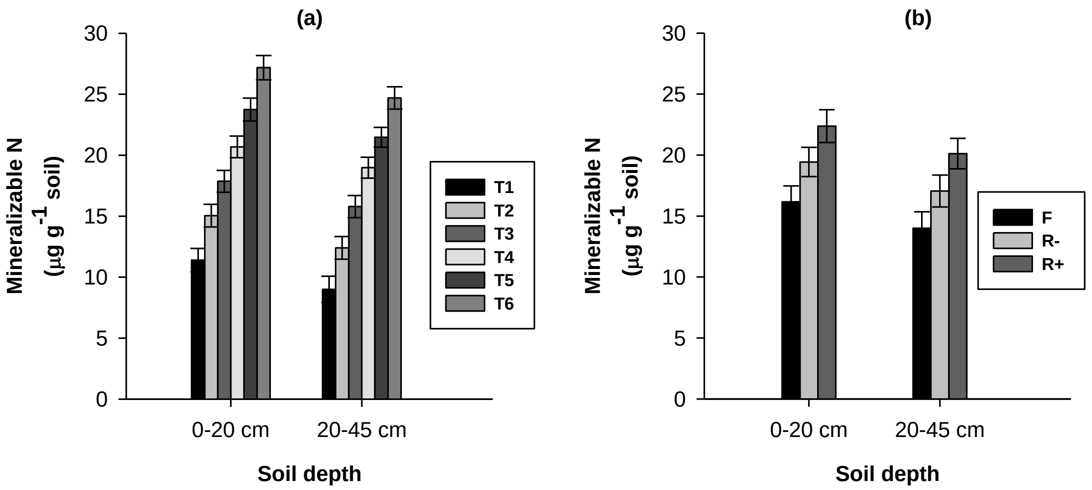

Fig. 72 Effect of (a) fertilizer treatments and (b) residues management practices on mineralizable N (µg g^{-1}) at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) of site Kotlai

Residue management practices had significant effect on Mineralizable N at both surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 317 and 318). R+ resulted in highest Mineralizable N followed by R-, while fallow plots had the lowest Mineralizable N (Table 38 and Fig. 72b).

4.2. Discussion

4.2.1. Effect of fertilizer treatments on soil properties

4.2.1.1. Soil pH

Soil pH decreased with the integrated supply of nutrients through inorganic fertilizers and farmyard manure (FYM). At the surface soil T6 (Application of 20 t FYM ha^{-1} and reducing commercial inorganic N fertilizer to 60 kg N ha^{-1}) decreased soil pH by 1.1, 1.6 and 1.9% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective decreases in soil pH at these sites were 1.3, 0.7 and 0.4%.

These results are contrary to those obtained by Kaihura *et al.* (1999) who reported significant increase in soil pH with the application of farmyard manure (FYM). Inorganic fertilizers had no effect on pH, which is supported by Kaihura *et al.* (1999) who reported that N and P fertilizers had no effects on soil pH. Patra *et al.* (2000) concluded that soil pH after harvest of mint did not significantly differ among the organic and inorganic fertilizers treatments.

4.2.1.2. Electrical conductivity

Effect of fertilizer treatments on soil electrical conductivity was statistically non-significant at all the three sites, i.e., Guljaba, Gado and Kotlai. Walker and Bernal (2008) also found similar results and reported that organic amendments in the soil did not affect soil electrical conductivity.

4.2.1.3. Soil bulk density

Effect of fertilizer treatments on soil bulk density was significant. Treatment T6 had the lowest bulk density followed by T5 at both surface and sub-surface soils of all the three sites. The maximum decrease occurred in T6 (Application of 20 t FYM ha^{-1} and reducing commercial inorganic N fertilizer to 60 kg N ha^{-1}). At the surface soil T6 decreased soil bulk density by 5.2, 3.6 and 0.7% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective decreases in soil bulk density at these sites were 5.1, 2.1 and 2.0%. Decrease in soil bulk density with integrated supply of nutrients could be attributed to higher organic matter content, better soil structure and soil aggregation.

Patra *et al.* (2000) observed significant decrease in soil bulk density with waste recycling over fertilizer application. Hati *et al.* (2006) observed the lowest bulk density in the surface soil in NPK +FYM treatment (Jadoon *et al.*, 2003; Hati *et al.*, 2006). Schjonning *et al.* (1994) also reported reduction in the bulk density of the soil due to application of cattle manure in a long-term integrated nutrient management experiment which was attributed to the higher organic matter content of the soil, better aggregation and increased root growth in the fertilizer and manure-treated plots. Soil bulk density decreased as a result of dilution of the denser soil mineral fraction and soil aeration increases because of the increase in soil porosity accompanying structural stability. These results are in agreement with Kay and VandenBygaart (2002), Tejada *et al.* (2006) and Tejada *et al.* (2009)

Manured plots have greater porosity and reduced bulk density (Celik *et al.*, 2004). Application of farmyard manure (FYM) decreased bulk density. Decrease in bulk density may be due to simple physical effect of mixing organic matter in the mineral fraction or formation of stable aggregates, which in turn improve permeability (Kaihura *et al.*, 1999; Herrick and Lal, 1995). Bulk density decreased as a result of the dilution of the denser soil mineral fraction and soil aeration increased because of the increase in soil porosity with the structural stability (Tejada *et al.*, 2008; Kay *et al.*, 1997; Tejada and Gonzalez, 2006; Tejada *et al.*, 2006).

4.2.1.4. Available water holding capacity

Effect of fertilizer treatments on available water holding capacity was significant. T6 had the highest available water holding capacity followed by T5, while control plots had the lowest available water holding capacity. The maximum increase occurred in T6 (Application of 20 t FYM ha^{-1} and reducing commercial inorganic N fertilizer to 60 kg N ha^{-1}). At the surface soil T6 increased AWHC by 5.8, 3.6 and 3.6% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in AWHC at these sites were 5.4, 2.6 and 2.1%.

AWHC is closely related to organic matter in the soil. Increasing organic matter in the soil will improve AWHC of the soil. Soils high in organic matter have greater AWHC than the soils of similar texture with less organic matter (Hudson, 1994; Barzegar *et al.*, 2002).

Gangwar *et al.*, (2006) reported considerable improvements in soil physical properties (25% more porosity, 16 times more water holding capacity and increased infiltration rate) due to manure applications.

4.2.1.5. Soil organic matter

Effect of fertilizer treatments on soil organic matter was significant at both surface and sub-surface soils. Soil organic matter increased with the application of fertilizers (both organic and inorganic) at both surface and sub-surface soils. Maximum increase occurred in T6 followed by T5 (integrated supply of nutrients through organic and inorganic fertilizers). At the surface soil T6 increased soil organic matter by 17, 9.3 and 7.7% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in soil organic matter at these sites were 12.4, 10.4 and 11.7%.

Supply of nutrients through integrated nutrient management increased soil organic matter, which in return improved soil physical condition for plant growth leading to better availability of plant nutrients. Organic amendments when coupled with fertilizer applications increased soil organic matter and fertility (Blair *et al.*, 2006), and are one of the most common rehabilitation practices to improve soil physiochemical properties (Celik *et al.*, 2004).

Hegde (1996) reported higher soil organic carbon (SOC) through integrated supply of nutrient as against application of all nutrients through fertilizers. Jadoon *et al.* (2003) reported significant increase in organic matter in the treatment plots receiving farmyard manure (FYM) over the treatments without farmyard manure (FYM). Yadav *et al.* (2000) found that combined use of manures and fertilizers increased soil organic carbon (SOC). Swarup (2001) reported considerable increase in soil organic carbon (SOC) by farmyard manure (FYM) application. Manna *et al.* (2005) concluded that soil organic carbon (SOC) content in soil was either maintained or improved with combined application of fertilizers and farmyard manure (FYM).

Dong *et al.* (2006) reported that over 20 years with farmyard manure (FYM) application, soil organic matter increased by 80 % compared to only 10 % with NPK. Hati *et al.* (2006) concluded that application of balanced fertilizers in combination with organic manures could sequester soil organic carbon (SOC) in the surface. These results are supported by other scientists (Swarup and Wanjari, 2000; Patra *et al.*, 2000; Chand *et al.*, 2006).

4.2.1.6. Potassium

Effect of fertilizer treatments on potassium content in soil was significant at both surface and sub-surface soils. Potassium content increased with the application of fertilizers (both organic and inorganic) at both surface and sub-surface soils. Maximum increase occurred in T6 followed by T5 (integrated supply of nutrients through organic and inorganic fertilizers). At the surface soil T6 increased potassium content in soil by 16.0, 18.5 and 12.8% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in potassium contents at these sites were 9.8, 16.8 and 18.4%.

Patra *et al.* (2000) reported higher available K content in soil with integrated supply of nutrients. Application of potassium fertilizer increased available K in soil (Zhang and Xu, 2005). Ellmer *et al.* (2000) reported that application of 15 t FYM ha^{-1} yr^{-1} gave a surplus of 99 kg K ha^{-1} yr^{-1} in soil. Kaihura *et al.*, (1999) concluded that farmyard manure (FYM) application significantly increased K content in soil.

4.2.1.7. Phosphorus

Effect of fertilizer treatments on phosphorus content in soil was significant at both surface and sub-surface soils. Phosphorus content in soil increased with the application of fertilizers (both organic and inorganic) at both surface and sub-surface soils. Maximum increase occurred in T6 followed by T5 (integrated supply of nutrients through organic and inorganic fertilizers). At the surface soil T6 increased phosphorus content by 21.8, 21.9 and 28.7% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in phosphorus content at these sites were 21.9, 24.9 and 21.8%.

Patra *et al.* (2000) indicated that integrated supply of nutrients increased available P in soil and concluded that integrated supply of nutrients helps in increasing the availability of nutrients. Yadav *et al.* (2000) also reported that available P content increased with P additions through fertilizers or manures. Swarup (2001) reported that addition of farmyard manure (FYM) (10-15 t ha^{-1}) has synergetic effect on improving efficiency of optimum doses of NPK (Chand *et al.*, 2006).

Ellmer *et al.*, (2000) farmyard manure (FYM) produced a surplus of 19 kg P ha^{-1} yr^{-1} in soil applied at the rate of 15 t ha^{-1} yr^{-1} compared to the control (without FYM). Kaihura *et al.*, (1999) Soil content of available P was significantly increased by farmyard manure (FYM) application. Meelu (1981) reported that application of 12 Mg ha^{-1} farmyard manure (FYM) produced a residual effect equivalent to 13 kg of P to the succeeding crop.

4.2.1.8. Mineral nitrogen

Effect of fertilizer treatments on mineral N was significant at both surface and sub-surface soils. Mineral N increased with the application of fertilizers (both organic and inorganic) at both surface and sub-surface soils. Maximum increase occurred in T3 followed by T5. At the surface soil T3 increased mineral N by 12.7, 13.9 and 25.6% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in mineral N at these sites were 14.4, 16.9 and 26.9%.

Nitrogen fertilization has been shown to increase soil NO3-N (Malhi *et al.*, 2006). Increasing rate of N fertilizer application enhanced residual soil N (Yang *et al.*, 2007). Larney and Janzen, (1997) Manure-derived NO3-N was less mobile in the moderately and severely eroded surfaces created by topsoil removal. This implies that eroded soils may accommodate high rates of manure without an associated NO3-N leaching problem, because of the absence of a network of macropores.

4.2.1.9. Total nitrogen

Effect of fertilizer treatments on total N was significant at both surface and sub-surface soils. Total N increased with the application of fertilizers (both organic and inorganic) at both surface and sub-surface soils. Maximum increase occurred in T3 followed by T6 (Application of 20 t FYM ha^{-1} and reducing commercial inorganic N fertilizer to 60 kg N ha^{-1}). At the surface soil T6 increased total N by 17, 9.8 and 7.7% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in total N at these sites were 9.9, 8.9 and 10.4%.

Nitrogen fertilization has been shown to enhance soil total N (203%) and C/N ratio (Habtegebrial *et al.*, 2007) gave an increase of 18% to 34% in residual soil N (Yang *et al.*, 2007). Total N was significantly correlated with organic matter concentration and was also related to the input of N fertilizer (Zhang and Xu, 2005; Zhang *et al.*, 1996). Swarup (2001) reported that addition of FYM (10-15 t ha^{-1}) has synergetic effect on improving efficiency of optimum doses of NPK (Chand *et al.*, 2006).

4.2.1.10. Soil biological properties

Effect of fertilizer treatments on microbial activity, microbial biomass C and N and mineralizable C and N was significant. Treatment T6 had better microbial properties followed by T5, which included farmyard manure (FYM) additions.

Soil microbial respiration, measured through carbon dioxide production is a direct indicator of microbial activity, and indirectly reflects the availability of organic material (Gomez *et al.*, 2001; Tejada and Gonzalez, 2003; Tejada *et al.*, 2006; Tejada and Gonzalez, 2006). Soil microbial biomass increase affects positively soil respiration and enzymatic activities (Tejada *et al.*, 2008). Garcia *et al.* (2000) found that soil biological and biochemical parameters are more sensitive indicators of changes occurring in the soil than physical or chemical parameters. Due to their sensitivity, these properties provide rapid and accurate information on changes in soil quality.

A single application of manure at a modest rate contributed to microbial conditions (Mabuhay *et al.*, 2006). Soil microbial biomass respond much more quickly to the changes in soil management practices as compared to total soil organic matter (Goyal *et al.*, 1999; Garcia *et al.*, 2000). Increase in biomass C can be attributed to a positive effect of organic materials in the soil, to the incorporation of easily degradable materials, which stimulate the autochthonous microbial activity of the soil as well to the incorporation of exogenous microorganisms (Blagodatsky *et al.*, 2000; Tejada *et al.*, 2008; Tejada *et al.*, 2006; Tejada and Gonzalez, 2006; Schaffers, 2000). Nitrogen fertilization has been shown increase organic N mineralization by 4.0 to 9.4% (Li *et al.*, 2003).

Several studies have indicated that soil microbial processes are directly and indirectly influenced by soil structure. The presence of small pores reduces accessibility of organic materials to decomposers, leading to physical protection of C and a reduction in N mineralization (Van Veen and Kuikman, 1990; Tejada *et al.*, 2006). The labile fraction of organic matter is the most degradable and therefore the most susceptible to mineralization, acting as an immediate energy source for microorganisms (Tejada *et al.*, 2009).

4.2.2. Effect of residues management practices on soil properties

4.2.2.1. Soil pH

Effect of residues management practices was significant only at surface soil. R+ (mungbean residues incorporated) had the lowest soil pH, followed by fallow, while R- (mungbean residues removed) had the highest soil pH. Incorporation of mungbean residues (R+) decreased soil pH by 1.1, 0.9 and 1.1% at Guljaba, Gado and Kotlai respectively. The results are supported by Rasmussen (1999) who reported that retaining plant residues on soil surface resulted in low soil pH.

4.2.2.2. Electrical conductivity

Effect of management practices on soil electrical conductivity at both surface and sub-surface soil was statistically non-significant at all the three sites, i.e., Guljaba, Gado and Kotlai.

4.2.2.3. Soil bulk density

Effect of residue management practices on soil bulk density was significant. R+ (mungbean residues incorporated) resulted in lowest bulk density followed by R- (mungbean residues removed), while fallow plots had the highest bulk density. At the surface soil incorporation of mungbean residues (R+) decreased soil bulk density by 3.0, 1.4 and 3.4% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective decreases in soil bulk density at these sites were 1.5, 2.1 and 1.4%.

Soil bulk density decreased as a result of dilution of the denser soil mineral fraction with mungbean residues increasing soil aeration because of higher soil porosity accompanying improved soil structure. These results are in agreement with Kay and VandenBygaart (2002), Tejada *et al.* (2006) and Tejada *et al.* (2009)

4.2.2.4. Available water holding capacity

Effect of residue management practices on available water holding capacity was significant. R+ (mungbean residues incorporated) resulted in highest AWHC followed by R- (mungbean residues removed), while fallow plots had the lowest AWHC. At the surface soil incorporation of mungbean residues (R+) increased AWHC by 3.3, 1.9 and 3.6% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in AWHC at these sites were 1.4, 2.6 and 1.9%.

Incorporation of mungbean residues improved AWHC considerably. Increase of 16 times more water holding capacity due to residue or manure applications has been reported (Gangwar *et al.*, 2006).

4.2.2.5. Soil organic matter

Effect of residue management practices on soil organic matter was significant. R+ (mungbean residues incorporated) resulted in highest soil organic matter followed by R- (mungbean residues removed), while fallow plots had the lowest soil organic matter. At the surface soil incorporation of mungbean residues (R+) increased soil organic matter by 28.9, 23.4 and 26.9% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in soil organic matter at these sites were 18.7, 22.4 and 27.9%.

Retention of plant residue, retained from the previous crop or incorporated, decompose over time and can make a valuable contribution to soil organic matter (Blair *et al.*, 2006; Anatoliy and Thelen, 2007; Gangwar *et al.*, 2006). Rasmussen, (1999) also reported that retaining plant residues on soil surface resulted in more organic mater, stable soil aggregates and better protection for erosion.

4.2.2.6. Potassium

Effect of residue management practices on potassium content in soil was significant. R+ (mungbean residues incorporated) resulted in highest potassium content in soil followed by R- (mungbean residues removed), while fallow plots had the lowest potassium content. At the surface soil incorporation of mungbean residues (R+) increased potassium content in soil by 6.4, 7.4 and 12.1% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in potassium content at these sites were 6.3, 6.2 and 4.7%.

Gangwar *et al.* (2006) reported that residues incorporation enhanced soil fertility through addition of organic matter and increased available P and K.

4.2.2.7. Phosphorus

Effect of residue management practices on phosphorus content in soil was significant. R+ (mungbean residues incorporated) resulted in highest phosphorus content in soil followed by R- (mungbean residues removed), while fallow plots had the lowest phosphorus content. At the surface soil incorporation of mungbean residues (R+) increased phosphorus content in soil by 5.0, 7.5 and 5.5% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in phosphorus content at these sites were 7.2, 4.3 and 0.4%.

Gangwar *et al.* (2006) reported that residues incorporation enhanced soil fertility through addition of organic matter and increased available P and K.

4.2.2.8. Nitrogen

Effect of residue management practices on mineral nitrogen in soil was significant. R+ (mungbean residues incorporated) resulted in highest mineral nitrogen followed by R- (mungbean residues removed), while fallow plots had the lowest mineral nitrogen. At the surface soil incorporation of mungbean residues (R+) increased mineral nitrogen in soil by 5.8, 4.5 and 12.2% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in mineral nitrogen at these sites were 0.4, 6.0 and 2.6%.

At the surface soil incorporation of mungbean residues (R+) increased total nitrogen in soil by 26.9, 21.6 and 24.6% at Guljaba, Gado and Kotlai respectively, while at the sub-surface the respective increases in total nitrogen at these sites were 17.7, 21.4 and 25.8%.

Peoples and Craswell, (1992) concluded that crop residues after harvest of legumes represent a potentially valuable source of N for improving soil N pools of poor soils.

4.2.2.9. Soil biological properties

Garcia *et al.* (2000) found that soil biological and biochemical parameters are more sensitive indicators of changes occurring in the soil than physical or chemical parameters. Due to their sensitivity, these properties provide rapid and accurate information on changes in soil quality.

All composted plant residues had a positive effect on soil biological properties (biomass C and the enzymatic activities) (Tejada *et al.*, 2009). Patra *et al.* (2000) reported significant increase in soil microbial biomass was observed with waste recycling over fertilizer application. Soil respiration and soil microbial biomass-C increased progressively with compost addition (Tejada *et al.*, 2009). Increase in biomass-C and soil respiration can be attributed to the incorporation of easily degradable materials, which stimulate the zymogeneous microbial activity of the soil, and to the incorporation of exogenous microorganisms (Blagodatsky *et al.*, 2000; Schaffers, 2000).

Application of green manures to soil stimulates soil microbial growth and activity, with subsequent mineralization of plant nutrients (Eriksen, 2005). The higher surface residue increased microbial activity (Bezdicek *et al.*. 2003). Soil microbial biomass respond much more quickly to the changes in soil management practices as compared to total soil organic matter (Goyal *et al.*, 1999; Garcia *et al.*, 2000). Increase in biomass C can be attributed to a positive effect of organic materials in the soil, to the incorporation of easily degradable materials, which stimulate the autochthonous microbial activity of the soil as well to the incorporation of exogenous microorganisms (Blagodatsky *et al.*, 2000; Tejada *et al.*, 2008; Tejada *et al.*, 2006; Tejada and Gonzalez, 2006; Schaffers, 2000).

Soil microbial respiration, measured through carbon dioxide production is a direct indicator of microbial activity, and indirectly reflects the availability of organic material (Gomez *et al.*, 2001; Tejada and Gonzalez, 2003; Tejada *et al.*, 2006; Tejada and Gonzalez, 2006). Soil microbial biomass increase affects positively soil respiration and enzymatic activities (Tejada *et al.*, 2008). The application of different green manures to soil increased microbial biomass-C and soil respiration rapidly (Tejada *et al.*, 2008; Goyal *et al.*, 1999; Fontaine *et al.*, 2003; Stark *et al.*, 2007).

4.3. Spatial and temporal changes in soil properties

Data given in the Tables given below show that differences in almost all soil physico-chemical properties of the three sites were statistically significant among each other. Following is an account of spatial and temporal variations in soil physical, chemical and biological properties of sites Guljaba, Gado and Kotlai.

4.3.1. Soil physical and chemical properties

4.3.1.1. Soil $pH_{(1:5)}$

Analysis of the data combined over seasons showed that soil pH differed significantly (P < 0.05) among Guljaba, Gado and Kotlai both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Appendix 319 and 326). Guljaba had the lowest soil pH (7.29) followed by Gado (7.61), while Kotlai (7.93) had the highest soil pH (Table 39 and Fig. 73).

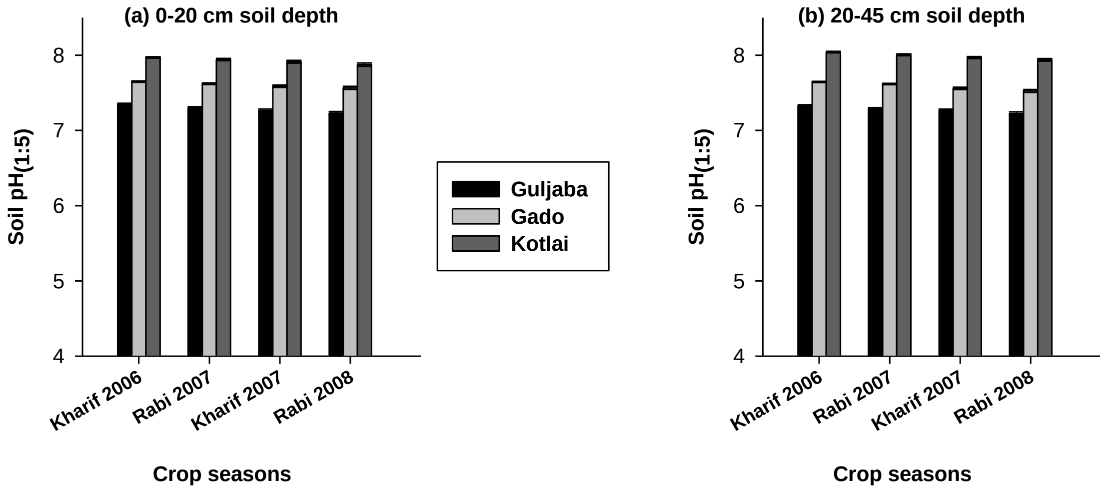

Fig. 73 Soil $pH_{(1:5)}$ of sites Gado, Guljaba and Kotlai over seasons at (a) surface and (b) sub-surface soil

Table 39: Surface and sub-surface soil $pH_{(1:5)}$ of site Gado, Guljaba and Kotlai over seasons

Site	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Mean
Soil depth = 0-20 cm					
Guljaba	7.35	7.30	7.27	7.23	7.29 c
Gado	7.65	7.62	7.59	7.57	7.61 b
Kotlai	7.97	7.94	7.91	7.88	7.93 a
Mean	7.66 a	7.62 b	7.59 c	7.56 d	
Soil depth = 20-45 cm					
Guljaba	7.33	7.29	7.26	7.23	7.28 c
Gado	7.64	7.62	7.56	7.53	7.59 b
Kotlai	8.04	8.01	7.97	7.94	7.99 a
Mean	7.67 a	7.64 b	7.60 c	7.56 d	

Analysis of the data combined over sites showed that soil pH decreased significantly (P < 0.05) over time (from Kharif 2006 to Rabi 2008) by 1.3% at surface

(0-20 cm soil depth) and 1.4% at sub-surface soils (20-45 cm soil depth) from its initial value during Kharif 2006 (Table 39 and Fig. 73) (Appendix 319 and 326).

4.3.1.2. Soil electrical conductivity

Analysis of the data combined over both sites and seasons showed that differences in $EC_{(1:5)}$ were statistically non-significant (p>0.05) among Guljaba, Gado and Kotlai and as well as among the four growing seasons (Kharif 2006 to Rabi 2008) both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 40 and Fig. 74) (Appendix 327-334). Soil electrical conductivity at all the three sites was very low and can be categorized as non-saline.

Table 40: Surface and sub-surface soil $EC_{(1:5)}$ of site Gado, Guljaba and Kotlai over seasons

Site	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Mean
Soil depth = 0-20 cm					
Guljaba	0.94	0.94	0.93	0.96	0.94 a
Gado	1.01	1.01	1.00	1.00	1.00 a
Kotlai	0.99	0.99	0.94	0.93	0.96 a
Mean	0.98 a	0.98 a	0.96 a	0.96 a	
Soil depth = 20-45 cm					
Guljaba	1.01	0.99	0.98	0.98	0.99 a
Gado	1.04	1.03	1.03	1.02	1.03 a
Kotlai	1.02	1.03	1.01	1.02	1.02 a
Mean	1.02 a	1.02 a	1.01 a	1.01 a	

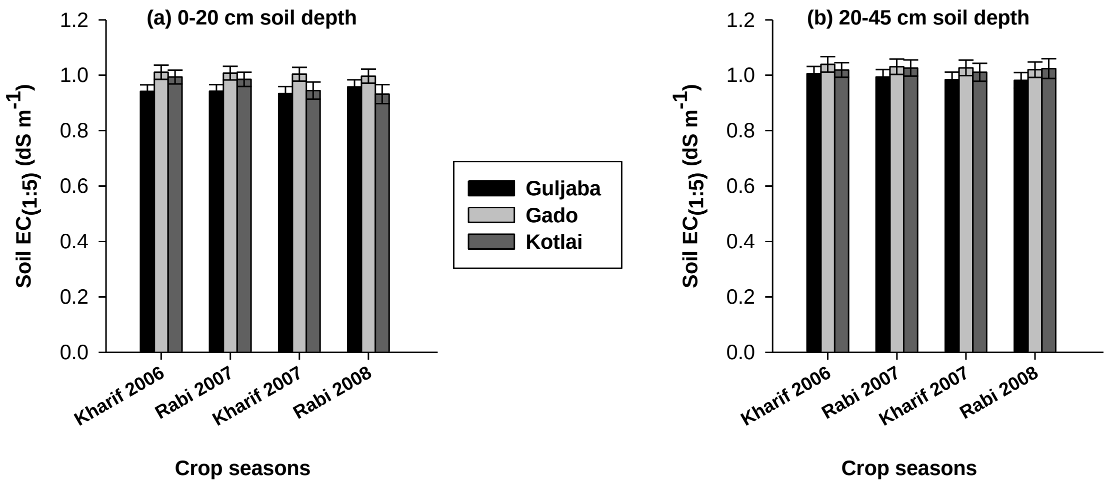

Fig. 74 Soil $EC_{(1:5)}$ of site Gado, Guljaba and Kotlai over seasons at (a) surface and (b) sub-surface soil

4.3.1.3. Soil organic matter

Analysis of the data combined over seasons showed that soil organic matter differed significantly (P < 0.05) among sites Guljaba, Gado and Kotlai both at surface

(0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 41 and Fig. 75) (Appendix 335-342). Guljaba had the highest soil organic matter followed by Gado, while Kotlai had the lowest soil organic matter both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). Soil organic matter was deficient at site Kotlai, while it was marginal at Guljaba and Gado.

Analysis of the data combined over sites showed that soil organic matter increased significantly ($P < 0.05$) over time (from Kharif 2006 to Rabi 2008) (Appendix 335-342) by 21.3% at surface (0-20 cm soil depth) and 11.9% at sub-surface soils (20-45 cm soil depth) from its initial value during Kharif 2006 (Table 41 and Fig. 75).

Table 41: Surface and sub-surface soil organic matter of sites Gado, Guljaba and Kotlai over seasons

Site	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Mean
Soil depth = 0-20 cm					
Guljaba	12.44	12.66	13.91	15.14	13.54 a
Gado	10.14	10.67	11.68	12.23	11.18 b
Kotlai	8.79	9.29	10.15	10.68	9.73 c
Mean	10.46 c	10.88 c	11.91 b	12.68 a	
Soil depth = 20-45 cm					
Guljaba	12.28	12.64	13.35	13.73	13.00 a
Gado	10.10	10.41	11.01	11.32	10.71 b
Kotlai	8.85	9.12	9.64	9.90	9.38 c
Mean	10.41 d	10.72 c	11.33 b	11.65 a	

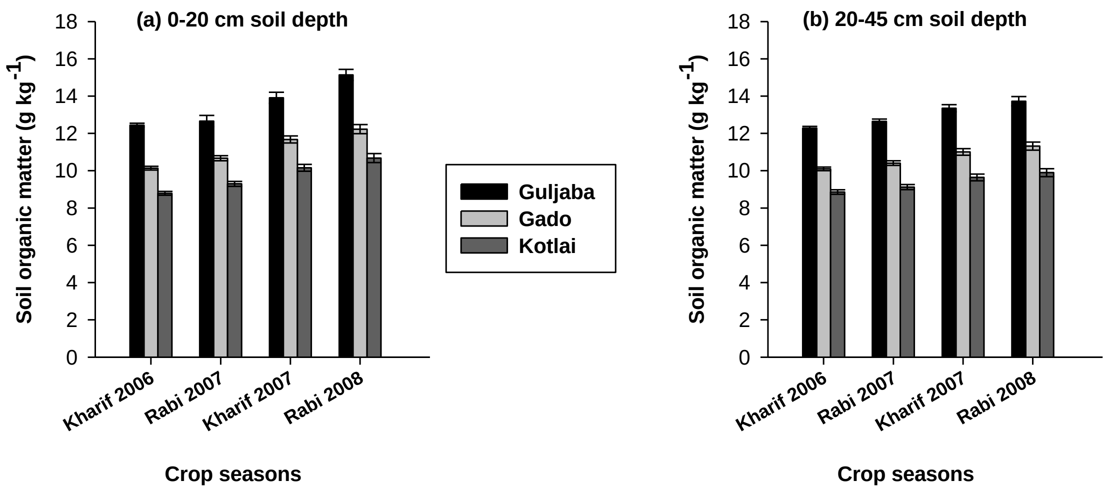

Fig. 75 Soil organic matter of sites Gado, Guljaba and Kotlai over seasons at (a) surface and (b) sub-surface soil

4.3.1.4. AB-DTPA extractable potassium

Analysis of the data combined over seasons showed that AB-DTPA Extractable Potassium differed significantly ($P < 0.05$) among Guljaba, Gado and

Kotlai at surface (0-20 cm soil depth), while at the sub-surface variation among sites was non-significant ($p>0.05$) (Table 42 and Fig. 76) (Appendix 343-350). Gado had the highest potassium concentration as compared to Guljaba and Kotlai at surface (0-20 cm soil depth). AB-DTPA Extractable Potassium at all the three sites was low and can be categorized as marginal.

Analysis of the data combined over sites showed that AB-DTPA Extractable K increased significantly ($P < 0.05$) over time (from Kharif 2006 to Rabi 2008) (Appendix 343-350)by 17.9% at surface (0-20 cm soil depth) and 17.1% at sub-surface soils (20-45 cm soil depth) from its initial value during Kharif 2006 (Table 42 and Fig. 76).

Table 42: Surface and sub-surface AB-DTPA Extractable Potassium of site Gado, Guljaba and Kotlai over seasons

Site	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Mean
Soil depth = 0-20 cm					
Guljaba	62.06	68.25	69.51	73.07	68.22 b
Gado	65.00	69.39	73.60	77.37	71.34 a
Kotlai	61.46	65.57	69.00	71.76	66.95 b
Mean	62.84 d	67.74 c	70.70 b	74.06 a	
Soil depth = 20-45 cm					
Guljaba	61.92	65.28	69.25	72.65	67.28 a
Gado	63.14	67.22	71.30	74.12	68.95 a
Kotlai	62.57	67.12	70.19	72.86	68.19 a
Mean	62.54 d	66.54 c	70.25 b	73.21 a	

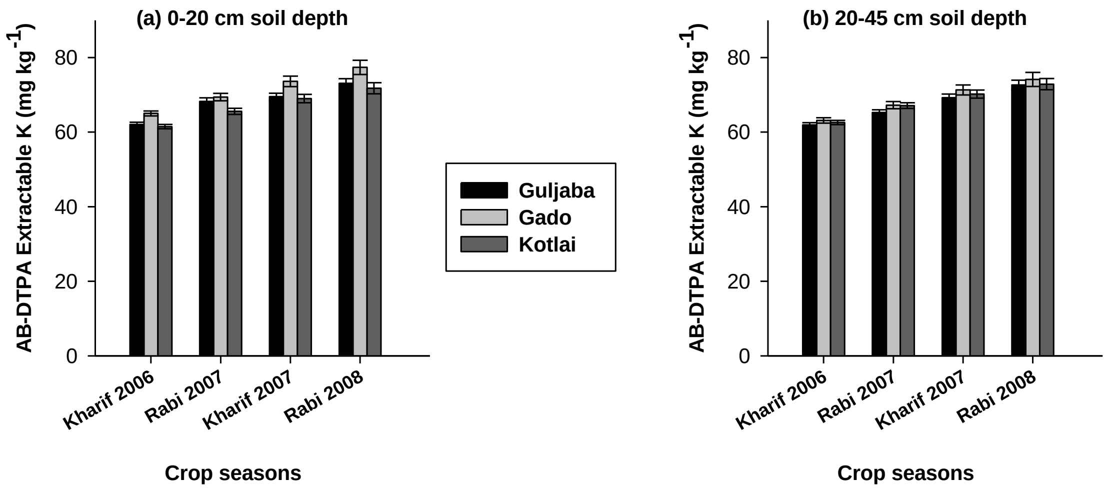

Fig. 76 AB-DTPA Extractable Potassium of site Gado, Guljaba and Kotlai over seasons at (a) surface and (b) sub-surface soil

4.3.1.5. AB-DTPA extractable phosphorus

Analysis of the data combined over seasons showed that AB-DTPA Extractable Phosphorus differed significantly ($P < 0.05$) among sites Guljaba, Gado and Kotlai both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 43 and Fig. 77) (Appendix 351-358). Guljaba had the highest P concentration followed by Gado, while Kotlai had the lowest P concentration both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). Phosphorus was deficient at all the three sites Guljaba, Gado and Kotlai.

Analysis of the data combined over sites showed that AB-DTPA Extractable P increased significantly (P < 0.05) over time (from Kharif 2006 to Rabi 2008) (Appendix 351-358)by 30.5% at surface (0-20 cm soil depth) and 30.8% at sub-surface soils (20-45 cm soil depth) from its initial value during Kharif 2006 (Table 43 and Fig. 77).

Table 43: Surface and sub-surface soil phosphorus of site Gado, Guljaba and Kotlai over seasons

Site	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Mean
Soil depth = 0-20 cm					
Guljaba	1.37	1.50	1.63	1.76	1.57 a
Gado	1.17	1.28	1.41	1.52	1.34 b
Kotlai	0.97	1.07	1.19	1.29	1.13 c
Mean	1.17 d	1.28 c	1.41 b	1.53 a	
Soil depth = 20-45 cm					
Guljaba	1.37	1.45	1.64	1.77	1.56 a
Gado	1.17	1.29	1.41	1.52	1.35 b
Kotlai	0.96	1.07	1.19	1.30	1.13 c
Mean	1.17 d	1.27 c	1.41 b	1.53 a	

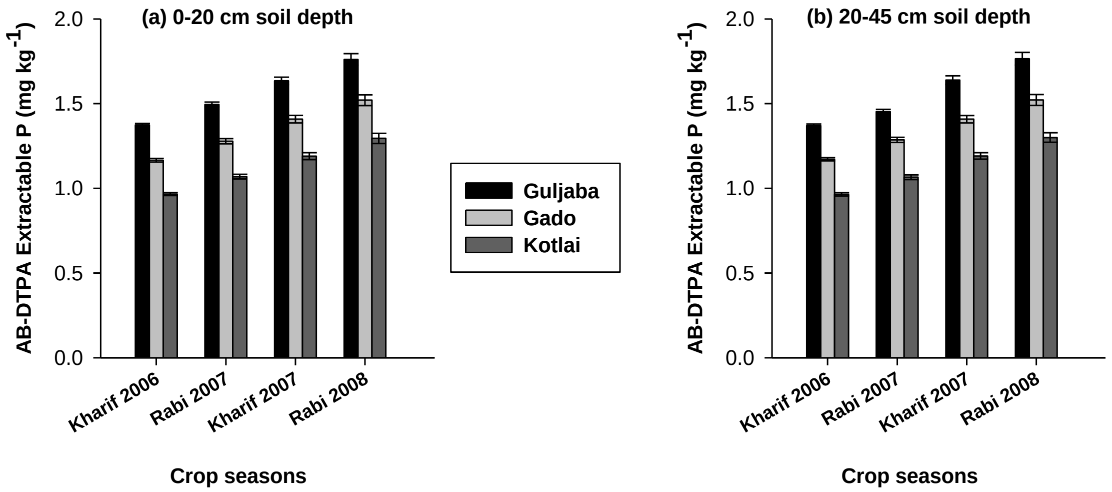

Fig. 77 Soil phosphorus of site Gado, Guljaba and Kotlai over seasons at (a) surface and (b) sub-surface soil

4.3.1.6. Mineral nitrogen

Analysis of the data combined over seasons showed that mineral nitrogen in soil differed significantly (P < 0.05) among sites Guljaba, Gado and Kotlai both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 44 and Fig. 78) (Appendix 359-366). Guljaba had the highest mineral nitrogen followed by Gado, while Kotlai had the lowest mineral nitrogen both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth).

Analysis of the data combined over sites showed that mineral N increased significantly ($P < 0.05$) over time (from Kharif 2006 to Rabi 2008) (Appendix 359-366) by 31.3% at surface (0-20 cm soil depth) and 29% at sub-surface soils (20-45 cm soil depth) from its initial value during Kharif 2006 (Table 44 and Fig. 78).

Table 44: Surface and sub-surface soil Mineral N (µg g^{-1}) of site Gado, Guljaba and Kotlai over seasons

Site	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Mean
Soil depth = 0-20 cm					
Guljaba	13.24	14.25	15.44	16.66	14.90 a
Gado	10.64	12.23	12.85	14.08	12.45 b
Kotlai	9.18	10.22	11.45	12.68	10.88 c
Mean	11.02 d	12.23 c	13.25 b	14.47 a	
Soil depth = 20-45 cm					
Guljaba	13.38	14.41	15.38	16.57	14.93 a
Gado	10.43	11.41	12.43	13.66	11.98 b
Kotlai	9.36	10.33	11.34	12.54	10.89 c
Mean	11.05 d	12.05 c	13.05 b	14.25 a	

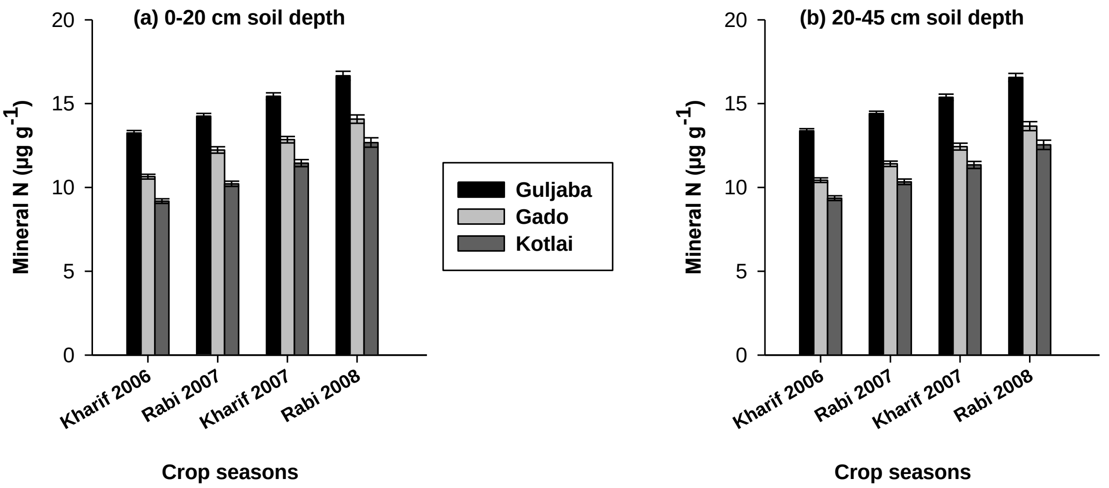

Fig. 78 Soil Mineral N (µg g^{-1}) of site Gado, Guljaba and Kotlai over seasons at (a) surface and (b) sub-surface soil

4.3.1.7. Bulk density

Analysis of the data combined over seasons showed that bulk density differed significantly ($P < 0.05$) among sites Guljaba, Gado and Kotlai both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 45 and Fig. 79) (Appendix 367-374). Guljaba had the lowest bulk density followed by Gado, while

Kotlai had the highest bulk density both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth).

Analysis of the data combined over sites showed that soil bulk density decreased significantly (P < 0.05) over time (from Kharif 2006 to Rabi 2008) (Appendix 367-374) by 6.5% at surface (0-20 cm soil depth) and 4.7% at sub-surface soils (20-45 cm soil depth) from its initial value during Kharif 2006 (Table 45 and Fig. 79).

Table 45: Surface and sub-surface soil bulk density of site Gado, Guljaba and Kotlai over seasons

Site	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Mean
Soil depth = 0-20 cm					
Guljaba	1.38	1.36	1.32	1.29	1.34 c
Gado	1.43	1.41	1.36	1.33	1.38 b
Kotlai	1.49	1.47	1.43	1.40	1.44 a
Mean	1.43 a	1.41 b	1.37 c	1.34 d	
Soil depth = 20-45 cm					
Guljaba	1.38	1.37	1.34	1.32	1.35 c
Gado	1.44	1.42	1.39	1.38	1.41 b
Kotlai	1.50	1.47	1.44	1.42	1.46 a
Mean	1.44 a	1.42 b	1.39 c	1.37 d	

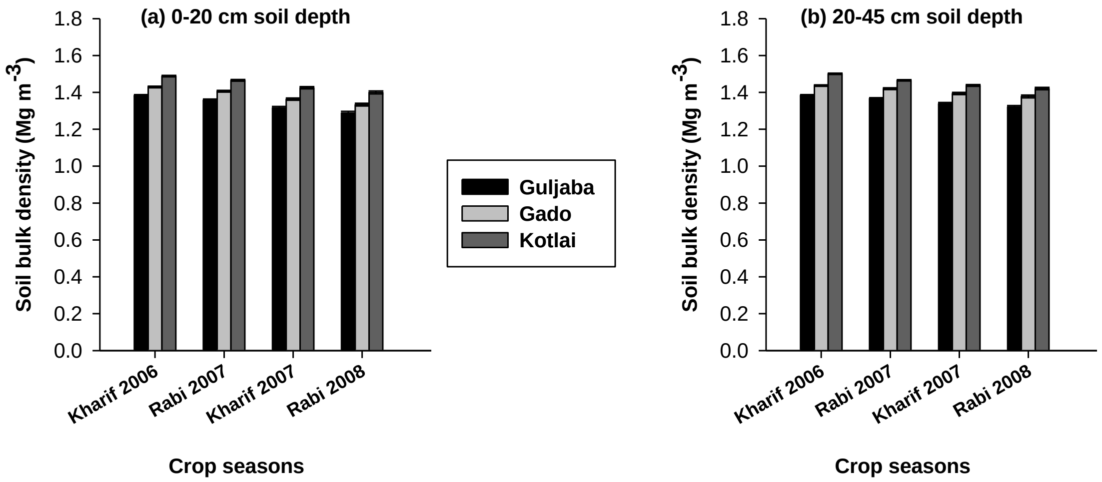

Fig. 79 Soil bulk density of site Gado, Guljaba and Kotlai over seasons at (a) surface and (b) sub-surface soil

4.3.1.8. Available water holding capacity

Analysis of the data combined over seasons showed that available water holding capacity (AWHC) in soil differed significantly (P < 0.05) among sites Guljaba, Gado and Kotlai both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 46 and Fig. 80) (Appendix 375-382). Guljaba had the highest AWHC followed by Gado, while Kotlai had the lowest AWHC both at surface

(0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth).

Analysis of the data combined over sites showed that AWHC increased significantly (P < 0.05) over time (from Kharif 2006 to Rabi 2008) (Appendix 375-382) by 7.2% at surface (0-20 cm soil depth) and 5.0% at sub-surface soils (20-45 cm soil depth) from its initial value during Kharif 2006 (Table 46 and Fig. 80).

Table 46: Surface and sub-surface soil AWHC of site Gado, Guljaba and Kotlai over seasons

Site	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Mean
Soil depth = 0-20 cm					
Guljaba	179.33	182.69	188.62	193.27	185.98 a
Gado	173.60	176.22	182.03	186.21	179.51 b
Kotlai	166.48	169.15	174.16	177.21	171.75 c
Mean	173.14 d	176.02 c	181.61 b	185.56 a	
Soil depth = 20-45 cm					
Guljaba	179.24	181.52	185.28	188.03	183.52 a
Gado	172.56	174.83	178.09	180.21	176.42 b
Kotlai	165.26	168.99	172.46	174.57	170.32 c
Mean	172.35 d	175.11 c	178.61 b	180.94 a	

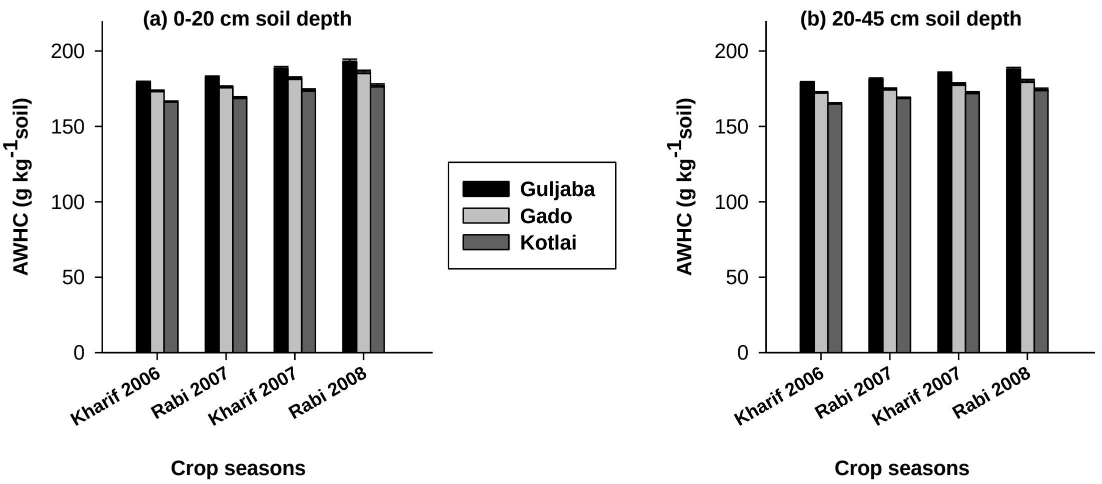

Fig. 80 Soil AWHC of site Gado, Guljaba and Kotlai over seasons at (a) surface and (b) sub-surface soil

4.3.1.9. Total nitrogen

Analysis of the data combined over seasons showed that total nitrogen in soil differed significantly (P < 0.05) among sites Guljaba, Gado and Kotlai both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 47 and Fig. 81) (Appendix 383-390). Guljaba had the highest total nitrogen followed by Gado, while Kotlai had the lowest total nitrogen both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth).

Analysis of the data combined over sites showed that total N increased significantly ($P < 0.05$) over time (from Kharif 2006 to Rabi 2008) (Appendix 383-390) by 20.1% at surface (0-20 cm soil depth) and 11.0% at sub-surface soils (20-45 cm soil depth) from its initial value during Kharif 2006 (Table 47 and Fig. 81).

Table 47: Surface and sub-surface soil Total N of site Gado, Guljaba and Kotlai over seasons

Site	Kharif 2006	Rabi 2007	Kharif 2007	Rabi 2008	Mean
Soil depth = 0-20 cm					
Guljaba	0.74	0.75	0.82	0.89	0.80 a
Gado	0.60	0.63	0.69	0.72	0.66 b
Kotlai	0.53	0.56	0.60	0.64	0.58 c
Mean	0.62 d	0.65 c	0.71 b	0.75 a	
Soil depth = 20-45 cm					
Guljaba	0.72	0.74	0.79	0.80	0.76 a
Gado	0.61	0.62	0.65	0.67	0.64 b
Kotlai	0.53	0.54	0.58	0.59	0.56 c
Mean	0.62 d	0.64 c	0.67 b	0.69 a	

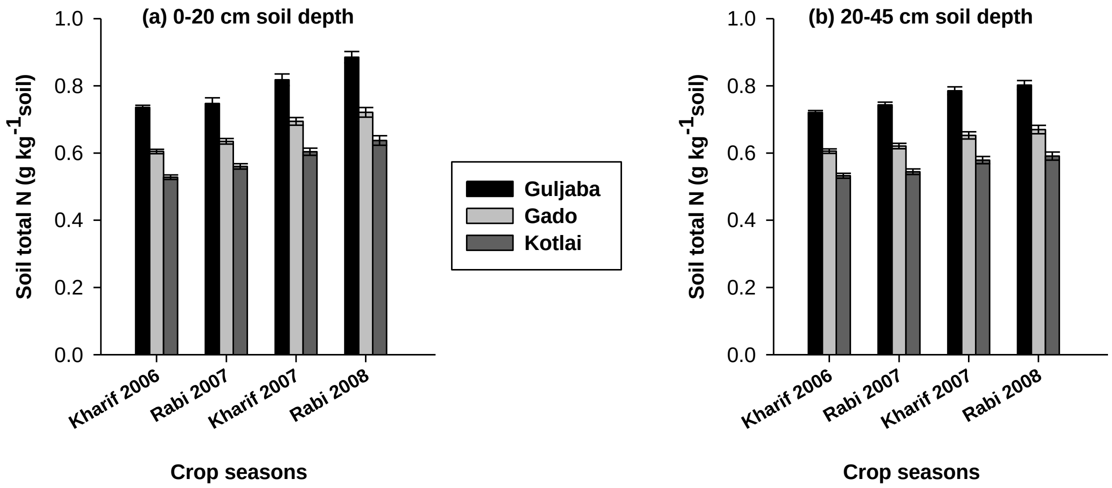

Fig. 81 Soil total N of site Gado, Guljaba and Kotlai over seasons at (a) surface and (b) sub-surface soil

4.3.2. Soil biological properties

Soil biological properties are important indicators of soil quality. Some important biological properties of the three sites were studied and compared in order to find recommended practices for soils under different degrees of erosion.

4.3.2.1. Soil respiration

Cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation of soil differed significantly ($P < 0.05$) among sites Guljaba, Gado and Kotlai both at surface

(0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 48 and Fig. 82) (Appendix 391-398). Guljaba had the highest microbial activity followed by Gado, while Kotlai had the lowest microbial activity both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth).

Table 48: Cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation of surface and sub-surface soil at site Gado, Guljaba and Kotlai

Site	2 Days	5 Days	10 Days	15 Days
Soil depth = 0-20 cm				
Guljaba	167.0 a	296.1 a	404.0 a	447.7 a
Gado	154.2 b	271.6 b	376.6 b	418.9 b
Kotlai	142.4 c	248.9 c	352.7 c	393.1 c
$LSD_{(0.05)}$	4.15	3.24	4.39	5.46
Soil depth = 20-45 cm				
Guljaba	144.4 a	274.4 a	383.3 a	422.2 a
Gado	134.4 b	251.6 b	352.1 b	393.2 b
Kotlai	120.2 c	226.8 c	326.6 c	368.9 c
$LSD_{(0.05)}$	3.19	3.46	2.764	5.64

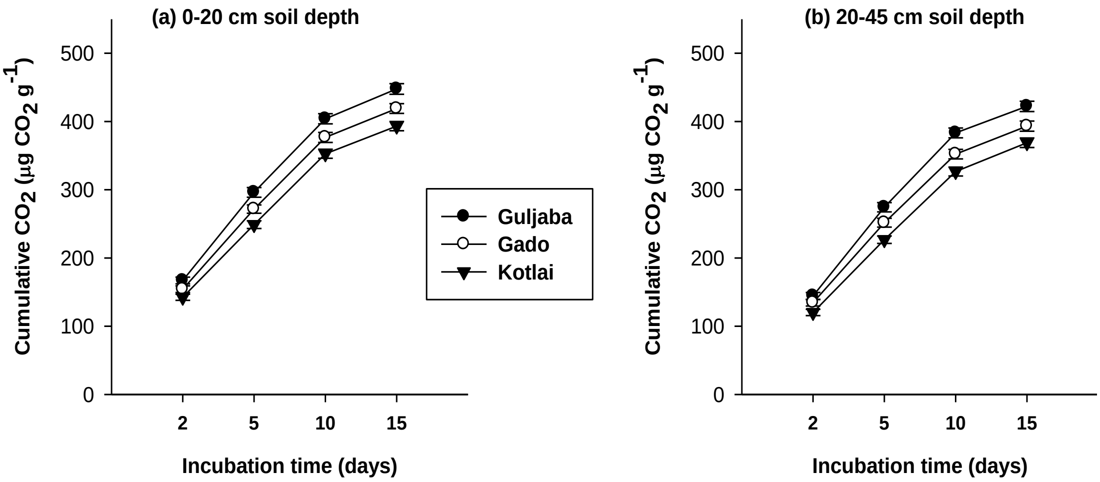

Fig. 82 Cumulative CO_2 evolved during 2, 5, 10 and 15 days incubation of (a) surface and (b) sub-surface soil at site Gado, Guljaba and Kotlai

4.3.2.2. Microbial biomass C

Microbial biomass C of soil differed significantly ($P < 0.05$) among sites Guljaba, Gado and Kotlai both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 49 and Fig. 83) (Appendix 399 and 400). Guljaba had the highest microbial biomass C followed by Gado, while Kotlai had the lowest microbial biomass C both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth).

Table 49: Microbial biomass C and N and mineralizable C and N at surface and sub-surface soil of site Gado, Guljaba and Kotlai

Site	MBC	MBN	C_{min}	N_{min}
Soil depth = 0-20 cm				
Guljaba	416.8 a	21.4 a	110.2 a	24.9 a
Gado	384.5 b	18.0 b	102.7 b	21.8 b
Kotlai	358.0 c	16.8 c	96.2 c	19.3 c
$LSD_{(0.05)}$	3.69	0.30	1.20	0.38
Soil depth = 20-45 cm				
Guljaba	387.0 a	19.3 a	104.5 a	22.7 a
Gado	352.5 b	16.0 b	96.0 b	19.3 b
Kotlai	327.7 c	14.6 c	89.1 c	17.1 c
$LSD_{(0.05)}$	3.34	0.36	0.75	0.42

MBC = Microbial biomass C (µg g^{-1} soil), MBN = Microbial biomass N (µg g^{-1} soil), C_{min} = mineralizable C (µg C g^{-1} soil), and N_{min} = mineralizable N (µg N g^{-1} soil)

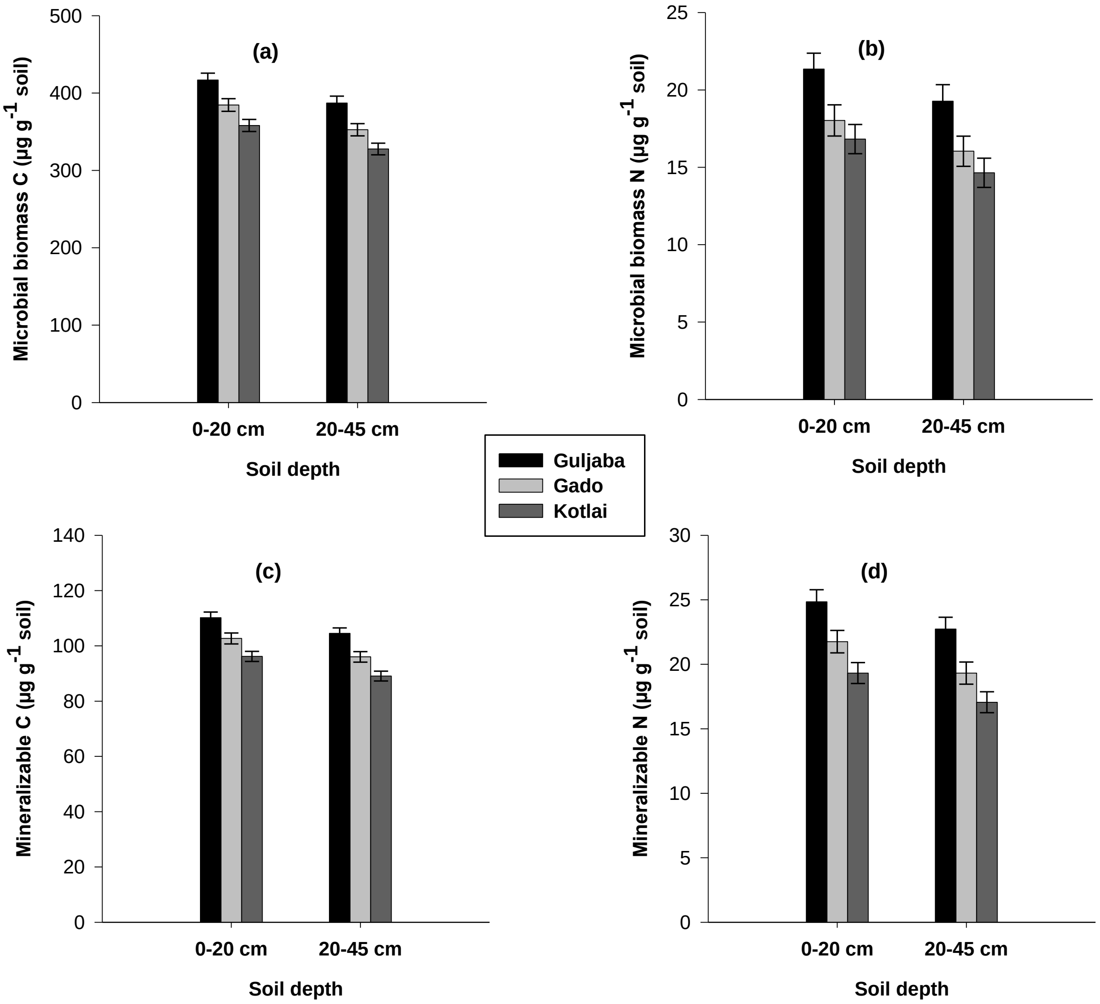

Fig. 83 (a) Microbial biomass C (b) Microbial biomass N (C) Mineralizable C and (d) Mineralizable N both at surface and sub-surface soil of sites Gado, Guljaba and Kotlai

4.3.2.3. Microbial biomass N

Microbial biomass N of soil differed significantly ($P < 0.05$) among sites Guljaba, Gado and Kotlai both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 49 and Fig. 84) (Appendix 401 and 402). Guljaba had the highest microbial biomass N followed by Gado, while Kotlai had the lowest microbial biomass N both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth).

4.3.2.4. Mineralizable C

Mineralizable C in soil differed significantly ($P < 0.05$) among sites Guljaba, Gado and Kotlai both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 49 and Fig. 85) (Appendix 403 and 404). Guljaba had the highest mineralizable C followed by Gado, while Kotlai had the lowest mineralizable C both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth).

4.3.2.5. Mineralizable N

Mineralizable N of soil differed significantly ($P < 0.05$) among sites Guljaba, Gado and Kotlai both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth) (Table 49 and Fig. 86) (Appendix 405 and 406). Guljaba had the highest Mineralizable N followed by Gado, while Kotlai had the lowest Mineralizable N both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth).

4.4. Discussion

4.4.1. Spatial changes in soil properties

It is evident from the results that all soil characteristics differed significantly among the sites Guljaba, Gado and Kotlai during all the four growing seasons (Kharif 2006 to Rabi 2008) both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). Slightly eroded soil Guljaba had the lowest soil pH followed by Gado (moderately eroded), while Kotlai (severely eroded soil) had the highest soil pH both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). Soil pH of all the sites was slightly alkaline.

Erosion appears to be involved in increasing exchangeable Ca^{+2} and Mg^{+2} contents by exposing the sub-surface material containing the bases that also result in an increase in soil pH. Cihacek and Swan (1994) also reported increase in soil pH with severity of erosion. Soil erosion exposes the $CaCO_3$ rich material that increases soil pH (Kaihura *et al.*, 1999).

Erosion influences several soil properties important among which is the loss of organic matter and plant nutrients. Organic matter was lost with the severity of erosion. Soil organic matter was deficient at site Kotlai, while it was marginal at Guljaba and Gado. Fenton *et al.* (2005) also reported that soil organic matter was significantly correlated with erosion.

Kaihura *et al.* (1999) concluded that severely eroded phases contained the least amount of plant nutrients and soil organic carbon (SOC) content. The soil organic carbon (SOC) content decreased on severely eroded soil class by 0.16%, 0.39% and 0.13% at Misufini 1, Mlingano 1 and Kirima Boro, respectively, compared to slightly or least eroded soil class. Murdock and Frye, (1983) believed that soil loss negatively affects characteristics associated with crop productivity including water holding capacity, soil nutrients, soil density, soil organic matter and others. Soil erosion decreases soil organic carbon (SOC) content (Rhoton and Tyler, 1990). Water erosion results in the mobilization and depletion of soil organic carbon (Jacinthe *et al.*, 2002). Available plant nutrients in the soil decreased with the severity of erosion. Guljaba had the highest plant nutrient followed by Gado, while Kotlai had the lowest. Lal (1988) indicated that low levels of N, P, K, and low cation exchange capacity (CEC) are among the most important chemical and nutritional constraints accentuated by soil erosion. Pimentel *et al.* (1995) observed that soil erosion causes loss of basic plant nutrients such as N, P, K^+ and Ca^{+2} and that water erosion selectively removes the fine organic particles leaving large particles and stones on the surface. Soil chemical constraints and nutritional disorders related to erosion include low cation exchange capacity (CEC), deficiency of major plant nutrients (N, P, K) and trace elements (Zn, S), nutrient toxicity (Al, Mn) and high soil acidity (Lal, 1981, 1998). Severely eroded phases contained the least amount of plant nutrients, the lowest soil pH, and soil organic carbon (SOC) content (Kaihura *et al.*, 1999). Plant nutrient content was generally lowest on severely eroded and the highest on least eroded soil classes. In general, there occurred a decline in P with the decrease in topsoil depth (TSD). Available P content decreased on severely eroded soil class by 41%, 62% and 61% at Misufini 1, Mlingano 1 and Kirima Boro, respectively, compared to slightly or least eroded soil class (Kaihura *et al.*, 1999). Lal (1998) pointed out that progressive soil erosion increases the magnitude of soil-related constraints to production. Among soil chemical constraints and nutritional disorders related to erosion include deficiency of major plant nutrients N, P and K (Lal, 1981, 1998).

Guljaba had the lowest bulk density followed by Gado, while Kotlai had the highest bulk density. Frye *et al.* (1982) concluded that soil erosion increases soil bulk density. The bulk density increased with increasing severity of erosion. The increase in bulk density may be due to decrease in aggregation of soil particles because of decline in soil organic carbon (SOC) content (Kaihura *et al.*, 1999). Photon and Tyler (1990) reported increase in bulk density with erosion and associated this with decrease in topsoil depth (TSD) to fragipan and decrease in soil organic carbon (SOC) content.

Guljaba had the highest AWHC followed by Gado, while Kotlai had the lowest AWHC. Soil erosion decreases the AWHC (Nizeyimana and Olson, 1988) and influences several soil properties, e.g., topsoil depth (TSD), soil organic carbon (SOC) content, nutrient status, soil texture and structure, available water holding capacity (AWHC) and water transmission characteristics that regulate soil quality and determine crop yield (Lal, 1998). Soil loss negatively affects characteristics associated with crop productivity including water holding capacity, soil nutrients, soil density, soil organic matter and others (Murdock and Frye, 1983).

Kort *et al.* (1998) and Andraski and Lowery (1992) reported that slightly eroded soil held 14% more water in the top 1 m than severely eroded soil and, when plant-extractable water fell to 55±60% of total water holding capacity under moisture stress conditions, corn on slightly eroded soil had significantly higher evapotranspiration levels.

Soil biological properties are important indicators of soil quality. It is evident from the data obtained that soil biological properties varied significantly with the degree of erosion. The results showed that the average rate of CO_2 evolution was higher at Guljaba (slightly eroded) followed by Gado, while it was lowest for Kotlai (severely eroded). Lal (1998) pointed out that progressive soil erosion increases the magnitude of soil-related constraints to production. The constraints can be physical, chemical or biological.

Biological constraints include low microbial biomass carbon and reduced activity of soil macrofauna (Lal, 1991). The increase in bulk density with increasing severity of erosion may be due to decrease in aggregation of soil particles because of decline in soil organic carbon (SOC) content that also reduces the microbial activities in the eroded soils (Kaihura *et al.*, 1999).

4.4.2. Temporal changes in soil properties

It is evident from the results that most soil properties were improved over time (from Kharif 2006 to Rabi 2008) from its initial value during Kharif 2006. Soil pH and soil bulk density decreased, while organic matter and AWHC increased over a period of time. This effect was due to increased organic matter content through addition of farmyard manure (FYM) and higher biomass production. Hati *et al.* (2006) observed the lowest bulk density in the surface soil in NPK + FYM treatment. Conservation of moisture by farmyard manure (FYM) application has been reported by many workers (NFDC, 1998; Jadoon *et al.*, 2003; Hati *et al.*, 2006). Levels of available K and P, mineral N and total N were increased over a period of time from their initial values during Kharif 2006 at all the three sites due to residual or cumulative effect through addition of inorganic fertilizers and farmyard manure. Yadav *et al.* (2000) reported that combined use of manures and inorganic fertilizers increased soil organic carbon (SOC) over time at locations where soils were initially low in organic C. Manna *et al.* (2005) found that NPK+FYM either maintained or improved soil organic carbon (SOC) over its initial content. These results are supported by the work of other scientists (Patra *et al.* (2006) reported that applying farmyard manure (FYM) plus NPK fertilizer significantly increased soil organic carbon (SOC), microbial biomass, dehydrogenase and phosphatase activities.

4.5. Effect of fertilizer treatments and residue management practices on crop productivity

4.5.1. Guljaba (slightly eroded soil)

4.5.1.1. Biological yield

Data in Table- show that effect of fertilizer treatments on biological yield of wheat was very highly significant ($p<0.001$) during both the years (Appendix 407 and 408). Treatment T6 gave the highest biological yield followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 87a). Analysis of the data combined over years (Appendix 409) revealed that maximum (10231 kg ha^{-1}) biological yield was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (7637 kg ha^{-1}) recorded in control. The respective increases in biological yield by T4, T5 and T6 over control were 29.0, 28.8 and 34.0% (Table 50).

Table 50: Effect of fertilizer treatments and residues management practices on biological yield (kg ha^{-1}) of wheat over time at site Guljaba

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(kg ha^{-1})……………………			
T1	7546 e	7728 e	7637 e	…
T2	8878 d	8952 d	8915 d	16.7
T3	9387 c	9455 c	9421 c	23.4
T4	9856 b	9849 b	9852 b	29.0
T5	9809 b	9869 b	9839 b	28.8
T6	10259 a	10202 a	10231 a	34.0
$LSD_{(0.05)}$	93.3	112.0	71.4	
F	8836 c	8922 c	8879 c	…
R-	9305 b	9322 b	9314 b	4.90
R+	9727 a	9783 a	9755 a	9.87
$LSD_{(0.05)}$	93.6	82.4	51.8	

Effect of Residue management practices on biological yield of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 407 and 408). R+ had the highest biological yield followed by R-, while fallow plots had the lowest biological yield during both the individual years (Fig. 87b). Analysis of the data combined over year (Appendix 409) revealed that maximum (9755 kg ha^{-1}) biological yield was recorded in plots treated with R+ followed by R- (9314 kg ha^{-1}), while fallow plots had the lowest biological yield (8879 kg ha^{-1}). The respective increases in biological yield by R- and R+ over fallow were 4.9 and 9.9% (Table 50).

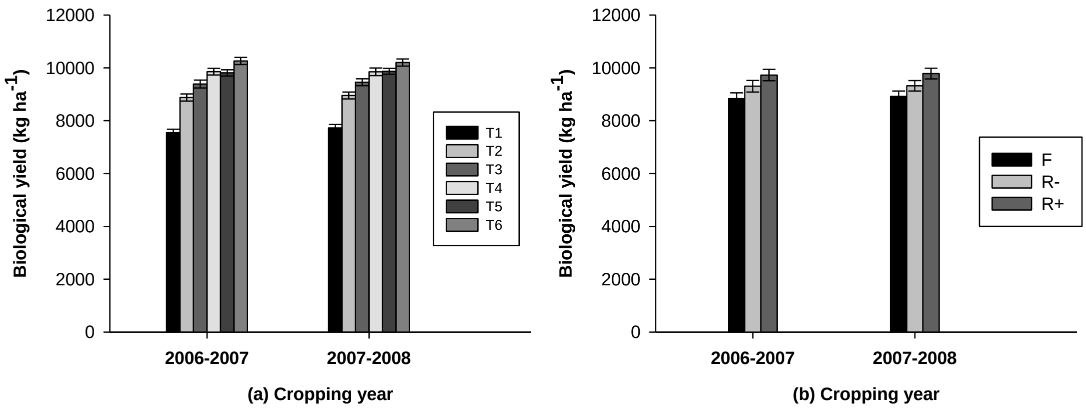

Fig. 87 Effect of (a) fertilizer treatments and (b) residues management practices on biological yield (kg ha^{-1}) of wheat over time at site Guljaba

4.5.1.2. Grain yield (kg ha^{-1})

Data in Table- show that effect of fertilizer treatments on grain yield of wheat was very highly significant ($p<0.001$) during both the years (Appendix 410 and 411). Treatment T6 gave the highest grain yield followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 88a). Analysis of the data combined over years (Appendix 412) revealed that maximum (3919 kg ha^{-1}) grain yield was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (2633 kg ha^{-1}) recorded in control. The respective increases in grain yield by T4, T5 and T6 over control were 41.2, 42.4 and 48.8% (Table 51).

Table 51: Effect of fertilizer treatments and residues management practices on grain yield (kg ha^{-1}) of wheat over time at site Guljaba

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(kg ha^{-1})……………………			
T1	2592 e	2673 e	2633 e	…
T2	3252 d	3299 d	3275 d	24.4
T3	3515 c	3558 c	3537 c	34.3
T4	3711 b	3728 b	3719 b	41.2
T5	3748 b	3752 b	3750 b	42.4
T6	3939 a	3898 a	3919 a	48.8
$LSD_{(0.05)}$	77.6	52.5	45.9	
F	3205 c	3288 c	3247 c	…
R-	3496 b	3468 b	3482 b	7.24
R+	3678 a	3699 a	3688 a	13.58
$LSD_{(0.05)}$	89.5	66.1	46.2	

Effect of Residue management practices on grain yield of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 410 and 411). R+

had the highest grain yield followed by R-, while fallow plots had the lowest grain yield during both the individual years (Fig. 88b). Analysis of the data combined over year (Appendix 412) revealed that maximum (3688 kg ha^{-1}) grain yield was recorded in plots treated with R+ followed by R-, while fallow plots had the lowest grain yield (3247 kg ha^{-1}). The respective increases in grain yield by R- and R+ over fallow were 7.2 and 13.6% (Table 51).

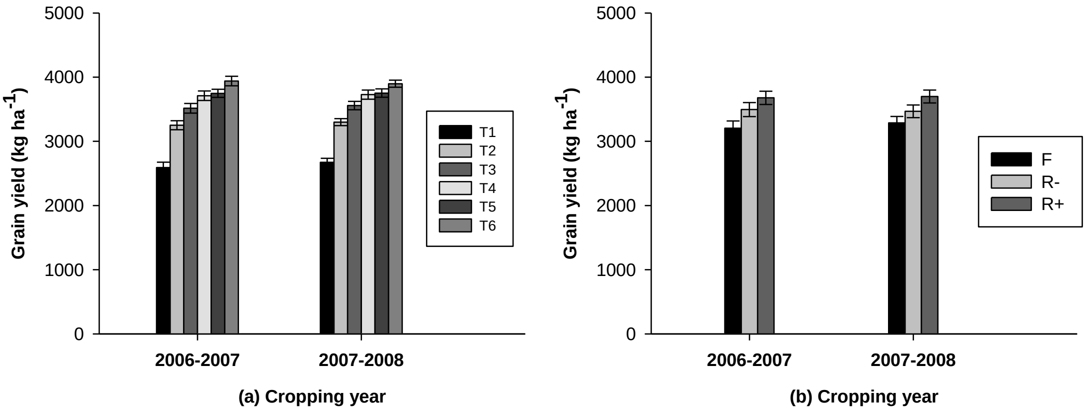

Fig. 88 Effect of (a) fertilizer treatments and (b) residues management practices on grain yield (kg ha^{-1}) of wheat over time at site Guljaba

4.5.1.3. Straw yield (kg ha^{-1})

Data in Table- show that effect of fertilizer treatments on straw yield of wheat was very highly significant ($p<0.001$) during both the years (Appendix 413 and 414). Treatment T6 gave the highest straw yield followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 89a). Analysis of the data combined over years (Appendix 415) revealed that maximum straw yield (6243 kg ha^{-1}) was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (4929 kg ha^{-1}) recorded in control. The respective increases in Straw yield by T4, T5 and T6 over control were 22.9, 22.3 and 26.7% (Table 52).

Effect of residue management practices on straw yield of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 413 and 414). R+ had the highest straw yield followed by R-, while fallow plots had the lowest straw yield during both the individual years (Fig. 89b). Analysis of the data combined over years (Appendix 415) revealed that maximum straw yield (6004 kg ha^{-1}) was recorded in plots treated with R+ followed by R-, fallow plots had the lowest straw yield (5554 kg ha^{-1}). The respective increases in straw yield by R- and R+ over fallow were 3.9 and 8.1% (Table 52).

Table 52: Effect of fertilizer treatments and residues management practices on straw yield (kg ha^{-1}) of wheat over time at site Guljaba

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(kg ha^{-1})……………………			
T1	4877 e	4981 e	4929 e	…
T2	5580 d	5580 d	5580 d	13.2
T3	5798 c	5844 c	5821 c	18.1
T4	6062 b	6056 b	6059 b	22.9
T5	6002 b	6052 b	6027 b	22.3
T6	6249 a	6238 a	6243 a	26.7
LSD$_{(0.05)}$	70.1	83.6	53.4	
F	5548 c	5559 c	5554 c	…
R-	5753 b	5791 b	5772 b	3.93
R+	5983 a	6026 a	6004 a	8.10
LSD$_{(0.05)}$	50.5	107.8	49.5	

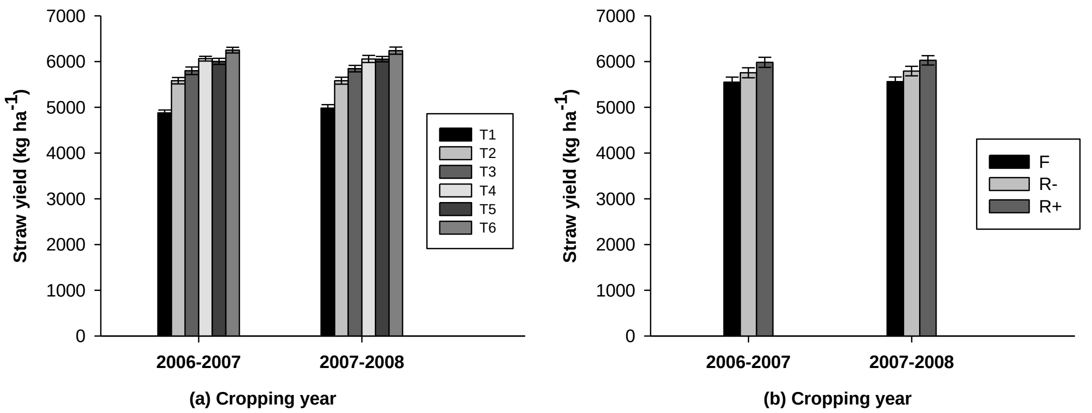

Fig. 89 Effect of (a) fertilizer treatments and (b) residues management practices on straw yield (kg ha^{-1}) of wheat over time at site Guljaba

4.5.1.4. Harvest index (%)

Data in Table- show that effect of fertilizer treatments on harvest index of wheat was very highly significant (p<0.001) during both the years (Appendix 416 and 417). Treatment T6 gave the highest harvest index followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 90a). Analysis of the data combined over years (Appendix 418) also revealed that maximum harvest index (38.3%) was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (34.4%) recorded in control. The respective increases in harvest index by T4, T5 and T6 over control were 9.6, 10.8 and 11.3% (Table 53).

Effect of residue management practices on harvest index of wheat was very highly significant (p<0.001) only during the first year (Appendix 416 and 417). Plots having R+ and R- had higher harvest index as compared to fallow plots during the first year (Fig. 90b). Analysis of the data combined over years (Appendix 418) revealed that R+ and R- had higher harvest index (37.7 and 37.3% respectively) as compared to fallow plots having lower harvest index (36.4%). The respective increases in harvest index by R- and R+ over fallow were 2.5 and 3.6% (Table 53).

Table 53: Effect of fertilizer treatments and residues management practices on harvest index (%) of wheat over time at site Guljaba

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(%)……………………			
T1	34.3 e	34.6 d	34.4 e	…
T2	36.6 d	36.8 c	36.7 d	6.7
T3	37.4 c	37.6 b	37.5 c	9.0
T4	37.6 bc	37.8 ab	37.7 bc	9.6
T5	38.2 ab	38.0 ab	38.1 ab	10.8
T6	38.4 a	38.2 a	38.3 a	11.3
$LSD_{(0.05)}$	0.69	0.47	0.41	
F	36.1 b	36.7	36.4 b	…
R-	37.4 a	37.1	37.3 a	2.47
R+	37.7 a	37.7	37.7 a	3.57
$LSD_{(0.05)}$	0.76	ns	0.48	

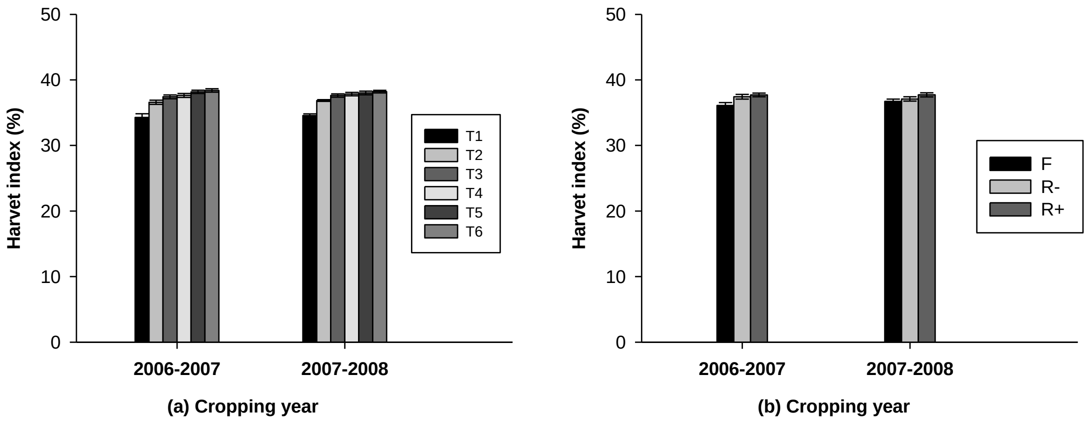

Fig. 90 Effect of (a) fertilizer treatments and (b) residues management practices on harvest index (%) of wheat over time at site Guljaba

4.5.1.5. 1000 grain weight (g)

Data in Table- show that effect of fertilizer treatments on 1000 grain weight of wheat was very highly significant ($p<0.001$) during both the years (Appendix 419 and 420). Treatment T6 gave the highest 1000 grain weight followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 91a). Analysis of the data combined over years (Appendix 421) revealed that maximum 1000 grain weight (41.4 g) was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (35.4 g) recorded in control. The respective increases in 1000-grain weight by T4, T5 and T6 over control were 12.7, 13.6 and 16.9% (Table 54).

Table 54: Effect of fertilizer treatments and residues management practices on 1000-grain weight (g) of wheat over time at site Guljaba

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(g)……………………			
T1	34.9 e	35.9 e	35.4 e	…
T2	37.9 d	38.3 d	38.1 d	7.6
T3	38.7 c	39.2 c	38.9 c	9.9
T4	39.7 b	40.2 b	39.9 b	12.7
T5	39.7 b	40.6 b	40.2 b	13.6
T6	41.2 a	41.6 a	41.4 a	16.9
LSD$_{(0.05)}$	0.57	0.50	0.37	
F	37.7 c	38.3 c	38.0 c	…
R-	38.7 b	39.2 b	39.0 b	2.63
R+	39.7 a	40.3 a	40.0 a	5.26
LSD$_{(0.05)}$	0.56	0.39	0.29	

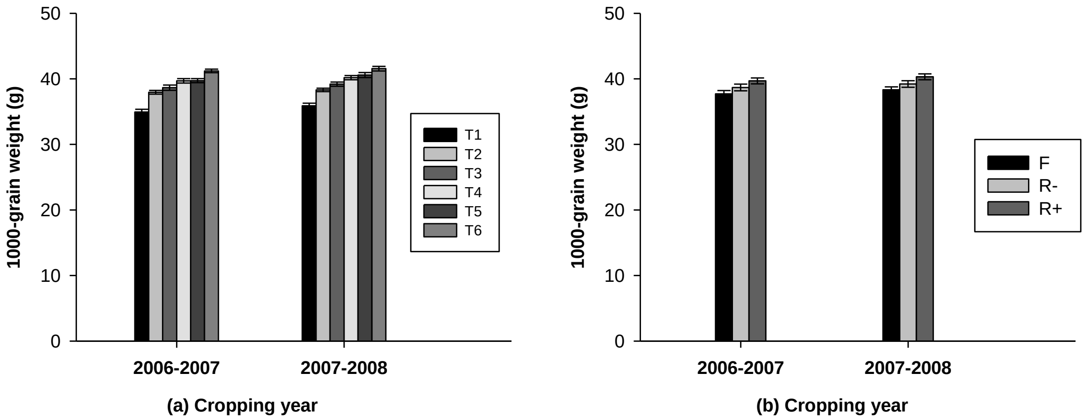

Fig. 91 Effect of (a) fertilizer treatments and (b) residues management practices on 1000-grain weight (g) of wheat over time at site Guljaba

Effect of residue management practices on 1000 grain weight of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 419 and 420). R+ had the highest 1000 grain weight followed by R-, while fallow plots had the lowest 1000 grain weight during both the individual years (Fig. 91b). Analysis of the data combined over years (Appendix 421) revealed that maximum 1000 grain weight (40.0 g) was recorded in plots treated with R+ followed by R-, while fallow plots had the lowest 1000 grain weight (38.0 g). The respective increases in 1000-grain weight by R- and R+ over fallow were 2.6 and 5.3% (Table 54).

4.5.2. Gado (moderately eroded soil)

4.5.2.1. Biological yield

Data in Table- show that effect of fertilizer treatments on biological yield of wheat was very highly significant (p<0.001) during both the years (Appendix 422 and 423). Treatment T6 gave the highest biological yield followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 92a). Analysis of the data combined over years (Appendix 424) revealed that maximum (9829 kg ha^{-1}) biological yield was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (6822 kg ha^{-1}) recorded in control. The respective increases in biological yield by T4, T5 and T6 over control were 36.3, 37.0 and 44.1% (Table 55).

Table 55: Effect of fertilizer treatments and residues management practices on biological yield (kg ha^{-1}) of wheat over time at site Gado

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(kg ha^{-1})……………………			
T1	6822 e	6822 e	6822 e	…
T2	8323 d	8350 d	8336 d	22.19
T3	8793 c	8867 c	8830 c	29.43
T4	9254 b	9345 b	9299 b	36.31
T5	9328 b	9370 b	9349 b	37.04
T6	9719 a	9938 a	9829 a	44.08
$LSD_{(0.05)}$	94.1	118.5	74.1	
F	8167 c	8225 c	8196 c	…
R-	8717 b	8834 b	8775 b	7.06
R+	9236 a	9287 a	9261 a	12.99
$LSD_{(0.05)}$	176.0	86.6	81.5	

Effect of Residue management practices on biological yield of wheat was also very highly significant (p<0.001) during both the years (Appendix 422 and 423). R+ had the highest biological yield followed by R-, while fallow plots had the lowest biological yield during both the individual years (Fig. 92b). Analysis of the data combined over year (Appendix 424) revealed that maximum (9261 kg ha^{-1}) biological yield was recorded in plots treated with R+ followed by R-, fallow plots had the lowest biological yield (8196 kg ha^{-1}). The respective increases in biological yield by R- and R+ over fallow were 7.1 and 12.9% (Table 55).

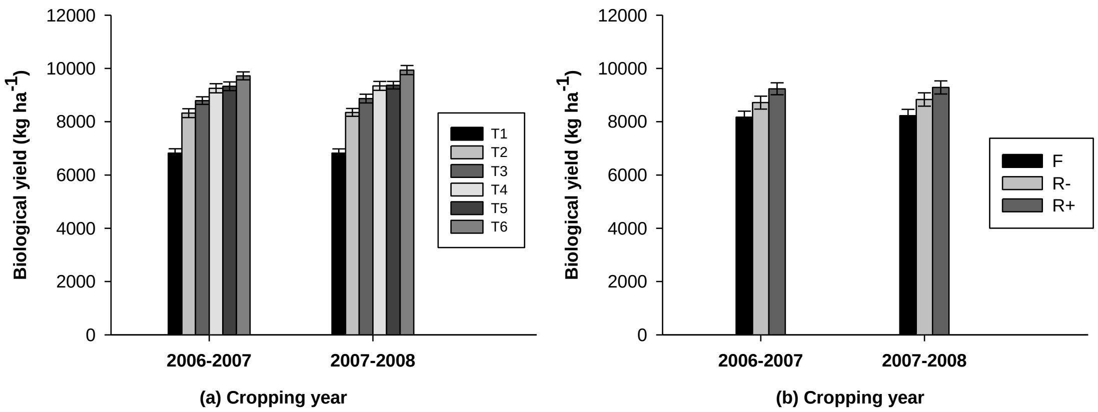

Fig. 92 Effect of (a) fertilizer treatments and (b) residues management practices on biological yield (kg ha^{-1}) of wheat over time at site Gado

4.5.2.2. Grain yield (kg ha^{-1})

Data in Table- show that effect of fertilizer treatments on grain yield of wheat was very highly significant ($p<0.001$) during both the years (Appendix 425 and 426). Treatment T6 gave the highest grain yield followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 93a). Analysis of the data combined over years (Appendix 427) revealed that maximum (3805 kg ha^{-1}) grain yield was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (2295 kg ha^{-1}) recorded in control. The respective increases in grain yield by T4, T5 and T6 over control were 53.8, 55.1 and 65.8% (Table 56).

Table 56: Effect of fertilizer treatments and residues management practices on grain yield (kg ha^{-1}) of wheat over time at site Gado

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(kg ha^{-1})……………………			
T1	2285 e	2306 e	2295 e	…
T2	3028 d	3048 d	3038 d	32.37
T3	3294 c	3295 c	3294 c	43.53
T4	3498 b	3562 b	3530 b	53.81
T5	3542 b	3576 b	3559 b	55.08
T6	3748 a	3862 a	3805 a	65.80
$LSD_{(0.05)}$	63.6	59.7	42.7	
F	2980 c	3006 c	2993 c	…
R-	3241 b	3294 b	3268 b	9.19
R+	3477 a	3524 a	3500 a	16.94
$LSD_{(0.05)}$	78.5	44.3	37.4	

Effect of Residue management practices on grain yield of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 425 and 426). R+ had the highest grain yield followed by R-, while fallow plots had the lowest grain yield during both the individual years (Fig. 93b). Analysis of the data combined over year (Appendix 427) revealed that maximum (3500 kg ha^{-1}) grain yield was recorded in plots treated with R+ followed by R-, fallow plots had the lowest grain yield (2993 kg ha^{-1}). The respective increases in grain yield by R- and R+ over fallow were 9.2 and 16.9% (Table 56).

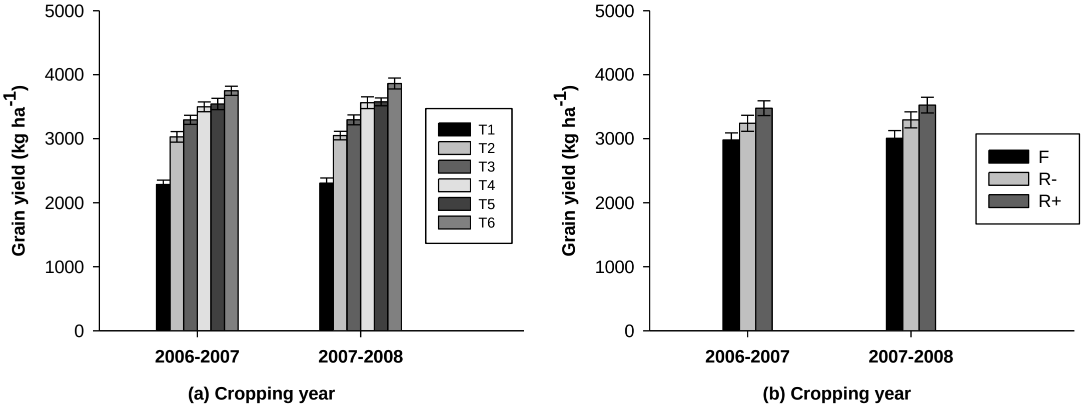

Fig. 93 Effect of (a) fertilizer treatments and (b) residues management practices on grain yield (kg ha^{-1}) of wheat over time at site Gado

4.5.2.3. Straw yield (kg ha^{-1})

Data in Table- show that effect of fertilizer treatments on straw yield of wheat was very highly significant ($p<0.001$) during both the years (Appendix 428 and 429). Treatment T6 gave the highest straw yield followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 94a). Analysis of the data combined over years (Appendix 430) revealed that maximum straw yield (5957 kg ha^{-1}) was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (4444 kg ha^{-1}) recorded in control. The respective increases in straw yield by T4, T5 and T6 over control were 28.5, 28.5 and 34.1% (Table 57).

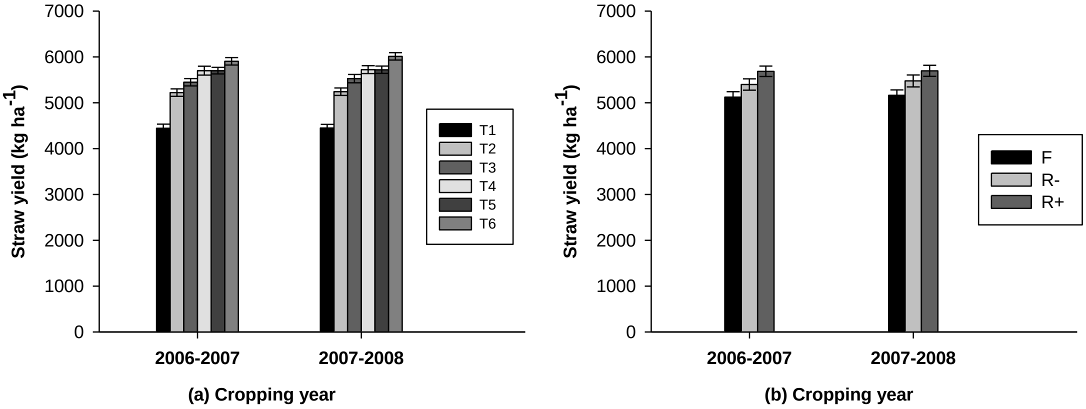

Fig. 94 Effect of (a) fertilizer treatments and (b) residues management practices on straw yield (kg ha^{-1}) of wheat over time at site Gado

Table 57: Effect of fertilizer treatments and residues management practices on straw yield (kg ha^{-1}) of wheat over time at site Gado

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(kg ha^{-1})……………………			
T1	4442 e	4447 e	4444 e	…
T2	5220 d	5241 d	5231 d	17.71
T3	5447 c	5525 c	5486 c	23.45
T4	5699 b	5721 b	5710 b	28.49
T5	5699 b	5719 b	5709 b	28.47
T6	5903 a	6011 a	5957 a	34.05
$LSD_{(0.05)}$	61.2	94.8	55.3	
F	5123 c	5161 c	5142 c	…
R-	5397 b	5476 b	5437 b	5.74
R+	5685 a	5695 a	5690 a	10.66
$LSD_{(0.05)}$	75.0	47.7	36.9	

Effect of residue management practices on straw yield of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 428 and 429). R+ had the highest straw yield followed by R-, while fallow plots had the lowest straw yield during both the individual years (Fig. 94b). Analysis of the data combined over years (Appendix 430) revealed that maximum straw yield (5690 kg ha^{-1}) was recorded in plots treated with R+ followed by R-, fallow plots had the lowest straw yield (5142 kg ha^{-1}). The respective increases in straw yield by R- and R+ over fallow were 5.7 and 10.7% (Table 57).

4.5.2.4. Harvest index (%)

Data in Table- show that effect of fertilizer treatments on harvest index of wheat was very highly significant ($p<0.001$) during both the years (Appendix 431 and 432). Treatment T6 gave the highest harvest index followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 95a). Analysis of the data combined over years (Appendix 433) also revealed that maximum harvest index (38.7%) was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (33.6%) recorded in control. The respective increases in straw yield by T4, T5 and T6 over control were 12.8, 13.1 and 15.2% (Table 58).

Effect of residue management practices on harvest index of wheat was also very highly significant ($p<0.001$) during both the individual years (Appendix 431 and 432). Plots having R+ had the hisghest harvest index followed by R-, while fallow plots had the lowest harvest index during both the individual years (Fig. 95b).

Analysis of the data combined over years (Appendix 433) also revealed that R+ had the highest harvest index (37.6%) followed by R-, while fallow plots had the lowest harvest index (36.3%). The respective increases in straw yield by R- and R+ over fallow were 1.9 and 3.6% (Table 58).

Table 58: Effect of fertilizer treatments and residues management practices on harvest index (%) of wheat over time at site Gado

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(%)……………………			
T1	33.5 d	33.7 d	33.6 e	…
T2	36.3 c	36.5 c	36.4 d	8.33
T3	37.4 b	37.1 c	37.3 c	11.01
T4	37.8 b	38.1 b	37.9 b	12.80
T5	37.9 b	38.2 b	38.0 b	13.10
T6	38.5 a	38.8 a	38.7 a	15.18
$LSD_{(0.05)}$	0.54	0.67	0.42	
F	36.3 c	36.3 c	36.3 c	…
R-	37.0 b	37.1 b	37.0 b	1.93
R+	37.5 a	37.8 a	37.6 a	3.58
$LSD_{(0.05)}$	0.29	0.37	0.20	

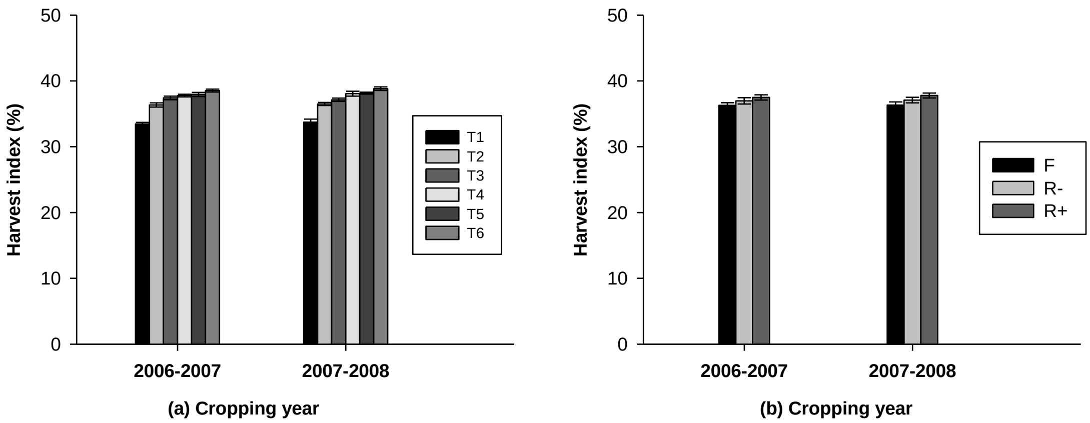

Fig. 95 Effect of (a) fertilizer treatments and (b) residues management practices on harvest index (%) of wheat over time at site Gado

4.5.2.5. 1000 grain weight (g)

Data in Table- show that effect of fertilizer treatments on 1000 grain weight (g) of wheat was very highly significant ($p<0.001$) during both the years (Appendix 434 and 435). Treatment T6 gave the highest 1000 grain weight (g) followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 96a). Analysis of the data combined over years (Appendix 436) revealed that maximum 1000 grain weight (40.9 g) was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (33.9 g) recorded in control. The respective increases in

1000 grain weight by T4, T5 and T6 over control were 17.4, 16.8 and 20.7% (Table 59).

Effect of residue management practices on 1000 grain weight (g) of wheat was also very highly significant (p<0.001) during both the years (Appendix 434 and 435). R+ had the highest 1000 grain weight (g) followed by R-, while fallow plots had the lowest 1000 grain weight (g) during both the individual years (Fig. 96b). Analysis of the data combined over years (Appendix 436) revealed that maximum 1000 grain weight (39.6 g) was recorded in plots treated with R+ followed by R-, while fallow plots had the lowest 1000 grain weight (37.2 g). The respective increases in 1000 grain weight by R- and R+ over fallow were 2.9 and 6.5% (Table 59).

Table 59: Effect of fertilizer treatments and residues management practices on 1000 grain wt (g) of wheat over time at site Gado

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(g)……………………			
T1	33.3 e	34.5 e	33.9 e	…
T2	37.4 d	37.8 d	37.6 d	10.91
T3	38.3 c	38.9 c	38.6 c	13.86
T4	39.8 b	39.9 b	39.8 b	17.40
T5	39.3 b	39.9 b	39.6 b	16.81
T6	41.0 a	40.9 a	40.9 a	20.65
$LSD_{(0.05)}$	0.54	0.51	0.36	
F	36.9 c	37.5 c	37.2 c	…
R-	38.1 b	38.5 b	38.3 b	2.96
R+	39.5 a	39.8 a	39.6 a	6.45
$LSD_{(0.05)}$	0.41	0.46	0.26	

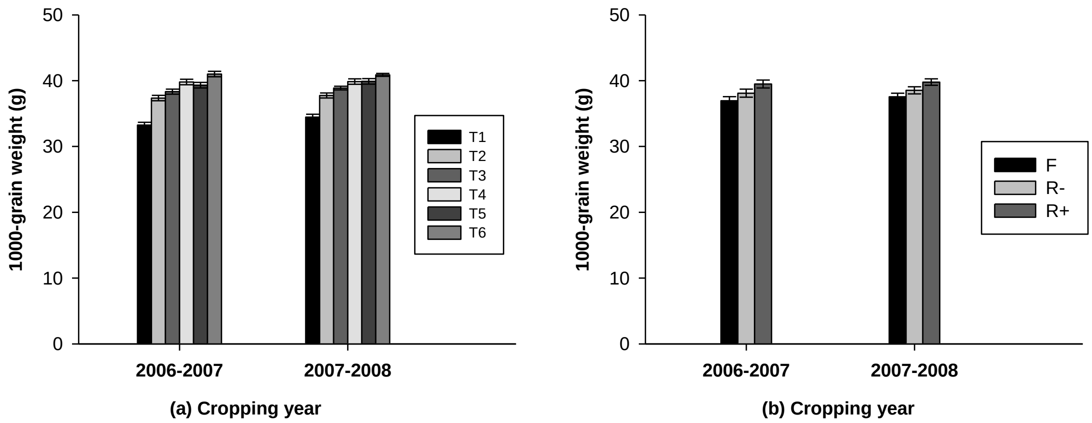

Fig. 96 Effect of (a) fertilizer treatments and (b) residues management practices on 1000 grain wt (g) of wheat over time at site Gado

4.5.3. Kotlai (severely eroded soil)

4.5.3.1. Biological yield

Data in Table- show that effect of fertilizer treatments on biological yield of wheat was very highly significant ($p<0.001$) during both the years (Appendix 437 and 438). Treatment T6 gave the highest biological yield followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 97a).Analysis of the data combined over years (Appendix 439) revealed that maximum (9575 kg ha^{-1}) biological yield was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (6514 kg ha^{-1}) recorded in control. The respective increases in biological yield by T4, T5 and T6 over control were 39.5, 39.2 and 46.9% (Table 60).

Table 60: Effect of fertilizer treatments and residues management practices on biological yield (kg ha^{-1}) of wheat over time at site Kotlai

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(kg ha^{-1})……………………			
T1	6454 e	6574 e	6514 e	…
T2	8017 d	8091 d	8054 d	23.64
T3	8493 c	8619 c	8556 c	31.35
T4	9073 b	9103 b	9088 b	39.51
T5	9088 b	9044 b	9066 b	39.18
T6	9515 a	9634 a	9575 a	46.99
$LSD_{(0.05)}$	100.4	115.3	74.9	
F	7949 c	7994 c	7971 c	…
R-	8399 b	8501 b	8450 b	6.01
R+	8973 a	9037 a	9005 a	12.97
$LSD_{(0.05)}$	138.6	127.7	78.3	

Effect of Residue management practices on biological yield of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 437 and 438). R+ had the highest biological yield followed by R-, while fallow plots had the lowest biological yield during both the individual years (Fig. 97b). Analysis of the data combined over year (Appendix 439) revealed that maximum (9005 kg ha^{-1}) biological yield was recorded in plots treated with R+ followed by R-, fallow plots had the lowest biological yield (7971 kg ha^{-1}). The respective increases in biological yield by R- and R+ over fallow were 6.0 and 12.9% (Table 60).

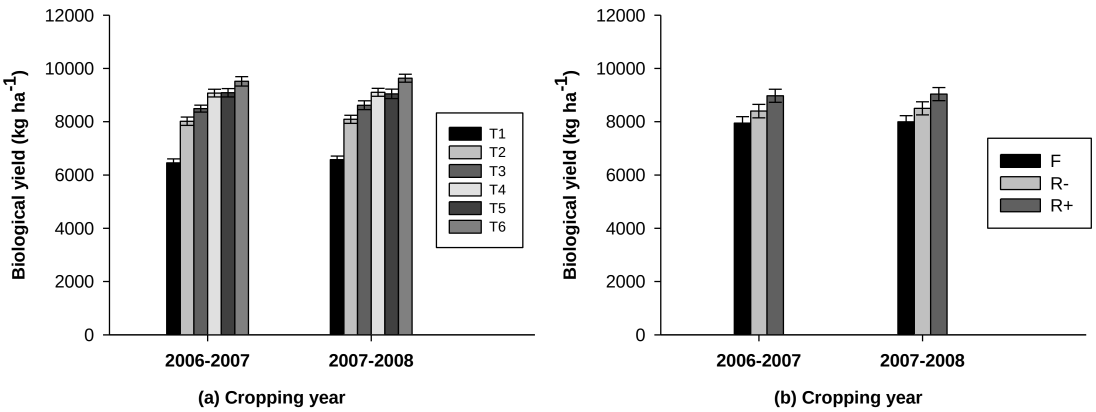

Fig. 97 **Effect of (a) fertilizer treatments and (b) residues management practices on biological yield (kg ha^{-1}) of wheat over time at site Kotlai**

4.5.3.2. Grain yield (kg ha^{-1})

Data in Table- show that effect of fertilizer treatments on grain yield of wheat was very highly significant ($p<0.001$) during both the years (Appendix 440 and 441). Treatment T6 gave the highest grain yield followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 98a). Analysis of the data combined over years (Appendix 442) revealed that maximum (3694 kg ha^{-1}) grain yield was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (2137 kg ha^{-1}) recorded in control. The respective increases in grain yield by T4, T5 and T6 over control were 60.4, 61.4 and 72.9% (Table 61).

Table 61: **Effect of fertilizer treatments and residues management practices on grain yield (kg ha^{-1}) of wheat over time at site Kotlai**

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(kg ha^{-1})……………………			
T1	2117 e	2158 e	2137 e	…
T2	2928 d	2958 d	2943 d	37.72
T3	3145 c	3200 c	3173 c	48.48
T4	3423 b	3432 b	3428 b	60.41
T5	3458 b	3438 b	3448 b	61.35
T6	3684 a	3704 a	3694 a	72.86
$LSD_{(0.05)}$	75.6	68.5	49.9	
F	2877 c	2880 c	2878 c	…
R-	3103 b	3149 b	3126 b	8.62
R+	3397 a	3416 a	3407 a	18.38
$LSD_{(0.05)}$	58.2	79.5	40.9	

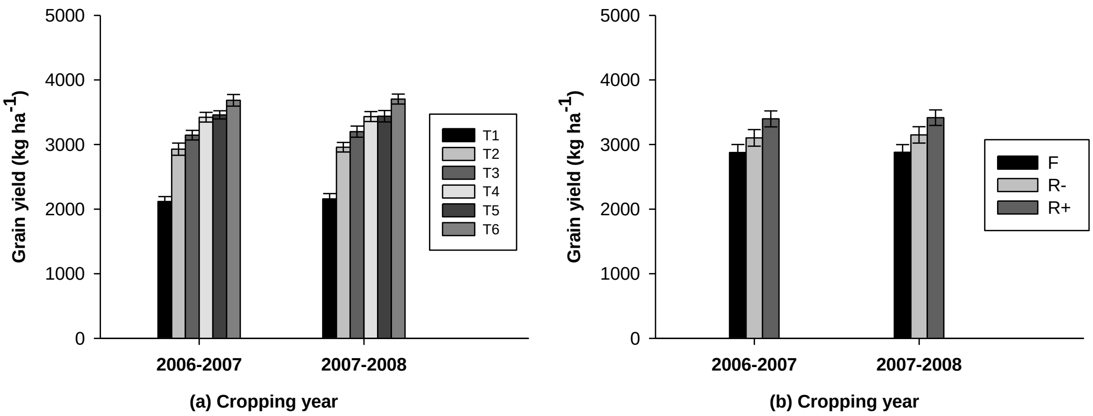

Fig. 98 Effect of (a) fertilizer treatments and (b) residues management practices on grain yield (kg ha^{-1}) of wheat over time at site Kotlai

Effect of residue management practices on grain yield of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 440 and 441). R+ had the highest grain yield followed by R-, while fallow plots had the lowest grain yield during both the individual years (Fig. 98b). Analysis of the data combined over year (Appendix 442) revealed that maximum (3407 kg ha^{-1}) grain yield was recorded in plots treated with R+ followed by R-, fallow plots had the lowest grain yield (2878 kg ha^{-1}). The respective increases in grain yield by R- and R+ over fallow were 8.6 and 18.4% (Table 61).

4.5.3.3. Straw yield (kg ha^{-1})

Data in Table- show that effect of fertilizer treatments on straw yield of wheat was very highly significant ($p<0.001$) during both the years (Appendix 443 and 444). Treatment T6 gave the highest straw yield followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 99a). Analysis of the data combined over years (Appendix 445) revealed that maximum straw yield (5810 kg ha^{-1}) was recorded in plots treated with T6 followed by T4 and T5, compared to minimum (4301 kg ha^{-1}) recorded in control. The respective increases in straw yield by T4, T5 and T6 over control were 30.3, 28.8 and 35.1% (Table 62).

Effect of residue management practices on straw yield of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 443 and 444). R+ had the highest straw yield followed by R-, while fallow plots had the lowest straw yield during both the individual years (Fig. 99b). Analysis of the data combined over years (Appendix 445) revealed that maximum straw yield (5533 kg ha^{-1}) was recorded in plots treated with R+ followed by R-, fallow plots had the lowest straw yield (5008 kg ha^{-1}). The respective increases in straw yield by R- and R+ over fallow were 5.2 and 10.5% (Table 62).

Table 62: Effect of fertilizer treatments and residues management practices on straw yield (kg ha^{-1}) of wheat over time at site Kotlai

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(kg ha^{-1})……………………			
T1	4272 e	4330 e	4301 f	…
T2	5028 d	5064 d	5046 e	17.32
T3	5273 c	5350 c	5312 d	23.51
T4	5608 b	5603 b	5606 b	30.34
T5	5548 b	5534 b	5541 c	28.83
T6	5761 a	5858 a	5810 a	35.08
LSD$_{(0.05)}$	70.4	75.2	50.5	
F	4993 c	5022 c	5008 c	…
R-	5236 b	5299 b	5268 b	5.19
R+	5516 a	5549 a	5533 a	10.48
LSD$_{(0.05)}$	71.9	69.5	41.5	

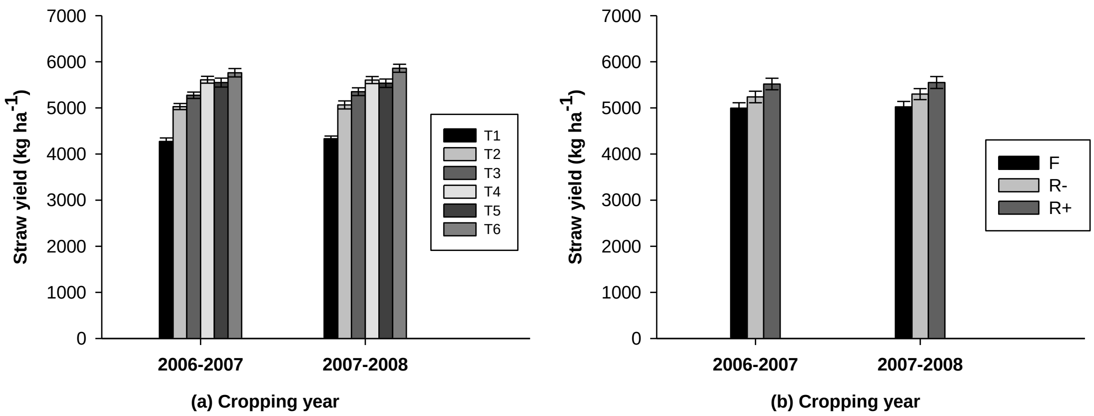

Fig. 99 Effect of (a) fertilizer treatments and (b) residues management practices on straw yield (kg ha^{-1}) of wheat over time at site Kotlai

4.5.3.4. Harvest index (%)

Data in Table- show that effect of fertilizer treatments on harvest index of wheat was very highly significant ($p<0.001$) during both the years (Appendix 446 and 447). Treatment T6 gave the highest harvest index followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 100a). Analysis of the data combined over years (Appendix 448) also revealed that maximum harvest index (38.6%) was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (32.7%) recorded in control. The respective increases in harvest index by T4, T5 and T6 over control were 15.3, 16.2 and 18.0% (Table 63).

Effect of residue management practices on harvest index of wheat was also very highly significant (p<0.001) during both the individual years (Appendix 446 and 447). Plots having R+ had the hisghest harvest index followed by R-, while fallow plots had the lowest harvest index during both the individual years (Fig. 100b). Analysis of the data combined over years (Appendix 448) also revealed that R+ had the highest harvest index (37.7%) followed by R- (36.8%), while fallow plots had the lowest harvest index (35.8%). The respective increases in harvest index by R- and R+ over fallow were 2.8 and 5.3% (Table 63).

Table 63: Effect of fertilizer treatments and residues management practices on harvest index (%) of wheat over time at site Kotlai

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(%)……………………			
T1	32.7 d	32.7 e	32.7 e	…
T2	36.5 c	36.5 d	36.5 d	11.62
T3	37.0 c	37.1 cd	37.0 c	13.15
T4	37.7 b	37.7 bc	37.7 b	15.29
T5	38.1 ab	38.0 ab	38.0 b	16.21
T6	38.7 a	38.4 a	38.6 a	18.04
LSD$_{(0.05)}$	0.67	0.66	0.46	
F	35.9 c	35.8 c	35.8 c	…
R-	36.7 b	36.8 b	36.8 b	2.79
R+	37.7 a	37.6 a	37.7 a	5.31
LSD$_{(0.05)}$	0.55	0.53	0.32	

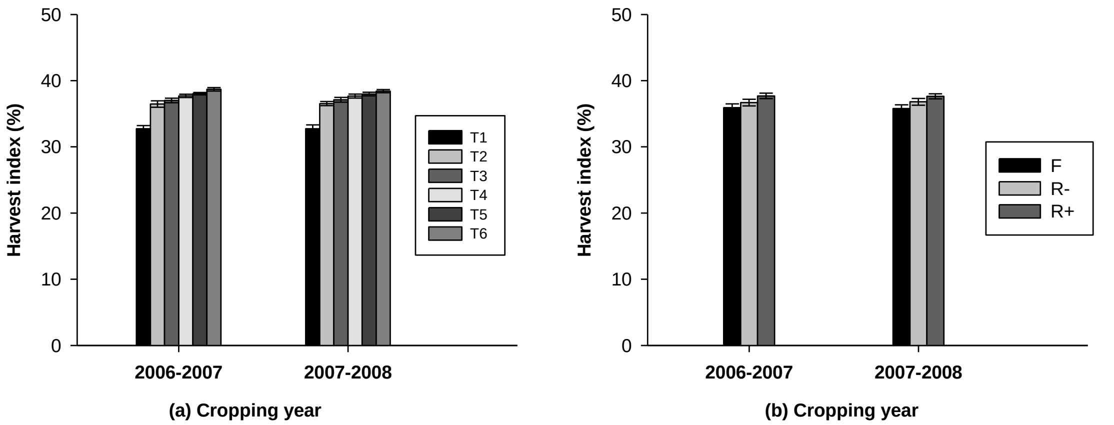

Fig. 100 Effect of (a) fertilizer treatments and (b) residues management practices on harvest index (%) of wheat over time at site Kotlai

4.5.3.5. 1000 grain weight (g)

Data in Table- show that effect of fertilizer treatments on 1000 grain weight (g) of wheat was very highly significant (p<0.001) during both the years (Appendix 449 and 450). Treatment T6 gave the highest 1000 grain weight (g) followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 101a). Analysis of the data combined over years (Appendix 451) revealed that maximum 1000 grain weight (40.4 g) was recorded in plots treated with T6 followed by T5 and T4, compared to minimum (32.7 g) recorded in control. The respective increases in 1000 grain wt by T4, T5 and T6 over control were 19.6, 18.9 and 23.6% (Table 64).

Table 64: Effect of fertilizer treatments and residues management practices on 1000 grain wt (g) of wheat over time at site Kotlai

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(g)……………………			
T1	32.4 e	33.0 e	32.7 e	…
T2	36.3 d	36.9 d	36.6 d	11.93
T3	37.7 c	38.1 c	37.9 c	15.90
T4	39.1 b	39.0 b	39.1 b	19.57
T5	38.8 b	39.1 b	38.9 b	18.96
T6	40.5 a	40.3 a	40.4 a	23.55
$LSD_{(0.05)}$	0.46	0.66	0.39	
F	36.2 c	36.6 c	36.4 c	…
R-	37.5 b	37.7 b	37.6 b	3.30
R+	38.8 a	38.9 a	38.8 a	6.59
$LSD_{(0.05)}$	0.74	0.43	0.35	

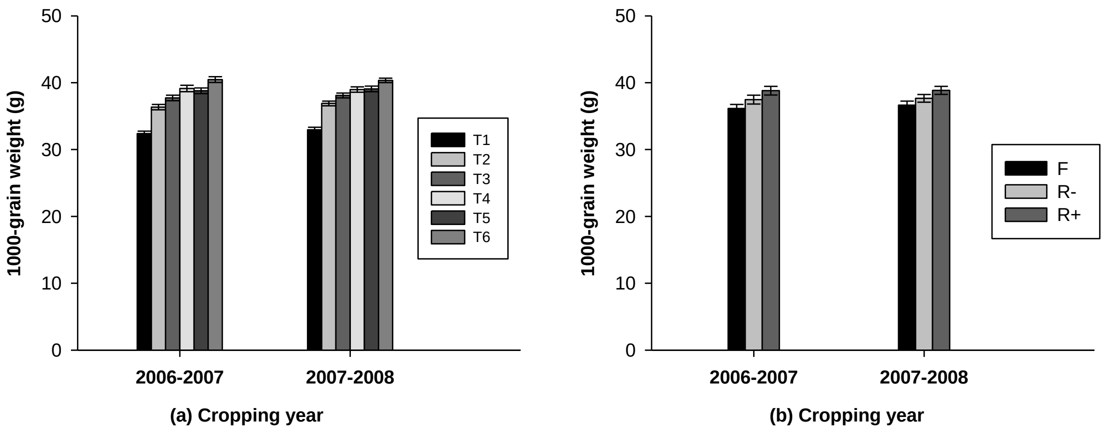

Fig. 101 Effect of (a) fertilizer treatments and (b) residues management practices on 1000 grain wt (g) of wheat over time at site Kotlai

Effect of residue management practices on 1000 grain weight (g) of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 449 and 450). R+ had the highest 1000 grain weight (g) followed by R-, while fallow plots had the lowest 1000 grain weight (g) during both the individual years (Fig. 101b). Analysis of the data combined over years (Appendix 451) revealed that maximum 1000 grain weight (38.8 g) was recorded in plots treated with R+ followed by R-, while fallow plots had the lowest 1000 grain weight (36.4 g). The respective increases in 1000 grain wt by R- and R+ over fallow were 3.3 and 6.6% (Table 64).

4.6. Discussion

4.6.1. Effect of fertilizer treatments

Yield attributes of wheat were improved with the integrated supply of nutrients through the addition of inorganic fertilizers and farmyard manure. Maximum biological yield, grain yield, straw yield, harvest index and 1000-grain weight of wheat were recorded in T6 (integrated supply of nutrients through organic and inorganic fertilizers with 20 t FYM ha^{-1}) followed by T5 and T4, compared to minimum recorded in control. Application of farmyard manure (FYM) improves AWHC and root growth in soil with unstable structure and low soil organic carbon (SOC) content (Gajri *et al.*, 1994).

Integrated supply of nutrients through organic and inorganic fertilizers (T6) performed well and the major reason for it was due to the effect of organic manures on soil moisture conservation and increase in soil organic carbon (SOC) (NFDC, 1998; Swarup, 2001; Jadoon *et al.*, 2003; Manna *et al.*, 2005; Dong *et al.*, 2006). Greater N uptake by wheat and remobilization after flowering results in better grain yield (Kichey *et al.*, 2007).

Positive effect of farmyard manure in combination with NPK fertilizers on the yield of wheat has been reported by many workers (Dong *et al.*, 2006; Hati *et al.*, 2006a; Manna *et al.*, 2006; Manna *et al.*, 2005; Ghosh *et al.*, 2004a; Bhatti, *et al.*, 2005; Bakhsh *et al.*, 1994). Wheat yield attributes significantly increased with increasing N application (Kibe *et al.*, 2006). Increased N fertilizer had increased grain yield by over 30% in wheat (Dang *et al.*, 2006). Zorita (2000) obtained a strong correlation between wheat grain yield and N fertilization. Patil *et al.*, (2006) obtained higher sorghum yield (18 and 23%) with the application of 25 and 50 kg N ha^{-1} when compared to control (produced 1393 kg ha^{-1} yield). Addition of N with irrigation treatments increased grain yield and other yield components (Zhai and Xiu LI, 2006). Nitrogen fertilization increased grain yield and 1000-grain weight (López-Bellido *et al.*, 1998). Maize grain yield was significantly improved by application of farmyard manure (FYM) and fertilizer (Kaihura *et al.*, 1999).

4.6.2. Effect of residue management practices

Yield attributes of wheat were improved with the incorporation of mungbean residues. Maximum biological yield, grain yield, straw yield, harvest index and 1000-grain weight were recorded with residues incorporation in the soil. Residues incorporation maintains soil moisture content and soil temperature, resulting in greater root growth, nutrient uptake and grain yields of wheat (Acharya and Sharma, 1994).

Incorporation of crop residues increases organic matter and total N in the soil (Huang *et al.,* 2007), improves soil structure resulting in better soil aeration and porosity and overall better conditions for crop growth (Tejada *et al.*, 2006). Plant residues incorporation had a positive effect on soil physico-chemical and biological properties, leading to better vegetation which will protect the soil against erosion contributing to its restoration (Tejada *et al.*, 2009).

Residue or manures, when added to the soil, retained from the previous crop (Anatoliy and Thelen, 2007) or incorporated (Gangwar *et al.,* 2006) decompose over time and result in improvement of crop productivity (Singh *et al.,* 2004; Anatoliy and Thelen, 2007). They are a main source of plant nutrients and can make a valuable contribution to soil organic matter (Blair *et al.,* 2006b). Organic amendments when coupled with fertilizer applications increased crop yields and soil organic matter and fertility (Blair *et al.,* 2006a).

Residue decomposition depends on the temperature and nature of the material. A proportion of the organic N, and the NH_4-N pool, are rapidly converted to nitrate-N but other organic fractions are slowly mineralized. This reflects the degree of stabilization. Approximately 90% of the available N (60% of total applied N) was converted to nitrate-N and 30% resisted mineralization (Smith *et al.*, 1998).

4.7. Effect of fertilizer treatments and residue management practices on crop uptake

4.7.1. Guljaba (slightly eroded soil)

4.7.1.1. Plant-N concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on plant-N concentration of wheat was very highly significant ($p<0.001$) during both the years

(Appendix 452 and 453). Treatment T6 gave the highest Plant-N followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 102a). Analysis of the data combined over years (Appendix 454) revealed that maximum plant-N concentration (12.77 g kg^{-1} DM) was recorded in plots treated with T6 followed by T5 (12.70 g kg^{-1} DM) and T4 (12.07 g kg^{-1} DM), compared to minimum (10.73 g kg^{-1} DM) recorded in control. The respective increases in plant-N concentration by T4, T5 and T6 over control were 12.5, 18.4 and 19.0% (Table 65).

Effect of residue management practices on plant-N concentration of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 452 and 453). R+ had the highest plant-N concentration followed by R-, while fallow plots had the lowest plant-N concentration during both the individual years (Fig. 102b). Analysis of the data combined over years (Appendix 454) revealed that maximum plant-N concentration (12.62 g kg^{-1} DM) was recorded in plots treated with R+ followed by R-, while fallow plots had the lowest plant-N concentration (11.3 g kg^{-1} DM). The respective increases in plant-N concentration by R- and R+ over fallow were 5.8 and 11.7% (Table 65).

Table 65: Effect of fertilizer treatments and residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Guljaba

Ttreatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(g kg^{-1} DM)……………………			
T1	10.56 d	10.89 d	10.73 d	…
T2	11.30 c	11.56 c	11.43 c	6.5
T3	11.88 b	12.21 b	12.05 b	12.3
T4	11.85 b	12.29 b	12.07 b	12.5
T5	12.57 a	12.84 a	12.70 a	18.4
T6	12.57 a	12.97 a	12.77 a	19.0
$LSD_{(0.05)}$	0.188	0.183	0.128	
F	11.19 c	11.42 c	11.30 c	…
R-	11.79 b	12.12 b	11.95 b	5.75
R+	12.39 a	12.85 a	12.62 a	11.68
$LSD_{(0.05)}$	0.149	0.173	0.094	

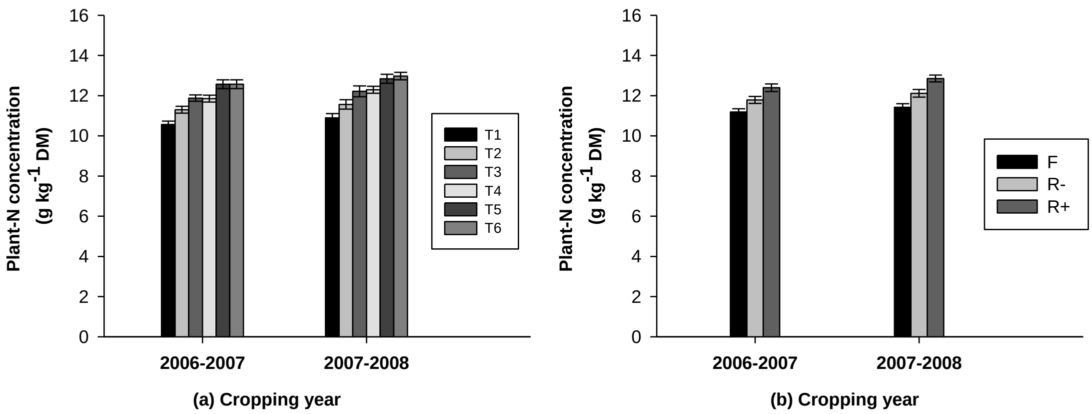

Fig. 102 **Effect of (a) fertilizer treatments and (b) residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Guljaba**

4.7.1.2. Plant-P concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on plant-P concentration of wheat was very highly significant ($p<0.001$) during both the years (Appendix 455 and 456). Treatment T6 and T5 gave higher plant-P concentration followed by T4 as compared to other treatments in both the individual years (Fig. 103a). Analysis of the data combined over years (Appendix 457) also revealed that maximum plant-P concentration (2.65 g kg^{-1} DM) was recorded in plots treated with T6 and T5 followed T4 and T3, compared to minimum (1.76 g kg^{-1} DM) recorded in control and T2. The respective increases in plant-P concentration by T4, T5 and T6 over control were 25.6, 48.3 and 50.6% (Table 66).

Table 66: **Effect of fertilizer treatments and residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Guljaba**

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(g kg^{-1} DM)……………………			
T1	1.69 c	1.82 c	1.76 c	…
T2	1.73 c	1.84 c	1.78 c	1.1
T3	2.11 b	2.26 b	2.19 b	24.4
T4	2.14 b	2.28 b	2.21 b	25.6
T5	2.52 a	2.70 a	2.61 a	48.3
T6	2.57 a	2.73 a	2.65 a	50.6
$LSD_{(0.05)}$	0.081	0.081	0.056	
F	2.14	2.25	2.20	…
R-	2.12	2.26	2.19	-0.45
R+	2.12	2.30	2.21	0.45
$LSD_{(0.05)}$	ns	ns	ns	

Effect of residue management practices on plant-P concentration of wheat was non-significant ($p>0.05$) during both the years (Table 66 and Fig. 103b) (Appendix 455 and 456). Analysis of the data combined over years (Appendix 457) also revealed that Effect of residue management practices on plant-P concentration of wheat was non-significant ($p>0.05$).

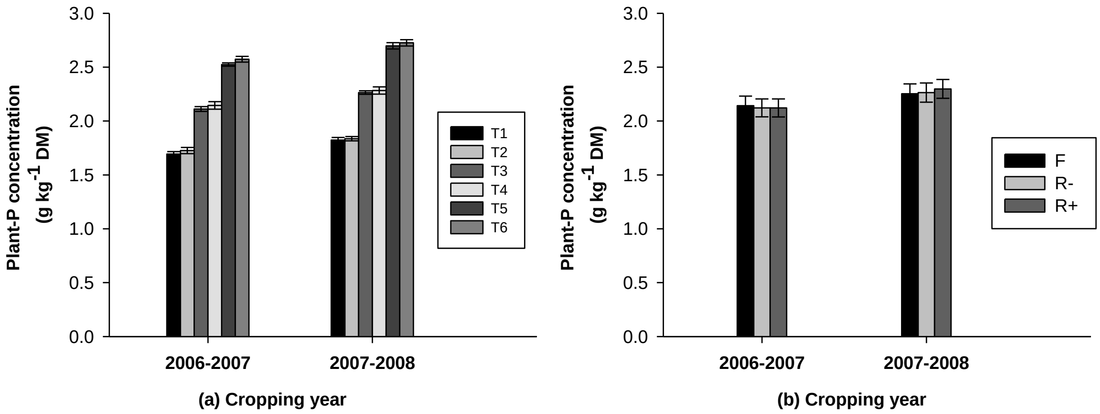

Fig. 103 Effect of (a) fertilizer treatments and (b) residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Guljaba

4.7.1.3. Grain-N concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on grain-N concentration of wheat was very highly significant ($p<0.001$) during both the years (Appendix 458 and 459). Treatment T6 gave the highest grain-N concentration as compared to other treatments, while the lowest grain-N concentration was recorded in control during both the individual years (Fig. 104a). Analysis of the data combined over years (Appendix 460) revealed that maximum grain-N concentration (31.11 g kg^{-1} DM) was recorded in plots treated with T6 as compared to other treatments, while minimum grain-N concentration (24.39 g kg^{-1} DM) was recorded in control. The respective increases in grain-N concentration by T4, T5 and T6 over control were 19.2, 19.2 and 27.6% (Table 67).

Effect of residue management practices on grain-N concentration of wheat was very highly significant ($p<0.001$) only during the first year (Appendix 458 and 459). Plots having R+ had the highest grain-N concentration followed by R-, while fallow plots had the lowest grain-N concentration during the first year (Fig. 104b). Analysis of the data combined over years (Appendix 460) revealed that maximum grain-N concentration (30.32 g kg^{-1} DM) was recorded in plots treated with R+ followed by R-, while fallow plots had the lowest grain-N concentration (25.98 g kg^{-1} DM). The respective increases in grain-N concentration by R- and R+ over fallow were 8.3 and 16.7% (Table 67).

Table 67: Effect of fertilizer treatments and residues management practices on grain-N concentration (g kg^{-1} DM) of wheat over time at site Guljaba

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..…………..(g kg^{-1} DM)……………………			
T1	23.10 d	25.69 d	24.39 e	…
T2	25.56 c	27.48 c	26.52 d	8.7
T3	27.55 b	29.83 b	28.69 c	17.6
T4	27.85 b	30.32 b	29.08 b	19.2
T5	27.86 b	30.27 b	29.07 b	19.2
T6	30.05 a	32.17 a	31.11 a	27.6
$LSD_{(0.05)}$	0.524	0.539	0.368	
F	25.08 c	26.88 c	25.98 c	…
R-	26.90 b	29.36 b	28.13 b	8.28
R+	29.00 a	31.64 a	30.32 a	16.71
$LSD_{(0.05)}$	0.781	0.408	0.366	

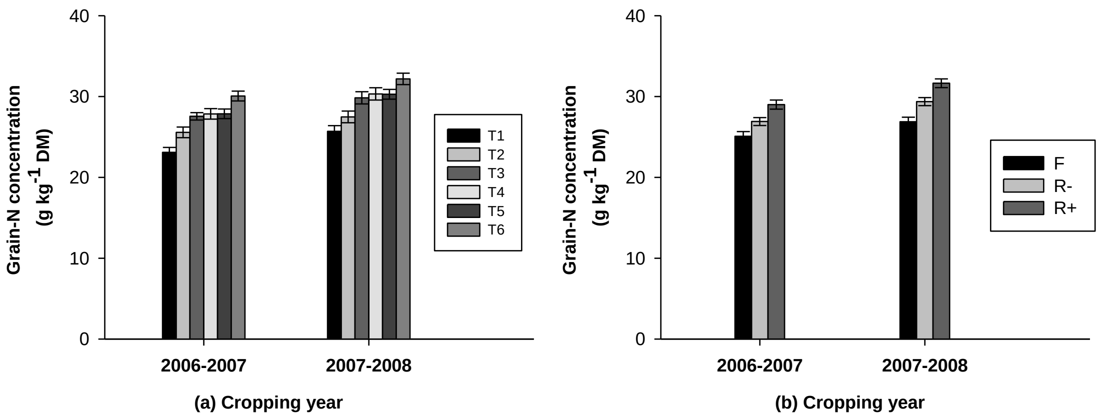

Fig. 104 Effect of (a) fertilizer treatments and (b) residues management practices on grain-N concentration (g kg^{-1} DM) of wheat over time at site Guljaba

4.7.1.4. Grain-P concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on grain-P concentration of wheat was very highly significant ($p<0.001$) during both the years (Appendix 461 and 462). Treatment T6 gave the highest grain-P concentration followed by T5 and T4 as compared to other treatments, while control had the lowest grain-P concentration during both the individual years (Fig. 105a). Analysis of the data combined over years (Appendix 463) also revealed that maximum grain-P concentration (3.29 g kg^{-1} DM) was recorded in plots treated with T6 followed T5 as compared to other treatments, while minimum grain-P concentration (2.26 g kg^{-1} DM) was recorded in control and T2. The respective increases in grain-P concentration by T4, T5 and T6 over control were 23.0, 45.1 and 45.6% (Table 68).

Effect of residue management practices on grain-P concentration of wheat was non-significant ($p>0.05$) during both the years (Table 68 and Fig. 105b) (Appendix 461 and 462). Analysis of the data combined over years (Appendix 463) also revealed that Effect of residue management practices on grain-P concentration of wheat was non-significant ($p>0.05$).

Table 68: Effect of fertilizer treatments and residues management practices on grain-P concentration (g kg^{-1} DM) of wheat over time at site Guljaba

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..…………..(g kg^{-1} DM)……………………			
T1	2.16 c	2.36 c	2.26 c	…
T2	2.16 c	2.35 c	2.25 c	-0.4
T3	2.61 b	2.94 b	2.78 b	23.0
T4	2.62 b	2.95 b	2.78 b	23.0
T5	3.15 a	3.41 a	3.28 a	45.1
T6	3.19 a	3.39 a	3.29 a	45.6
LSD$_{(0.05)}$	0.091	0.068	0.056	
F	2.63	2.88	2.76	…
R-	2.65	2.93	2.79	1.09
R+	2.66	2.89	2.78	0.72
LSD$_{(0.05)}$	ns	ns	ns	

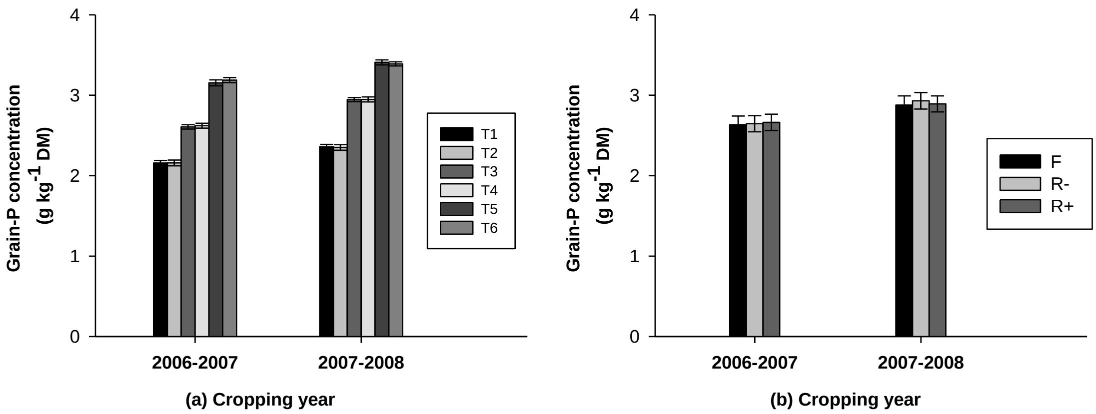

Fig. 105 Effect of (a) fertilizer treatments and (b) residues management practices on grain-P concentration (g kg^{-1} DM) of wheat over time at site Guljaba

4.7.2. Gado (moderately eroded soil)

4.7.2.1. Plant-N concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on plant-N concentration of wheat was very highly significant ($p<0.001$) during both the years (Appendix 464 and 465). Treatment T6 gave the highest plant-N concentration followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 106a). Analysis of the data combined over years (Appendix 466) revealed that maximum plant-N concentration (12.62 g kg^{-1} DM) was recorded in plots treated with T6 and T5 followed by T4, compared to minimum (10.34 g kg^{-1} DM) recorded in control. The respective increases in plant-P concentration by T4, T5 and T6 over control were 13.9, 21.1 and 22.1% (Table 69).

Effect of residue management practices on plant-N concentration of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 464 and 465). R+ had the highest plant-N concentration followed by R-, while fallow plots had the lowest plant-N concentration during both the individual years (Fig. 106b). Analysis of the data combined over years (Appendix 466) revealed that maximum plant-N concentration (12.38 g kg^{-1} DM) was recorded in plots treated with R+ followed by R-, while fallow plots had the lowest plant-N concentration (10.96 g kg^{-1} DM). The respective increases in plant-P concentration by R- and R+ over fallow were 6.7 and 12.9% (Table 69).

Table 69: Effect of fertilizer treatments and residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Gado

Treatment	2006-2007	2007-2008	Average	Increase (%)
	……..…………..(g kg^{-1} DM)……………………			
T1	10.24 d	10.44 e	10.34 d	…
T2	10.99 c	11.10 d	11.04 c	6.77
T3	11.80 b	11.72 c	11.76 b	13.73
T4	11.63 b	11.93 b	11.78 b	13.93
T5	12.50 a	12.54 a	12.52 a	21.08
T6	12.55 a	12.70 a	12.62 a	22.05
$LSD_{(0.05)}$	0.207	0.207	0.143	
F	10.90 c	11.02 c	10.96 c	…
R-	11.61 b	11.77 b	11.69 b	6.66
R+	12.34 a	12.41 a	12.38 a	12.96
$LSD_{(0.05)}$	0.072	0.207	0.091	

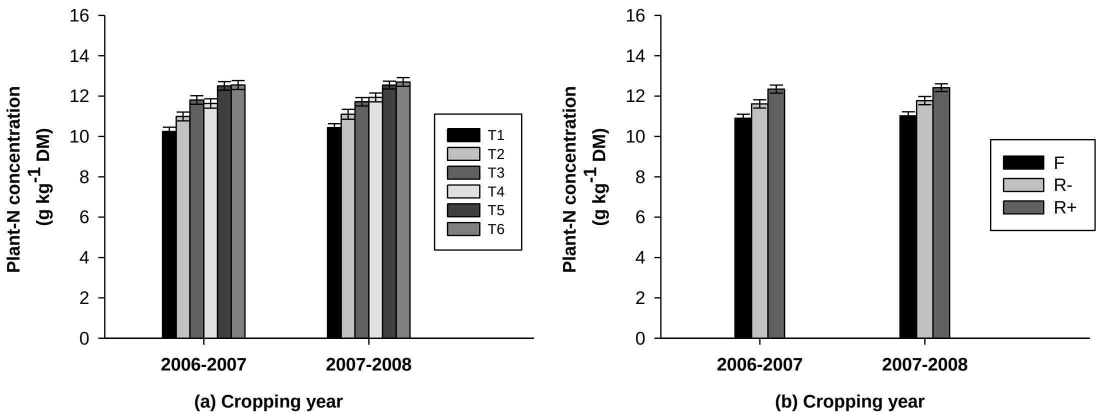

Fig. 106 Effect of (a) fertilizer treatments and (b) residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Gado

4.7.2.2. Plant-P concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on plant-P concentration of wheat was very highly significant (p<0.001) during both the years (Appendix 467 and 468). Treatment T6 and T5 gave higher plant-P concentration followed by T4 as compared to other treatments in both the individual years (Fig. 107a). Analysis of the data combined over years (Appendix 469) also revealed that maximum plant-P concentration (1.7 g kg^{-1} DM) was recorded in plots treated with T6 and T5 followed T4 and T3, compared to minimum (2.5 g kg^{-1} DM) recorded in control and T2. The respective increases in plant-P concentration by T4, T5 and T6 over control were 27.1, 50.0 and 48.8% (Table 70).

Table 70: Effect of fertilizer treatments and residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Gado

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(g kg^{-1} DM)……………………			
T1	1.64 c	1.77 c	1.70 d	…
T2	1.63 c	1.74 c	1.69 d	-0.59
T3	2.04 b	2.15 b	2.10 c	23.53
T4	2.10 b	2.21 b	2.16 b	27.06
T5	2.48 a	2.62 a	2.55 a	50.00
T6	2.49 a	2.58 a	2.53 a	48.82
$LSD_{(0.05)}$	0.075	0.081	0.056	
F	2.04	2.17	2.11	…
R-	2.10	2.18	2.14	1.42
R+	2.05	2.19	2.12	0.47
$LSD_{(0.05)}$	ns	ns	ns	

Effect of residue management practices on plant-P concentration of wheat was non-significant (p>0.05) during both the years (Table 70 and Fig. 107b) (Appendix 467 and 468). Analysis of the data combined over years (Appendix 469) also revealed that Effect of residue management practices on plant-P concentration of wheat was non-significant (p>0.05).

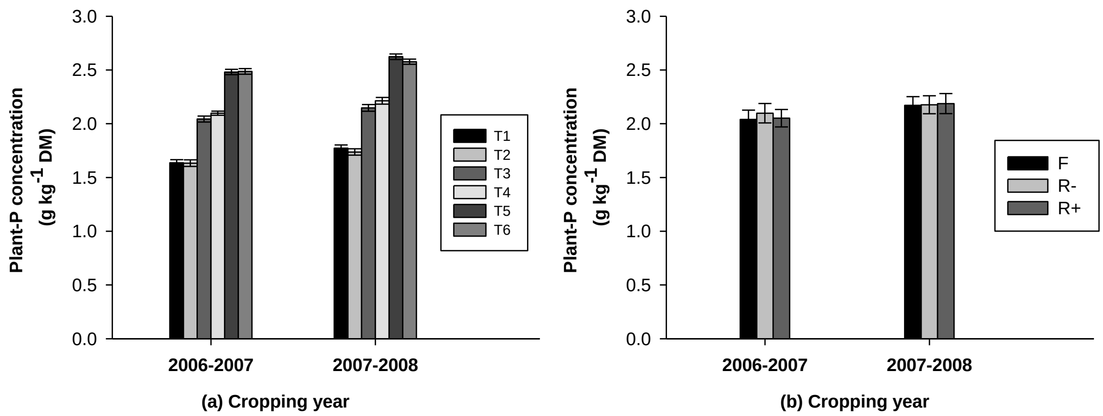

Fig. 107 Effect of (a) fertilizer treatments and (b) residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Gado

4.7.2.3. Grain-N concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on grain-N concentration of wheat was very highly significant (p<0.001) during both the years (Appendix 470 and 471). Treatment T6 gave the highest grain-N concentration as compared to other treatments, while the lowest grain-N concentration was recorded in control during both the individual years (Fig. 108a). Analysis of the data combined over years (Appendix 472) revealed that maximum grain-N concentration (29.3 g kg^{-1} DM) was recorded in plots treated with T6 as compared to other treatments, while minimum grain-N concentration (22.4 g kg^{-1} DM) was recorded in control. The respective increases in N-Grain by T4, T5 and T6 over control were 20.1, 21.1 and 30.8% (Table 71).

Effect of residue management practices on grain-N concentration of wheat was very highly significant (p<0.001) only during the first year (Appendix 470 and 471). Plots having R+ had the highest grain-N concentration followed by R-, while fallow plots had the lowest grain-N concentration during the first year (Fig. 108b). Analysis of the data combined over years (Appendix 472) revealed that maximum grain-N concentration (28.5 g kg^{-1} DM) was recorded in plots treated with R+

followed by R- (26.4 g kg^{-1} DM), while fallow plots had the lowest grain-N concentration (23.9 g kg^{-1} DM). The respective increases in N-Grain by R- and R+ over fallow were 10.3 and 19.2% (Table 71).

Table 71: Effect of fertilizer treatments and residues management practices on N-Grain (g kg^{-1} DM) of wheat over time at site Gado

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(g kg^{-1} DM)……………………			
T1	21.96 d	22.83 d	22.39 d	…
T2	24.29 c	25.09 c	24.69 c	10.27
T3	26.77 b	27.23 b	27.00 b	20.59
T4	26.42 b	27.38 b	26.90 b	20.14
T5	26.71 b	27.51 b	27.11 b	21.08
T6	28.90 a	29.69 a	29.29 a	30.82
$LSD_{(0.05)}$	0.457	0.516	0.337	
F	23.61 c	24.14 c	23.88 c	…
R-	25.86 b	26.85 b	26.35 b	10.34
R+	28.06 a	28.87 a	28.46 a	19.18
$LSD_{(0.05)}$	0.485	0.391	0.259	

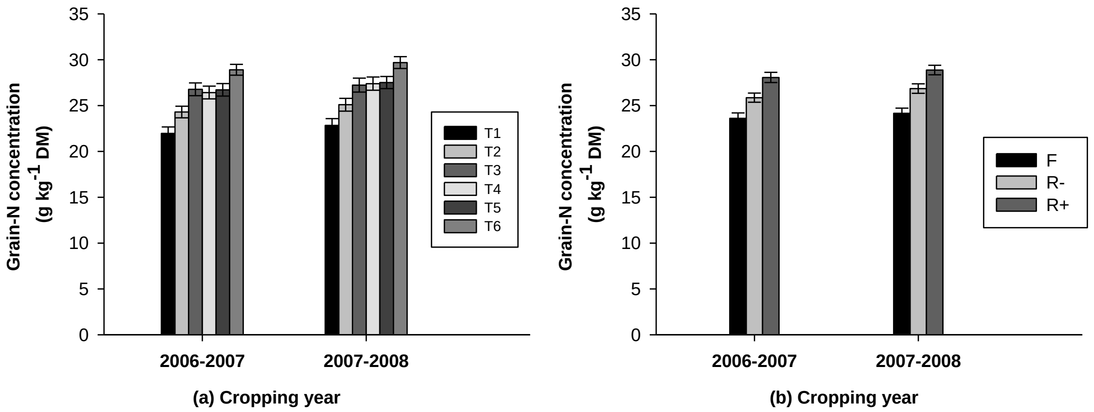

Fig. 108 Effect of (a) fertilizer treatments and (b) residues management practices on N-Grain (g kg^{-1} DM) of wheat over time at site Gado

4.7.2.4. Grain-P concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on grain-P concentration of wheat was very highly significant ($p<0.001$) during both the years (Appendix 473 and 474). Treatment T6 and T5 gave the higher grain-P concentration followed by T4 and T3, while control and T2 had the lowest grain-P concentration during both the individual years (Fig. 109a). Analysis of the data combined over years (Appendix 475) also revealed that maximum grain-P concentration (3.2 g kg^{-1} DM) was recorded in plots treated with T6 and T5 followed T4 and T3, while minimum grain-P concentration (2.2 g kg^{-1} DM) was recorded in control and T2. The respective increases in P-Grain by T4, T5 and T6 over control were 24.9, 49.8 and 47.5% (Table 72).

Effect of residue management practices on grain-P concentration of wheat was non-significant (p>0.05) during both the years (Table 72 and Fig. 109b) (Appendix 473 and 474). Analysis of the data combined over years (Appendix 475) also revealed that effect of residue management practices on grain-P concentration of wheat was non-significant (p>0.05).

Table 72: Effect of fertilizer treatments and residues management practices on P-Grain (g kg^{-1} DM) of wheat over time at site Gado

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..…………(g kg^{-1} DM)……………………			
T1	2.17 c	2.16 c	2.17 c	…
T2	2.13 c	2.23 c	2.18 c	0.46
T3	2.70 b	2.68 b	2.69 b	23.96
T4	2.71 b	2.72 b	2.71 b	24.88
T5	3.21 a	3.29 a	3.25 a	49.77
T6	3.16 a	3.24 a	3.20 a	47.47
$LSD_{(0.05)}$	0.097	0.081	0.059	
F	2.68	2.72	2.70	…
R-	2.69	2.73	2.71	0.37
R+	2.67	2.71	2.69	-0.37
$LSD_{(0.05)}$	ns	Ns	ns	

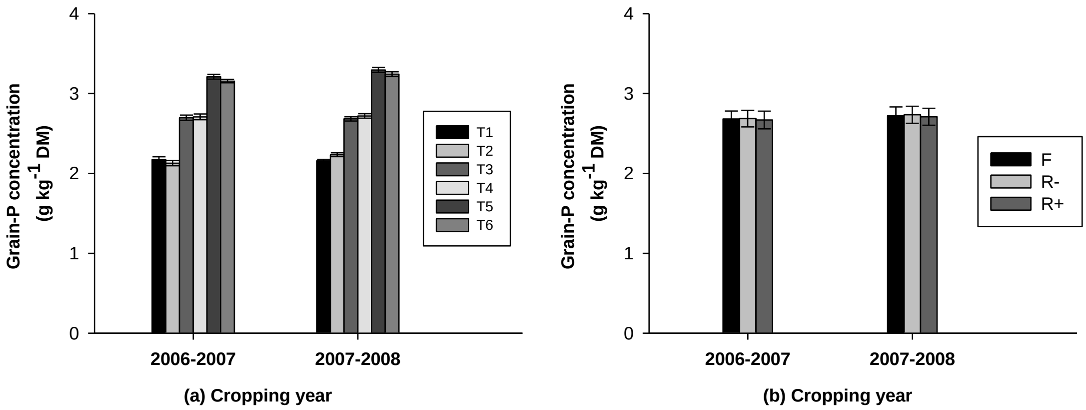

Fig. 109 Effect of (a) fertilizer treatments and (b) residues management practices on P-Grain (g kg^{-1} DM) of wheat over time at site Gado

4.7.3. Kotlai (severely eroded soil)

4.7.3.1. Plant-N concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on plant-N concentration of wheat was very highly significant (p<0.001) during both the years

(Appendix 476 and 477). Treatment T6 gave the highest plant-N concentration followed by T5 and T4 as compared to other treatments in both the individual years (Fig. 110a). Analysis of the data combined over years (Appendix 478) revealed that maximum plant-N concentration (12.41 g kg^{-1} DM) was recorded in plots treated with T6 and T5 followed by T4, compared to minimum (10.13 g kg^{-1} DM) recorded in control. The respective increases in plant-P concentration by T4, T5 and T6 over control were 13.4, 19.5 and 22.5% (Table 73).

Table 73: Effect of fertilizer treatments and residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Kotlai

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(g kg^{-1} DM)……………………			
T1	10.07 e	10.20 e	10.13 e	…
T2	10.76 d	10.79 d	10.78 d	6.42
T3	11.40 c	11.51 c	11.46 c	13.13
T4	11.44 c	11.55 c	11.49 c	13.43
T5	11.96 b	12.23 b	12.10 b	19.45
T6	12.34 a	12.48 a	12.41 a	22.51
$LSD_{(0.05)}$	0.193	0.180	0.128	
F	10.63 c	10.80 c	10.72 c	…
R-	11.31 b	11.47 b	11.39 b	6.25
R+	12.05 a	12.11 a	12.08 a	12.69
$LSD_{(0.05)}$	0.072	0.137	0.064	

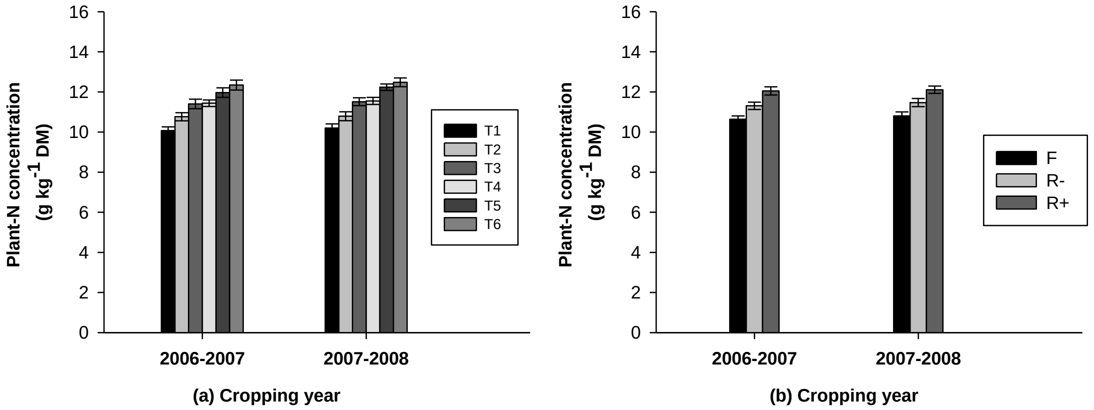

Fig. 110 Effect of (a) fertilizer treatments and (b) residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Kotlai

Effect of residue management practices on plant-N concentration of wheat was also very highly significant ($p<0.001$) during both the years (Appendix 476 and 477). R+ had the highest plant-N concentration followed by R-, while fallow plots had the lowest plant-N concentration during both the individual years (Fig. 110b). Analysis of the data combined over years (Appendix 478) revealed that maximum plant-N concentration (12.08 g kg^{-1} DM) was recorded in plots treated with R+ followed by R-, while fallow plots had the lowest plant-N concentration (10.72 g kg^{-1} DM). The respective increases in plant-P concentration by R- and R+ over fallow were 6.3 and 12.7% (Table 73).

4.7.3.2. Plant-P concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on plant-P concentration of wheat was very highly significant ($p<0.001$) during both the years (Appendix 479 and 480). Treatment T6 and T5 gave higher plant-P concentration followed by T4 as compared to other treatments in both the individual years (Fig. 111a). Analysis of the data combined over years (Appendix 481) also revealed that maximum plant-P concentration (2.50 g kg^{-1} DM) was recorded in plots treated with T6 and T5 followed T4 and T3, compared to minimum (1.57 g kg^{-1} DM) recorded in control and T2. The respective increases in plant-P concentration by T4, T5 and T6 over control were 29.3, 59.2 and 58.6% (Table 74).

Table 74: Effect of fertilizer treatments and residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Kotlai

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(g kg^{-1} DM)……………………			
T1	1.54 c	1.59 c	1.57 c	…
T2	1.51 c	1.63 c	1.57 c	0.00
T3	1.97 b	2.06 b	2.01 b	28.03
T4	1.97 b	2.10 b	2.03 b	29.30
T5	2.46 a	2.55 a	2.50 a	59.24
T6	2.40 a	2.57 a	2.49 a	58.60
$LSD_{(0.05)}$	0.075	0.081	0.052	
F	1.97	2.06	2.01	…
R-	1.98	2.11	2.05	1.99
R+	1.97	2.08	2.02	0.50
$LSD_{(0.05)}$	ns	ns	ns	

Effect of residue management practices on plant-P concentration of wheat was non-significant ($p>0.05$) during both the years (Table 74 and Fig. 111b) (Appendix 479 and 480). Analysis of the data combined over years (Appendix 481) also revealed that Effect of residue management practices on plant-P concentration of wheat was non-significant ($p>0.05$).

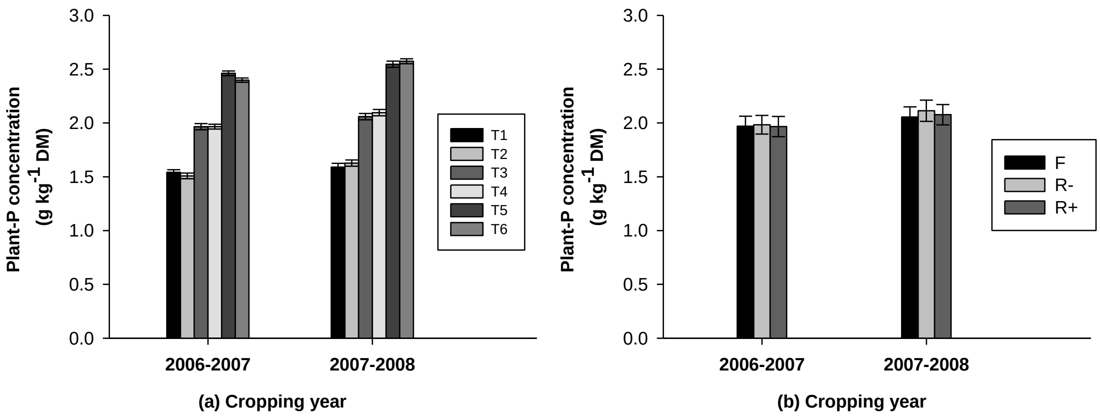

Fig. 111 Effect of (a) fertilizer treatments and (b) residues management practices on plant-P concentration (g kg^{-1} DM) of wheat over time at site Kotlai

4.7.3.3. Grain-N concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on grain-N concentration of wheat was very highly significant ($p<0.001$) during both the years (Appendix 482 and 483). Treatment T6 gave the highest grain-N concentration as compared to other treatments, while the lowest grain-N concentration was recorded in control during both the individual years (Fig. 112a). Analysis of the data combined over years (Appendix 484) revealed that maximum grain-N concentration (27.26 g kg^{-1} DM) was recorded in plots treated with T6 as compared to other treatments, while minimum grain-N concentration (20.32 g kg^{-1} DM) was recorded in control. The respective increases in grain-N concentration by T4, T5 and T6 over control were 23.4, 22.2 and 34.2% (Table 75).

Effect of residue management practices on grain-N concentration of wheat was very highly significant ($p<0.001$) only during the first year (Appendix 482 and 483). Plots having R+ had the highest grain-N concentration followed by R-, while fallow plots had the lowest grain-N concentration during the first year (Fig. 112b). Analysis of the data combined over years (Appendix 484) revealed that maximum grain-N concentration (25.33 g kg^{-1} DM) was recorded in plots treated with R+ followed by R-, while fallow plots had the lowest grain-N concentration (23.08 g kg^{-1} DM). The respective increases in grain-N concentration by R- and R+ over fallow were 4.2 and 9.8% (Table 75).

Table 75: Effect of fertilizer treatments and residues management practices on grain-N concentration (g kg^{-1} DM) of wheat over time at site Kotlai

Treatment	2006-2007	2007-2008	Average	**Increase (%)**
	……..……………(g kg^{-1} DM)……………………			
T1	21.52 d	19.12 d	20.32 d	…
T2	23.79 c	21.61 c	22.70 c	11.71
T3	25.70 b	23.77 b	24.74 b	21.75
T4	26.10 b	24.06 b	25.08 b	23.43
T5	25.58 b	24.10 b	24.84 b	22.24
T6	28.47 a	26.05 a	27.26 a	34.15
$LSD_{(0.05)}$	0.589	0.530	0.388	
F	22.96 c	23.20	23.08 c	…
R-	25.11 b	22.99	24.05 b	4.20
R+	27.50 a	23.17	25.33 a	9.75
$LSD_{(0.05)}$	0.482	ns	0.263	

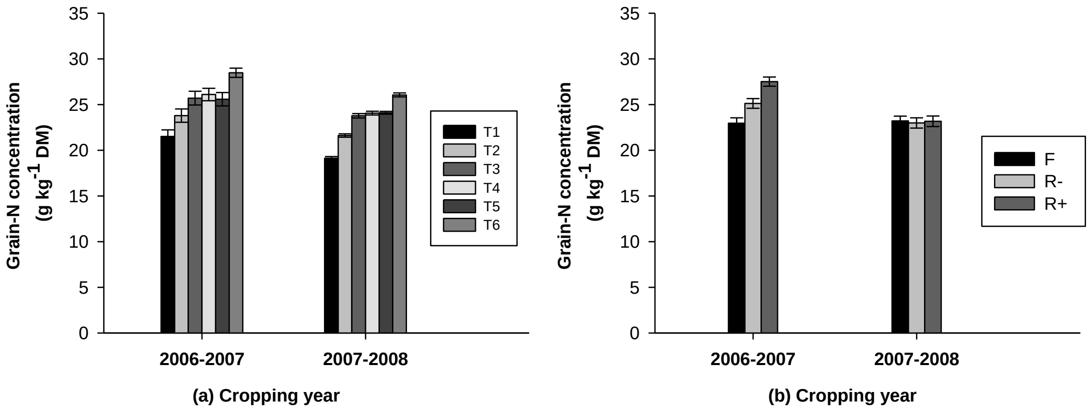

Fig. 112 Effect of (a) fertilizer treatments and (b) residues management practices on grain-N concentration (g kg^{-1} DM) of wheat over time at site Kotlai

4.7.3.4. Grain-P concentration (g kg^{-1} DM)

Data in Table- show that effect of fertilizer treatments on grain-P concentration of wheat was very highly significant ($p<0.001$) during both the years (Appendix 485 and 486). Treatment T6 and T5 gave the higher grain-P concentration followed by T4 and T3, while control and T2 had the lowest grain-P concentration during both the individual years (Fig. 113a). Analysis of the data combined over years (Appendix 487) also revealed that maximum grain-P concentration (3.1 g kg^{-1} DM) was recorded in plots treated with T6 and T5 followed by T4 and T3, while minimum grain-P concentration (2.1 g kg^{-1} DM) was recorded in control and T2. The respective increases in grain-P concentration by T4, T5 and T6 over control were 21.5, 45.3 and 44.4% (Table 76).

Effect of residue management practices on grain-P concentration of wheat was non-significant ($p>0.05$) during both the years (Table 76 and Fig. 113b) (Appendix 485 and 486). Analysis of the data combined over years (Appendix 487) also revealed that Effect of residue management practices on grain-P concentration of wheat was non-significant ($p>0.05$).

Table 76: Effect of fertilizer treatments and residues management practices on grain-P concentration (g kg^{-1} DM) of wheat over time at site Kotlai

Treatment	2006-2007	2007-2008	Average	Increase (%)
	……..……………(g kg^{-1} DM)……………………			
T1	2.14 c	2.13 c	2.14 c	…
T2	2.11 c	2.15 c	2.13 c	-0.47
T3	2.60 b	2.63 b	2.61 b	21.96
T4	2.63 b	2.57 b	2.60 b	21.50
T5	3.15 a	3.08 a	3.11 a	45.33
T6	3.09 a	3.08 a	3.09 a	44.39
LSD$_{(0.05)}$	0.101	0.101	0.069	
F	2.65	2.59	2.62	…
R-	2.59	2.60	2.60	-0.76
R+	2.62	2.62	2.62	0.00
LSD$_{(0.05)}$	ns	ns	ns	

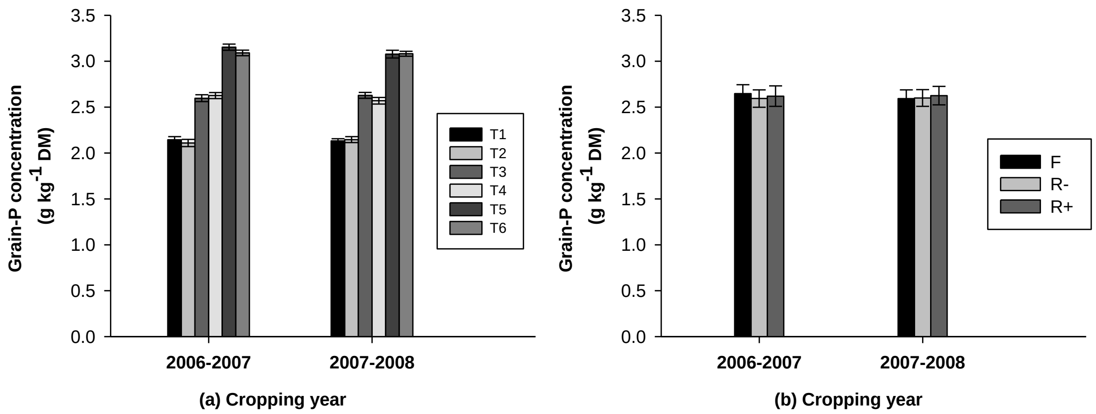

Fig. 113 Effect of (a) fertilizer treatments and (b) residues management practices on grain-P concentration (g kg^{-1} DM) of wheat over time at site Kotlai

4.8. Discussion

4.8.1. Effect of fertilizer treatments

Uptake of N and P by wheat was increased with the integrated supply of nutrients through the addition of inorganic fertilizers and farmyard manure. Maximum plant and grain N and P concentration of wheat were recorded in T6 and T5 (integrated supply of nutrient through organic and inorganic fertilizers) followed by T4, compared to minimum recorded in control.

N fertilizer improves soil and plant attributes, for example N uptake in wheat (Malhi *et al.*, 2006), total grain N in wheat (Halvorson *et al.*, 2001b) and grain yield (Melaj *et al.*, 2003). Plant N uptake is influenced by levels, types and times of N application (Iqbal *et al.*, 2005). Fan *et al.*, 2005 reported that applications of more than120 kg N ha^{-1} increased N uptake of wheat. Total wheat N uptake was in the range of 50 to 127 kg N ha^{-1} while seed N uptake fluctuated between 34 and 107 kg N ha^{-1} (López-Bellido *et al.*, 2003). Izaurralde *et al.* (1998) reported that grain-P concentrations changed little with P applications but were diluted with respect to controls as the levels of N increased.

4.8.2. Effect of residue management practices

Uptake of N and P by wheat was increased with the incorporation of mungbean residues. Maximum plant and grain N and P concentration of wheat were recorded with residues incorporation in the soil.

Residues incorporation maintains soil moisture content and soil temperature, resulting in greater root growth, nutrient uptake and grain yields of wheat (Acharya and Sharma, 1994). Greater N uptake by wheat and remobilization after flowering results in better grain yield (Kichey *et al.*, 2007). Incorporation of mungbean residue resulted in recycling of about 77 kg N ha^{-1} y^{-1} (Sharma and Prasad, 1999). Mungbean residue incorporation significantly increased rice yield over fallow by 0.6-0.8 t ha^{-1} y^{-1} and wheat yield by 0.5 t ha^{-1} y^{-1}. Mungbean without residue incorporation was no better than no summer crop. Mungbean residue incorporation significantly increased straw yields of rice and wheat. Mungbean without residue incorporation gave significantly higher straw yields of wheat than no summer crop. Incorporation of mungbean residue was effective for plant-N uptake by the rice-wheat cropping system, the increase over no summer crop being 17-30 kg N ha^{-1} y^{-1} (Sharma and Prasad, 1999).

Inclusion of mungbean in crop rotation with wheat improved the yield of wheat as well as organic fertility of soil (Shah *et al.*, 2003). Crop residues after harvest of legumes represent a poetentially valuable source of N for improving soil N pools of poor soils (Peoples and Craswell, 1992).

Growing of summer mungbean is generally practiced by some farmers in semi-arid areas. It is a very useful crop as its pods can be picked for grain and its residues can be incorporated for green manuring. It increases productivity as well as plant-N uptake and is also a source of pulse grain (Sharma and Prasad, 1999).

4.9. Economic analysis of fertilizer use on wheat

Economic analysis of fertilizer use on wheat was done during each year for all the three sites Guljaba, Gado and Kotlai (Appendix 488). For this purpose relative increase in income (RII) was calculated for each treatment. The results obtained from different fertilizer treatments revealed that all the treatments gave higher RII compared with the control during both the years (2006-2007 and 2007-2008). During 2006-2007, T6 (Application of 20 t FYM ha^{-1} and reducing commercial inorganic N fertilizer to 60 kg N ha^{-1}) gave the highest RII (20, 26 and 31% at Guljaba, Gado and Kotlai respectively). During 2007-2008, T4 gave the highest RII (16.9%) only at Guljaba which was just a little higher than that of T6 (16.7%), while at the other two sites Gado and Kotlai, T6 gave the highest RII (30 and 31% at Gado and Kotlai respectively) (Tables 77-79).

The results suggest that fertilizer management practices gave a better response at all the three sites Guljaba (slightly eroded), Gado (moderately eroded) and Kotlai (severely eroded), which were helpful for the restoration of crop productivity at these eroded lands. T6 involves addition of 20 t FYM ha^{-1} along with inorganic fertilizers. A better response of T6 in terms of farmer’s income would mean sustainability of these practices for the future and the restoration of eroded land over time.

4.10. Economic analysis of residues management practices

Economic analysis of residues management practices was done during each year for all the three sites, Guljaba, Gado and Kotlai (Appendix 489). For this purpose relative increase in income (RII) was calculated for each residues management practice compared with fallow plots. The results obtained from the three management practices revealed that leaving the plots fallow gave negative RII during both the years (2006-2007 and 2007-2008), while R- (mungbean residues removed) and R+ (mungbean residues incorporated into soil) gave positive RII at each site. During 2006-2007, R- gave higher RII (89, 86 and 81% at Guljaba, Gado and Kotlai respectively) than R+ (60% each at Guljaba, Gado and Kotlai). During 2007-2008, RII of R- (84, 86 and 81% at Guljaba, Gado and Kotlai respectively) was higher than R+ (57, 61 and 59% at Guljaba, Gado and Kotlai respectively) (Tables 80-82).

Higher RII for R- and R+ suggest that mungbean crop in rotation was helpful in improving farmer's income whether its residues incorporated or removed and gave a better response at all the three sites Guljaba (slightly eroded), Gado (moderately eroded) and Kotlai (severely eroded). Mungbean was helpful for the restoration of crop productivity of the eroded land. Inclusion of leguminous crop in rotation is beneficial as it fixes atmospheric nitrogen. Incorporation of mungbean residues compared to its removal was better in improving soil fertility of the eroded land but in terms of farmer's income removal of mungbean residue gave higher RII. The choice of mungbean residues management is upto the farmers, as its pods can be picked and the crop biomass used as a fodder crop but biomass incorporation would improve the fertility of soil. In any case mungbean crop gave better response in terms of farmer's income, which shows the sustainability of management practice over time and a better option for the restoration of eroded land.

Table 77: Economic analysis of organic and inorganic fertilizer treatments at site Guljaba

Year	Trt [a]	Grain yld	Straw yld	Grain val [b]	Straw val	G. I.	G.I.C.	T.E.	N.I.C.	RII (%)
		------------(kg ha^{-1})-------------		--(US $ [c])---						
2006-2007	**T1**	2930	5512	507.1	360.4	867.5	0.0	0.0	0.0	-
	T2	3675	6306	636.0	412.3	1048.3	180.8	42.5	138.3	15.9
	T3	3973	6552	687.6	428.4	1116.0	248.5	97.9	150.5	17.3
	T4	4194	6851	725.8	447.9	1173.8	306.3	134.8	171.4	19.7
	T5	4235	6783	732.9	443.5	1176.4	308.9	162.6	146.2	16.8
	T6	4452	7061	770.5	461.6	1232.2	364.7	190.5	174.2	20.0
2007-2008	**T1**	3021	5629	580.9	389.7	970.6	0.0	0.0	0.0	-
	T2	3729	6306	717.1	436.5	1153.6	183.0	46.5	136.4	14.0
	T3	4021	6605	773.2	457.2	1230.5	259.8	108.0	151.7	15.6
	T4	4213	6844	810.1	473.8	1284.0	313.3	148.7	164.6	16.9
	T5	4240	6839	815.3	473.4	1288.8	318.1	175.5	142.6	14.6
	T6	4405	7049	847.1	488.0	1335.1	364.4	202.3	162.1	16.7

[a] Trt = Treatment, Grain yld = Grain Yield, Straw yld = Straw Yield, Grain val = Grain Value, Straw val = Straw Value, G.I. = Gross Income, G.I.C. = Gross Income over control, T.E. = Total Expenditure, N.I.C. = Net Income over control, and RII = Relative Increase in Income.
[b] Prices are based on local market prices during 2006-2007.
[c] US $ = US Dollar (equivalency = Rs. 65 during 2006-2007)

Table 78: Economic analysis of organic and inorganic fertilizer treatments at site Gado

Year	Trt [a]	Grain yld	Straw yld	Grain val [b]	Straw val	G. I.	G.I.C.	T.E.	N.I.C.	RII (%)
		------------(kg ha^{-1})-----------		---(US $ [c])---						
2006-2007	**T1**	2583	5020	447.0	328.2	775.2	0.0	0.0	0.0	-
	T2	3422	5899	592.2	385.7	977.9	202.6	42.5	160.1	21
	T3	3723	6155	644.3	402.4	1046.8	271.5	97.9	173.5	22
	T4	3953	6441	684.1	421.1	1105.3	330.0	134.8	195.1	25
	T5	4003	6441	692.8	421.1	1113.9	338.6	162.6	176.0	23
	T6	4236	6671	733.1	436.1	1169.3	394.0	190.5	203.5	26
2007-2008	**T1**	2606	5025	501.1	347.8	849.0	0.0	0.0	0.0	-
	T2	3445	5923	662.5	410.0	1072.5	223.5	46.5	176.9	21
	T3	3724	6244	716.1	432.2	1148.4	299.3	108.0	191.2	22
	T4	4026	6466	774.2	447.6	1221.8	372.8	148.7	224.1	26
	T5	4041	6463	777.1	447.4	1224.5	375.5	175.5	199.9	23
	T6	4364	6793	839.2	470.2	1309.5	460.4	202.3	258.1	30

[a] Trt = Treatment, Grain yld = Grain Yield, Straw yld = Straw Yield, Grain val = Grain Value, Straw val = Straw Value, G.I. = Gross Income, G.I.C. = Gross Income over control, T.E. = Total Expenditure, N.I.C. = Net Income over control, and RII = Relative Increase in Income.

[b] Prices are based on local market prices during 2006-2007.

[c] US $ = US Dollar (equivalency = Rs. 65 during 2006-2007)

Table 79: Economic analysis of organic and inorganic fertilizer treatments at site Kotlai

Year	Trt [a]	Grain yld	Straw yld	Grain val [b]	Straw val	G. I.	G.I.C.	T.E.	N.I.C.	RII (%)
		-------------($kg\ ha^{-1}$)--------------		----------------------------------(US $ [c])----------------------------------						
2006-2007	**T1**	2393	4829	414.1	315.7	729.9	0.0	0.0	0.0	-
	T2	3309	5682	572.7	371.5	944.2	214.3	42.5	171.7	23
	T3	3554	5959	615.1	389.6	1004.7	274.8	97.9	176.9	24
	T4	3868	6338	669.4	414.4	1083.8	353.9	134.8	219.1	30
	T5	3909	6270	676.5	409.9	1086.5	356.6	162.6	193.9	26
	T6	4164	6511	720.6	425.7	1146.4	416.4	190.5	225.9	31
2007-2008	**T1**	2439	4894	469.0	338.8	807.8	0.0	0.0	0.0	-
	T2	3343	5723	642.8	396.2	1039.0	231.2	46.5	184.6	23
	T3	3617	6046	695.5	418.5	1114.1	306.2	108.0	198.1	24
	T4	3879	6332	745.9	438.3	1184.3	376.4	148.7	227.7	28
	T5	3885	6254	747.1	432.9	1180.0	372.2	175.5	196.6	24
	T6	4186	6621	805.0	458.3	1263.3	455.5	202.3	253.1	31

[a] Trt = Treatment, Grain yld = Grain Yield, Straw yld = Straw Yield, Grain val = Grain Value, Straw val = Straw Value, G.I. = Gross Income, G.I.C. = Gross Income over control, T.E. = Total Expenditure, N.I.C. = Net Income over control, and RII = Relative Increase in Income.

[b] Prices are based on local market prices during 2006-2007.

[c] US $ = US Dollar (equivalency = Rs. 65 during 2006-2007).

Table 80: Economic analysis of residues management practices at site Guljaba

		-----------------Wheat-----------------				----------------Mungbean---------------								
Years	**Trt [a]**	**G. yld**	**S. yld**	**G. val [b]**	**S. val**	**G. yld**	**Bio. yld**	**G. val**	**B. val**	**G. I.**	**G. I. C.**	**T. E.**	**N. I. C.**	**RII (%)**
		------(kg ha^{-1})------		-------(US $ [c])------		-------(kg ha^{-1})------		---(US $)---						
2006-2007	**F**	3205	5548	555	363	0	0	0	0	917	0	105	-105	-11
	R-	3496	5753	605	376	1172	6960	541	321	1843	926	110	816	89
	R+	3678	5983	637	391	1202	0	555	0	1583	665	110	556	60
2007-2008	**F**	3288	5559	569	363	0	0	0	0	933	0	114	-114	-12
	R-	3468	5791	600	379	1198	6747	553	311	1843	911	119	792	84
	R+	3699	6026	640	394	1191	0	550	0	1584	651	119	533	57

[a] Trt = Treatment, G. yld = Grain Yield, S. yld = Straw Yield, G. val = Grain Value, S. val = Straw Value, G.I. = Gross Income, G.I.C. = Gross Income over control, T.E. = Total Expenditure, N.I.C. = Net Income over control, and RII = Relative Increase in Income.

[b] Prices are based on local market prices during 2006-2007.

[c] US $ = US Dollar (equivalency = Rs. 65 during 2006-2007)

Table 81: Economic analysis of residues management practices at site Gado

		----Wheat----				----Mungbean----								
Years	Trt [a]	G. yld	S. yld	G. val [b]	S. val	G. yld	Bio. yld	G. val	B. val	G. I.	G. I. C.	T. E.	N. I. C.	RII (%)
		---(kg ha^{-1})---		---(US $ [c])---		---(kg ha^{-1})---		----(US $)----						
2006-2007	**F**	2980	5123	516	335	0	0	0	0	851	0	105	-105	-12
	R-	3241	5397	561	353	1074	6131	496	283	1692	842	110	732	86
	R+	3477	5685	602	372	1082	0	499	0	1473	622	110	513	60
2007-2008	**F**	3006	5161	520	337	0	0	0	0	858	0	114	-114	-13
	R-	3294	5476	570	358	1099	6113	507	282	1718	860	119	741	86
	R+	3524	5695	610	372	1120	0	517	0	1499	641	119	523	61

[a] Trt = Treatment, G. yld = Grain Yield, S. yld = Straw Yield, G. val = Grain Value, S. val = Straw Value, G.I. = Gross Income, G.I.C. = Gross Income over control, T.E. = Total Expenditure, N.I.C. = Net Income over control, and RII = Relative Increase in Income.

[b] Prices are based on local market prices during 2006-2007.

[c] US $ = US Dollar (equivalency = Rs. 65 during 2006-2007)

Table 82: Economic analysis of residues management practices at site Kotlai

		Wheat				Mungbean								
Years	**Trt [a]**	**G. yld**	**S. yld**	**G. val [b]**	**S. val**	**G. yld**	**Bio. yld**	**G. val**	**B. val**	**G. I.**	**G. I. C.**	**T. E.**	**N. I. C.**	**RII (%)**
		(kg ha^{-1})		(US $ [c])		(kg ha^{-1})		(US $)						
2006-2007	**F**	2877	4993	498	326	0	0	0	0	824	0	105	-105	-13
	R-	3103	5236	537	342	1037	5301	479	245	1603	778	110	669	81
	R+	3397	5516	588	361	1045	0	482	0	1431	607	110	497	60
2007-2008	**F**	2880	5022	498	328	0	0	0	0	827	0	114	-114	-14
	R-	3149	5299	545	346	1040	5320	480	246	1617	790	119	671	81
	R+	3416	5549	591	363	1035	0	478	0	1432	605	119	486	59

[a] Trt = Treatment, G. yld = Grain Yield, S. yld = Straw Yield, G. val = Grain Value, S. val = Straw Value, G.I. = Gross Income, G.I.C. = Gross Income over control, T.E. = Total Expenditure, N.I.C. = Net Income over control, and RII = Relative Increase in Income.

[b] Prices are based on local market prices during 2006-2007.

[c] US $ = US Dollar (equivalency = Rs. 65 during 2006-2007)

5. SUMMARY

The present research was initiated at Tehsil Kabal district Swat of North West Frontier Province, Pakistan to study integrated nutrient management for soil fertility and crop productivity of water eroded lands. A survey was made for the selection of three sites, based on the past history of soil erosion as slightly eroded, moderately eroded and severely eroded. The three sites were classified following USDA soil classification system. Site Guljaba belongs to Pirsabak soil series and was categorized as slightly eroded, site Gado belongs to Missa soil series and categorized as moderately eroded, while Kotlai belongs to Missa gullied soil series and was categorized as severely eroded soil.

Before the experiment triplicate soil samples were taken both from 0-20 cm and 20-45 cm soil depths from each site and analyzed at the laboratory of Soil and Environmental Sciences, NWFP Agricultural University, Peshawar. Field experiments were started at each site during July 2006 for four seasons under wheat-mungbean-wheat cropping system. The experiments were laid out in RCBD split-plot arrangement with 2 factors. Main-plot factor was residue management practices, which included 3 residue management practices, i.e., F (fallow), R– (Mungbean residues removed) and R+ (Mungbean residues incorporated). Sub-plot factor consisted of six fertilizers treatments T1 (control), T2 (120 kg N ha^{-1}), T3 (120-90-0 kg N-P_2O_5-K_2O ha^{-1}), T4 (120-90-60 kg N-P_2O_5-K_2O ha^{-1}), T5 (90-90-60 kg N-P_2O_5-K_2O ha^{-1} + 10 t FYM ha^{-1}) and T6 (60-90-60 kg N-P_2O_5-K_2O ha^{-1} + 20 t FYM ha^{-1}).

In July 2006 during kharif, mungbean variety Swat 97 was first sown in two of the three main-plots with a basal dose of 25-60-0 kg N-P_2O_5-K_2O ha^{-1}, while the third main-plot was left fallow. After about 60 days of growth, 1 m^2 area was harvested in each treatment plot of mungbean and data were recorded on biomass yield, grain yield, and 1000-grain weight (g). Mungbean crop was harvested in October 2006. Immediately after harvesting, aboveground residues of Mungbean crop were either completely removed (R-) or incorporated with the help of cultivator (R+) into respective plots according to the plan.

In November 2006 during winter wheat variety Tatara was sown in all the plots. Sub-plot size was 5 m x 4 m. All the fertilizer treatments were applied to their respective plots. All the fertilizers were applied at the time of sowing of wheat crop and were incorporated into the soil. In case of NPK treatments, half N plus all P, and K were applied at sowing and the remaining half N after about one month. Farmyard manure was applied @10 Mg ha^{-1} to T5 and 20 Mg ha^{-1} to T6 plots about one month before sowing of wheat crop during the two winter seasons. Wheat crop was harvested from a net area of 1 m^2 in duplicate from each treatment plot in June and threshed after sun drying in the field. Biological yield, grain yield, straw yield (kg ha^{-1}), 1000-grain weight (g) and harvest index (%) data were recorded.

Three main- plots were maintained at each site. Each main-plot was divided into six sub-plots. Residue management practices were done in main-plots while fertilizer treatments were applied to sub-plots. After harvesting of each crop at each site, soil and plant samples were collected from each treatment plot and brought to the laboratory of Departemt of Soil & Environmental Sciences, NWFP Agricultural University, Peshawar. Soil samples were dried, ground and sieved through 2 mm sieve, which were stored in the clean, dry and labelled plastic bottles for further analysis. All shoot and grain samples were oven dried at 80 $^{\circ}$C to a constant mass, weighed, then finely ground (<0.1 mm) and stored in plastic bags. The soil samples were analyzed for physical, chemical and biological properties i.e., bulk density, AWHC, soil organic matter, soil electrical conductivity, soil pH, lime content, AB-DTPA extractable P, K, Mineral N, total N, microbial activity, microbial biomass C and N and mineralizable C and N, while plant and grain samples were analyzed for P and N concentrations.

The data collected on different soil properties, crop yields and nutrients uptake by wheat were analyzed statistically using two Factors RCBD Split-plot with 3 replications using MS Excel and statistical package MStatC. Fertilizer treatments and residues management practices were compared using LSD test of significance according to Gomez and Gomez (1976).

For the restoration of the eroded sites different fertilizer treatments and residues management practices were applied at each site. It is evident from the results that organic and inorganic fertilizers and residues management practices affected almost all soil physical, chemical and biological properties.

Effect of fertilizer treatments and residue management practices on soil physical, chemical and biological properties was significant. Soil pH and bulk density were highest in the control plots, while lowest in T6. Similarly R+ had the lowest soil pH and bulk density as compared to R- and fallow plots. The effect on bulk density was due to increase in organic matter through the addition of farmyard manure (FYM) and increased biomass production, as a result of more moisture conservation and structural stability leading to more aeration. Treatment T6 had the highest organic matter, available water holding capacity, and more plant nutrients, microbial activity, microbial biomass C and N and mineralizable C and N followed by T5, compared to minimum in control plots. Residue management practices had also significant effect on these properties.

Analysis of the data combined over both seasons and sites showed that all soil characteristics differed significantly among the sites Guljaba, Gado and Kotlai, as well as among seasons, both at surface (0-20 cm soil depth) and sub-surface soils (20-45 cm soil depth). The deleterious effect of erosion on soil properties was more prominent in severely eroded soil as compared to slightly and moderately eroded soil. Soil properties were improved over time from their initial values during Kharif 2006 at all the three sites due to residual or cumulative effect through addition of inorganic fertilizers, farmyard manure and mungbean residues management, which implies that soil fertility status was improving with integrated plant nutrient management practices.

The highest soil pH and bulk density were found at severely eroded soil (Kotlai) as compared to moderately eroded (Gado) and slightly eroded (Guljaba) soils. As soil erosion exposes the $CaCO_3$ rich material that increases soil pH. The increase in bulk density may be due to decrease in aggregation of soil particles because of decline in soil organic carbon (SOC) content. Organic matter and plant nutrients were lowest at Kotlai as compared to Gado and Guljaba. Soil organic matter and plant nutrients were deficient at site Kotlai, while marginal at Guljaba and Gado as soil erosion causes loss of basic plant nutrients such as N, P and K. Guljaba had the highest AWHC followed by Gado, while Kotlai had the lowest AWHC. Microbial activity, microbial biomass C and N and mineralizable C and N were higher at Guljaba followed by Gado, while they were lowest at Kotlai.

Yield attributes of wheat were improved with the integrated supply of nutrients through the addition of inorganic fertilizers and farmyard manure as well as with the incorporation of mungbean residues. Maximum biological yield, grain yield, straw yield, harvest index and 1000-grain weight of wheat were recorded in 20 t FYM ha^{-1} treated plots (T6) followed by T5 and T4, compared to minimum recorded in control and in mungbean incorporated plots (R+). The major reason for the performance of T6 was due to the effect of organic manures on soil moisture conservation and increase in soil organic carbon (SOC).

Concentration of N and P in wheat plant and grains were increased with the integrated supply of nutrients through the addition of inorganic fertilizers and farmyard manure as well as with the incorporation of mungbean residues. Maximum concentration of N and P in wheat plant and grains were recorded in plots with integrated supply of nutrients (T6 and T5) followed by T4, compared to minimum recorded in control. Concentration of N and P in wheat plant and grains also increased with the incorporation of mungbean residues.

Incorporation of mungbean residues maintains soil moisture content and soil temperature, resulting in greater root growth, nutrient uptake and grain yields of wheat. Inclusion of mungbean in crop rotation with wheat improved the yield of wheat as well as fertility of soil. It is a very useful crop as its pods can be picked for grain and its residues can be incorporated for green manuring. It increases productivity as well as plant-N uptake and is also a source of pulse grain.

Economic analyses of fertilizer use on wheat as well as residues management practices were done during each year for all the three sites Guljaba, Gado and Kotlai. For this purpose relative increase in income (RII) was calculated for each treatment. The results obtained from different fertilizer treatments revealed that all the treatments gave higher RII compared with the control during both the years (2006-2007 and 2007-2008). T6 (Application of 20 t FYM ha^{-1} and reducing commercial inorganic N fertilizer to 60 kg N ha^{-1}) gave the highest RII at all the three sites during both the years. The results suggest that fertilizer management practices gave a better response at all the three sites Guljaba (slightly eroded), Gado (moderately eroded) and Kotlai (severely eroded), which were helpful for the restoration of crop productivity at these eroded lands. T6 involves addition of 20 t FYM ha^{-1} along with inorganic fertilizers. A better response of T6 in terms of farmer's income would mean sustainability of these practices for the future and the restoration of eroded land over time.

Leaving the plots fallow (F) gave negative RII during both the years (2006-2007 and 2007-2008), while R- (mungbean residues removed) and R+ (mungbean residues incorporated into soil) gave positive RII at each site. R- gave higher RII than R+ at all the three site during both the years. Higher RII for R- and R+ suggest that mungbean crop in rotation was helpful in improving farmer's income whether its residues incorporated or removed and gave a better response at all the three sites. Mungbean was helpful for the restoration of crop productivity of the eroded land. Inclusion of leguminous crop in rotation is beneficial as it fixes atmospheric nitrogen. Incorporation of mungbean residues compared to its removal was better in improving soil fertility of the eroded land but in terms of farmer's income removal of mungbean residue gave higher RII. The choice of mungbean residues management is upto the farmers, as its pods can be picked and the crop biomass used as a fodder crop but biomass incorporation would improve the fertility of soil. In any case mungbean crop gave better response in terms of farmer's income, which shows the sustainability of management practice over time and a better option for the restoration of eroded land.

It can be concluded from this study that application of balanced rate of fertilizers in combination with farmyard manure (FYM) would improve soil physical, chemical and biological properties and restore crop productivity under wheat-mungbean-wheat cropping system on sustainable basis. Keeping in view the importance of legumes in cereal legume rotation, wheat-mungbean-wheat cropping system is recommended for restoring crop productivity on eroded lands.

6. CONCLUSIONS

The following conclusions could be drawn from the findings of the present research work:

- Soils of all the three sites were poor in soil fertility in the order Kotlai > Gado > Guljaba. Application of organic and inorganic fertilizers and residues management improved soil fertility (physical, chemical and biological properties) of the three sites.

- Application of farmyard manure (FYM) combined with inorganic fertilizers (T6 = 60-90-60 kg N-P_2O_5-K_2O ha^{-1} + 20 t FYM ha^{-1}) gave the best results in improving soil fertility. At site Guljaba, T6 compared with control increased organic matter by 17%, potassium by 16%, phosphorus by 21.8%, AWHC by 5.8%, total N by 17% and decreased bulk density by 5.2%. Similarly T6 also improved soil fertility at sites Gado and Kotlai.

- T6 improved yield and yield attributes and nutrient uptake of wheat. At site Guljaba, T6 compared with control increased biological yield by 34%, grain yield by 48.8%, straw yield by 26.7%, harvest index by 11.3%, 1000-grain weight by 16.9%, plant-N concentration by 19%, plant-P concentration by 50.6%, grain-N concentration by 27.6% and grain-P concentration by 45.6%. Similarly T6 also improved yield and yield attributes and nutrient uptake of wheat at sites Gado and Kotlai.

- Mungbean (leguminous crop) improved soil fertility, while its incorporation gave the best results. R- and R+ over fallow increased organic matter by 21.7 and 28.9%, potassium by 4.4 and 6.4%, phosphorus by 0.4 and 5.0%, mineral N by 2.8 and 5.8%, AWHC by 0.6 and 3.3%, total N by 19.9 and 26.9%, bulk density by -0.7 and -3.0% respectively. Similarly R- and R+ also improved soil fertility at sites Gado and Kotlai.

- R- and R+ also improved yield and yield attributes and nutrient uptake of wheat. R- and R+ over fallow increased biological yield by 4.9 and 9.9%, grain yield by 7.2 and 13.6%, straw yield by 3.9 and 8.1%, harvest index by 2.5 and 3.6%, 1000-

grain weight by 2.6 and 5.3%, plant-N concentration by 5.8 and 11.7% and grain-N concentration by 8.3 and 16.7% respectively. Similarly R- and R+ also improved yield and yield attributes and nutrient uptake of wheat at sites Gado and Kotlai.

- Economic analysis of fertilizer treatments revealed that during 2006-2007, T6 gave the highest RII (20, 26 and 31% at Guljaba, Gado and Kotlai respectively). During 2007-2008, T4 gave the highest RII (16.9%) only at Guljaba which was just a little higher than that of T6 (16.7%), while at the other two sites Gado and Kotlai, T6 gave the highest RII (30 and 31% at Gado and Kotlai respectively).

- Economic analysis of residues management practices revealed that leaving the plots fallow gave negative RII during both the years (2006-2007 and 2007-2008), while R- and R+ gave positive RII at each site. During 2006-2007, R- gave higher RII (89, 86 and 81% at Guljaba, Gado and Kotlai respectively) than R+ (60% each at Guljaba, Gado and Kotlai). During 2007-2008, RII of R- (84, 86 and 81% at Guljaba, Gado and Kotlai respectively) was higher than R+ (57, 61 and 59% at Guljaba, Gado and Kotlai respectively).

- Mungbean is a very useful crop, as its pods can be picked and the crop biomass can be incorporated to improve soil fertility.

- Inclusion of mungbean will also have impact on environment through providing cover during monsoon rains and reducing soil erosion.

- Soil fertility and hence crop productivity of eroded lands can be restored by employing integrated nutrient management (organic and inorganic fertilizers, growing of legumes and crop residues incorporation) in order to feed the ever increasing population.

7. RECOMMENDATIONS

The following recommendations are given for eroded lands with slight to severe degree of erosion based on the findings of the present research work:

- Application of 20 t FYM ha^{-1} and reducing commercial inorganic N fertilizer to 60 kg N ha^{-1} is recommended for eroded lands.

- Legumes must be included in the crop rotation. Wheat-mungbean-wheat cropping system is recommended for eroded lands at District Swat. Mungbean is a very useful crop as its pods can be picked for grain and its residues can be incorporated for green manuring to increase crop productivity as well as plant-N uptake.

- Mungbean residues should be incorporated to increase organic matter in the soil, which will conserve soil moisture and will improve overall soil condition for plant growth.

- For future studies, the results should be confirmed through a long-term experiment. Decomposition rates of crop residues for release of plant nutrients should be studied.

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APPENDICES

Appendix 1: ANOVA for soil pH at 0-20 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0593	0.0297	4.3282	0.0998
MP (A)	2	0.038	0.019	2.7739	0.1755 ns
Error (a)	4	0.0274	0.0069		
Fertilizer (B)	5	0.035	0.007	0.6006	0.6997 ns
A x B	10	0.0873	0.0087	0.7494	0.6738
Error (b)	30	0.3496	0.0117		
Total	53	0.5967	0.0113		

Appendix 2: ANOVA for soil pH at 0-20 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0836	0.0418	5.3149	0.0747
MP (A)	2	0.0941	0.0471	5.9861	0.0627 ns
Error (a)	4	0.0315	0.0079		
Fertilizer (B)	5	0.0173	0.0035	0.2557	0.9336 ns
A x B	10	0.0746	0.0075	0.5515	0.8391
Error (b)	30	0.4056	0.0135		
Total	53	0.7066	0.0133		

Appendix 3: ANOVA for soil pH at 0-20 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0667	0.0334	1.7081	0.2909
MP (A)	2	0.2848	0.1424	7.2925	0.0463 *
Error (a)	4	0.0781	0.0195		
Fertilizer (B)	5	0.0761	0.0152	1.0327	0.4165 ns
A x B	10	0.1075	0.0107	0.7296	0.6910
Error (b)	30	0.4419	0.0147		
Total	53	1.0551	0.0199		

Appendix 4: ANOVA for soil pH at 0-20 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0195	0.0097	0.3862	0.7024
MP (A)	2	0.3937	0.1969	7.8014	0.0416 *
Error (a)	4	0.1009	0.0252		
Fertilizer (B)	5	0.1961	0.0392	2.5548	0.0485 *
A x B	10	0.1542	0.0154	1.0047	0.4618
Error (b)	30	0.4604	0.0153		
Total	53	1.3249	0.025		

Appendix 5: ANOVA for Soil pH combined over seasons at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.408	0.136	9.1495	0.0009 ***
R(S)	8	0.229	0.029	1.9261	0.1259
MP (A)	2	0.662	0.331	22.263	0.0000 ***
S x A	6	0.149	0.025	1.6655	0.1937
Error	16	0.238	0.015		
Fertilizer (B)	5	0.157	0.031	2.2765	0.0512 ns
S x B	15	0.167	0.011	0.8069	
A x B	10	0.344	0.034	2.4901	0.0095
S x A x B	30	0.08	0.003	0.1921	
Error	120	1.657	0.014		
Total	215	4.091			

Appendix 6: ANOVA for soil pH at 20-45 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0462	0.0231	4.0966	0.1076
MP (A)	2	0.0438	0.0219	3.8866	0.1154 ns
Error (a)	4	0.0225	0.0056		
Fertilizer (B)	5	0.0356	0.0071	0.706	0.6235 ns
A x B	10	0.1382	0.0138	1.3692	0.2414
Error (b)	30	0.3029	0.0101		
Total	53	0.5893	0.0111		

Appendix 7: ANOVA for soil pH at 20-45 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.1031	0.0515	12.3119	0.0195
MP (A)	2	0.0141	0.0071	1.6894	0.2939 ns
Error (a)	4	0.0167	0.0042		
Fertilizer (B)	5	0.1311	0.0262	1.814	0.1402 ns
A x B	10	0.1449	0.0145	1.0024	0.4635
Error (b)	30	0.4335	0.0145		
Total	53	0.8434	0.0159		

Appendix 8: ANOVA for soil pH at 20-45 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0659	0.033	3.9553	0.1127
MP (A)	2	0.0038	0.0019	0.2282	0.8056 ns
Error (a)	4	0.0333	0.0083		
Fertilizer (B)	5	0.2519	0.0504	3.46	0.0138 *
A x B	10	0.2057	0.0206	1.4128	0.2222
Error (b)	30	0.4368	0.0146		
Total	53	0.9973	0.0188		

Appendix 9: ANOVA for soil pH at 20-45 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0674	0.0337	1.7898	0.2784
MP (A)	2	0.0633	0.0317	1.6815	0.2951 ns
Error (a)	4	0.0753	0.0188		
Fertilizer (B)	5	0.4259	0.0852	6.159	0.0005 ***
A x B	10	0.2575	0.0258	1.8619	0.0918
Error (b)	30	0.4149	0.0138		
Total	53	1.3044	0.0246		

Appendix 10: ANOVA for soil pH combined over seasons at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.295	0.098	10.6385	0.0004 ***
R(S)	8	0.283	0.035	3.8206	0.0108
MP (A)	2	0.002	0.001	0.0866	
S x A	6	0.123	0.021	2.2259	0.0942
Error	16	0.148	0.009		
Fertilizer (B)	5	0.627	0.125	9.4783	0.0000 ***
S x B	15	0.217	0.014	1.0947	0.3685
A x B	10	0.672	0.067	5.0796	0.0000
S x A x B	30	0.074	0.002	0.1865	
Error	120	1.588	0.013		
Total	215	4.029			

Appendix 11: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0187	0.0094	0.724	0.5390
MP (A)	2	0.1015	0.0508	3.9223	0.1140 ns
Error (a)	4	0.0518	0.0129		
Fertilizer (B)	5	0.2461	0.0492	1.6796	0.1700 ns
A x B	10	0.3032	0.0303	1.0348	0.4395
Error (b)	30	0.8791	0.0293		
Total	53	1.6006	0.0302		

Appendix 12: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0296	0.0148	1.119	0.4111
MP (A)	2	0.1232	0.0616	4.6614	0.0901 ns
Error (a)	4	0.0529	0.0132		
Fertilizer (B)	5	0.2885	0.0577	2.3252	0.0673 ns
A x B	10	0.378	0.0378	1.5234	0.1795
Error (b)	30	0.7444	0.0248		
Total	53	1.6166	0.0305		

Appendix 13: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0284	0.0142	1.2602	0.3763
MP (A)	2	0.1521	0.0761	6.7482	0.0523 ns
Error (a)	4	0.0451	0.0113		
Fertilizer (B)	5	0.3325	0.0665	2.453	0.0561 ns
A x B	10	0.4422	0.0442	1.6308	0.1454
Error (b)	30	0.8134	0.0271		
Total	53	1.8137	0.0342		

Appendix 14: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0186	0.0093	0.5504	0.6149
MP (A)	2	0.1652	0.0826	4.887	0.0843 ns
Error (a)	4	0.0676	0.0169		
Fertilizer (B)	5	0.3355	0.0671	2.3558	0.0644 ns
A x B	10	0.4884	0.0488	1.7144	0.1233
Error (b)	30	0.8546	0.0285		
Total	53	1.9299	0.0364		

Appendix 15: ANOVA for soil electrical conductivity combined over seasons at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.016	0.005	0.3976	
R(S)	8	0.095	0.012	0.8773	
MP (A)	2	0.535	0.268	19.7091	0.0000 ***
S x A	6	0.007	0.001	0.0815	
Error	16	0.217	0.014		
Fertilizer (B)	5	1.189	0.238	8.6709	0.0000 ***
S x B	15	0.013	0.001	0.0327	
A x B	10	1.563	0.156	5.6975	0.0000
S x A x B	30	0.049	0.002	0.0596	
Error	120	3.292	0.027		
Total	215	6.977			

Appendix 16: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0092	0.0046	0.4555	0.6634
MP (A)	2	0.0083	0.0042	0.4126	0.6872 ns
Error (a)	4	0.0404	0.0101		
Fertilizer (B)	5	0.139	0.0278	0.6635	0.6539 ns
A x B	10	0.491	0.0491	1.1721	0.3468
Error (b)	30	1.2566	0.0419		
Total	53	1.9445	0.0367		

Appendix 17: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0113	0.0057	0.4698	0.6557
MP (A)	2	0.0062	0.0031	0.256	0.7859 ns
Error (a)	4	0.0481	0.012		
Fertilizer (B)	5	0.1793	0.0359	0.7674	0.5806 ns
A x B	10	0.4408	0.0441	0.9434	0.5095
Error (b)	30	1.4018	0.0467		
Total	53	2.0874	0.0394		

Appendix 18: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0091	0.0046	0.4292	0.6778
MP (A)	2	0.0102	0.0051	0.4773	0.6518 ns
Error (a)	4	0.0426	0.0106		
Fertilizer (B)	5	0.1727	0.0345	0.7194	0.6140 ns
A x B	10	0.4694	0.0469	0.9775	0.4826
Error (b)	30	1.4406	0.048		
Total	53	2.1445	0.0405		

Appendix 19: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.01	0.005	0.34	0.7305
MP (A)	2	0.0158	0.0079	0.5378	0.6211 ns
Error (a)	4	0.0589	0.0147		
Fertilizer (B)	5	0.1588	0.0318	0.618	0.6870 ns
A x B	10	0.5179	0.0518	1.008	0.4593
Error (b)	30	1.5413	0.0514		
Total	53	2.3027	0.0434		

Appendix 20: ANOVA for soil electrical conductivity combined over seasons at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.019	0.006	0.5367	
R(S)	8	0.04	0.005	0.4175	
MP (A)	2	0.028	0.014	1.1697	0.3356 ns
S x A	6	0.013	0.002	0.1784	
Error	16	0.19	0.012		
Fertilizer (B)	5	0.642	0.128	2.7306	0.0226 *
S x B	15	0.008	0.001	0.0114	
A x B	10	1.882	0.188	4.0038	0.0001
S x A x B	30	0.037	0.001	0.0263	
Error	120	5.64	0.047		
Total	215	8.498			

Appendix 21: ANOVA for soil organic matter at 0-20 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.1478	0.0739	0.1327	0.8794
MP (A)	2	16.9478	8.4739	15.215	0.0135 *
Error (a)	4	2.2278	0.5569		
Fertilizer (B)	5	1.5022	0.3004	1.2819	0.2976 ns
A x B	10	1.8767	0.1877	0.8007	0.6291
Error (b)	30	7.0311	0.2344		
Total	53	29.7333	0.561		

Appendix 22: ANOVA for soil organic matter at 0-20 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0404	0.0202	0.0487	0.9529
MP (A)	2	160.8293	80.4146	194.2035	0.0001 ***
Error (a)	4	1.6563	0.4141		
Fertilizer (B)	5	85.2904	17.0581	60.1814	0.0000 ***
A x B	10	3.4463	0.3446	1.2159	0.3206
Error (b)	30	8.5033	0.2834		
Total	53	259.7659	4.9012		

Appendix 23: ANOVA for soil organic matter at 0-20 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0381	0.0191	0.0462	0.9553
MP (A)	2	157.397	78.6985	190.4423	0.0001 ***
Error (a)	4	1.653	0.4132		
Fertilizer (B)	5	82.037	16.4074	57.5325	0.0000 ***
A x B	10	2.8474	0.2847	0.9984	0.4666
Error (b)	30	8.5556	0.2852		
Total	53	252.5281	4.7647		

Appendix 24: ANOVA for soil organic matter at 0-20 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.1544	0.0772	0.1961	0.8294
MP (A)	2	163.17	81.585	207.1269	0.0001 ***
Error (a)	4	1.5756	0.3939		
Fertilizer (B)	5	83.6417	16.7283	64.1478	0.0000 ***
A x B	10	2.4233	0.2423	0.9293	0.5208
Error (b)	30	7.8233	0.2608		
Total	53	258.7883	4.8828		

Appendix 25: ANOVA for soil organic matter combined over seasons at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	251.984	83.995	188.9485	0.0000 ***
R(S)	8	0.381	0.048	0.1071	
MP (A)	2	436.172	218.086	490.5911	0.0000 ***
S x A	6	62.172	10.362	23.3097	0.0000
Error	16	7.113	0.445		
Fertilizer (B)	5	201.003	40.201	151.1614	0.0000 ***
S x B	15	51.469	3.431	12.9021	0.0000
A x B	10	9.954	0.995	3.7429	0.0002
S x A x B	30	0.64	0.021	0.0802	
Error	120	31.913	0.266		
Total	215	1052.8			

Appendix 26: ANOVA for soil organic matter at 20-45 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.2711	0.1356	1.6542	0.2995
MP (A)	2	14.7678	7.3839	90.1085	0.0005 ***
Error (a)	4	0.3278	0.0819		
Fertilizer (B)	5	1.0661	0.2132	0.9405	0.4692 ns
A x B	10	2.2011	0.2201	0.9709	0.4878
Error (b)	30	6.8011	0.2267		
Total	53	25.435	0.4799		

Appendix 27: ANOVA for soil organic matter at 20-45 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.63	0.315	2.6129	0.1879
MP (A)	2	27.7211	13.8606	114.9724	0.0003 ***
Error (a)	4	0.4822	0.1206		
Fertilizer (B)	5	7.1222	1.4244	6.1213	0.0005 ***
A x B	10	2.4167	0.2417	1.0385	0.4367
Error (b)	30	6.9811	0.2327		
Total	53	45.3533	0.8557		

Appendix 28: ANOVA for soil organic matter at 20-45 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.8715	0.4357	4.1757	0.1048
MP (A)	2	65.2959	32.648	312.8642	0.0000 ***
Error (a)	4	0.4174	0.1044		
Fertilizer (B)	5	30.8459	6.1692	23.1216	0.0000 ***
A x B	10	3.1396	0.314	1.1767	0.3440
Error (b)	30	8.0044	0.2668		
Total	53	108.5748	2.0486		

Appendix 29: ANOVA for soil organic matter at 20-45 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.4337	0.7169	5.7776	0.0661
MP (A)	2	92.807	46.4035	373.9985	0.0000 ***
Error (a)	4	0.4963	0.1241		
Fertilizer (B)	5	75.3504	15.0701	52.96	0.0000 ***
A x B	10	3.0396	0.304	1.0682	0.4155
Error (b)	30	8.5367	0.2846		
Total	53	181.6637	3.4276		

Appendix 30: ANOVA for soil organic matter combined over seasons at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	69.563	23.188	215.2361	0.0000 ***
R(S)	8	3.206	0.401	3.7202	0.0122
MP (A)	2	177.569	88.785	824.1291	0.0000 ***
S x A	6	23.023	3.837	35.6173	0.0000
Error	16	1.724	0.108		
Fertilizer (B)	5	68.016	13.603	53.8329	0.0000 ***
S x B	15	46.368	3.091	12.233	0.0000
A x B	10	9.915	0.992	3.9238	0.0001
S x A x B	30	0.882	0.029	0.1163	
Error	120	30.323	0.253		
Total	215	430.59			

Appendix 31: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	12.2493	6.1246	0.4355	0.6743
MP (A)	2	104.4915	52.2457	3.7146	0.1225 ns
Error (a)	4	56.2596	14.0649		
Fertilizer (B)	5	17.1237	3.4247	0.1518	0.9779 ns
A x B	10	100.8819	10.0882	0.4472	0.9102
Error (b)	30	676.7644	22.5588		
Total	53	967.7704	18.2598		

Appendix 32: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	32.5278	16.2639	0.4345	0.6749
MP (A)	2	192.63	96.315	2.5728	0.1913 ns
Error (a)	4	149.7422	37.4356		
Fertilizer (B)	5	1087.575	217.515	7.8744	0.0001 ***
A x B	10	207.19	20.719	0.7501	0.6732
Error (b)	30	828.69	27.623		
Total	53	2498.355	47.1388		

Appendix 33: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	34.0459	17.023	0.4435	0.6699
MP (A)	2	192.4381	96.2191	2.5066	0.1969 ns
Error (a)	4	153.543	38.3857		
Fertilizer (B)	5	1091.2615	218.2523	7.815	0.0001 ***
A x B	10	209.1507	20.9151	0.7489	0.6742
Error (b)	30	837.8178	27.9273		
Total	53	2518.257	47.5143		

Appendix 34: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	25.3981	12.6991	0.3144	0.7467
MP (A)	2	415.3026	207.6513	5.1403	0.0785 ns
Error (a)	4	161.5874	40.3969		
Fertilizer (B)	5	2906.8876	581.3775	21.0173	0.0000 ***
A x B	10	232.2863	23.2286	0.8397	0.5955
Error (b)	30	829.8544	27.6618		
Total	53	4571.3165	86.2513		

Appendix 35: ANOVA for AB-DTPA extractable K combined over seasons at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	3408.543	1136.181	34.8835	0.0000 ***
R(S)	8	104.221	13.028	0.4	
MP (A)	2	665.027	332.513	10.209	0.0014 ***
S x A	6	239.835	39.973	1.2273	0.3434
Error	16	521.132	32.571		
Fertilizer (B)	5	3382.488	676.498	25.5835	0.0000 ***
S x B	15	1720.36	114.691	4.3373	0.0000
A x B	10	693.693	69.369	2.6234	0.0064
S x A x B	30	55.817	1.861	0.0704	
Error	120	3173.127	26.443		
Total	215	13964.242			

Appendix 36: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	57.8059	28.903	0.5343	0.6227
MP (A)	2	19.6781	9.8391	0.1819	0.8402 ns
Error (a)	4	216.3752	54.0938		
Fertilizer (B)	5	98.9943	19.7989	1.2738	0.3009 ns
A x B	10	242.7352	24.2735	1.5617	0.1666
Error (b)	30	466.2789	15.5426		
Total	53	1101.8676	20.79		

Appendix 37: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	56.1026	28.0513	0.4647	0.6584
MP (A)	2	84.0904	42.0452	0.6965	0.5501 ns
Error (a)	4	241.4663	60.3666		
Fertilizer (B)	5	255.9098	51.182	2.6551	0.0421 *
A x B	10	246.7074	24.6707	1.2798	0.2853
Error (b)	30	578.3111	19.277		
Total	53	1462.5876	27.596		

Appendix 38: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	41.61	20.805	0.3369	0.7324
MP (A)	2	321.6344	160.8172	2.6042	0.1887 ns
Error (a)	4	247.0089	61.7522		
Fertilizer (B)	5	1028.2461	205.6492	9.9369	0.0000 ***
A x B	10	329.6078	32.9608	1.5926	0.1568
Error (b)	30	620.8678	20.6956		
Total	53	2588.975	48.8486		

Appendix 39: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	118.89	59.445	1.1883	0.3935
MP (A)	2	639.5833	319.7917	6.3924	0.0568 ns
Error (a)	4	200.1067	50.0267		
Fertilizer (B)	5	2926.1239	585.2248	29.5156	0.0000 ***
A x B	10	347.7811	34.7781	1.754	0.1139
Error (b)	30	594.83	19.8277		
Total	53	4827.315	91.0814		

Appendix 40: ANOVA for AB-DTPA extractable K combined over seasons at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	3534.02	1178.007	20.8276	0.0000 ***
R(S)	8	274.409	34.301	0.6065	
MP (A)	2	706.756	353.378	6.2479	0.0099 ***
S x A	6	358.231	59.705	1.0556	0.4277
Error	16	904.957	56.56		
Fertilizer (B)	5	2508.413	501.683	26.6346	0.0000 ***
S x B	15	1800.861	120.057	6.3739	0.0000
A x B	10	1082.12	108.212	5.745	0.0000
S x A x B	30	84.712	2.824	0.1499	
Error	120	2260.288	18.836		
Total	215	13514.765			

Appendix 41: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0109	0.0055	0.8419	0.4952
MP (A)	2	0.0051	0.0026	0.3933	0.6983 ns
Error (a)	4	0.026	0.0065		
Fertilizer (B)	5	0.0467	0.0093	2.2745	0.0724 ns
A x B	10	0.0437	0.0044	1.0634	0.4189
Error (b)	30	0.1232	0.0041		
Total	53	0.2557	0.0048		

Appendix 42: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0089	0.0045	0.8362	0.4972
MP (A)	2	0.0247	0.0123	2.312	0.2151 ns
Error (a)	4	0.0214	0.0053		
Fertilizer (B)	5	0.3103	0.0621	12.7301	0.0000 ***
A x B	10	0.0373	0.0037	0.7643	0.6608
Error (b)	30	0.1462	0.0049		
Total	53	0.5487	0.0104		

Appendix 43: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0081	0.0041	0.7182	0.5413
MP (A)	2	0.1432	0.0716	12.673	0.0186 *
Error (a)	4	0.0226	0.0056		
Fertilizer (B)	5	1	0.2	35.8387	0.0000 ***
A x B	10	0.042	0.0042	0.7525	0.6710
Error (b)	30	0.1674	0.0056		
Total	53	1.3833	0.0261		

Appendix 44: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0091	0.0045	0.8243	0.5014
MP (A)	2	0.3181	0.159	28.9047	0.0042 ***
Error (a)	4	0.022	0.0055		
Fertilizer (B)	5	2.6971	0.5394	77.9813	0.0000 ***
A x B	10	0.0609	0.0061	0.8797	0.5617
Error (b)	30	0.2075	0.0069		
Total	53	3.3147	0.0625		

Appendix 45: ANOVA for AB-DTPA extractable P combined over seasons at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	4.564	1.521	264.6217	0.0000 ***
R(S)	8	0.037	0.005	0.806	
MP (A)	2	0.264	0.132	22.9757	0.0000 ***
S x A	6	0.227	0.038	6.5784	0.0012
Error	16	0.092	0.006		
Fertilizer (B)	5	2.451	0.49	91.2835	0.0000 ***
S x B	15	1.603	0.107	19.9013	0.0000
A x B	10	0.176	0.018	3.286	0.0009
S x A x B	30	0.007	0	0.0455	
Error	120	0.644	0.005		
Total	215	10.066			

Appendix 46: **ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Kharif 2006 at site Guljaba**

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0235	0.0118	6.8228	0.0513
MP (A)	2	0.0092	0.0046	2.6563	0.1845 ns
Error (a)	4	0.0069	0.0017		
Fertilizer (B)	5	0.0411	0.0082	1.5949	0.1918 ns
A x B	10	0.054	0.0054	1.0466	0.4309
Error (b)	30	0.1548	0.0052		
Total	53	0.2895	0.0055		

Appendix 47: **ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Rabi 2007 at site Guljaba**

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0162	0.0081	2.5961	0.1893
MP (A)	2	0.019	0.0095	3.048	0.1570 ns
Error (a)	4	0.0125	0.0031		
Fertilizer (B)	5	0.2808	0.0562	8.9087	0.0000 ***
A x B	10	0.0409	0.0041	0.6485	0.7609
Error (b)	30	0.1891	0.0063		
Total	53	0.5585	0.0105		

Appendix 48: **ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Kharif 2007 at site Guljaba**

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0263	0.0132	9.2798	0.0314
MP (A)	2	0.2704	0.1352	95.2524	0.0004 ***
Error (a)	4	0.0057	0.0014		
Fertilizer (B)	5	1.3347	0.2669	41.6856	0.0000 ***
A x B	10	0.0583	0.0058	0.9101	0.5365
Error (b)	30	0.1921	0.0064		
Total	53	1.8875	0.0356		

Appendix 49: **ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Rabi 2008 at site Guljaba**

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0262	0.0131	17.2836	0.0107
MP (A)	2	0.4681	0.2341	309.0171	0.0000 ***
Error (a)	4	0.003	0.0008		
Fertilizer (B)	5	3.1945	0.6389	88.1699	0.0000 ***
A x B	10	0.0675	0.0068	0.9318	0.5188
Error (b)	30	0.2174	0.0072		
Total	53	3.9767	0.075		

Appendix 50: **ANOVA for AB-DTPA extractable P combined over seasons at sub-surface soil of Guljaba**

S.O.V.	DF	SS	MS	F	P-value
Season	3	5.181	1.727	983.6306	0.0000 ***
R(S)	8	0.092	0.012	6.5685	0.0007
MP (A)	2	0.503	0.251	143.1433	0.0000 ***
S x A	6	0.264	0.044	25.0646	0.0000
Error	16	0.028	0.002		
Fertilizer (B)	5	3.098	0.62	98.6928	0.0000 ***
S x B	15	1.753	0.117	18.616	0.0000
A x B	10	0.105	0.011	1.6749	0.0943
S x A x B	30	0.116	0.004	0.6133	
Error	120	0.753	0.006		
Total	215	11.893			

Appendix 51: ANOVA for mineral N at 0-20 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.1348	0.5674	0.3821	0.7049
MP (A)	2	2.0507	1.0254	0.6905	0.5526 ns
Error (a)	4	5.9398	1.485		
Fertilizer (B)	5	9.5367	1.9073	1.5779	0.1965 ns
A x B	10	8.9304	0.893	0.7388	0.6830
Error (b)	30	36.2638	1.2088		
Total	53	63.8563	1.2048		

Appendix 52: ANOVA for mineral N at 0-20 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.2077	0.6039	0.4399	0.6719
MP (A)	2	1.7418	0.8709	0.6345	0.5763 ns
Error (a)	4	5.4907	1.3727		
Fertilizer (B)	5	17.0444	3.4089	2.6672	0.0414 *
A x B	10	10.4716	1.0472	0.8193	0.6130
Error (b)	30	38.3427	1.2781		
Total	53	74.2989	1.4019		

Appendix 53: ANOVA for mineral N at 0-20 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.9302	0.4651	0.3688	0.7128
MP (A)	2	9.1019	4.551	3.6088	0.1271 ns
Error (a)	4	5.0442	1.2611		
Fertilizer (B)	5	51.8602	10.372	7.6259	0.0001 ***
A x B	10	9.5646	0.9565	0.7032	0.7140
Error (b)	30	40.8033	1.3601		
Total	53	117.3045	2.2133		

Appendix 54: ANOVA for mineral N at 0-20 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.8935	0.4467	0.4229	0.6813
MP (A)	2	28.3356	14.1678	13.4111	0.0168 *
Error (a)	4	4.2257	1.0564		
Fertilizer (B)	5	117.0124	23.4025	15.0961	0.0000 ***
A x B	10	9.9424	0.9942	0.6413	0.7669
Error (b)	30	46.507	1.5502		
Total	53	206.9166	3.9041		

Appendix 55: ANOVA for mineral N combined over seasons at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	353.787	117.929	91.1507	0.0000 ***
R(S)	8	4.166	0.521	0.4025	
MP (A)	2	25.446	12.723	9.8338	0.0016 ***
S x A	6	15.784	2.631	2.0334	0.1203
Error	16	20.7	1.294		
Fertilizer (B)	5	122.76	24.552	18.1959	0.0000 ***
S x B	15	72.694	4.846	3.5917	0.0000
A x B	10	38.547	3.855	2.8568	0.0032
S x A x B	30	0.362	0.012	0.0089	
Error	120	161.917	1.349		
Total	215	816.164			

Appendix 56: ANOVA for mineral N at 20-45 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0535	0.0268	0.0833	0.9216
MP (A)	2	0.7301	0.3651	1.136	0.4067 ns
Error (a)	4	1.2855	0.3214		
Fertilizer (B)	5	6.9761	1.3952	2.1988	0.0807 ns
A x B	10	16.661	1.6661	2.6257	0.0199
Error (b)	30	19.0361	0.6345		
Total	53	44.7423	0.8442		

Appendix 57: ANOVA for mineral N at 20-45 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0562	0.0281	0.064	0.9389
MP (A)	2	0.9568	0.4784	1.0898	0.4190 ns
Error (a)	4	1.756	0.439		
Fertilizer (B)	5	19.3039	3.8608	6.7936	0.0002 ***
A x B	10	16.6007	1.6601	2.9211	0.0111
Error (b)	30	17.0488	0.5683		
Total	53	55.7225	1.0514		

Appendix 58: ANOVA for mineral N at 20-45 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0776	0.0388	0.0578	0.9445
MP (A)	2	1.0531	0.5265	0.7844	0.5159 ns
Error (a)	4	2.685	0.6712		
Fertilizer (B)	5	59.5431	11.9086	21.4016	0.0000 ***
A x B	10	17.3372	1.7337	3.1158	0.0076
Error (b)	30	16.6931	0.5564		
Total	53	97.389	1.8375		

Appendix 59: ANOVA for mineral N at 20-45 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.2746	0.1373	0.2093	0.8195
MP (A)	2	6.2312	3.1156	4.7484	0.0878 ns
Error (a)	4	2.6245	0.6561		
Fertilizer (B)	5	122.2479	24.4496	43.1127	0.0000 ***
A x B	10	16.8196	1.682	2.9659	0.0102
Error (b)	30	17.0133	0.5671		
Total	53	165.2111	3.1172		

Appendix 60: ANOVA for mineral N combined over seasons at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	300.541	100.18	191.9392	0.0000 ***
R(S)	8	0.462	0.058	0.1106	
MP (A)	2	4.033	2.017	3.8638	0.0427 *
S x A	6	4.938	0.823	1.5768	0.2175
Error	16	8.351	0.522		
Fertilizer (B)	5	138.998	27.8	47.7991	0.0000 ***
S x B	15	69.073	4.605	7.9176	0.0000
A x B	10	67.127	6.713	11.5419	0.0000
S x A x B	30	0.291	0.01	0.0167	
Error	120	69.791	0.582		
Total	215	663.606			

Appendix 61: ANOVA for bulk density at 0-20 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0013	0.0007	1.2857	0.3705
MP (A)	2	0.002	0.001	1.989	0.2514 ns
Error (a)	4	0.002	0.0005		
Fertilizer (B)	5	0.006	0.0012	1.2676	0.3036 ns
A x B	10	0.0136	0.0014	1.4272	0.2162
Error (b)	30	0.0286	0.001		
Total	53	0.0536	0.001		

Appendix 62: ANOVA for bulk density at 0-20 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0026	0.0013	2.1731	0.2296
MP (A)	2	0.0101	0.0051	8.442	0.0367 *
Error (a)	4	0.0024	0.0006		
Fertilizer (B)	5	0.0208	0.0042	3.4719	0.0136 *
A x B	10	0.0178	0.0018	1.4839	0.1938
Error (b)	30	0.0359	0.0012		
Total	53	0.0896	0.0017		

Appendix 63: ANOVA for bulk density at 0-20 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0031	0.0015	2.0571	0.2430
MP (A)	2	0.0327	0.0163	21.9032	0.0070 ***
Error (a)	4	0.003	0.0007		
Fertilizer (B)	5	0.0522	0.0104	7.6725	0.0001 ***
A x B	10	0.0195	0.0019	1.4323	0.2141
Error (b)	30	0.0408	0.0014		
Total	53	0.1512	0.0029		

Appendix 64: ANOVA for bulk density at 0-20 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0036	0.0018	2.2708	0.2192
MP (A)	2	0.0684	0.0342	42.7708	0.0020 ***
Error (a)	4	0.0032	0.0008		
Fertilizer (B)	5	0.0797	0.0159	8.4397	0.0000 ***
A x B	10	0.023	0.0023	1.2178	0.3195
Error (b)	30	0.0566	0.0019		
Total	53	0.2345	0.0044		

Appendix 65: ANOVA for soil bulk density combined over seasons at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.291	0.097	146.1973	0.0000 ***
R(S)	8	0.011	0.001	2.0007	0.1132
MP (A)	2	0.071	0.036	53.8289	0.0000 ***
S x A	6	0.042	0.007	10.5381	0.0001
Error	16	0.011	0.001		
Fertilizer (B)	5	0.13	0.026	19.3113	0.0000 ***
S x B	15	0.028	0.002	1.3997	0.1582
A x B	10	0.071	0.007	5.2577	0.0000
S x A x B	30	0.003	0	0.0712	
Error	120	0.162	0.001		
Total	215	0.82			

Appendix 66: ANOVA for bulk density at 20-45 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0017	0.0009	1.4273	0.3405
MP (A)	2	0.0001	0.0001	0.1182	0.8915 ns
Error (a)	4	0.0024	0.0006		
Fertilizer (B)	5	0.0055	0.0011	1.234	0.3179 ns
A x B	10	0.0057	0.0006	0.6412	0.7671
Error (b)	30	0.0269	0.0009		
Total	53	0.0425	0.0008		

Appendix 67: ANOVA for bulk density at 20-45 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0023	0.0012	5.2	0.0771
MP (A)	2	0.0012	0.0006	2.775	0.1754 ns
Error (a)	4	0.0009	0.0002		
Fertilizer (B)	5	0.015	0.003	2.7328	0.0377 *
A x B	10	0.0094	0.0009	0.8593	0.5788
Error (b)	30	0.0329	0.0011		
Total	53	0.0618	0.0012		

Appendix 68: ANOVA for bulk density at 20-45 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0029	0.0015	3.4143	0.1364
MP (A)	2	0.009	0.0045	10.5206	0.0255 *
Error (a)	4	0.0017	0.0004		
Fertilizer (B)	5	0.0374	0.0075	6.5213	0.0003 ***
A x B	10	0.0095	0.0009	0.8261	0.6071
Error (b)	30	0.0344	0.0011		
Total	53	0.095	0.0018		

Appendix 69: ANOVA for bulk density at 20-45 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0028	0.0014	8	0.0400
MP (A)	2	0.0131	0.0066	36.9687	0.0026 ***
Error (a)	4	0.0007	0.0002		
Fertilizer (B)	5	0.0729	0.0146	10.2265	0.0000 ***
A x B	10	0.0147	0.0015	1.034	0.4400
Error (b)	30	0.0428	0.0014		
Total	53	0.1471	0.0028		

Appendix 70: ANOVA for soil bulk density combined over seasons at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.127	0.042	117.4824	0.0000 ***
R(S)	8	0.01	0.001	3.4127	0.0175
MP (A)	2	0.013	0.007	18.179	0.0001 ***
S x A	6	0.01	0.002	4.8371	0.0054
Error	16	0.006	0		
Fertilizer (B)	5	0.087	0.017	15.1821	0.0000 ***
S x B	15	0.044	0.003	2.5798	0.0022
A x B	10	0.036	0.004	3.1138	0.0015
S x A x B	30	0.004	0	0.1124	
Error	120	0.137	0.001		
Total	215	0.473			

Appendix 71: ANOVA for AWHC at 0-20 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	20.5411	10.2706	1.5542	0.3166
MP (A)	2	29.5633	14.7817	2.2369	0.2228 ns
Error (a)	4	26.4322	6.6081		
Fertilizer (B)	5	107.1439	21.4288	1.2369	0.3166 ns
A x B	10	240.1811	24.0181	1.3863	0.2337
Error (b)	30	519.7467	17.3249		
Total	53	943.6083	17.8039		

Appendix 72: ANOVA for AWHC at 0-20 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	41.4633	20.7317	1.4027	0.3454
MP (A)	2	210.4711	105.2356	7.1203	0.0481 *
Error (a)	4	59.1189	14.7797		
Fertilizer (B)	5	406.1244	81.2249	3.5384	0.0124 *
A x B	10	345.9178	34.5918	1.5069	0.1854
Error (b)	30	688.6578	22.9553		
Total	53	1751.7533	33.0519		

Appendix 73: ANOVA for AWHC at 0-20 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	42.6804	21.3402	2.455	0.2015
MP (A)	2	717.8937	358.9469	41.2943	0.0021 ***
Error (a)	4	34.7696	8.6924		
Fertilizer (B)	5	1264.1543	252.8309	8.3097	0.0001 ***
A x B	10	451.7641	45.1764	1.4848	0.1935
Error (b)	30	912.7767	30.4259		
Total	53	3424.0387	64.6045		

Appendix 74: ANOVA for AWHC at 0-20 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	72.1826	36.0913	1.7814	0.2797
MP (A)	2	1513.5737	756.7869	37.3534	0.0026 ***
Error (a)	4	81.0407	20.2602		
Fertilizer (B)	5	1818.9104	363.7821	7.7514	0.0001 ***
A x B	10	550.8196	55.082	1.1737	0.3458
Error (b)	30	1407.9367	46.9312		
Total	53	5444.4637	102.7257		

Appendix 75: ANOVA for AWHC combined over seasons at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	6225.017	2075.006	164.8782	0.0000 ***
R(S)	8	176.867	22.108	1.7567	0.1606
MP (A)	2	1513.878	756.939	60.1458	0.0000 ***
S x A	6	957.623	159.604	12.682	0.0000
Error	16	201.361	12.585		
Fertilizer (B)	5	2874.125	574.825	19.5457	0.0000 ***
S x B	15	722.208	48.147	1.6371	0.0737
A x B	10	1485.767	148.577	5.052	0.0000
S x A x B	30	102.916	3.431	0.1166	
Error	120	3529.118	29.409		
Total	215	17788.88			

Appendix 76: ANOVA for AWHC at 20-45 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	40.607	20.3035	1.561	0.3154
MP (A)	2	9.727	4.8635	0.3739	0.7098 ns
Error (a)	4	52.0285	13.0071		
Fertilizer (B)	5	91.6504	18.3301	1.3399	0.2746 ns
A x B	10	117.5152	11.7515	0.859	0.5791
Error (b)	30	410.3978	13.6799		
Total	53	721.9259	13.6212		

Appendix 77: ANOVA for AWHC at 20-45 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	45.0937	22.5469	5.7458	0.0666
MP (A)	2	32.5048	16.2524	4.1417	0.1060 ns
Error (a)	4	15.6963	3.9241		
Fertilizer (B)	5	323.3748	64.675	3.2249	0.0190 *
A x B	10	195.9019	19.5902	0.9768	0.4832
Error (b)	30	601.65	20.055		
Total	53	1214.2215	22.9098		

Appendix 78: ANOVA for AWHC at 20-45 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	47.2844	23.6422	2.5683	0.1916
MP (A)	2	171.8344	85.9172	9.3335	0.0311 *
Error (a)	4	36.8211	9.2053		
Fertilizer (B)	5	731.8994	146.3799	5.7645	0.0008 ***
A x B	10	213.7811	21.3781	0.8419	0.5936
Error (b)	30	761.7944	25.3931		
Total	53	1963.415	37.0456		

Appendix 79: ANOVA for AWHC at 20-45 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	85.0433	42.5217	17.7626	0.0102
MP (A)	2	307.2411	153.6206	64.172	0.0009 ***
Error (a)	4	9.5756	2.3939		
Fertilizer (B)	5	1674.9617	334.9923	9.8818	0.0000 ***
A x B	10	327.1322	32.7132	0.965	0.4924
Error (b)	30	1016.9944	33.8998		
Total	53	3420.9483	64.5462		

Appendix 80: ANOVA for AWHC combined over seasons at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	2472.069	824.023	115.5293	0.0000 ***
R(S)	8	218.028	27.254	3.821	0.0108
MP (A)	2	306.116	153.058	21.459	0.0000 ***
S x A	6	215.192	35.865	5.0284	0.0045
Error	16	114.121	7.133		
Fertilizer (B)	5	1921.172	384.234	16.5213	0.0000 ***
S x B	15	900.714	60.048	2.5819	0.0022
A x B	10	766.889	76.689	3.2975	0.0008
S x A x B	30	87.442	2.915	0.1253	
Error	120	2790.836	23.257		
Total	215	9792.58			

Appendix 81: ANOVA for total N at 0-20 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0013	0.0007	0.274	0.7735
MP (A)	2	0.0383	0.0191	7.8995	0.0408 *
Error (a)	4	0.0097	0.0024		
Fertilizer (B)	5	0.0042	0.0008	0.6466	0.6662 ns
A x B	10	0.0218	0.0022	1.6804	0.1319
Error (b)	30	0.0389	0.0013		
Total	53	0.1142	0.0022		

Appendix 82: ANOVA for total N at 0-20 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0021	0.001	0.6703	0.5609
MP (A)	2	0.5162	0.2581	165.8096	0.0001 ***
Error (a)	4	0.0062	0.0016		
Fertilizer (B)	5	0.2574	0.0515	36.4293	0.0000 ***
A x B	10	0.0161	0.0016	1.1414	0.3661
Error (b)	30	0.0424	0.0014		
Total	53	0.8404	0.0159		

Appendix 83: ANOVA for total N at 0-20 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0019	0.0009	0.3137	0.7472
MP (A)	2	0.4786	0.2393	80.6031	0.0006 ***
Error (a)	4	0.0119	0.003		
Fertilizer (B)	5	0.2939	0.0588	39.4538	0.0000 ***
A x B	10	0.0112	0.0011	0.7515	0.6719
Error (b)	30	0.0447	0.0015		
Total	53	0.8421	0.0159		

Appendix 84: ANOVA for total N at 0-20 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0001	0.0001	0.0252	0.9752
MP (A)	2	0.5112	0.2556	126.8138	0.0002 ***
Error (a)	4	0.0081	0.002		
Fertilizer (B)	5	0.2438	0.0488	31.1804	0.0000 ***
A x B	10	0.0118	0.0012	0.7515	0.6719
Error (b)	30	0.0469	0.0016		
Total	53	0.8218	0.0155		

Appendix 85: ANOVA for total N combined over seasons at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.777	0.259	115.6392	0.0000 ***
R(S)	8	0.005	0.001	0.3	
MP (A)	2	1.328	0.664	296.4476	0.0000 ***
S x A	6	0.216	0.036	16.0569	0.0000
Error	16	0.036	0.002		
Fertilizer (B)	5	0.625	0.125	86.7348	0.0000 ***
S x B	15	0.174	0.012	8.0653	0.0000
A x B	10	0.034	0.003	2.3886	0.0128
S x A x B	30	0.026	0.001	0.612	
Error	120	0.173	0.001		
Total	215	3.396			

Appendix 86: ANOVA for total N at 20-45 cm soil depth during Kharif 2006 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0002	0.0001	0.2359	0.8000
MP (A)	2	0.0361	0.018	51.2291	0.0014 ***
Error (a)	4	0.0014	0.0004		
Fertilizer (B)	5	0.0059	0.0012	0.8123	0.5503 ns
A x B	10	0.0076	0.0008	0.5212	0.8615
Error (b)	30	0.0438	0.0015		
Total	53	0.095	0.0018		

Appendix 87: ANOVA for total N at 20-45 cm soil depth during Rabi 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0023	0.0012	1.8225	0.2737
MP (A)	2	0.0871	0.0436	67.8371	0.0008 ***
Error (a)	4	0.0026	0.0006		
Fertilizer (B)	5	0.0202	0.004	2.7511	0.0367 *
A x B	10	0.0147	0.0015	1.0006	0.4649
Error (b)	30	0.044	0.0015		
Total	53	0.1709	0.0032		

Appendix 88: ANOVA for total N at 20-45 cm soil depth during Kharif 2007 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0034	0.0017	1.5664	0.3144
MP (A)	2	0.2139	0.1069	98.4779	0.0004 ***
Error (a)	4	0.0043	0.0011		
Fertilizer (B)	5	0.1025	0.0205	13.5974	0.0000 ***
A x B	10	0.0259	0.0026	1.7194	0.1220
Error (b)	30	0.0452	0.0015		
Total	53	0.3953	0.0075		

Appendix 89: ANOVA for total N at 20-45 cm soil depth during Rabi 2008 at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.004	0.002	15.6595	0.0128
MP (A)	2	0.3064	0.1532	1199.1866	0.0000 ***
Error (a)	4	0.0005	0.0001		
Fertilizer (B)	5	0.1874	0.0375	34.1253	0.0000 ***
A x B	10	0.0078	0.0008	0.7121	0.7063
Error (b)	30	0.033	0.0011		
Total	53	0.5391	0.0102		

Appendix 90: ANOVA for total N combined over seasons at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.227	0.076	137.0596	0.0000 ***
R(S)	8	0.01	0.001	2.2441	0.0803
MP (A)	2	0.559	0.28	506.3594	0.0000 ***
S x A	6	0.084	0.014	25.504	0.0000
Error	16	0.009	0.001		
Fertilizer (B)	5	0.177	0.035	25.5274	0.0000 ***
S x B	15	0.139	0.009	6.7189	0.0000
A x B	10	0.034	0.003	2.4327	0.0112
S x A x B	30	0.022	0.001	0.5392	
Error	120	0.166	0.001		
Total	215	1.427			

Appendix 91: ANOVA for cumulative CO2 evolution during 2 days incubation at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	215.508	107.754	0.7221	
MP (A)	2	22336.677	11168.339	74.8436	0.0007 ***
Error	4	596.89	149.222		
Fertilizer (B)	5	45563.554	9112.711	290.3051	0.0000 ***
A x B	10	268.508	26.851	0.8554	
Error	30	941.704	31.39		
Total	53	69922.841			

Appendix 92: ANOVA for cumulative CO2 evolution during 5 days incubation at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	34.948	17.474	0.1696	
MP (A)	2	61387.411	30693.705	297.9514	0.0000 ***
Error	4	412.063	103.016		
Fertilizer (B)	5	76464.51	15292.902	186.4689	0.0000 ***
A x B	10	1052.549	105.255	1.2834	0.2834
Error	30	2460.395	82.013		
Total	53	141811.876			

Appendix 93: ANOVA for cumulative CO2 evolution during 10 days incubation at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	518.997	259.498	1.6876	0.2941
MP (A)	2	54762.735	27381.367	178.0729	0.0001 ***
Error	4	615.06	153.765		
Fertilizer (B)	5	98901.696	19780.339	224.4068	0.0000 ***
A x B	10	1542.961	154.296	1.7505	0.1148
Error	30	2644.35	88.145		
Total	53	158985.79			

Appendix 94: ANOVA for cumulative CO2 evolution during 15 days incubation at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	142.728	71.364	0.3945	
MP (A)	2	60409.466	30204.733	166.9559	0.0001 ***
Error	4	723.658	180.914		
Fertilizer (B)	5	107109.313	21421.863	218.4777	0.0000 ***
A x B	10	817.049	81.705	0.8333	
Error	30	2941.517	98.051		
Total	53	172143.73			

Appendix 95: ANOVA for cumulative CO2 evolution during 2 days incubation at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	51.986	25.993	0.5635	
MP (A)	2	24924.23	12462.115	270.1712	0.0001 ***
Error	4	184.507	46.127		
Fertilizer (B)	5	48334.525	9666.905	135.0389	0.0000 ***
A x B	10	414.627	41.463	0.5792	
Error	30	2147.582	71.586		
Total	53	76057.458			

Appendix 96: ANOVA for cumulative CO_2 evolution during 5 days incubation at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	627.745	313.873	8.647	0.0353
MP (A)	2	52905.389	26452.695	728.7516	0.0000 ***
Error	4	145.195	36.299		
Fertilizer (B)	5	75526.213	15105.243	200.5742	0.0000 ***
A x B	10	567.178	56.718	0.7531	
Error	30	2259.3	75.31		
Total	53	132031.02			

Appendix 97: ANOVA for cumulative CO_2 evolution during 10 days incubation at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	232.001	116.001	5.0196	0.0812
MP (A)	2	51242.22	25621.11	1108.6859	0.0000 ***
Error	4	92.438	23.109		
Fertilizer (B)	5	91188.015	18237.603	140.9199	0.0000 ***
A x B	10	1347.875	134.787	1.0415	0.4346
Error	30	3882.546	129.418		
Total	53	147985.095			

Appendix 98: ANOVA for cumulative CO_2 evolution during 15 days incubation at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	242.62	121.31	1.6088	0.3071
MP (A)	2	58636.373	29318.186	388.8225	0.0000 ***
Error	4	301.61	75.402		
Fertilizer (B)	5	101340.941	20268.188	193.9195	0.0000 ***
A x B	10	897.984	89.798	0.8592	
Error	30	3135.557	104.519		
Total	53	164555.084			

Appendix 99: ANOVA for microbial biomass C at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	149.085	74.543	1.4205	0.3419
MP (A)	2	130667.758	65333.879	1245.043	0.0000 ***
Error	4	209.901	52.475		
Fertilizer (B)	5	89494.946	17898.989	294.0304	0.0000 ***
A x B	10	440.516	44.052	0.7236	
Error	30	1826.239	60.875		
Total	53	222788.445			

Appendix 100: ANOVA for microbial biomass C at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	64.178	32.089	3.2929	0.1428
MP (A)	2	130083.745	65041.873	6674.4101	0.0000 ***
Error	4	38.98	9.745		
Fertilizer (B)	5	99872.544	19974.509	290.8198	0.0000 ***
A x B	10	1388.414	138.841	2.0215	0.0667
Error	30	2060.504	68.683		
Total	53	233508.364			

Appendix 101: ANOVA for microbial biomass N at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.708	0.854	1.576	0.3128
MP (A)	2	600.601	300.301	554.1922	0.0000 ***
Error	4	2.167	0.542		
Fertilizer (B)	5	2364.998	473	784.1147	0.0000 ***
A x B	10	4.869	0.487	0.8071	
Error	30	18.097	0.603		
Total	53	2992.44			

Appendix 102: ANOVA for microbial biomass N at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.158	0.079	0.0584	
MP (A)	2	547.748	273.874	203.0541	0.0001 ***
Error	4	5.395	1.349		
Fertilizer (B)	5	2684.542	536.908	1076.1222	0.0000 ***
A x B	10	4.103	0.41	0.8224	
Error	30	14.968	0.499		
Total	53	3256.913			

Appendix 103: ANOVA for mineralizable C at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	38.611	19.305	1.6871	0.2942
MP (A)	2	4073.016	2036.508	177.9746	0.0001 ***
Error	4	45.771	11.443		
Fertilizer (B)	5	7356.056	1471.211	224.5393	0.0000 ***
A x B	10	114.711	11.471	1.7507	0.1147
Error	30	196.564	6.552		
Total	53	11824.729			

Appendix 104: ANOVA for mineralizable C at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	17.285	8.642	5.0282	0.0810
MP (A)	2	3810.923	1905.461	1108.6205	0.0000 ***
Error	4	6.875	1.719		
Fertilizer (B)	5	6781.679	1356.336	140.9183	0.0000 ***
A x B	10	100.262	10.026	1.0417	0.4345
Error	30	288.749	9.625		
Total	53	11005.773			

Appendix 105: ANOVA for mineralizable N at surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.112	0.056	0.0528	
MP (A)	2	428.144	214.072	202.2313	0.0001 ***
Error	4	4.234	1.059		
Fertilizer (B)	5	2029.403	405.881	556.4587	0.0000 ***
A x B	10	3.546	0.355	0.4862	
Error	30	21.882	0.729		
Total	53	2487.322			

Appendix 106: ANOVA for mineralizable N at sub-surface soil of Guljaba

S.O.V.	DF	SS	MS	F	P-value
Replication	2	2.365	1.182	0.6845	
MP (A)	2	424.822	212.411	122.979	0.0003 ***
Error	4	6.909	1.727		
Fertilizer (B)	5	1928.186	385.637	629.6768	0.0000 ***
A x B	10	5.935	0.593	0.969	
Error	30	18.373	0.612		
Total	53	2386.589			

Appendix 107: ANOVA for soil pH at 0-20 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0064	0.0032	0.4547	0.6638
MP (A)	2	0.0009	0.0005	0.0645	0.9385 ns
Error (a)	4	0.0284	0.0071		
Fertilizer (B)	5	0.0063	0.0013	0.2418	0.9407 ns
A x B	10	0.0339	0.0034	0.6531	0.7570
Error (b)	30	0.1559	0.0052		
Total	53	0.2318	0.0044		

Appendix 108: ANOVA for soil pH at 0-20 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0026	0.0013	0.1947	0.8304
MP (A)	2	0.0183	0.0092	1.3536	0.3557 ns
Error (a)	4	0.0271	0.0068		
Fertilizer (B)	5	0.0478	0.0096	1.4459	0.2368 ns
A x B	10	0.0463	0.0046	0.7002	0.7166
Error (b)	30	0.1985	0.0066		
Total	53	0.3407	0.0064		

Appendix 109: ANOVA for soil pH at 0-20 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0053	0.0026	0.1259	0.8850
MP (A)	2	0.079	0.0395	1.8847	0.2651 ns
Error (a)	4	0.0838	0.021		
Fertilizer (B)	5	0.2207	0.0441	6.1717	0.0005 ***
A x B	10	0.0628	0.0063	0.878	0.5631
Error (b)	30	0.2145	0.0072		
Total	53	0.6661	0.0126		

Appendix 110: ANOVA for soil pH at 0-20 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0002	0.0001	0.0041	0.9958
MP (A)	2	0.1727	0.0863	3.3799	0.1382 ns
Error (a)	4	0.1022	0.0255		
Fertilizer (B)	5	0.4349	0.087	8.8621	0.0000 ***
A x B	10	0.1004	0.01	1.0227	0.4483
Error (b)	30	0.2945	0.0098		
Total	53	1.1049	0.0208		

Appendix 111: ANOVA for soil pH combined over seasons at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.217	0.072	4.7935	0.0144 *
R(S)	8	0.015	0.002	0.1207	
MP (A)	2	0.178	0.089	5.8823	0.0122 *
S x A	6	0.093	0.016	1.0314	0.4409
Error	16	0.241	0.015		
Fertilizer (B)	5	0.433	0.087	12.0347	0.0000 ***
S x B	15	0.277	0.018	2.5649	0.0024
A x B	10	0.174	0.017	2.4165	0.0118
S x A x B	30	0.07	0.002	0.3223	
Error	120	0.863	0.007		
Total	215	2.561			

Appendix 112: ANOVA for soil pH at 20-45 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0051	0.0026	1.0022	0.4438
MP (A)	2	0.0207	0.0103	4.0544	0.1091 ns
Error (a)	4	0.0102	0.0026		
Fertilizer (B)	5	0.0302	0.006	1.5642	0.2003 ns
A x B	10	0.0217	0.0022	0.5629	0.8304
Error (b)	30	0.1158	0.0039		
Total	53	0.2037	0.0038		

Appendix 113: ANOVA for soil pH at 20-45 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0018	0.0009	0.2842	0.7666
MP (A)	2	0.0167	0.0083	2.6173	0.1876 ns
Error (a)	4	0.0127	0.0032		
Fertilizer (B)	5	0.0196	0.0039	0.7918	0.5640 ns
A x B	10	0.012	0.0012	0.242	0.9889
Error (b)	30	0.1486	0.005		
Total	53	0.2115	0.004		

Appendix 114: ANOVA for soil pH at 20-45 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0005	0.0002	0.0357	0.9651
MP (A)	2	0.068	0.034	4.9344	0.0832 ns
Error (a)	4	0.0276	0.0069		
Fertilizer (B)	5	0.2289	0.0458	5.4107	0.0012 ***
A x B	10	0.0595	0.006	0.7034	0.7138
Error (b)	30	0.2539	0.0085		
Total	53	0.6384	0.012		

Appendix 115: ANOVA for soil pH at 20-45 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0153	0.0077	0.4895	0.6454
MP (A)	2	0.1411	0.0706	4.5007	0.0947 ns
Error (a)	4	0.0627	0.0157		
Fertilizer (B)	5	0.4931	0.0986	10.4389	0.0000 ***
A x B	10	0.0466	0.0047	0.4937	0.8806
Error (b)	30	0.2834	0.0094		
Total	53	1.0423	0.0197		

Appendix 116: ANOVA for soil pH combined over seasons at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.474	0.158	22.3492	0.0000 ***
R(S)	8	0.023	0.003	0.4022	
MP (A)	2	0.151	0.076	10.6989	0.0011 ***
S x A	6	0.095	0.016	2.2391	0.0926
Error	16	0.113	0.007		
Fertilizer (B)	5	0.454	0.091	13.5869	0.0000 ***
S x B	15	0.318	0.021	3.1726	0.0002
A x B	10	0.095	0.01	1.4234	0.1780
S x A x B	30	0.045	0.001	0.2235	
Error	120	0.802	0.007		
Total	215	2.57			

Appendix 117: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0115	0.0057	0.2784	0.7705
MP (A)	2	0.0188	0.0094	0.4563	0.6630 ns
Error (a)	4	0.0824	0.0206		
Fertilizer (B)	5	0.2368	0.0474	1.8006	0.1429 ns
A x B	10	0.7442	0.0744	2.8297	0.0133
Error (b)	30	0.789	0.0263		
Total	53	1.8827	0.0355		

Appendix 118: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0138	0.0069	0.3761	0.7084
MP (A)	2	0.0388	0.0194	1.0582	0.4277 ns
Error (a)	4	0.0733	0.0183		
Fertilizer (B)	5	0.1839	0.0368	1.4123	0.2482 ns
A x B	10	0.6335	0.0634	2.4333	0.0291
Error (b)	30	0.7811	0.026		
Total	53	1.7244	0.0325		

Appendix 119: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.005	0.0025	0.1593	0.8578
MP (A)	2	0.0397	0.0199	1.2759	0.3727 ns
Error (a)	4	0.0623	0.0156		
Fertilizer (B)	5	0.1895	0.0379	1.5481	0.2050 ns
A x B	10	0.7221	0.0722	2.9496	0.0105
Error (b)	30	0.7344	0.0245		
Total	53	1.7529	0.0331		

Appendix 120: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0006	0.0003	0.0157	0.9844
MP (A)	2	0.0486	0.0243	1.3122	0.3646 ns
Error (a)	4	0.0741	0.0185		
Fertilizer (B)	5	0.167	0.0334	1.3784	0.2603 ns
A x B	10	0.8281	0.0828	3.4175	0.0043
Error (b)	30	0.727	0.0242		
Total	53	1.8454	0.0348		

Appendix 121: ANOVA for soil electrical conductivity combined over seasons at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.006	0.002	0.1163	
R(S)	8	0.031	0.004	0.2109	
MP (A)	2	0.137	0.069	3.7534	0.0461 *
S x A	6	0.009	0.001	0.0811	
Error	16	0.292	0.018		
Fertilizer (B)	5	0.768	0.154	6.0783	0.0000 ***
S x B	15	0.009	0.001	0.0247	
A x B	10	2.897	0.29	11.4698	0.0000
S x A x B	30	0.03	0.001	0.0402	
Error	120	3.031	0.025		
Total	215	7.212			

Appendix 122: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0407	0.0204	0.7604	0.5249
MP (A)	2	0.0894	0.0447	1.6704	0.2969 ns
Error (a)	4	0.1071	0.0268		
Fertilizer (B)	5	0.3083	0.0617	1.3599	0.2671 ns
A x B	10	0.3027	0.0303	0.6677	0.7446
Error (b)	30	1.3601	0.0453		
Total	53	2.2083	0.0417		

Appendix 123: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0403	0.0202	0.4794	0.6506
MP (A)	2	0.0817	0.0408	0.9713	0.4531 ns
Error (a)	4	0.1682	0.042		
Fertilizer (B)	5	0.3223	0.0645	1.4864	0.2237 ns
A x B	10	0.3043	0.0304	0.7018	0.7152
Error (b)	30	1.3009	0.0434		
Total	53	2.2177	0.0418		

Appendix 124: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0346	0.0173	0.4135	0.6867
MP (A)	2	0.0838	0.0419	1.0031	0.4435 ns
Error (a)	4	0.1672	0.0418		
Fertilizer (B)	5	0.3351	0.067	1.5696	0.1988 ns
A x B	10	0.3678	0.0368	0.8615	0.5770
Error (b)	30	1.2808	0.0427		
Total	53	2.2692	0.0428		

Appendix 125: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0243	0.0121	0.2713	0.7753
MP (A)	2	0.109	0.0545	1.2168	0.3866 ns
Error (a)	4	0.1791	0.0448		
Fertilizer (B)	5	0.3632	0.0726	1.8665	0.1300 ns
A x B	10	0.3664	0.0366	0.9415	0.5110
Error (b)	30	1.1675	0.0389		
Total	53	2.2095	0.0417		

Appendix 126: ANOVA for soil electrical conductivity combined over seasons at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.011	0.004	0.0902	
R(S)	8	0.14	0.017	0.4501	
MP (A)	2	0.359	0.18	4.6226	0.0260 *
S x A	6	0.005	0.001	0.0205	
Error	16	0.622	0.039		
Fertilizer (B)	5	1.316	0.263	6.1807	0.0000 ***
S x B	15	0.013	0.001	0.0204	
A x B	10	1.318	0.132	3.0961	0.0015
S x A x B	30	0.023	0.001	0.018	
Error	120	5.109	0.043		
Total	215	8.915			

Appendix 127: ANOVA for soil organic matter at 0-20 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.2737	0.1369	0.6743	0.5593
MP (A)	2	14.8159	7.408	36.4991	0.0027 ***
Error (a)	4	0.8119	0.203		
Fertilizer (B)	5	0.5543	0.1109	0.5228	0.7570 ns
A x B	10	4.1463	0.4146	1.9555	0.0761
Error (b)	30	6.3611	0.212		
Total	53	26.9631	0.5087		

Appendix 128: ANOVA for soil organic matter at 0-20 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.5881	0.2941	1.0292	0.4359
MP (A)	2	35.007	17.5035	61.2566	0.0010 ***
Error (a)	4	1.143	0.2857		
Fertilizer (B)	5	4.4654	0.8931	3.5554	0.0121 *
A x B	10	4.4374	0.4437	1.7666	0.1111
Error (b)	30	7.5356	0.2512		
Total	53	53.1765	1.0033		

Appendix 129: ANOVA for soil organic matter at 0-20 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.647	0.3235	0.7501	0.5288
MP (A)	2	68.2515	34.1257	79.1237	0.0006 ***
Error (a)	4	1.7252	0.4313		
Fertilizer (B)	5	19.7987	3.9597	14.1288	0.0000 ***
A x B	10	4.1285	0.4129	1.4731	0.1979
Error (b)	30	8.4078	0.2803		
Total	53	102.9587	1.9426		

Appendix 130: ANOVA for soil organic matter at 0-20 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.3678	0.1839	0.4069	0.6904
MP (A)	2	115.9744	57.9872	128.3061	0.0002 ***
Error (a)	4	1.8078	0.4519		
Fertilizer (B)	5	42.9972	8.5994	30.2876	0.0000 ***
A x B	10	3.4633	0.3463	1.2198	0.3183
Error (b)	30	8.5178	0.2839		
Total	53	173.1283	3.2666		

Appendix 131: ANOVA for soil organic matter combined over seasons at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	145.638	48.546	141.5389	0.0000 ***
R(S)	8	1.877	0.235	0.6839	
MP (A)	2	204.935	102.467	298.7506	0.0000 ***
S x A	6	29.114	4.852	14.1475	0.0000
Error	16	5.488	0.343		
Fertilizer (B)	5	42.06	8.412	32.7507	0.0000 ***
S x B	15	25.755	1.717	6.6848	0.0000
A x B	10	15.624	1.562	6.083	0.0000
S x A x B	30	0.551	0.018	0.0715	
Error	120	30.822	0.257		
Total	215	501.864			

Appendix 132: ANOVA for soil organic matter at 20-45 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.4844	0.2422	1.09	0.4189
MP (A)	2	18.07	9.035	40.6575	0.0022 ***
Error (a)	4	0.8889	0.2222		
Fertilizer (B)	5	0.0689	0.0138	0.0566	0.9977 ns
A x B	10	1.6011	0.1601	0.6574	0.7534
Error (b)	30	7.3067	0.2436		
Total	53	28.42	0.5362		

Appendix 133: ANOVA for soil organic matter at 20-45 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.3793	0.1896	0.84	0.4959
MP (A)	2	29.2548	14.6274	64.7974	0.0009 ***
Error (a)	4	0.903	0.2257		
Fertilizer (B)	5	4.7748	0.955	3.6615	0.0105 *
A x B	10	1.6607	0.1661	0.6368	0.7708
Error (b)	30	7.8244	0.2608		
Total	53	44.797	0.8452		

Appendix 134: ANOVA for soil organic matter at 20-45 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.2604	0.1302	0.5274	0.6262
MP (A)	2	57.1393	28.5696	115.7359	0.0003 ***
Error (a)	4	0.9874	0.2469		
Fertilizer (B)	5	18.1059	3.6212	13.0694	0.0000 ***
A x B	10	1.7919	0.1792	0.6467	0.7624
Error (b)	30	8.3122	0.2771		
Total	53	86.597	1.6339		

Appendix 135: ANOVA for soil organic matter at 20-45 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.6544	0.3272	1.2721	0.3735
MP (A)	2	81.2133	40.6067	157.8661	0.0002 ***
Error (a)	4	1.0289	0.2572		
Fertilizer (B)	5	40.0756	8.0151	26.9667	0.0000 ***
A x B	10	2.6244	0.2624	0.883	0.5589
Error (b)	30	8.9167	0.2972		
Total	53	134.5133	2.538		

Appendix 136: ANOVA for soil organic matter combined over seasons at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	50.054	16.685	70.101	0.0000 ***
R(S)	8	1.779	0.222	0.9341	
MP (A)	2	168.571	84.285	354.1263	0.0000 ***
S x A	6	17.107	2.851	11.9791	0.0000
Error	16	3.808	0.238		
Fertilizer (B)	5	40.511	8.102	30.0452	0.0000 ***
S x B	15	22.514	1.501	5.5659	0.0000
A x B	10	6.905	0.69	2.5605	0.0077
S x A x B	30	0.773	0.026	0.0956	
Error	120	32.36	0.27		
Total	215	344.382			

Appendix 137: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	45.5659	22.783	6.8402	0.0511
MP (A)	2	4.277	2.1385	0.6421	0.5730 ns
Error (a)	4	13.323	3.3307		
Fertilizer (B)	5	209.1148	41.823	1.6299	0.1825 ns
A x B	10	163.6207	16.3621	0.6377	0.7700
Error (b)	30	769.7778	25.6593		
Total	53	1205.6793	22.7487		

Appendix 138: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	48.0559	24.028	1.677	0.2958
MP (A)	2	194.7737	97.3869	6.7968	0.0517 ns
Error (a)	4	57.313	14.3282		
Fertilizer (B)	5	1517.8476	303.5695	10.1165	0.0000 ***
A x B	10	185.7663	18.5766	0.6191	0.7855
Error (b)	30	900.2244	30.0075		
Total	53	2903.9809	54.7921		

Appendix 139: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	47.4359	23.718	0.6033	0.5902
MP (A)	2	325.4915	162.7457	4.1396	0.1061 ns
Error (a)	4	157.2574	39.3144		
Fertilizer (B)	5	3855.5298	771.106	24.7354	0.0000 ***
A x B	10	361.5885	36.1589	1.1599	0.3544
Error (b)	30	935.2267	31.1742		
Total	53	5682.5298	107.2175		

Appendix 140: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	94.0633	47.0317	0.9486	0.4600
MP (A)	2	858.1144	429.0572	8.6534	0.0352 *
Error (a)	4	198.3289	49.5822		
Fertilizer (B)	5	7723.7689	1544.7538	51.1477	0.0000 ***
A x B	10	496.11	49.611	1.6426	0.1421
Error (b)	30	906.0544	30.2018		
Total	53	10276.44	193.8951		

Appendix 141: ANOVA for AB-DTPA extractable K combined over seasons at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	4610.663	1536.888	57.6934	0.0000 ***
R(S)	8	235.121	29.39	1.1033	0.4103
MP (A)	2	948.124	474.062	17.7959	0.0001 ***
S x A	6	434.532	72.422	2.7187	0.0514
Error	16	426.222	26.639		
Fertilizer (B)	5	10115.08	2023.016	69.1377	0.0000 ***
S x B	15	3191.182	212.745	7.2707	0.0000
A x B	10	1041.598	104.16	3.5597	0.0004
S x A x B	30	165.488	5.516	0.1885	
Error	120	3511.283	29.261		
Total	215	24679.295			

Appendix 142: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.0248	0.5124	0.0098	0.9902
MP (A)	2	42.0337	21.0169	0.403	0.6927 ns
Error (a)	4	208.6296	52.1574		
Fertilizer (B)	5	168.7676	33.7535	1.1552	0.3538 ns
A x B	10	251.6285	25.1629	0.8612	0.5772
Error (b)	30	876.5589	29.2186		
Total	53	1548.6431	29.2197		

Appendix 143: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	16.2711	8.1356	0.0944	0.9118
MP (A)	2	189.6144	94.8072	1.1002	0.4162 ns
Error (a)	4	344.6844	86.1711		
Fertilizer (B)	5	907.9711	181.5942	5.7086	0.0008 ***
A x B	10	237.5878	23.7588	0.7469	0.6760
Error (b)	30	954.3244	31.8108		
Total	53	2650.4533	50.0086		

Appendix 144: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	21.3581	10.6791	0.0852	0.9199
MP (A)	2	436.747	218.3735	1.7427	0.2856 ns
Error (a)	4	501.2407	125.3102		
Fertilizer (B)	5	2760.7459	552.1492	13.3142	0.0000 ***
A x B	10	347.6463	34.7646	0.8383	0.5967
Error (b)	30	1244.1211	41.4707		
Total	53	5311.8593	100.2238		

Appendix 145: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	11.2737	5.6369	0.0311	0.9695
MP (A)	2	1197.0293	598.5146	3.3071	0.1420 ns
Error (a)	4	723.9041	180.976		
Fertilizer (B)	5	6022.5965	1204.5193	22.4645	0.0000 ***
A x B	10	542.193	54.2193	1.0112	0.4569
Error (b)	30	1608.5622	53.6187		
Total	53	10105.5587	190.6709		

Appendix 146: ANOVA for AB-DTPA extractable K combined over seasons at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	3731.843	1243.948	11.1912	0.0003 ***
R(S)	8	49.928	6.241	0.0561	
MP (A)	2	1311.428	655.714	5.8992	0.0120 *
S x A	6	553.997	92.333	0.8307	
Error	16	1778.459	111.154		
Fertilizer (B)	5	6566.861	1313.372	33.6506	0.0000 ***
S x B	15	3293.221	219.548	5.6252	0.0000
A x B	10	1197.286	119.729	3.0676	0.0017
S x A x B	30	181.77	6.059	0.1552	
Error	120	4683.567	39.03		
Total	215	23348.358			

Appendix 147: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0159	0.0079	2.2533	0.2211
MP (A)	2	0.0104	0.0052	1.4698	0.3322 ns
Error (a)	4	0.0141	0.0035		
Fertilizer (B)	5	0.0205	0.0041	0.5599	0.7298 ns
A x B	10	0.0317	0.0032	0.4318	0.9191
Error (b)	30	0.2202	0.0073		
Total	53	0.3127	0.0059		

Appendix 148: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.018	0.009	3.2437	0.1454
MP (A)	2	0.0825	0.0412	14.8496	0.0141 *
Error (a)	4	0.0111	0.0028		
Fertilizer (B)	5	0.2973	0.0595	7.841	0.0001 ***
A x B	10	0.0353	0.0035	0.4659	0.8987
Error (b)	30	0.2275	0.0076		
Total	53	0.6717	0.0127		

Appendix 149: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0185	0.0092	2.9233	0.1650
MP (A)	2	0.2248	0.1124	35.5386	0.0028 ***
Error (a)	4	0.0127	0.0032		
Fertilizer (B)	5	0.876	0.1752	22.3172	0.0000 ***
A x B	10	0.0461	0.0046	0.5872	0.8114
Error (b)	30	0.2355	0.0079		
Total	53	1.4136	0.0267		

Appendix 150: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0228	0.0114	4.4001	0.0976
MP (A)	2	0.3943	0.1972	75.9401	0.0007 ***
Error (a)	4	0.0104	0.0026		
Fertilizer (B)	5	2.1859	0.4372	52.8351	0.0000 ***
A x B	10	0.0501	0.005	0.6054	0.7966
Error (b)	30	0.2482	0.0083		
Total	53	2.9118	0.0549		

Appendix 151: ANOVA for AB-DTPA extractable P combined over seasons at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	3.857	1.286	426.4278	0.0000 ***
R(S)	8	0.075	0.009	3.1192	0.0252
MP (A)	2	0.547	0.273	90.6846	0.0000 ***
S x A	6	0.165	0.028	9.1283	0.0002
Error	16	0.048	0.003		
Fertilizer (B)	5	2.169	0.434	55.8791	0.0000 ***
S x B	15	1.211	0.081	10.4034	0.0000
A x B	10	0.156	0.016	2.0082	0.0381
S x A x B	30	0.007	0	0.0315	
Error	120	0.931	0.008		
Total	215	9.167			

Appendix 152: ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0035	0.0017	0.1954	0.8299
MP (A)	2	0.0037	0.0018	0.206	0.8219 ns
Error (a)	4	0.0355	0.0089		
Fertilizer (B)	5	0.0083	0.0017	0.2955	0.9116 ns
A x B	10	0.0448	0.0045	0.7932	0.6356
Error (b)	30	0.1695	0.0056		
Total	53	0.2653	0.005		

Appendix 153: ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0071	0.0036	0.3881	0.7014
MP (A)	2	0.0366	0.0183	1.9897	0.2513 ns
Error (a)	4	0.0368	0.0092		
Fertilizer (B)	5	0.347	0.0694	11.1052	0.0000 ***
A x B	10	0.0537	0.0054	0.8599	0.5783
Error (b)	30	0.1875	0.0063		
Total	53	0.6689	0.0126		

Appendix 154: ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0052	0.0026	0.2887	0.7636
MP (A)	2	0.1156	0.0578	6.3608	0.0572 ns
Error (a)	4	0.0364	0.0091		
Fertilizer (B)	5	0.9519	0.1904	26.8671	0.0000 ***
A x B	10	0.0563	0.0056	0.7943	0.6347
Error (b)	30	0.2126	0.0071		
Total	53	1.3781	0.026		

Appendix 155: ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.009	0.0045	0.4261	0.6795
MP (A)	2	0.2374	0.1187	11.2621	0.0227 *
Error (a)	4	0.0422	0.0105		
Fertilizer (B)	5	2.3732	0.4746	66.3532	0.0000 ***
A x B	10	0.0563	0.0056	0.7868	0.6411
Error (b)	30	0.2146	0.0072		
Total	53	2.9326	0.0553		

Appendix 156: ANOVA for AB-DTPA extractable P combined over seasons at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	3.705	1.235	130.9833	0.0000 ***
R(S)	8	0.025	0.003	0.3294	
MP (A)	2	0.262	0.131	13.88	0.0003 ***
S x A	6	0.132	0.022	2.3257	0.0831
Error	16	0.151	0.009		
Fertilizer (B)	5	2.491	0.498	76.251	0.0000 ***
S x B	15	1.189	0.079	12.1318	0.0000
A x B	10	0.204	0.02	3.1181	0.0014
S x A x B	30	0.007	0	0.0376	
Error	120	0.784	0.007		
Total	215	8.95			

Appendix 157: ANOVA for mineral N at 0-20 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	4.6338	2.3169	1.7641	0.2823
MP (A)	2	1.0236	0.5118	0.3897	0.7005 ns
Error (a)	4	5.2534	1.3133		
Fertilizer (B)	5	2.9817	0.5963	0.5986	0.7013 ns
A x B	10	13.7805	1.378	1.3832	0.2351
Error (b)	30	29.8884	0.9963		
Total	53	57.5613	1.0861		

Appendix 158: ANOVA for mineral N at 0-20 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	4.8378	2.4189	1.707	0.2910
MP (A)	2	2.7219	1.361	0.9604	0.4564 ns
Error (a)	4	5.6682	1.4171		
Fertilizer (B)	5	42.3291	8.4658	7.8895	0.0001 ***
A x B	10	16.2267	1.6227	1.5122	0.1835
Error (b)	30	32.1916	1.0731		
Total	53	103.9754	1.9618		

Appendix 159: ANOVA for mineral N at 0-20 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	4.8073	2.4037	1.6629	0.2981
MP (A)	2	2.5645	1.2822	0.8871	0.4799 ns
Error (a)	4	5.7817	1.4454		
Fertilizer (B)	5	42.2469	8.4494	7.6525	0.0001 ***
A x B	10	15.9484	1.5948	1.4444	0.2092
Error (b)	30	33.1241	1.1041		
Total	53	104.4729	1.9712		

Appendix 160: ANOVA for mineral N at 0-20 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	5.2496	2.6248	2.2936	0.2169
MP (A)	2	14.7339	7.367	6.4375	0.0562 ns
Error (a)	4	4.5775	1.1444		
Fertilizer (B)	5	102.7189	20.5438	17.2777	0.0000 ***
A x B	10	16.4006	1.6401	1.3793	0.2368
Error (b)	30	35.671	1.189		
Total	53	179.3515	3.384		

Appendix 161: ANOVA for mineral N combined over seasons at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	330.684	110.228	82.8749	0.0000 ***
R(S)	8	19.529	2.441	1.8353	0.1434
MP (A)	2	11.061	5.53	4.158	0.0351 *
S x A	6	9.983	1.664	1.251	0.3330
Error	16	21.281	1.33		
Fertilizer (B)	5	123.056	24.611	22.5662	0.0000 ***
S x B	15	67.22	4.481	4.109	0.0000
A x B	10	61.776	6.178	5.6642	0.0000
S x A x B	30	0.58	0.019	0.0177	
Error	120	130.875	1.091		
Total	215	776.045			

Appendix 162: ANOVA for mineral N at 20-45 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	3.8248	1.9124	3.8724	0.1159
MP (A)	2	2.7674	1.3837	2.8018	0.1735 ns
Error (a)	4	1.9755	0.4939		
Fertilizer (B)	5	6.4743	1.2949	1.4227	0.2446 ns
A x B	10	13.2039	1.3204	1.4508	0.2066
Error (b)	30	27.3033	0.9101		
Total	53	55.5491	1.0481		

Appendix 163: ANOVA for mineral N at 20-45 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	3.9693	1.9847	4.226	0.1031
MP (A)	2	2.4585	1.2292	2.6175	0.1876 ns
Error (a)	4	1.8785	0.4696		
Fertilizer (B)	5	24.6827	4.9365	5.3761	0.0012 ***
A x B	10	12.6102	1.261	1.3733	0.2395
Error (b)	30	27.5474	0.9182		
Total	53	73.1467	1.3801		

Appendix 164: ANOVA for mineral N at 20-45 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	4.3607	2.1804	2.9186	0.1653
MP (A)	2	2.514	1.257	1.6826	0.2949 ns
Error (a)	4	2.9882	0.7471		
Fertilizer (B)	5	69.8839	13.9768	15.2328	0.0000 ***
A x B	10	12.8135	1.2814	1.3965	0.2292
Error (b)	30	27.5263	0.9175		
Total	53	120.0867	2.2658		

Appendix 165: ANOVA for mineral N at 20-45 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	5.0774	2.5387	3.1703	0.1496
MP (A)	2	14.3022	7.1511	8.9301	0.0335 *
Error (a)	4	3.2032	0.8008		
Fertilizer (B)	5	145.554	29.1108	31.9675	0.0000 ***
A x B	10	13.6301	1.363	1.4968	0.1891
Error (b)	30	27.3191	0.9106		
Total	53	209.0861	3.945		

Appendix 166: ANOVA for mineral N combined over seasons at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	309.679	103.226	164.4164	0.0000 ***
R(S)	8	17.232	2.154	3.4309	0.0171
MP (A)	2	17.705	8.852	14.0997	0.0003 ***
S x A	6	4.338	0.723	1.1515	0.3786
Error	16	10.045	0.628		
Fertilizer (B)	5	176.081	35.216	38.5241	0.0000 ***
S x B	15	70.514	4.701	5.1425	0.0000
A x B	10	51.801	5.18	5.6667	0.0000
S x A x B	30	0.457	0.015	0.0167	
Error	120	109.696	0.914		
Total	215	767.547			

Appendix 167: ANOVA for bulk density at 0-20 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0005	0.0003	0.3077	0.7511
MP (A)	2	0.0032	0.0016	1.8108	0.2754 ns
Error (a)	4	0.0036	0.0009		
Fertilizer (B)	5	0.0063	0.0013	1.2192	0.3244 ns
A x B	10	0.0085	0.0009	0.8227	0.6101
Error (b)	30	0.031	0.001		
Total	53	0.0532	0.001		

Appendix 168: ANOVA for bulk density at 0-20 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0004	0.0002	0.3084	0.7506
MP (A)	2	0.0019	0.0009	1.5299	0.3210 ns
Error (a)	4	0.0025	0.0006		
Fertilizer (B)	5	0.0164	0.0033	3.2402	0.0186 *
A x B	10	0.0124	0.0012	1.2212	0.3176
Error (b)	30	0.0303	0.001		
Total	53	0.0638	0.0012		

Appendix 169: ANOVA for bulk density at 0-20 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0014	0.0007	1.0377	0.4334
MP (A)	2	0.0108	0.0054	8.159	0.0388 *
Error (a)	4	0.0027	0.0007		
Fertilizer (B)	5	0.0337	0.0067	5.4227	0.0011 ***
A x B	10	0.0119	0.0012	0.9589	0.4972
Error (b)	30	0.0373	0.0012		
Total	53	0.0978	0.0018		

Appendix 170: ANOVA for bulk density at 0-20 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0014	0.0007	1.0597	0.4272
MP (A)	2	0.0406	0.0203	31.1705	0.0036 ***
Error (a)	4	0.0026	0.0007		
Fertilizer (B)	5	0.0719	0.0144	10.5131	0.0000 ***
A x B	10	0.0104	0.001	0.7581	0.6662
Error (b)	30	0.041	0.0014		
Total	53	0.1679	0.0032		

Appendix 171: ANOVA for soil bulk density combined over seasons at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.297	0.099	140.382	0.0000 ***
R(S)	8	0.004	0	0.6529	
MP (A)	2	0.021	0.01	14.6726	0.0002 ***
S x A	6	0.036	0.006	8.4635	0.0003
Error	16	0.011	0.001		
Fertilizer (B)	5	0.103	0.021	17.7511	0.0000 ***
S x B	15	0.025	0.002	1.4291	0.1445
A x B	10	0.041	0.004	3.5126	0.0004
S x A x B	30	0.002	0	0.0647	
Error	120	0.14	0.001		
Total	215	0.68			

Appendix 172: ANOVA for bulk density at 20-45 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0022	0.0011	4.5227	0.0940
MP (A)	2	0.0009	0.0004	1.7955	0.2777 ns
Error (a)	4	0.001	0.0002		
Fertilizer (B)	5	0.0028	0.0006	0.6159	0.6886 ns
A x B	10	0.0103	0.001	1.1279	0.3749
Error (b)	30	0.0273	0.0009		
Total	53	0.0444	0.0008		

Appendix 173: ANOVA for bulk density at 20-45 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0022	0.0011	1.1936	0.3921
MP (A)	2	0.005	0.0025	2.6594	0.1842 ns
Error (a)	4	0.0037	0.0009		
Fertilizer (B)	5	0.0189	0.0038	3.9816	0.0069 ***
A x B	10	0.0109	0.0011	1.1457	0.3634
Error (b)	30	0.0284	0.0009		
Total	53	0.0691	0.0013		

Appendix 174: ANOVA for bulk density at 20-45 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0027	0.0014	7.7188	0.0423
MP (A)	2	0.0187	0.0094	52.625	0.0013 ***
Error (a)	4	0.0007	0.0002		
Fertilizer (B)	5	0.0458	0.0092	9.1037	0.0000 ***
A x B	10	0.0119	0.0012	1.1784	0.3429
Error (b)	30	0.0302	0.001		
Total	53	0.1101	0.0021		

Appendix 175: ANOVA for bulk density at 20-45 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0019	0.0009	9.2909	0.0313
MP (A)	2	0.0392	0.0196	192.2364	0.0001 ***
Error (a)	4	0.0004	0.0001		
Fertilizer (B)	5	0.0692	0.0138	12.1027	0.0000 ***
A x B	10	0.0121	0.0012	1.0609	0.4206
Error (b)	30	0.0343	0.0011		
Total	53	0.1571	0.003		

Appendix 176: ANOVA for soil bulk density combined over seasons at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.111	0.037	101.8026	0.0000 ***
R(S)	8	0.009	0.001	3.1151	0.0253
MP (A)	2	0.045	0.022	61.522	0.0000 ***
S x A	6	0.019	0.003	8.6531	0.0003
Error	16	0.006	0		
Fertilizer (B)	5	0.109	0.022	21.7641	0.0000 ***
S x B	15	0.028	0.002	1.8411	0.0363
A x B	10	0.043	0.004	4.3086	0.0000
S x A x B	30	0.002	0	0.0647	
Error	120	0.12	0.001		
Total	215	0.492			

Appendix 177: ANOVA for AWHC at 0-20 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	7.4115	3.7057	0.3006	0.7557
MP (A)	2	62.0093	31.0046	2.5148	0.1962 ns
Error (a)	4	49.3152	12.3288		
Fertilizer (B)	5	112.7037	22.5407	1.4188	0.2460 ns
A x B	10	164.453	16.4453	1.0351	0.4392
Error (b)	30	476.6067	15.8869		
Total	53	872.4993	16.4623		

Appendix 178: ANOVA for AWHC at 0-20 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	5.4248	2.7124	0.4088	0.6893
MP (A)	2	53.6993	26.8496	4.0464	0.1094 ns
Error (a)	4	26.5419	6.6355		
Fertilizer (B)	5	309.4854	61.8971	3.6173	0.0112 *
A x B	10	207.0363	20.7036	1.2099	0.3241
Error (b)	30	513.34	17.1113		
Total	53	1115.5276	21.0477		

Appendix 179: ANOVA for AWHC at 0-20 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	28.3078	14.1539	1.0439	0.4317
MP (A)	2	209.83	104.915	7.7382	0.0422 *
Error (a)	4	54.2322	13.5581		
Fertilizer (B)	5	693.975	138.795	5.8072	0.0007 ***
A x B	10	203.93	20.393	0.8532	0.5840
Error (b)	30	717.0133	23.9004		
Total	53	1907.2883	35.9866		

Appendix 180: ANOVA for AWHC at 0-20 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	26.9359	13.468	1.5483	0.3177
MP (A)	2	833.047	416.5235	47.8844	0.0016 ***
Error (a)	4	34.7941	8.6985		
Fertilizer (B)	5	1521.0637	304.2127	11.7887	0.0000 ***
A x B	10	195.693	19.5693	0.7583	0.6660
Error (b)	30	774.1633	25.8054		
Total	53	3385.697	63.8811		

Appendix 181: ANOVA for AWHC combined over seasons at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	5237.352	1745.784	169.4079	0.0000 ***
R(S)	8	68.08	8.51	0.8258	
MP (A)	2	454.86	227.43	22.0694	0.0000 ***
S x A	6	703.725	117.288	11.3814	0.0001
Error	16	164.883	10.305		
Fertilizer (B)	5	2058.392	411.678	19.9109	0.0000 ***
S x B	15	578.836	38.589	1.8664	0.0332
A x B	10	717.35	71.735	3.4695	0.0005
S x A x B	30	53.762	1.792	0.0867	
Error	120	2481.123	20.676		
Total	215	12518.364			

Appendix 182: ANOVA for AWHC at 20-45 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	20.3804	10.1902	1.9604	0.2550
MP (A)	2	11.0893	5.5446	1.0667	0.4253 ns
Error (a)	4	20.7919	5.198		
Fertilizer (B)	5	49.6987	9.9397	0.7269	0.6087 ns
A x B	10	147.7552	14.7755	1.0806	0.4068
Error (b)	30	410.2078	13.6736		
Total	53	659.9231	12.4514		

Appendix 183: ANOVA for AWHC at 20-45 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	49.4337	24.7169	1.3777	0.3506
MP (A)	2	105.5526	52.7763	2.9417	0.1638 ns
Error (a)	4	71.7619	17.9405		
Fertilizer (B)	5	336.0831	67.2166	4.6083	0.0031 ***
A x B	10	172.3007	17.2301	1.1813	0.3412
Error (b)	30	437.5844	14.5861		
Total	53	1172.7165	22.1267		

Appendix 184: ANOVA for AWHC at 20-45 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	54.8978	27.4489	13.6543	0.0163
MP (A)	2	286.8744	143.4372	71.3519	0.0007 ***
Error (a)	4	8.0411	2.0103		
Fertilizer (B)	5	861.3439	172.2688	9.3417	0.0000 ***
A x B	10	221.2233	22.1223	1.1996	0.3301
Error (b)	30	553.2278	18.4409		
Total	53	1985.6083	37.4643		

Appendix 185: ANOVA for AWHC at 20-45 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	31.3078	15.6539	16.8725	0.0112
MP (A)	2	634.7144	317.3572	342.0617	0.0000 ***
Error (a)	4	3.7111	0.9278		
Fertilizer (B)	5	1312.5617	262.5123	13.7663	0.0000 ***
A x B	10	285.6789	28.5679	1.4981	0.1886
Error (b)	30	572.0744	19.0691		
Total	53	2840.0483	53.5858		

Appendix 186: ANOVA for AWHC combined over seasons at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	1864.078	621.359	95.3133	0.0000 ***
R(S)	8	156.02	19.502	2.9916	0.0296
MP (A)	2	725.758	362.879	55.6638	0.0000 ***
S x A	6	312.472	52.079	7.9886	0.0004
Error	16	104.306	6.519		
Fertilizer (B)	5	2036.563	407.313	24.772	0.0000 ***
S x B	15	523.125	34.875	2.121	0.0130
A x B	10	766.144	76.614	4.6596	0.0000
S x A x B	30	60.814	2.027	0.1233	
Error	120	1973.094	16.442		
Total	215	8522.375			

Appendix 187: ANOVA for total N at 0-20 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0024	0.0012	9.3474	0.0310
MP (A)	2	0.0524	0.0262	204.0746	0.0001 ***
Error (a)	4	0.0005	0.0001		
Fertilizer (B)	5	0.003	0.0006	0.3896	0.8520 ns
A x B	10	0.0145	0.0015	0.9423	0.5103
Error (b)	30	0.0462	0.0015		
Total	53	0.119	0.0022		

Appendix 188: ANOVA for total N at 0-20 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0041	0.0021	1.8255	0.2733
MP (A)	2	0.1055	0.0528	46.8287	0.0017 ***
Error (a)	4	0.0045	0.0011		
Fertilizer (B)	5	0.0203	0.0041	3.37	0.0156 *
A x B	10	0.0337	0.0034	2.7974	0.0142
Error (b)	30	0.0361	0.0012		
Total	53	0.2042	0.0039		

Appendix 189: ANOVA for total N at 0-20 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0034	0.0017	0.6284	0.5790
MP (A)	2	0.2117	0.1058	38.8543	0.0024 ***
Error (a)	4	0.0109	0.0027		
Fertilizer (B)	5	0.0749	0.015	11.124	0.0000 ***
A x B	10	0.0184	0.0018	1.3645	0.2435
Error (b)	30	0.0404	0.0013		
Total	53	0.3597	0.0068		

Appendix 190: ANOVA for total N at 0-20 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0012	0.0006	0.4043	0.6919
MP (A)	2	0.3514	0.1757	115.8857	0.0003 ***
Error (a)	4	0.0061	0.0015		
Fertilizer (B)	5	0.1423	0.0285	17.161	0.0000 ***
A x B	10	0.0208	0.0021	1.2527	0.2998
Error (b)	30	0.0497	0.0017		
Total	53	0.5715	0.0108		

Appendix 191: ANOVA for total N combined over seasons at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.462	0.154	112.1878	0.0000 ***
R(S)	8	0.011	0.001	1.0155	0.4628
MP (A)	2	0.639	0.32	232.7252	0.0000 ***
S x A	6	0.082	0.014	9.8944	0.0001
Error	16	0.022	0.001		
Fertilizer (B)	5	0.15	0.03	20.8971	0.0000 ***
S x B	15	0.09	0.006	4.1904	0.0000
A x B	10	0.065	0.006	4.5113	0.0000
S x A x B	30	0.023	0.001	0.522	
Error	120	0.172	0.001		
Total	215	1.717			

Appendix 192: ANOVA for total N at 20-45 cm soil depth during Kharif 2006 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0013	0.0006	0.5016	0.6391
MP (A)	2	0.0616	0.0308	24.042	0.0059 ***
Error (a)	4	0.0051	0.0013		
Fertilizer (B)	5	0.0038	0.0008	0.4769	0.7905 ns
A x B	10	0.0103	0.001	0.6481	0.7613
Error (b)	30	0.0475	0.0016		
Total	53	0.1295	0.0024		

Appendix 193: ANOVA for total N at 20-45 cm soil depth during Rabi 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0019	0.0009	0.3862	0.7025
MP (A)	2	0.1015	0.0508	20.8142	0.0077 ***
Error (a)	4	0.0098	0.0024		
Fertilizer (B)	5	0.013	0.0026	1.7247	0.1594 ns
A x B	10	0.0125	0.0013	0.8288	0.6049
Error (b)	30	0.0453	0.0015		
Total	53	0.184	0.0035		

Appendix 194: ANOVA for total N at 20-45 cm soil depth during Kharif 2007 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0009	0.0004	0.4	0.6944
MP (A)	2	0.2007	0.1003	92.3264	0.0004 ***
Error (a)	4	0.0043	0.0011		
Fertilizer (B)	5	0.0584	0.0117	5.9634	0.0006 ***
A x B	10	0.0068	0.0007	0.3469	0.9597
Error (b)	30	0.0587	0.002		
Total	53	0.3297	0.0062		

Appendix 195: ANOVA for total N at 20-45 cm soil depth during Rabi 2008 at site Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0054	0.0027	1.9	0.2629
MP (A)	2	0.2607	0.1304	91.4582	0.0005 ***
Error (a)	4	0.0057	0.0014		
Fertilizer (B)	5	0.1182	0.0236	14.3294	0.0000 ***
A x B	10	0.0165	0.0016	1	0.4654
Error (b)	30	0.0495	0.0016		
Total	53	0.456	0.0086		

Appendix 196: ANOVA for total N combined over seasons at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.138	0.046	29.5422	0.0000 ***
R(S)	8	0.009	0.001	0.7585	
MP (A)	2	0.562	0.281	180.2524	0.0000 ***
S x A	6	0.063	0.01	6.7178	0.0011
Error	16	0.025	0.002		
Fertilizer (B)	5	0.126	0.025	15.0509	0.0000 ***
S x B	15	0.067	0.004	2.6794	0.0015
A x B	10	0.025	0.002	1.4751	0.1569
S x A x B	30	0.021	0.001	0.4249	
Error	120	0.201	0.002		
Total	215	1.237			

Appendix 197: ANOVA for cumulative CO2 evolution during 2 days incubation at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	67.815	33.907	0.3206	
MP (A)	2	22181.037	11090.518	104.8783	0.0004 ***
Error	4	422.986	105.747		
Fertilizer (B)	5	40858.911	8171.782	165.0857	0.0000 ***
A x B	10	471.519	47.152	0.9526	
Error	30	1485.008	49.5		
Total	53	65487.275			

Appendix 198: ANOVA for cumulative CO2 evolution during 5 days incubation at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	196.069	98.034	1.5982	0.3090
MP (A)	2	47061.428	23530.714	383.6074	0.0000 ***
Error	4	245.362	61.341		
Fertilizer (B)	5	58311.966	11662.393	154.1916	0.0000 ***
A x B	10	590.339	59.034	0.7805	
Error	30	2269.072	75.636		
Total	53	108674.236			

Appendix 199: ANOVA for cumulative CO2 evolution during 10 days incubation at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	203.525	101.763	2.2288	0.2237
MP (A)	2	53212.538	26606.269	582.7394	0.0000 ***
Error	4	182.629	45.657		
Fertilizer (B)	5	93501.658	18700.332	207.9652	0.0000 ***
A x B	10	580.572	58.057	0.6457	
Error	30	2697.615	89.92		
Total	53	150378.537			

Appendix 200: ANOVA for cumulative CO2 evolution during 15 days incubation at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	194.059	97.029	0.4473	
MP (A)	2	54053.855	27026.928	124.6027	0.0002 ***
Error	4	867.62	216.905		
Fertilizer (B)	5	89062.445	17812.489	240.3476	0.0000 ***
A x B	10	473.218	47.322	0.6385	
Error	30	2223.341	74.111		
Total	53	146874.538			

Appendix 201: ANOVA for cumulative CO2 evolution during 2 days incubation at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	286.043	143.021	3.966	0.1124
MP (A)	2	24002.568	12001.284	332.7947	0.0000 ***
Error	4	144.248	36.062		
Fertilizer (B)	5	41656.095	8331.219	160.2467	0.0000 ***
A x B	10	409.163	40.916	0.787	
Error	30	1559.699	51.99		
Total	53	68057.816			

Appendix 202: ANOVA for cumulative CO2 evolution during 5 days incubation at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	227.213	113.606	2.9109	0.1659
MP (A)	2	42159.994	21079.997	540.1315	0.0000 ***
Error	4	156.11	39.028		
Fertilizer (B)	5	68924.653	13784.931	156.8957	0.0000 ***
A x B	10	806.328	80.633	0.9177	
Error	30	2635.814	87.86		
Total	53	114910.112			

Appendix 203: ANOVA for Cumulative CO2 evolution during 10 days incubation at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	336.085	168.043	1.719	0.2892
MP (A)	2	48441.01	24220.505	247.7596	0.0001 ***
Error	4	391.032	97.758		
Fertilizer (B)	5	86213.381	17242.676	250.8117	0.0000 ***
A x B	10	1530.775	153.077	2.2267	0.0441
Error	30	2062.425	68.747		
Total	53	138974.708			

Appendix 204: ANOVA for cumulative CO2 evolution during 15 days incubation at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	152.445	76.223	0.5394	
MP (A)	2	56946.636	28473.318	201.5022	0.0001 ***
Error	4	565.221	141.305		
Fertilizer (B)	5	96338.211	19267.642	187.9084	0.0000 ***
A x B	10	560.709	56.071	0.5468	
Error	30	3076.122	102.537		
Total	53	157639.345			

Appendix 205: ANOVA for microbial biomass C at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	72.293	36.147	0.3701	
MP (A)	2	118351.486	59175.743	605.8528	0.0000 ***
Error	4	390.694	97.673		
Fertilizer (B)	5	73791.463	14758.293	312.5035	0.0000 ***
A x B	10	516.584	51.658	1.0939	0.3977
Error	30	1416.78	47.226		
Total	53	194539.301			

Appendix 206: ANOVA for microbial biomass C at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	24.721	12.36	0.1035	
MP (A)	2	104560.456	52280.228	437.8797	0.0000 ***
Error	4	477.576	119.394		
Fertilizer (B)	5	72543.052	14508.61	292.1993	0.0000 ***
A x B	10	288.583	28.858	0.5812	
Error	30	1489.594	49.653		
Total	53	179383.981			

Appendix 207: ANOVA for microbial biomass N at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.512	0.256	0.662	
MP (A)	2	518.196	259.098	670.492	0.0000 ***
Error	4	1.546	0.386		
Fertilizer (B)	5	2372.78	474.556	1111.5738	0.0000 ***
A x B	10	5.464	0.546	1.2798	0.2853
Error	30	12.808	0.427		
Total	53	2911.305			

Appendix 208: ANOVA for microbial biomass N at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.231	0.116	0.1815	
MP (A)	2	465.571	232.786	365.6778	0.0000 ***
Error	4	2.546	0.637		
Fertilizer (B)	5	2246.011	449.202	691.3341	0.0000 ***
A x B	10	2.249	0.225	0.3461	
Error	30	19.493	0.65		
Total	53	2736.101			

Appendix 209: ANOVA for mineralizable C at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	15.139	7.57	2.2255	0.2240
MP (A)	2	3958.173	1979.087	581.8641	0.0000 ***
Error	4	13.605	3.401		
Fertilizer (B)	5	6954.838	1390.968	208.0609	0.0000 ***
A x B	10	43.22	4.322	0.6465	
Error	30	200.562	6.685		
Total	53	11185.537			

Appendix 210: ANOVA for mineralizable C at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	24.965	12.483	1.7222	0.2887
MP (A)	2	3602.269	1801.135	248.4985	0.0001 ***
Error	4	28.992	7.248		
Fertilizer (B)	5	6412.932	1282.586	250.834	0.0000 ***
A x B	10	113.767	11.377	2.2249	0.0443
Error	30	153.399	5.113		
Total	53	10336.325			

Appendix 211: ANOVA for mineralizable N at surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.013	0.006	0.0143	
MP (A)	2	422.206	211.103	466.3575	0.0000 ***
Error	4	1.811	0.453		
Fertilizer (B)	5	1716.02	343.204	380.3431	0.0000 ***
A x B	10	6.867	0.687	0.761	
Error	30	27.071	0.902		
Total	53	2173.987			

Appendix 212: ANOVA for mineralizable N at sub-surface soil of Gado

S.O.V.	DF	SS	MS	F	P-value
Replication	2	2.539	1.27	7.0945	0.0484
MP (A)	2	393.716	196.858	1099.9242	0.0000 ***
Error	4	0.716	0.179		
Fertilizer (B)	5	1689.33	337.866	435.6781	0.0000 ***
A x B	10	6.138	0.614	0.7915	
Error	30	23.265	0.775		
Total	53	2115.704			

Appendix 213: ANOVA for soil pH at 0-20 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0079	0.0039	1.5664	0.3144
MP (A)	2	0.0071	0.0036	1.4163	0.3427 ns
Error (a)	4	0.0101	0.0025		
Fertilizer (B)	5	0.019	0.0038	0.8175	0.5468 ns
A x B	10	0.049	0.0049	1.0568	0.4236
Error (b)	30	0.1392	0.0046		
Total	53	0.2323	0.0044		

Appendix 214: ANOVA for soil pH at 0-20 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0022	0.0011	0.2682	0.7775
MP (A)	2	0.0844	0.0422	10.1401	0.0271 *
Error (a)	4	0.0167	0.0042		
Fertilizer (B)	5	0.0901	0.018	1.6368	0.1807 ns
A x B	10	0.0837	0.0084	0.76	0.6645
Error (b)	30	0.3302	0.011		
Total	53	0.6073	0.0115		

Appendix 215: ANOVA for soil pH at 0-20 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0185	0.0092	1.2005	0.3904
MP (A)	2	0.148	0.074	9.609	0.0297 *
Error (a)	4	0.0308	0.0077		
Fertilizer (B)	5	0.3422	0.0684	6.3028	0.0004 ***
A x B	10	0.1249	0.0125	1.15	0.3607
Error (b)	30	0.3258	0.0109		
Total	53	0.9902	0.0187		

Appendix 216: ANOVA for soil pH at 0-20 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0097	0.0048	0.7273	0.5377
MP (A)	2	0.2468	0.1234	18.5495	0.0095 ***
Error (a)	4	0.0266	0.0067		
Fertilizer (B)	5	0.6102	0.122	9.3426	0.0000 ***
A x B	10	0.1215	0.0121	0.9299	0.5203
Error (b)	30	0.3919	0.0131		
Total	53	1.4067	0.0265		

Appendix 217: ANOVA for soil pH combined over seasons at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.269	0.09	17.0812	0.0000 ***
R(S)	8	0.038	0.005	0.9101	
MP (A)	2	0.394	0.197	37.4506	0.0000 ***
S x A	6	0.093	0.015	2.9325	0.0399
Error	16	0.084	0.005		
Fertilizer (B)	5	0.75	0.15	15.1723	0.0000 ***
S x B	15	0.311	0.021	2.0961	0.0143
A x B	10	0.324	0.032	3.2797	0.0009
S x A x B	30	0.055	0.002	0.184	
Error	120	1.187	0.01		
Total	215	3.506			

Appendix 218: ANOVA for soil pH at 20-45 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0008	0.0004	0.1584	0.8586
MP (A)	2	0.0001	0	0.0148	0.9854 ns
Error (a)	4	0.0105	0.0026		
Fertilizer (B)	5	0.0125	0.0025	0.402	0.8435 ns
A x B	10	0.0708	0.0071	1.1361	0.3695
Error (b)	30	0.187	0.0062		
Total	53	0.2817	0.0053		

Appendix 219: ANOVA for soil pH at 20-45 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0138	0.0069	3.0853	0.1546
MP (A)	2	0.0052	0.0026	1.174	0.3971 ns
Error (a)	4	0.0089	0.0022		
Fertilizer (B)	5	0.085	0.017	1.9946	0.1082 ns
A x B	10	0.0835	0.0084	0.9796	0.4810
Error (b)	30	0.2558	0.0085		
Total	53	0.4523	0.0085		

Appendix 220: ANOVA for soil pH at 20-45 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0199	0.01	7.5445	0.0439
MP (A)	2	0.0216	0.0108	8.1668	0.0387 *
Error (a)	4	0.0053	0.0013		
Fertilizer (B)	5	0.1559	0.0312	4.2178	0.0051 ***
A x B	10	0.0737	0.0074	0.997	0.4676
Error (b)	30	0.2217	0.0074		
Total	53	0.4981	0.0094		

Appendix 221: ANOVA for soil pH at 20-45 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0248	0.0124	17.888	0.0101
MP (A)	2	0.0611	0.0306	44.024	0.0019 ***
Error (a)	4	0.0028	0.0007		
Fertilizer (B)	5	0.3777	0.0755	7.5063	0.0001 ***
A x B	10	0.1484	0.0148	1.4743	0.1975
Error (b)	30	0.3019	0.0101		
Total	53	0.9167	0.0173		

Appendix 222: ANOVA for soil pH combined over seasons at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.324	0.108	62.7678	0.0000 ***
R(S)	8	0.059	0.007	4.3164	0.0062
MP (A)	2	0.047	0.024	13.7699	0.0003 ***
S x A	6	0.041	0.007	3.9403	0.0131
Error	16	0.028	0.002		
Fertilizer (B)	5	0.44	0.088	10.9178	0.0000 ***
S x B	15	0.191	0.013	1.5853	0.0876
A x B	10	0.297	0.03	3.6932	0.0002
S x A x B	30	0.079	0.003	0.3268	
Error	120	0.966	0.008		
Total	215	2.473			

Appendix 223: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0054	0.0027	0.0351	0.9658
MP (A)	2	0.0069	0.0035	0.0448	0.9567 ns
Error (a)	4	0.3098	0.0775		
Fertilizer (B)	5	0.1676	0.0335	1.0666	0.3983 ns
A x B	10	0.3547	0.0355	1.1284	0.3746
Error (b)	30	0.943	0.0314		
Total	53	1.7874	0.0337		

Appendix 224: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0369	0.0185	0.2304	0.8040
MP (A)	2	0.0107	0.0053	0.0667	0.9365 ns
Error (a)	4	0.3206	0.0802		
Fertilizer (B)	5	0.1072	0.0214	0.5772	0.7170 ns
A x B	10	0.2863	0.0286	0.771	0.6549
Error (b)	30	1.1142	0.0371		
Total	53	1.8759	0.0354		

Appendix 225: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0357	0.0178	0.2374	0.7990
MP (A)	2	0.0093	0.0046	0.0618	0.9409 ns
Error (a)	4	0.3005	0.0751		
Fertilizer (B)	5	0.1927	0.0385	0.7029	0.6256 ns
A x B	10	0.5534	0.0553	1.0091	0.4585
Error (b)	30	1.6452	0.0548		
Total	53	2.7367	0.0516		

Appendix 226: ANOVA for soil electrical conductivity at 0-20 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0248	0.0124	0.1552	0.8611
MP (A)	2	0.0178	0.0089	0.1112	0.8974 ns
Error (a)	4	0.3197	0.0799		
Fertilizer (B)	5	0.261	0.0522	0.7387	0.6005 ns
A x B	10	0.6308	0.0631	0.8925	0.5510
Error (b)	30	2.1202	0.0707		
Total	53	3.3742	0.0637		

Appendix 227: ANOVA for soil electrical conductivity combined over seasons at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.148	0.049	0.6302	
R(S)	8	0.103	0.013	0.1645	
MP (A)	2	0.018	0.009	0.1137	
S x A	6	0.027	0.004	0.0574	
Error	16	1.251	0.078		
Fertilizer (B)	5	0.576	0.115	2.3726	0.0431 *
S x B	15	0.153	0.01	0.2102	
A x B	10	1.645	0.165	3.3911	0.0006
S x A x B	30	0.18	0.006	0.1235	
Error	120	5.822	0.049		
Total	215	9.922			

Appendix 228: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.2273	0.1137	10.3774	0.0261
MP (A)	2	0.104	0.052	4.7472	0.0879 ns
Error (a)	4	0.0438	0.011		
Fertilizer (B)	5	0.194	0.0388	1.0396	0.4127 ns
A x B	10	0.2842	0.0284	0.7615	0.6632
Error (b)	30	1.1197	0.0373		
Total	53	1.973	0.0372		

Appendix 229: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.337	0.1685	13.8561	0.0159
MP (A)	2	0.0377	0.0189	1.5519	0.3171 ns
Error (a)	4	0.0486	0.0122		
Fertilizer (B)	5	0.2742	0.0548	1.2306	0.3193 ns
A x B	10	0.4166	0.0417	0.9347	0.5165
Error (b)	30	1.3371	0.0446		
Total	53	2.4513	0.0463		

Appendix 230: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.4089	0.2045	6.9875	0.0495
MP (A)	2	0.0245	0.0122	0.4181	0.6841 ns
Error (a)	4	0.1171	0.0293		
Fertilizer (B)	5	0.2859	0.0572	1.0486	0.4079 ns
A x B	10	0.5082	0.0508	0.9319	0.5188
Error (b)	30	1.6361	0.0545		
Total	53	2.9808	0.0562		

Appendix 231: ANOVA for soil electrical conductivity at 20-45 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.4665	0.2332	5.2842	0.0753
MP (A)	2	0.0433	0.0217	0.4909	0.6447 ns
Error (a)	4	0.1766	0.0441		
Fertilizer (B)	5	0.4022	0.0804	1.1468	0.3579 ns
A x B	10	0.4306	0.0431	0.6139	0.7897
Error (b)	30	2.1043	0.0701		
Total	53	3.6235	0.0684		

Appendix 232: ANOVA for soil electrical conductivity combined over seasons at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.008	0.003	0.1043	
R(S)	8	1.44	0.18	7.4587	0.0004
MP (A)	2	0.163	0.082	3.3793	0.0597 ns
S x A	6	0.046	0.008	0.3209	
Error	16	0.386	0.024		
Fertilizer (B)	5	1.043	0.209	4.0383	0.0020 ***
S x B	15	0.114	0.008	0.1467	
A x B	10	1.332	0.133	2.5784	0.0073
S x A x B	30	0.308	0.01	0.1988	
Error	120	6.197	0.052		
Total	215	11.036			

Appendix 233: ANOVA for soil organic matter at 0-20 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.7693	0.3846	2.3129	0.2150
MP (A)	2	17.6281	8.8141	53.0022	0.0013 ***
Error (a)	4	0.6652	0.1663		
Fertilizer (B)	5	1.4209	0.2842	1.3052	0.2882 ns
A x B	10	2.3052	0.2305	1.0587	0.4222
Error (b)	30	6.5322	0.2177		
Total	53	29.3209	0.5532		

Appendix 234: ANOVA for soil organic matter at 0-20 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.7511	0.3756	1.7378	0.2863
MP (A)	2	36.7411	18.3706	85.0051	0.0005 ***
Error (a)	4	0.8644	0.2161		
Fertilizer (B)	5	3.4306	0.6861	2.4394	0.0572 ns
A x B	10	1.7833	0.1783	0.6341	0.7730
Error (b)	30	8.4378	0.2813		
Total	53	52.0083	0.9813		

Appendix 235: ANOVA for soil organic matter at 0-20 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.7893	0.3946	1.5331	0.3204
MP (A)	2	68.197	34.0985	132.4691	0.0002 ***
Error (a)	4	1.0296	0.2574		
Fertilizer (B)	5	14.092	2.8184	8.9054	0.0000 ***
A x B	10	2.5919	0.2592	0.819	0.6133
Error (b)	30	9.4944	0.3165		
Total	53	96.1943	1.815		

Appendix 236: ANOVA for soil organic matter at 0-20 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.0833	0.5417	1.8969	0.2634
MP (A)	2	109.4344	54.7172	191.6167	0.0001 ***
Error (a)	4	1.1422	0.2856		
Fertilizer (B)	5	36.5467	7.3093	23.4079	0.0000 ***
A x B	10	4.6589	0.4659	1.492	0.1908
Error (b)	30	9.3678	0.3123		
Total	53	162.2333	3.061		

Appendix 237: ANOVA for soil organic matter combined over seasons at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	116.461	38.82	167.8044	0.0000 ***
R(S)	8	3.393	0.424	1.8333	0.1438
MP (A)	2	206.468	103.234	446.2396	0.0000 ***
S x A	6	25.532	4.255	18.3943	0.0000
Error	16	3.701	0.231		
Fertilizer (B)	5	31.164	6.233	22.1073	0.0000 ***
S x B	15	24.326	1.622	5.7522	0.0000
A x B	10	10.244	1.024	3.6336	0.0003
S x A x B	30	1.095	0.036	0.1295	
Error	120	33.832	0.282		
Total	215	456.218			

Appendix 238: ANOVA for soil organic matter at 20-45 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.6104	0.3052	1.1667	0.3988
MP (A)	2	28.4226	14.2113	54.3299	0.0013 ***
Error (a)	4	1.0463	0.2616		
Fertilizer (B)	5	1.8809	0.3762	1.5203	0.2132 ns
A x B	10	1.1707	0.1171	0.4731	0.8941
Error (b)	30	7.4233	0.2474		
Total	53	40.5543	0.7652		

Appendix 239: ANOVA for soil organic matter at 20-45 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.1626	0.0813	0.1342	0.8781
MP (A)	2	36.7304	18.3652	30.3186	0.0038 ***
Error (a)	4	2.423	0.6057		
Fertilizer (B)	5	3.4609	0.6922	2.4915	0.0531 ns
A x B	10	1.1763	0.1176	0.4234	0.9238
Error (b)	30	8.3344	0.2778		
Total	53	52.2876	0.9866		

Appendix 240: ANOVA for soil organic matter at 20-45 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.1226	0.0613	0.1737	0.8465
MP (A)	2	66.7826	33.3913	94.6028	0.0004 ***
Error (a)	4	1.4119	0.353		
Fertilizer (B)	5	13.1904	2.6381	8.6789	0.0000 ***
A x B	10	2.1841	0.2184	0.7185	0.7007
Error (b)	30	9.1189	0.304		
Total	53	92.8104	1.7511		

Appendix 241: ANOVA for soil organic matter at 20-45 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.2315	0.1157	0.2434	0.7947
MP (A)	2	81.2893	40.6446	85.4843	0.0005 ***
Error (a)	4	1.9019	0.4755		
Fertilizer (B)	5	32.4037	6.4807	19.3007	0.0000 ***
A x B	10	3.0196	0.302	0.8993	0.5454
Error (b)	30	10.0733	0.3358		
Total	53	128.9193	2.4324		

Appendix 242: ANOVA for soil organic matter combined over seasons at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	36.662	12.221	28.8266	0.0000 ***
R(S)	8	1.127	0.141	0.3323	
MP (A)	2	201.251	100.625	237.3604	0.0000 ***
S x A	6	11.974	1.996	4.7075	0.0061
Error	16	6.783	0.424		
Fertilizer (B)	5	30.041	6.008	20.6291	0.0000 ***
S x B	15	20.895	1.393	4.7828	0.0000
A x B	10	6.623	0.662	2.274	0.0178
S x A x B	30	0.928	0.031	0.1062	
Error	120	34.95	0.291		
Total	215	351.233			

Appendix 243: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	11.0048	5.5024	0.1269	0.8842
MP (A)	2	125.467	62.7335	1.447	0.3366 ns
Error (a)	4	173.413	43.3532		
Fertilizer (B)	5	143.4743	28.6949	1.8238	0.1383 ns
A x B	10	34.8085	3.4809	0.2212	0.9921
Error (b)	30	472.0156	15.7339		
Total	53	960.1831	18.1167		

Appendix 244: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	9.8981	4.9491	0.081	0.9236
MP (A)	2	560.6859	280.343	4.5891	0.0921 ns
Error (a)	4	244.3563	61.0891		
Fertilizer (B)	5	557.7237	111.5447	6.1992	0.0005 ***
A x B	10	52.7407	5.2741	0.2931	0.9775
Error (b)	30	539.7989	17.9933		
Total	53	1965.2037	37.0793		

Appendix 245: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	3.1381	1.5691	0.0312	0.9695
MP (A)	2	959.8115	479.9057	9.534	0.0301 *
Error (a)	4	201.3452	50.3363		
Fertilizer (B)	5	1615.9676	323.1935	13.9422	0.0000 ***
A x B	10	154.4374	15.4437	0.6662	0.7458
Error (b)	30	695.43	23.181		
Total	53	3630.1298	68.493		

Appendix 246: ANOVA for AB-DTPA extractable K at 0-20 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	6.207	3.1035	0.0513	0.9505
MP (A)	2	1511.2604	755.6302	12.4972	0.0190 *
Error (a)	4	241.8563	60.4641		
Fertilizer (B)	5	3449.6254	689.9251	23.5737	0.0000 ***
A x B	10	124.3396	12.434	0.4248	0.9230
Error (b)	30	878.0033	29.2668		
Total	53	6211.292	117.1942		

Appendix 247: ANOVA for AB-DTPA extractable K combined over seasons at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	3201.471	1067.157	19.8317	0.0000 ***
R(S)	8	30.248	3.781	0.0703	
MP (A)	2	2731.103	1365.551	25.377	0.0000 ***
S x A	6	426.122	71.02	1.3198	0.3045
Error	16	860.971	53.811		
Fertilizer (B)	5	3650.407	730.081	33.8883	0.0000 ***
S x B	15	2116.384	141.092	6.5491	0.0000
A x B	10	217.148	21.715	1.0079	0.4408
S x A x B	30	149.178	4.973	0.2308	
Error	120	2585.248	21.544		
Total	215	15968.28			

Appendix 248: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	32.5033	16.2517	0.6236	0.5811
MP (A)	2	4.0011	2.0006	0.0768	0.9274 ns
Error (a)	4	104.2456	26.0614		
Fertilizer (B)	5	95.9311	19.1862	1.0793	0.3916 ns
A x B	10	139.5544	13.9554	0.7851	0.6427
Error (b)	30	533.2844	17.7761		
Total	53	909.52	17.1608		

Appendix 249: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	38.8548	19.4274	0.4846	0.6479
MP (A)	2	97.8981	48.9491	1.2209	0.3856 ns
Error (a)	4	160.3674	40.0919		
Fertilizer (B)	5	452.1276	90.4255	4.2709	0.0047 ***
A x B	10	267.673	26.7673	1.2642	0.2936
Error (b)	30	635.1778	21.1726		
Total	53	1652.0987	31.1717		

Appendix 250: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	24.13	12.065	0.2798	0.7695
MP (A)	2	324.7778	162.3889	3.7662	0.1203 ns
Error (a)	4	172.4689	43.1172		
Fertilizer (B)	5	1840.2444	368.0489	14.3844	0.0000 ***
A x B	10	204.9711	20.4971	0.8011	0.6288
Error (b)	30	767.6011	25.5867		
Total	53	3334.1933	62.9093		

Appendix 251: ANOVA for AB-DTPA extractable K at 20-45 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	24.3004	12.1502	0.2651	0.7795
MP (A)	2	607.3126	303.6563	6.6264	0.0538 ns
Error (a)	4	183.3019	45.8255		
Fertilizer (B)	5	4375.5831	875.1166	28.0148	0.0000 ***
A x B	10	272.8141	27.2814	0.8733	0.5670
Error (b)	30	937.1311	31.2377		
Total	53	6400.4431	120.7631		

Appendix 252: ANOVA for AB-DTPA extractable K combined over seasons at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	3164.803	1054.934	27.2073	0.0000 ***
R(S)	8	119.789	14.974	0.3862	
MP (A)	2	728.575	364.288	9.3952	0.0020 ***
S x A	6	305.414	50.902	1.3128	0.3073
Error	16	620.384	38.774		
Fertilizer (B)	5	4152.783	830.557	34.6885	0.0000 ***
S x B	15	2611.103	174.074	7.2702	0.0000
A x B	10	751.406	75.141	3.1383	0.0014
S x A x B	30	133.606	4.454	0.186	
Error	120	2873.195	23.943		
Total	215	15461.059			

Appendix 253: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0025	0.0013	0.1937	0.8311
MP (A)	2	0.0024	0.0012	0.1817	0.8403 ns
Error (a)	4	0.026	0.0065		
Fertilizer (B)	5	0.0557	0.0111	2.6165	0.0444 *
A x B	10	0.0234	0.0023	0.5482	0.8416
Error (b)	30	0.1278	0.0043		
Total	53	0.2377	0.0045		

Appendix 254: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0014	0.0007	0.1598	0.8574
MP (A)	2	0.0221	0.0111	2.5993	0.1891 ns
Error (a)	4	0.017	0.0043		
Fertilizer (B)	5	0.3028	0.0606	11.4131	0.0000 ***
A x B	10	0.0211	0.0021	0.3968	0.9376
Error (b)	30	0.1592	0.0053		
Total	53	0.5235	0.0099		

Appendix 255: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0015	0.0007	0.1564	0.8601
MP (A)	2	0.0983	0.0491	10.2981	0.0264 *
Error (a)	4	0.0191	0.0048		
Fertilizer (B)	5	0.8808	0.1762	29.5317	0.0000 ***
A x B	10	0.0259	0.0026	0.4339	0.9179
Error (b)	30	0.179	0.006		
Total	53	1.2045	0.0227		

Appendix 256: ANOVA for AB-DTPA extractable P at 0-20 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.005	0.0025	0.3396	0.7307
MP (A)	2	0.209	0.1045	14.3147	0.0150 *
Error (a)	4	0.0292	0.0073		
Fertilizer (B)	5	2.027	0.4054	58.9337	0.0000 ***
A x B	10	0.0374	0.0037	0.5433	0.8452
Error (b)	30	0.2064	0.0069		
Total	53	2.5139	0.0474		

Appendix 257: ANOVA for AB-DTPA extractable P combined over seasons at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	3.314	1.105	193.6789	0.0000 ***
R(S)	8	0.01	0.001	0.2263	
MP (A)	2	0.211	0.105	18.4547	0.0001 ***
S x A	6	0.121	0.02	3.543	0.0200
Error	16	0.091	0.006		
Fertilizer (B)	5	2.198	0.44	78.4697	0.0000 ***
S x B	15	1.068	0.071	12.7118	0.0000
A x B	10	0.091	0.009	1.6311	0.1057
S x A x B	30	0.016	0.001	0.0969	
Error	120	0.672	0.006		
Total	215	7.794			

Appendix 258: ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0038	0.0019	0.4851	0.6476
MP (A)	2	0.0368	0.0184	4.686	0.0895 ns
Error (a)	4	0.0157	0.0039		
Fertilizer (B)	5	0.0281	0.0056	1.1683	0.3476 ns
A x B	10	0.0332	0.0033	0.6891	0.7262
Error (b)	30	0.1445	0.0048		
Total	53	0.2621	0.0049		

Appendix 259: ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0044	0.0022	0.9058	0.4737
MP (A)	2	0.0112	0.0056	2.2906	0.2173 ns
Error (a)	4	0.0098	0.0024		
Fertilizer (B)	5	0.325	0.065	13.8329	0.0000 ***
A x B	10	0.0337	0.0034	0.7171	0.7019
Error (b)	30	0.141	0.0047		
Total	53	0.5251	0.0099		

Appendix 260: ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0101	0.005	2.9305	0.1645
MP (A)	2	0.0422	0.0211	12.2649	0.0197 *
Error (a)	4	0.0069	0.0017		
Fertilizer (B)	5	0.7809	0.1562	30.8977	0.0000 ***
A x B	10	0.036	0.0036	0.7131	0.7054
Error (b)	30	0.1516	0.0051		
Total	53	1.0277	0.0194		

Appendix 261: ANOVA for AB-DTPA extractable P at 20-45 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0111	0.0055	2.1418	0.2331
MP (A)	2	0.1215	0.0607	23.4866	0.0062 ***
Error (a)	4	0.0103	0.0026		
Fertilizer (B)	5	1.9843	0.3969	75.2672	0.0000 ***
A x B	10	0.0371	0.0037	0.7028	0.7143
Error (b)	30	0.1582	0.0053		
Total	53	2.3224	0.0438		

Appendix 262: ANOVA for AB-DTPA extractable P combined over seasons at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	3.467	1.156	432.7594	0.0000 ***
R(S)	8	0.029	0.004	1.3763	0.2785
MP (A)	2	0.071	0.035	13.2062	0.0004 ***
S x A	6	0.141	0.024	8.8106	0.0002
Error	16	0.043	0.003		
Fertilizer (B)	5	2.091	0.418	84.3017	0.0000 ***
S x B	15	1.027	0.068	13.807	0.0000
A x B	10	0.135	0.014	2.7242	0.0047
S x A x B	30	0.005	0	0.0326	
Error	120	0.595	0.005		
Total	215	7.604			

Appendix 263: ANOVA for mineral N at 0-20 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.8264	0.4132	1.4296	0.3400
MP (A)	2	5.1846	2.5923	8.9688	0.0332 *
Error (a)	4	1.1561	0.289		
Fertilizer (B)	5	1.5661	0.3132	0.3307	0.8904 ns
A x B	10	16.3112	1.6311	1.722	0.1214
Error (b)	30	28.4174	0.9472		
Total	53	53.4619	1.0087		

Appendix 264: ANOVA for mineral N at 0-20 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.0033	0.5017	1.9387	0.2578
MP (A)	2	6.2976	3.1488	12.1689	0.0199 *
Error (a)	4	1.035	0.2588		
Fertilizer (B)	5	20.216	4.0432	4.676	0.0028 ***
A x B	10	15.1551	1.5155	1.7527	0.1142
Error (b)	30	25.9404	0.8647		
Total	53	69.6475	1.3141		

Appendix 265: ANOVA for mineral N at 0-20 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.4361	0.718	3.4267	0.1358
MP (A)	2	19.2654	9.6327	45.9697	0.0017 ***
Error (a)	4	0.8382	0.2095		
Fertilizer (B)	5	65.8253	13.1651	14.9381	0.0000 ***
A x B	10	14.1217	1.4122	1.6024	0.1538
Error (b)	30	26.4392	0.8813		
Total	53	127.9259	2.4137		

Appendix 266: ANOVA for mineral N at 0-20 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.4323	0.7162	3.7627	0.1204
MP (A)	2	40.9827	20.4914	107.6625	0.0003 ***
Error (a)	4	0.7613	0.1903		
Fertilizer (B)	5	141.5504	28.3101	31.8673	0.0000 ***
A x B	10	14.9289	1.4929	1.6805	0.1319
Error (b)	30	26.6512	0.8884		
Total	53	226.3068	4.2699		

Appendix 267: ANOVA for mineral N combined over seasons at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	371.351	123.784	522.4772	0.0000 ***
R(S)	8	4.698	0.587	2.4788	0.0582
MP (A)	2	56.668	28.334	119.5938	0.0000 ***
S x A	6	15.063	2.51	10.5964	0.0001
Error	16	3.791	0.237		
Fertilizer (B)	5	157.401	31.48	35.1576	0.0000 ***
S x B	15	71.757	4.784	5.3426	0.0000
A x B	10	59.838	5.984	6.6829	0.0000
S x A x B	30	0.678	0.023	0.0253	
Error	120	107.448	0.895		
Total	215	848.693			

Appendix 268: ANOVA for mineral N at 20-45 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	2.5823	1.2912	2.114	0.2363
MP (A)	2	0.2575	0.1287	0.2108	0.8184 ns
Error (a)	4	2.4431	0.6108		
Fertilizer (B)	5	7.1114	1.4223	1.2187	0.3246 ns
A x B	10	10.1742	1.0174	0.8718	0.5683
Error (b)	30	35.0122	1.1671		
Total	53	57.5806	1.0864		

Appendix 269: ANOVA for mineral N at 20-45 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	3.0409	1.5205	2.5187	0.1959
MP (A)	2	0.1732	0.0866	0.1434	0.8707 ns
Error (a)	4	2.4147	0.6037		
Fertilizer (B)	5	26.6539	5.3308	4.9524	0.0020 ***
A x B	10	12.2079	1.2208	1.1341	0.3708
Error (b)	30	32.2922	1.0764		
Total	53	76.7828	1.4487		

Appendix 270: ANOVA for mineral N at 20-45 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	2.9617	1.4808	2.1722	0.2297
MP (A)	2	0.1467	0.0733	0.1076	0.9005 ns
Error (a)	4	2.7269	0.6817		
Fertilizer (B)	5	74.4415	14.8883	13.5118	0.0000 ***
A x B	10	13.21	1.321	1.1989	0.3306
Error (b)	30	33.0563	1.1019		
Total	53	126.543	2.3876		

Appendix 271: ANOVA for mineral N at 20-45 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	3.1526	1.5763	2.3863	0.2079
MP (A)	2	6.1572	3.0786	4.6605	0.0902 ns
Error (a)	4	2.6423	0.6606		
Fertilizer (B)	5	155.1063	31.0213	27.9425	0.0000 ***
A x B	10	14.225	1.4225	1.2813	0.2845
Error (b)	30	33.3055	1.1102		
Total	53	214.5888	4.0488		

Appendix 272: ANOVA for mineral N combined over seasons at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	302.385	100.795	157.6926	0.0000 ***
R(S)	8	11.738	1.467	2.2954	0.0748
MP (A)	2	2.781	1.391	2.1754	0.1460 ns
S x A	6	3.953	0.659	1.0309	0.4412
Error	16	10.227	0.639		
Fertilizer (B)	5	191.566	38.313	34.396	0.0000 ***
S x B	15	71.747	4.783	4.2941	0.0000
A x B	10	49.38	4.938	4.4331	0.0000
S x A x B	30	0.437	0.015	0.0131	
Error	120	133.666	1.114		
Total	215	777.881			

Appendix 273: ANOVA for bulk density at 0-20 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0002	0.0001	0.0988	0.9080
MP (A)	2	0.0003	0.0001	0.1231	0.8874 ns
Error (a)	4	0.0046	0.0011		
Fertilizer (B)	5	0.0073	0.0015	1.7718	0.1490 ns
A x B	10	0.0053	0.0005	0.6424	0.7660
Error (b)	30	0.0247	0.0008		
Total	53	0.0424	0.0008		

Appendix 274: ANOVA for bulk density at 0-20 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0016	0.0008	0.7095	0.5448
MP (A)	2	0.0111	0.0056	4.8885	0.0843 ns
Error (a)	4	0.0046	0.0011		
Fertilizer (B)	5	0.0132	0.0026	2.8119	0.0337 *
A x B	10	0.0058	0.0006	0.6147	0.7891
Error (b)	30	0.0282	0.0009		
Total	53	0.0645	0.0012		

Appendix 275: ANOVA for bulk density at 0-20 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.001	0.0005	0.3004	0.7558
MP (A)	2	0.033	0.0165	9.6714	0.0294 *
Error (a)	4	0.0068	0.0017		
Fertilizer (B)	5	0.0229	0.0046	4.0485	0.0063 ***
A x B	10	0.0055	0.0006	0.4897	0.8833
Error (b)	30	0.0339	0.0011		
Total	53	0.1031	0.0019		

Appendix 276: ANOVA for bulk density at 0-20 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0006	0.0003	0.1763	0.8445
MP (A)	2	0.0775	0.0387	23.4891	0.0062 ***
Error (a)	4	0.0066	0.0016		
Fertilizer (B)	5	0.0451	0.009	6.4597	0.0003 ***
A x B	10	0.0153	0.0015	1.0931	0.3982
Error (b)	30	0.0419	0.0014		
Total	53	0.1869	0.0035		

Appendix 277: ANOVA for soil bulk density combined over seasons at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.253	0.084	59.7331	0.0000 ***
R(S)	8	0.003	0	0.3058	
MP (A)	2	0.082	0.041	28.9713	0.0000 ***
S x A	6	0.04	0.007	4.7575	0.0058
Error	16	0.023	0.001		
Fertilizer (B)	5	0.062	0.012	11.5888	0.0000 ***
S x B	15	0.026	0.002	1.6363	0.0739
A x B	10	0.024	0.002	2.2778	0.0177
S x A x B	30	0.007	0	0.2311	
Error	120	0.129	0.001		
Total	215	0.65			

Appendix 278: ANOVA for bulk density at 20-45 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0002	0.0001	0.1103	0.8981
MP (A)	2	0.0003	0.0001	0.1374	0.8755 ns
Error (a)	4	0.0041	0.001		
Fertilizer (B)	5	0.0084	0.0017	2.0969	0.0934 ns
A x B	10	0.0059	0.0006	0.7319	0.6890
Error (b)	30	0.0241	0.0008		
Total	53	0.043	0.0008		

Appendix 279: ANOVA for bulk density at 20-45 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0021	0.001	0.3687	0.7128
MP (A)	2	0.0014	0.0007	0.2421	0.7957 ns
Error (a)	4	0.0112	0.0028		
Fertilizer (B)	5	0.0018	0.0004	0.629	0.6789 ns
A x B	10	0.0105	0.001	1.8686	0.0906
Error (b)	30	0.0168	0.0006		
Total	53	0.0437	0.0008		

Appendix 280: ANOVA for bulk density at 20-45 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0034	0.0017	0.4942	0.6429
MP (A)	2	0.0122	0.0061	1.7752	0.2807 ns
Error (a)	4	0.0138	0.0034		
Fertilizer (B)	5	0.0081	0.0016	2.0866	0.0948 ns
A x B	10	0.0119	0.0012	1.5354	0.1754
Error (b)	30	0.0232	0.0008		
Total	53	0.0726	0.0014		

Appendix 281: ANOVA for bulk density at 20-45 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0042	0.0021	0.5032	0.6383
MP (A)	2	0.0262	0.0131	3.1038	0.1536 ns
Error (a)	4	0.0169	0.0042		
Fertilizer (B)	5	0.0257	0.0051	5.0664	0.0017 ***
A x B	10	0.0112	0.0011	1.1069	0.3888
Error (b)	30	0.0305	0.001		
Total	53	0.1148	0.0022		

Appendix 282: ANOVA for soil bulk density combined over seasons at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.198	0.066	22.9944	0.0000 ***
R(S)	8	0.01	0.001	0.4327	
MP (A)	2	0.021	0.011	3.7031	0.0477 *
S x A	6	0.019	0.003	1.0893	0.4099
Error	16	0.046	0.003		
Fertilizer (B)	5	0.02	0.004	4.9655	0.0004 ***
S x B	15	0.024	0.002	2.0642	0.0161
A x B	10	0.03	0.003	3.8319	0.0002
S x A x B	30	0.009	0	0.3923	
Error	120	0.095	0.001		
Total	215	0.472			

Appendix 283: ANOVA for AWHC at 0-20 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	4.4133	2.2067	0.3165	0.7454
MP (A)	2	3.7878	1.8939	0.2716	0.7751 ns
Error (a)	4	27.8889	6.9722		
Fertilizer (B)	5	92.9172	18.5834	1.6924	0.1669 ns
A x B	10	59.4833	5.9483	0.5417	0.8465
Error (b)	30	329.4244	10.9808		
Total	53	517.915	9.772		

Appendix 284: ANOVA for AWHC at 0-20 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	21.7937	10.8969	0.5362	0.6218
MP (A)	2	178.7381	89.3691	4.3979	0.0977 ns
Error (a)	4	81.283	20.3207		
Fertilizer (B)	5	245.5481	49.1096	3.6028	0.0114 *
A x B	10	83.4219	8.3422	0.612	0.7913
Error (b)	30	408.93	13.631		
Total	53	1019.7148	19.2399		

Appendix 285: ANOVA for AWHC at 0-20 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	3.0281	1.5141	0.0723	0.9314
MP (A)	2	553.5737	276.7869	13.216	0.0173 *
Error (a)	4	83.773	20.9432		
Fertilizer (B)	5	358.672	71.7344	3.5882	0.0116 *
A x B	10	121.9374	12.1937	0.6099	0.7930
Error (b)	30	599.7589	19.992		
Total	53	1720.7431	32.4669		

Appendix 286: ANOVA for AWHC at 0-20 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	15.7604	7.8802	0.3108	0.7491
MP (A)	2	1306.8381	653.4191	25.7678	0.0052 ***
Error (a)	4	101.4319	25.358		
Fertilizer (B)	5	780.5231	156.1046	7.0911	0.0002 ***
A x B	10	214.1107	21.4111	0.9726	0.4864
Error (b)	30	660.4211	22.014		
Total	53	3079.0854	58.096		

Appendix 287: ANOVA for AWHC combined over seasons at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	3787.681	1262.56	68.6229	0.0000 ***
R(S)	8	44.996	5.624	0.3057	
MP (A)	2	1321.747	660.873	35.9199	0.0000 ***
S x A	6	721.191	120.198	6.533	0.0012
Error	16	294.377	18.399		
Fertilizer (B)	5	985.907	197.181	11.8396	0.0000 ***
S x B	15	491.754	32.784	1.9685	0.0229
A x B	10	346.543	34.654	2.0808	0.0311
S x A x B	30	132.41	4.414	0.265	
Error	120	1998.534	16.654		
Total	215	10125.139			

Appendix 288: ANOVA for AWHC at 20-45 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	3.4937	1.7469	0.1189	0.8909
MP (A)	2	3.5793	1.7896	0.1218	0.8885 ns
Error (a)	4	58.7807	14.6952		
Fertilizer (B)	5	98.3743	19.6749	2.0849	0.0950 ns
A x B	10	84.7452	8.4745	0.898	0.5464
Error (b)	30	283.0989	9.4366		
Total	53	532.072	10.0391		

Appendix 289: ANOVA for AWHC at 20-45 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	31.3448	15.6724	0.387	0.7020
MP (A)	2	16.0459	8.023	0.1981	0.8279 ns
Error (a)	4	161.9741	40.4935		
Fertilizer (B)	5	18.5837	3.7167	0.4394	0.8174 ns
A x B	10	133.5585	13.3559	1.5791	0.1610
Error (b)	30	253.7411	8.458		
Total	53	615.2481	11.6085		

Appendix 290: ANOVA for AWHC at 20-45 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	28.5693	14.2846	0.3284	0.7378
MP (A)	2	196.5881	98.2941	2.2599	0.2204 ns
Error (a)	4	173.983	43.4957		
Fertilizer (B)	5	119.6215	23.9243	1.9182	0.1207 ns
A x B	10	203.0141	20.3014	1.6277	0.1464
Error (b)	30	374.1744	12.4725		
Total	53	1095.9504	20.6783		

Appendix 291: ANOVA for AWHC at 20-45 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	64.8604	32.4302	0.5079	0.6359
MP (A)	2	515.397	257.6985	4.0356	0.1098 ns
Error (a)	4	255.4263	63.8566		
Fertilizer (B)	5	401.6081	80.3216	5.1545	0.0016 ***
A x B	10	168.9452	16.8945	1.0842	0.4043
Error (b)	30	467.4867	15.5829		
Total	53	1873.7237	35.3533		

Appendix 292: ANOVA for AWHC combined over seasons at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	2704.598	901.533	22.186	0.0000 ***
R(S)	8	128.268	16.034	0.3946	
MP (A)	2	363.601	181.8	4.474	0.0286 *
S x A	6	368.01	61.335	1.5094	0.2376
Error	16	650.164	40.635		
Fertilizer (B)	5	259.306	51.861	4.5146	0.0008 ***
S x B	15	378.881	25.259	2.1988	0.0097
A x B	10	437.783	43.778	3.8109	0.0002
S x A x B	30	152.48	5.083	0.4425	
Error	120	1378.501	11.488		
Total	215	6821.593			

Appendix 293: ANOVA for total N at 0-20 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0009	0.0004	0.3822	0.7048
MP (A)	2	0.058	0.029	25.7907	0.0052 ***
Error (a)	4	0.0045	0.0011		
Fertilizer (B)	5	0.0037	0.0007	0.4612	0.8018 ns
A x B	10	0.0061	0.0006	0.3822	0.9446
Error (b)	30	0.0477	0.0016		
Total	53	0.1208	0.0023		

Appendix 294: ANOVA for total N at 0-20 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0029	0.0015	2.6649	0.1838
MP (A)	2	0.0881	0.044	80.7101	0.0006 ***
Error (a)	4	0.0022	0.0005		
Fertilizer (B)	5	0.0164	0.0033	1.6299	0.1825 ns
A x B	10	0.0137	0.0014	0.6794	0.7345
Error (b)	30	0.0604	0.002		
Total	53	0.1836	0.0035		

Appendix 295: ANOVA for total N at 0-20 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0025	0.0013	0.4754	0.6527
MP (A)	2	0.2051	0.1026	38.6952	0.0024 ***
Error (a)	4	0.0106	0.0027		
Fertilizer (B)	5	0.0439	0.0088	4.9915	0.0019 ***
A x B	10	0.0089	0.0009	0.5081	0.8707
Error (b)	30	0.0528	0.0018		
Total	53	0.3239	0.0061		

Appendix 296: ANOVA for total N at 0-20 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.007	0.0035	14.2805	0.0150
MP (A)	2	0.3673	0.1836	746.4417	0.0000 ***
Error (a)	4	0.001	0.0002		
Fertilizer (B)	5	0.1344	0.0269	19.388	0.0000 ***
A x B	10	0.0214	0.0021	1.5414	0.1734
Error (b)	30	0.0416	0.0014		
Total	53	0.5727	0.0108		

Appendix 297: ANOVA for total N combined over seasons at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.374	0.125	109.0971	0.0000 ***
R(S)	8	0.013	0.002	1.4579	0.2475
MP (A)	2	0.625	0.312	273.6034	0.0000 ***
S x A	6	0.094	0.016	13.6978	0.0000
Error	16	0.018	0.001		
Fertilizer (B)	5	0.102	0.02	12.144	0.0000 ***
S x B	15	0.096	0.006	3.7899	0.0000
A x B	10	0.034	0.003	2.0112	0.0378
S x A x B	30	0.016	0.001	0.3186	
Error	120	0.202	0.002		
Total	215	1.575			

Appendix 298: ANOVA for total N at 20-45 cm soil depth during Kharif 2006 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.002	0.001	1.2284	0.3837
MP (A)	2	0.0984	0.0492	59.9775	0.0010 ***
Error (a)	4	0.0033	0.0008		
Fertilizer (B)	5	0.0079	0.0016	1.3102	0.2862 ns
A x B	10	0.0088	0.0009	0.7233	0.6965
Error (b)	30	0.0364	0.0012		
Total	53	0.1568	0.003		

Appendix 299: ANOVA for total N at 20-45 cm soil depth during Rabi 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0007	0.0003	0.1577	0.8591
MP (A)	2	0.101	0.0505	23.6397	0.0061 ***
Error (a)	4	0.0085	0.0021		
Fertilizer (B)	5	0.0312	0.0062	5.2211	0.0015 ***
A x B	10	0.0166	0.0017	1.3908	0.2317
Error (b)	30	0.0359	0.0012		
Total	53	0.1939	0.0037		

Appendix 300: ANOVA for total N at 20-45 cm soil depth during Kharif 2007 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0016	0.0008	0.908	0.4730
MP (A)	2	0.2304	0.1152	134.8519	0.0002 ***
Error (a)	4	0.0034	0.0009		
Fertilizer (B)	5	0.035	0.007	4.6032	0.0031 ***
A x B	10	0.0092	0.0009	0.6023	0.7992
Error (b)	30	0.0456	0.0015		
Total	53	0.3251	0.0061		

Appendix 301: ANOVA for total N at 20-45 cm soil depth during Rabi 2008 at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.0026	0.0013	1.6364	0.3024
MP (A)	2	0.2233	0.1117	138.9519	0.0002 ***
Error (a)	4	0.0032	0.0008		
Fertilizer (B)	5	0.1024	0.0205	13.7151	0.0000 ***
A x B	10	0.0244	0.0024	1.6379	0.1434
Error (b)	30	0.0448	0.0015		
Total	53	0.4008	0.0076		

Appendix 302: ANOVA for total N combined over seasons at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	3	0.125	0.042	36.0485	0.0000 ***
R(S)	8	0.007	0.001	0.7444	
MP (A)	2	0.619	0.31	268.4377	0.0000 ***
S x A	6	0.034	0.006	4.8801	0.0052
Error	16	0.018	0.001		
Fertilizer (B)	5	0.106	0.021	15.7129	0.0000 ***
S x B	15	0.07	0.005	3.4452	0.0001
A x B	10	0.027	0.003	1.9724	0.0421
S x A x B	30	0.032	0.001	0.7939	
Error	120	0.163	0.001		
Total	215	1.201			

Appendix 303: ANOVA for cumulative CO2 evolution during 2 days incubation at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	34.047	17.023	0.4436	
MP (A)	2	22900.268	11450.134	298.3457	0.0000 ***
Error	4	153.515	38.379		
Fertilizer (B)	5	34696.552	6939.31	212.2027	0.0000 ***
A x B	10	870.709	87.071	2.6626	0.0185
Error	30	981.04	32.701		
Total	53	59636.13			

Appendix 304: ANOVA for cumulative CO2 evolution during 5 days incubation at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	70.855	35.428	2.3625	0.2102
MP (A)	2	39346.832	19673.416	1311.9204	0.0000 ***
Error	4	59.984	14.996		
Fertilizer (B)	5	48482.472	9696.494	139.2344	0.0000 ***
A x B	10	863.134	86.313	1.2394	0.3073
Error	30	2089.245	69.642		
Total	53	90912.522			

Appendix 305: ANOVA for cumulative CO2 evolution during 10 days incubation at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	358.204	179.102	1.3758	0.3510
MP (A)	2	49481.106	24740.553	190.0464	0.0001 ***
Error	4	520.727	130.182		
Fertilizer (B)	5	72240.031	14448.006	118.3002	0.0000 ***
A x B	10	1041.441	104.144	0.8527	
Error	30	3663.902	122.13		
Total	53	127305.41			

Appendix 306: ANOVA for cumulative CO2 evolution during 15 days incubation at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	162.719	81.359	0.7406	
MP (A)	2	50703.491	25351.746	230.7811	0.0001 ***
Error	4	439.408	109.852		
Fertilizer (B)	5	76536.467	15307.293	156.9453	0.0000 ***
A x B	10	951.89	95.189	0.976	
Error	30	2925.98	97.533		
Total	53	131719.954			

Appendix 307: ANOVA for cumulative CO_2 evolution during 2 days incubation at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	35.255	17.627	0.1934	
MP (A)	2	25146.521	12573.26	137.9494	0.0002 ***
Error	4	364.576	91.144		
Fertilizer (B)	5	35678.133	7135.627	157.8066	0.0000 ***
A x B	10	387.791	38.779	0.8576	
Error	30	1356.526	45.218		
Total	53	62968.802			

Appendix 308: ANOVA for cumulative CO_2 evolution during 5 days incubation at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.862	0.931	0.0072	
MP (A)	2	35559.509	17779.754	137.856	0.0002 ***
Error	4	515.894	128.973		
Fertilizer (B)	5	45718.46	9143.692	319.5399	0.0000 ***
A x B	10	1086.841	108.684	3.7981	0.0022
Error	30	858.455	28.615		
Total	53	83741.02			

Appendix 309: ANOVA for cumulative CO_2 evolution during 10 days incubation at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	83.311	41.655	4.392	0.0979
MP (A)	2	45305.303	22652.652	2388.4365	0.0000 ***
Error	4	37.937	9.484		
Fertilizer (B)	5	71066.768	14213.354	124.6124	0.0000 ***
A x B	10	583.501	58.35	0.5116	
Error	30	3421.815	114.061		
Total	53	120498.636			

Appendix 310: ANOVA for cumulative CO_2 evolution during 15 days incubation at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	348.301	174.15	0.9846	
MP (A)	2	49916.437	24958.219	141.1104	0.0002 ***
Error	4	707.481	176.87		
Fertilizer (B)	5	86160.121	17232.024	230.3387	0.0000 ***
A x B	10	879.54	87.954	1.1757	0.3446
Error	30	2244.35	74.812		
Total	53	140256.23			

Appendix 311: ANOVA for microbial biomass C at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	5.768	2.884	0.035	
MP (A)	2	102821.851	51410.926	624.4371	0.0000 ***
Error	4	329.327	82.332		
Fertilizer (B)	5	69506.933	13901.387	323.3842	0.0000 ***
A x B	10	436.401	43.64	1.0152	0.4540
Error	30	1289.616	42.987		
Total	53	174389.896			

Appendix 312: ANOVA for microbial biomass C at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	71.896	35.948	0.5836	
MP (A)	2	96849.135	48424.567	786.0936	0.0000 ***
Error	4	246.406	61.602		
Fertilizer (B)	5	64259.518	12851.904	282.1923	0.0000 ***
A x B	10	590.152	59.015	1.2958	0.2770
Error	30	1366.292	45.543		
Total	53	163383.4			

Appendix 313: ANOVA for microbial biomass N at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.078	0.039	0.0629	
MP (A)	2	498.908	249.454	403.753	0.0000 ***
Error	4	2.471	0.618		
Fertilizer (B)	5	2013.612	402.722	697.1866	0.0000 ***
A x B	10	5.724	0.572	0.9909	
Error	30	17.329	0.578		
Total	53	2538.121			

Appendix 314: ANOVA for microbial biomass N at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	3.201	1.6	10.0536	0.0275
MP (A)	2	490.471	245.235	1540.5672	0.0000 ***
Error	4	0.637	0.159		
Fertilizer (B)	5	2029.782	405.956	1015.8381	0.0000 ***
A x B	10	3.265	0.327	0.8171	
Error	30	11.989	0.4		
Total	53	2539.345			

Appendix 315: ANOVA for mineralizable C at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	26.596	13.298	1.3758	0.3510
MP (A)	2	3680.175	1840.087	190.3797	0.0001 ***
Error	4	38.661	9.665		
Fertilizer (B)	5	5373.546	1074.709	118.3078	0.0000 ***
A x B	10	77.538	7.754	0.8536	
Error	30	272.52	9.084		
Total	53	9469.037			

Appendix 316: ANOVA for mineralizable C at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	6.225	3.113	4.4112	0.0973
MP (A)	2	3369.604	1684.802	2387.7433	0.0000 ***
Error	4	2.822	0.706		
Fertilizer (B)	5	5286.093	1057.219	124.5748	0.0000 ***
A x B	10	43.376	4.338	0.5111	
Error	30	254.599	8.487		
Total	53	8962.719			

Appendix 317: ANOVA for mineralizable N at surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	3.021	1.51	1.6668	0.2975
MP (A)	2	347.787	173.894	191.897	0.0001 ***
Error	4	3.625	0.906		
Fertilizer (B)	5	1497.971	299.594	631.7311	0.0000 ***
A x B	10	9.437	0.944	1.9899	0.0710
Error	30	14.227	0.474		
Total	53	1876.068			

Appendix 318: ANOVA for mineralizable N at sub-surface soil of Kotlai

S.O.V.	DF	SS	MS	F	P-value
Replication	2	2.498	1.249	1.1719	0.3976
MP (A)	2	335.869	167.935	157.5602	0.0002 ***
Error	4	4.263	1.066		
Fertilizer (B)	5	1527.769	305.554	447.0208	0.0000 ***
A x B	10	3.288	0.329	0.4811	
Error	30	20.506	0.684		
Total	53	1894.194			

Appendix 319: ANOVA for soil pH combined over sites at 0-20 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	10.506	5.253	957.3297	0.0000 ***
R(L)	6	0.074	0.012	2.2377	0.1108
MP (A)	2	0.021	0.01	1.8855	0.1941 ns
L x A	4	0.025	0.006	1.1564	0.3774
Error	12	0.066	0.005		
Fertilizer (B)	5	0.006	0.001	0.1706	
L x B	10	0.054	0.005	0.7558	
A x B	10	0.031	0.003	0.439	
L x A x B	20	0.139	0.007	0.9692	
Error	90	0.645	0.007		
Total	161	11.567			

Appendix 320: ANOVA for soil pH combined over sites at 0-20 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	11.162	5.581	891.0096	0.0000 ***
R(L)	6	0.088	0.015	2.3535	0.0976
MP (A)	2	0.163	0.081	12.9864	0.0010 ***
L x A	4	0.034	0.009	1.3654	0.3030
Error	12	0.075	0.006		
Fertilizer (B)	5	0.096	0.019	1.8552	0.1101 ns
L x B	10	0.059	0.006	0.5675	
A x B	10	0.043	0.004	0.4112	
L x A x B	20	0.162	0.008	0.7796	
Error	90	0.934	0.01		
Total	161	12.816			

Appendix 321: ANOVA for soil pH combined over sites at 0-20 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	11.304	5.652	351.845	0.0000 ***
R(L)	6	0.09	0.015	0.9388	
MP (A)	2	0.459	0.23	14.2872	0.0007 ***
L x A	4	0.053	0.013	0.8222	
Error	12	0.193	0.016		
Fertilizer (B)	5	0.554	0.111	10.1483	0.0000 ***
L x B	10	0.085	0.009	0.7805	
A x B	10	0.058	0.006	0.5297	
L x A x B	20	0.237	0.012	1.0873	0.3766
Error	90	0.982	0.011		
Total	161	14.015			

Appendix 322: ANOVA for soil pH combined over sites at 0-20 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	11.291	5.646	294.8993	0.0000 ***
R(L)	6	0.029	0.005	0.2558	
MP (A)	2	0.76	0.38	19.8471	0.0002 ***
L x A	4	0.053	0.013	0.6962	
Error	12	0.23	0.019		
Fertilizer (B)	5	1.155	0.231	18.1304	0.0000 ***
L x B	10	0.086	0.009	0.6758	
A x B	10	0.079	0.008	0.6192	
L x A x B	20	0.297	0.015	1.166	0.3021
Error	90	1.147	0.013		
Total	161	15.128			

Appendix 323: ANOVA for soil pH combined over sites at 20-45 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	13.838	6.919	1918.6792	0.0000 ***
R(L)	6	0.052	0.009	2.4091	0.0919
MP (A)	2	0.037	0.018	5.1236	0.0246 *
L x A	4	0.028	0.007	1.9154	0.1725
Error	12	0.043	0.004		
Fertilizer (B)	5	0.04	0.008	1.1836	0.3235 ns
L x B	10	0.039	0.004	0.5726	
A x B	10	0.088	0.009	1.3129	0.2358
L x A x B	20	0.142	0.007	1.0582	0.4066
Error	90	0.606	0.007		
Total	161	14.913			

Appendix 324: ANOVA for soil pH combined over sites at 20-45 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	14.037	7.019	1874.7421	0.0000 ***
R(L)	6	0.118	0.02	5.2495	0.0072
MP (A)	2	0.011	0.005	1.4325	0.2768 ns
L x A	4	0.035	0.009	2.3241	0.1158
Error	12	0.045	0.004		
Fertilizer (B)	5	0.27	0.054	5.6383	0.0001 ***
L x B	10	0.06	0.006	0.6267	
A x B	10	0.08	0.008	0.8341	
L x A x B	20	0.167	0.008	0.8731	
Error	90	0.862	0.01		
Total	161	15.685			

Appendix 325: ANOVA for soil pH combined over sites at 20-45 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	13.514	6.757	1225.2093	0.0000 ***
R(L)	6	0.086	0.014	2.6095	0.0742
MP (A)	2	0.037	0.019	3.3715	0.0689 ns
L x A	4	0.056	0.014	2.5478	0.0939
Error	12	0.066	0.006		
Fertilizer (B)	5	0.559	0.112	11.036	0.0000 ***
L x B	10	0.077	0.008	0.7624	
A x B	10	0.15	0.015	1.4776	0.1608
L x A x B	20	0.189	0.009	0.9327	
Error	90	0.912	0.01		
Total	161	15.647			

Appendix 326: ANOVA for soil pH combined over sites at 20-45 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	13.851	6.925	590.3355	0.0000 ***
R(L)	6	0.108	0.018	1.5283	0.2501
MP (A)	2	0.234	0.117	9.9662	0.0028 ***
L x A	4	0.032	0.008	0.6762	
Error	12	0.141	0.012		
Fertilizer (B)	5	1.218	0.244	21.9184	0.0000 ***
L x B	10	0.079	0.008	0.7083	
A x B	10	0.238	0.024	2.1441	0.0287
L x A x B	20	0.214	0.011	0.9638	
Error	90	1	0.011		
Total	161	17.114			

Appendix 327: ANOVA for soil electrical conductivity combined over sites at 0-20 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.141	0.07	1.9022	0.1916 ns
R(L)	6	0.036	0.006	0.1606	
MP (A)	2	0.027	0.014	0.3661	
L x A	4	0.1	0.025	0.677	
Error	12	0.444	0.037		
Fertilizer (B)	5	0.074	0.015	0.511	
L x B	10	0.576	0.058	1.9867	0.0439
A x B	10	0.326	0.033	1.1246	0.3530
L x A x B	20	1.076	0.054	1.8541	0.0261
Error	90	2.611	0.029		
Total	161	5.411			

Appendix 328: ANOVA for soil electrical conductivity combined over sites at 0-20 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.119	0.059	1.5925	0.2435 ns
R(L)	6	0.08	0.013	0.3594	
MP (A)	2	0.035	0.017	0.4645	
L x A	4	0.138	0.035	0.9271	
Error	12	0.447	0.037		
Fertilizer (B)	5	0.02	0.004	0.1381	
L x B	10	0.559	0.056	1.9069	0.0542
A x B	10	0.326	0.033	1.113	0.3614
L x A x B	20	0.971	0.049	1.6561	0.0566
Error	90	2.64	0.029		
Total	161	5.336			

Appendix 329: ANOVA for soil electrical conductivity combined over sites at 0-20 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.153	0.076	2.2454	0.1485 ns
R(L)	6	0.069	0.012	0.3386	
MP (A)	2	0.052	0.026	0.7634	
L x A	4	0.149	0.037	1.0979	0.4014
Error	12	0.408	0.034		
Fertilizer (B)	5	0.089	0.018	0.5018	
L x B	10	0.626	0.063	1.7638	0.0788
A x B	10	0.409	0.041	1.1531	0.3330
L x A x B	20	1.309	0.065	1.8442	0.0271
Error	90	3.193	0.035		
Total	161	6.456			

Appendix 330: ANOVA for soil electrical conductivity combined over sites at 0-20 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.149	0.075	1.9454	0.1854 ns
R(L)	6	0.038	0.006	0.1647	
MP (A)	2	0.091	0.046	1.1889	0.3380 ns
L x A	4	0.103	0.026	0.6712	
Error	12	0.46	0.038		
Fertilizer (B)	5	0.105	0.021	0.511	
L x B	10	0.707	0.071	1.726	0.0868
A x B	10	0.451	0.045	1.0995	0.3713
L x A x B	20	1.423	0.071	1.7361	0.0415
Error	90	3.688	0.041		
Total	161	7.214			

Appendix 331: ANOVA for soil electrical conductivity combined over sites at 20-45 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.031	0.015	0.966	
R(L)	6	0.277	0.046	2.8978	0.0552
MP (A)	2	0.135	0.068	4.2335	0.0406 *
L x A	4	0.067	0.017	1.0467	0.4236
Error	12	0.191	0.016		
Fertilizer (B)	5	0.237	0.047	1.1399	0.3453 ns
L x B	10	0.405	0.04	0.9746	
A x B	10	0.472	0.047	1.1371	0.3441
L x A x B	20	0.606	0.03	0.7296	
Error	90	3.736	0.042		
Total	161	6.157			

Appendix 332: ANOVA for soil electrical conductivity combined over sites at 20-45 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.044	0.022	1.0003	0.3965 ns
R(L)	6	0.389	0.065	2.9337	0.0532
MP (A)	2	0.078	0.039	1.769	0.2122 ns
L x A	4	0.047	0.012	0.5375	
Error	12	0.265	0.022		
Fertilizer (B)	5	0.361	0.072	1.6093	0.1657 ns
L x B	10	0.415	0.041	0.9237	
A x B	10	0.531	0.053	1.1823	0.3133
L x A x B	20	0.631	0.032	0.7029	
Error	90	4.04	0.045		
Total	161	6.801			

Appendix 333: ANOVA for soil electrical conductivity combined over sites at 20-45 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.049	0.025	0.9028	
R(L)	6	0.453	0.075	2.7702	0.0628
MP (A)	2	0.047	0.024	0.8689	
L x A	4	0.071	0.018	0.6532	
Error	12	0.327	0.027		
Fertilizer (B)	5	0.368	0.074	1.5202	0.1914 ns
L x B	10	0.426	0.043	0.8793	
A x B	10	0.691	0.069	1.4282	0.1808
L x A x B	20	0.654	0.033	0.6753	
Error	90	4.357	0.048		
Total	161	7.444			

Appendix 334: ANOVA for soil electrical conductivity combined over sites at 20-45 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.059	0.03	0.8558	
R(L)	6	0.501	0.083	2.4163	0.0912
MP (A)	2	0.065	0.032	0.9393	
L x A	4	0.103	0.026	0.7471	
Error	12	0.415	0.035		
Fertilizer (B)	5	0.39	0.078	1.4596	0.2110 ns
L x B	10	0.534	0.053	0.9983	
A x B	10	0.714	0.071	1.3349	0.2243
L x A x B	20	0.601	0.03	0.5619	
Error	90	4.813	0.053		
Total	161	8.195			

Appendix 335: ANOVA for soil organic matter combined over sites at 0-20 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	369.483	184.741	598.3822	0.0000 ***
R(L)	6	1.191	0.198	0.6428	
MP (A)	2	49.111	24.556	79.5367	0.0000 ***
L x A	4	0.28	0.07	0.227	
Error	12	3.705	0.309		
Fertilizer (B)	5	1.303	0.261	1.1771	0.3267 ns
L x B	10	2.174	0.217	0.9822	
A x B	10	3.577	0.358	1.6156	0.1148
L x A x B	20	4.751	0.238	1.0731	0.3910
Error	90	19.924	0.221		
Total	161	455.5			

Appendix 336: ANOVA for soil organic matter combined over sites at 0-20 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	414.092	207.046	651.2909	0.0000 ***
R(L)	6	1.563	0.26	0.8194	
MP (A)	2	117.207	58.603	184.3446	0.0000 ***
L x A	4	0.697	0.174	0.5483	
Error	12	3.815	0.318		
Fertilizer (B)	5	19.038	3.808	14.5769	0.0000 ***
L x B	10	3.961	0.396	1.5164	0.1465
A x B	10	2.893	0.289	1.1076	0.3653
L x A x B	20	5.394	0.27	1.0325	0.4342
Error	90	23.509	0.261		
Total	161	592.169			

Appendix 337: ANOVA for soil organic matter combined over sites at 0-20 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	494.279	247.14	696.2894	0.0000 ***
R(L)	6	1.547	0.258	0.7266	
MP (A)	2	229.223	114.611	322.9051	0.0000 ***
L x A	4	1.58	0.395	1.113	0.3951
Error	12	4.259	0.355		
Fertilizer (B)	5	71.522	14.304	51.6197	0.0000 ***
L x B	10	5.482	0.548	1.9783	0.0449
A x B	10	3.554	0.355	1.2826	0.2522
L x A x B	20	5.538	0.277	0.9993	
Error	90	24.94	0.277		
Total	161	841.926			

Appendix 338: ANOVA for soil organic matter combined over sites at 0-20 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	554.014	277.007	734.515	0.0000 ***
R(L)	6	1.606	0.268	0.7096	
MP (A)	2	385.166	192.583	510.6548	0.0000 ***
L x A	4	3.413	0.853	2.2625	0.1229
Error	12	4.526	0.377		
Fertilizer (B)	5	156.471	31.294	109.5527	0.0000 ***
L x B	10	6.714	0.671	2.3505	0.0162
A x B	10	4.574	0.457	1.6013	0.1189
L x A x B	20	5.971	0.299	1.0452	0.4204
Error	90	25.709	0.286		
Total	161	1148.164			

Appendix 339: ANOVA for soil organic matter combined over sites at 20-45 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	325.486	162.743	862.9909	0.0000 ***
R(L)	6	1.366	0.228	1.2072	0.3666
MP (A)	2	59.712	29.856	158.3188	0.0000 ***
L x A	4	1.549	0.387	2.0532	0.1505
Error	12	2.263	0.189		
Fertilizer (B)	5	1.313	0.263	1.0977	0.3673 ns
L x B	10	1.703	0.17	0.7118	
A x B	10	2.708	0.271	1.1321	0.3476
L x A x B	20	2.265	0.113	0.4733	
Error	90	21.531	0.239		
Total	161	419.895			

Appendix 340: ANOVA for soil organic matter combined over sites at 20-45 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	343.438	171.719	541.1105	0.0000 ***
R(L)	6	1.172	0.195	0.6154	
MP (A)	2	92.468	46.234	145.6894	0.0000 ***
L x A	4	1.239	0.31	0.9757	
Error	12	3.808	0.317		
Fertilizer (B)	5	12.718	2.544	9.8927	0.0000 ***
L x B	10	2.64	0.264	1.0269	0.4276
A x B	10	2.849	0.285	1.1079	0.3651
L x A x B	20	2.405	0.12	0.4677	
Error	90	23.14	0.257		
Total	161	485.876			

Appendix 341: ANOVA for soil organic matter combined over sites at 20-45 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	379.651	189.825	808.7238	0.0000 ***
R(L)	6	1.254	0.209	0.8907	
MP (A)	2	187.743	93.872	399.9262	0.0000 ***
L x A	4	1.475	0.369	1.5707	0.2448
Error	12	2.817	0.235		
Fertilizer (B)	5	57.976	11.595	41.0279	0.0000 ***
L x B	10	4.166	0.417	1.4741	0.1621
A x B	10	4.018	0.402	1.4219	0.1835
L x A x B	20	3.097	0.155	0.5479	
Error	90	25.436	0.283		
Total	161	667.633			

Appendix 342: ANOVA for soil organic matter combined over sites at 20-45 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	404.588	202.294	708.3464	0.0000 ***
R(L)	6	2.32	0.387	1.3537	0.3078
MP (A)	2	253.258	126.629	443.4003	0.0000 ***
L x A	4	2.051	0.513	1.7959	0.1945
Error	12	3.427	0.286		
Fertilizer (B)	5	140.082	28.016	91.6014	0.0000 ***
L x B	10	7.747	0.775	2.5331	0.0098
A x B	10	5.229	0.523	1.7095	0.0906
L x A x B	20	3.455	0.173	0.5648	
Error	90	27.527	0.306		
Total	161	849.684			

Appendix 343: ANOVA for AB-DTPA extractable K combined over sites at 0-20 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	387.843	193.922	9.5766	0.0033 ***
R(L)	6	68.82	11.47	0.5664	
MP (A)	2	79.773	39.887	1.9697	0.1821 ns
L x A	4	154.462	38.616	1.907	0.1740
Error	12	242.996	20.25		
Fertilizer (B)	5	79.168	15.834	0.7428	
L x B	10	290.545	29.054	1.363	0.2104
A x B	10	160.019	16.002	0.7507	
L x A x B	20	139.292	6.965	0.3267	
Error	90	1918.558	21.317		
Total	161	3521.476			

Appendix 344: ANOVA for AB-DTPA extractable K combined over sites at 0-20 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	488.258	244.129	7.3274	0.0083 ***
R(L)	6	78.529	13.088	0.3928	
MP (A)	2	662.216	331.108	9.938	0.0028 ***
L x A	4	185.098	46.275	1.3889	0.2957
Error	12	399.807	33.317		
Fertilizer (B)	5	1754.19	350.838	14.5723	0.0000 ***
L x B	10	532.672	53.267	2.2125	0.0238
A x B	10	128.05	12.805	0.5319	
L x A x B	20	225.414	11.271	0.4681	
Error	90	2166.804	24.076		
Total	161	6621.038			

Appendix 345: ANOVA for AB-DTPA extractable K combined over sites at 0-20 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	686.763	343.382	8.0457	0.0061 ***
R(L)	6	84.62	14.103	0.3305	
MP (A)	2	1216.687	608.343	14.254	0.0007 ***
L x A	4	261.054	65.264	1.5292	0.2555
Error	12	512.145	42.679		
Fertilizer (B)	5	5843.576	1168.715	42.6111	0.0000 ***
L x B	10	719.183	71.918	2.6221	0.0076
A x B	10	277.926	27.793	1.0133	0.4387
L x A x B	20	447.251	22.363	0.8153	
Error	90	2468.474	27.427		
Total	161	12517.68			

Appendix 346: ANOVA for AB-DTPA extractable K combined over sites at 0-20 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	929.824	464.912	9.2708	0.0037 ***
R(L)	6	125.669	20.945	0.4177	
MP (A)	2	2553.114	1276.557	25.4559	0.0000 ***
L x A	4	231.563	57.891	1.1544	0.3782
Error	12	601.773	50.148		
Fertilizer (B)	5	13093.236	2618.647	90.163	0.0000 ***
L x B	10	987.046	98.705	3.3985	0.0008
A x B	10	280.895	28.09	0.9672	
L x A x B	20	571.841	28.592	0.9845	
Error	90	2613.912	29.043		
Total	161	21988.873			

Appendix 347: ANOVA for AB-DTPA extractable K combined over sites at 20-45 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	39.9	19.95	0.4523	
R(L)	6	91.334	15.222	0.3451	
MP (A)	2	8.775	4.387	0.0995	
L x A	4	56.938	14.235	0.3227	
Error	12	529.25	44.104		
Fertilizer (B)	5	199.558	39.912	1.9146	0.0996 ns
L x B	10	164.135	16.414	0.7874	
A x B	10	285.581	28.558	1.37	0.2071
L x A x B	20	348.337	17.417	0.8355	
Error	90	1876.122	20.846		
Total	161	3599.931			

Appendix 348: ANOVA for AB-DTPA extractable K combined over sites at 20-45 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	129.335	64.667	1.0395	0.3834 ns
R(L)	6	111.229	18.538	0.298	
MP (A)	2	333.769	166.885	2.6826	0.1089 ns
L x A	4	37.834	9.458	0.152	
Error	12	746.518	62.21		
Fertilizer (B)	5	1380.782	276.156	11.465	0.0000 ***
L x B	10	235.227	23.523	0.9766	
A x B	10	452.308	45.231	1.8778	0.0586
L x A x B	20	299.66	14.983	0.622	
Error	90	2167.814	24.087		
Total	161	5894.475			

Appendix 349: ANOVA for AB-DTPA extractable K combined over sites at 20-45 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	114.156	57.078	0.7439	
R(L)	6	87.098	14.516	0.1892	
MP (A)	2	1059.038	529.519	6.9014	0.0101 *
L x A	4	24.122	6.03	0.0786	
Error	12	920.718	76.727		
Fertilizer (B)	5	5303.497	1060.699	36.262	0.0000 ***
L x B	10	325.739	32.574	1.1136	0.3609
A x B	10	542.398	54.24	1.8543	0.0623
L x A x B	20	339.827	16.991	0.5809	
Error	90	2632.59	29.251		
Total	161	11349.184			

Appendix 350: ANOVA for AB-DTPA extractable K combined over sites at 20-45 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	68.486	34.243	0.3711	
R(L)	6	154.464	25.744	0.279	
MP (A)	2	2360.753	1180.376	12.7918	0.0011 ***
L x A	4	83.173	20.793	0.2253	
Error	12	1107.313	92.276		
Fertilizer (B)	5	12894.055	2578.811	73.9026	0.0000 ***
L x B	10	430.25	43.025	1.233	0.2812
A x B	10	774.476	77.448	2.2195	0.0233
L x A x B	20	388.312	19.416	0.5564	
Error	90	3140.523	34.895		
Total	161	21401.804			

Appendix 351: ANOVA for AB-DTPA extractable P combined over sites at 0-20 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	4.503	2.251	408.9104	0.0000 ***
R(L)	6	0.029	0.005	0.8883	
MP (A)	2	0.003	0.002	0.2857	
L x A	4	0.015	0.004	0.6669	
Error	12	0.066	0.006		
Fertilizer (B)	5	0.059	0.012	2.2654	0.0546 ns
L x B	10	0.064	0.006	1.2165	0.2914
A x B	10	0.051	0.005	0.9667	
L x A x B	20	0.048	0.002	0.4595	
Error	90	0.471	0.005		
Total	161	5.309			

Appendix 352: ANOVA for AB-DTPA extractable P combined over sites at 0-20 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	4.899	2.449	594.01	0.0000 ***
R(L)	6	0.028	0.005	1.1442	0.3951
MP (A)	2	0.115	0.058	14.0018	0.0007 ***
L x A	4	0.014	0.003	0.8368	
Error	12	0.049	0.004		
Fertilizer (B)	5	0.871	0.174	29.409	0.0000 ***
L x B	10	0.04	0.004	0.67	
A x B	10	0.044	0.004	0.7501	
L x A x B	20	0.049	0.002	0.4157	
Error	90	0.533	0.006		
Total	161	6.643			

Appendix 353: ANOVA for AB-DTPA extractable P combined over sites at 0-20 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	5.343	2.671	589.9885	0.0000 ***
R(L)	6	0.028	0.005	1.0344	0.4498
MP (A)	2	0.45	0.225	49.7179	0.0000 ***
L x A	4	0.016	0.004	0.8858	
Error	12	0.054	0.005		
Fertilizer (B)	5	2.703	0.541	83.6202	0.0000 ***
L x B	10	0.054	0.005	0.8293	
A x B	10	0.039	0.004	0.5984	
L x A x B	20	0.075	0.004	0.5822	
Error	90	0.582	0.006		
Total	161	9.344			

Appendix 354: ANOVA for AB-DTPA extractable P combined over sites at 0-20 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	5.868	2.934	571.5618	0.0000 ***
R(L)	6	0.037	0.006	1.1973	0.3709
MP (A)	2	0.906	0.453	88.2406	0.0000 ***
L x A	4	0.015	0.004	0.7547	
Error	12	0.062	0.005		
Fertilizer (B)	5	6.839	1.368	185.9076	0.0000 ***
L x B	10	0.072	0.007	0.972	
A x B	10	0.059	0.006	0.802	
L x A x B	20	0.089	0.004	0.607	
Error	90	0.662	0.007		
Total	161	14.608			

Appendix 355: ANOVA for AB-DTPA extractable P combined over sites at 20-45 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	4.437	2.219	458.0533	0.0000 ***
R(L)	6	0.031	0.005	1.06	0.4364
MP (A)	2	0.006	0.003	0.6707	
L x A	4	0.043	0.011	2.2261	0.1272
Error	12	0.058	0.005		
Fertilizer (B)	5	0.045	0.009	1.7123	0.1398 ns
L x B	10	0.033	0.003	0.6343	
A x B	10	0.031	0.003	0.6025	
L x A x B	20	0.101	0.005	0.9659	
Error	90	0.469	0.005		
Total	161	5.254			

Appendix 356: ANOVA for AB-DTPA extractable P combined over sites at 20-45 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	4.976	2.488	592.8616	0.0000 ***
R(L)	6	0.036	0.006	1.4201	0.2844
MP (A)	2	0.069	0.034	8.2161	0.0057 ***
L x A	4	0.062	0.016	3.7008	0.0347
Error	12	0.05	0.004		
Fertilizer (B)	5	1.133	0.227	40.9486	0.0000 ***
L x B	10	0.054	0.005	0.9834	
A x B	10	0.036	0.004	0.6522	
L x A x B	20	0.1	0.005	0.8999	
Error	90	0.498	0.006		
Total	161	7.014			

Appendix 357: ANOVA for AB-DTPA extractable P combined over sites at 20-45 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	5.415	2.708	664.2164	0.0000 ***
R(L)	6	0.042	0.007	1.7037	0.2034
MP (A)	2	0.344	0.172	42.2209	0.0000 ***
L x A	4	0.084	0.021	5.1518	0.0119
Error	12	0.049	0.004		
Fertilizer (B)	5	2.986	0.597	96.6029	0.0000 ***
L x B	10	0.082	0.008	1.3227	0.2306
A x B	10	0.027	0.003	0.4316	
L x A x B	20	0.124	0.006	1.0024	0.4676
Error	90	0.556	0.006		
Total	161	9.709			

Appendix 358: ANOVA for AB-DTPA extractable P combined over sites at 20-45 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	5.847	2.924	631.8475	0.0000 ***
R(L)	6	0.046	0.008	1.6656	0.2127
MP (A)	2	0.755	0.378	81.6281	0.0000 ***
L x A	4	0.072	0.018	3.8646	0.0305
Error	12	0.056	0.005		
Fertilizer (B)	5	7.434	1.487	226.7462	0.0000 ***
L x B	10	0.118	0.012	1.7947	0.0728
A x B	10	0.032	0.003	0.49	
L x A x B	20	0.129	0.006	0.9816	
Error	90	0.59	0.007		
Total	161	15.079			

Appendix 359: ANOVA for mineral N combined over sites at 0-20 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	457.274	228.637	222.1687	0.0000 ***
R(L)	6	6.595	1.099	1.0681	0.4323
MP (A)	2	5.672	2.836	2.7556	0.1036 ns
L x A	4	2.587	0.647	0.6285	
Error	12	12.349	1.029		
Fertilizer (B)	5	4.266	0.853	0.8119	
L x B	10	9.819	0.982	0.9344	
A x B	10	15.621	1.562	1.4866	0.1574
L x A x B	20	23.401	1.17	1.1135	0.3506
Error	90	94.57	1.051		
Total	161	632.153			

Appendix 360: ANOVA for mineral N combined over sites at 0-20 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	453.176	226.588	232.5596	0.0000 ***
R(L)	6	7.13	1.188	1.2196	0.3612
MP (A)	2	5.311	2.655	2.7253	0.1057 ns
L x A	4	3.638	0.909	0.9334	
Error	12	11.692	0.974		
Fertilizer (B)	5	35.545	7.109	6.6253	0.0000 ***
L x B	10	10.863	1.086	1.0124	0.4394
A x B	10	15.794	1.579	1.4719	0.1630
L x A x B	20	25.02	1.251	1.1659	0.3023
Error	90	96.57	1.073		
Total	161	664.738			

Appendix 361: ANOVA for mineral N combined over sites at 0-20 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	443.19	221.595	227.9761	0.0000 ***
R(L)	6	7.174	1.196	1.23	0.3567
MP (A)	2	27.031	13.516	13.9047	0.0008 ***
L x A	4	3.901	0.975	1.0033	0.4434
Error	12	11.664	0.972		
Fertilizer (B)	5	148.839	29.768	26.6932	0.0000 ***
L x B	10	11.093	1.109	0.9947	
A x B	10	14.459	1.446	1.2966	0.2445
L x A x B	20	25.176	1.259	1.1288	0.3361
Error	90	100.367	1.115		
Total	161	792.894			

Appendix 362: ANOVA for mineral N combined over sites at 0-20 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	441.097	220.548	276.7075	0.0000 ***
R(L)	6	7.575	1.263	1.5841	0.2341
MP (A)	2	80.502	40.251	50.5003	0.0000 ***
L x A	4	3.55	0.888	1.1135	0.3949
Error	12	9.565	0.797		
Fertilizer (B)	5	349.598	69.92	57.8223	0.0000 ***
L x B	10	11.684	1.168	0.9663	
A x B	10	15.823	1.582	1.3086	0.2381
L x A x B	20	25.448	1.272	1.0523	0.4129
Error	90	108.829	1.209		
Total	161	1053.672			

Appendix 363: ANOVA for mineral N combined over sites at 20-45 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	467.608	233.804	491.8716	0.0000 ***
R(L)	6	6.461	1.077	2.2653	0.1075
MP (A)	2	0.627	0.313	0.6594	
L x A	4	3.128	0.782	1.6452	0.2268
Error	12	5.704	0.475		
Fertilizer (B)	5	0.833	0.167	0.1843	
L x B	10	19.729	1.973	2.1826	0.0258
A x B	10	8.76	0.876	0.9692	
L x A x B	20	31.279	1.564	1.7302	0.0425
Error	90	81.352	0.904		
Total	161	625.48			

Appendix 364: ANOVA for mineral N combined over sites at 20-45 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	481.566	240.783	477.6484	0.0000 ***
R(L)	6	7.066	1.178	2.3363	0.0994
MP (A)	2	0.38	0.19	0.3771	
L x A	4	3.208	0.802	1.5911	0.2397
Error	12	6.049	0.504		
Fertilizer (B)	5	50.081	10.016	11.7243	0.0000 ***
L x B	10	20.559	2.056	2.4065	0.0139
A x B	10	9.898	0.99	1.1586	0.3292
L x A x B	20	31.521	1.576	1.8448	0.0270
Error	90	76.888	0.854		
Total	161	687.218			

Appendix 365: ANOVA for mineral N combined over sites at 20-45 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	470.562	235.281	336.1107	0.0000 ***
R(L)	6	7.4	1.233	1.7619	0.1901
MP (A)	2	0.402	0.201	0.2875	
L x A	4	3.311	0.828	1.1826	0.3671
Error	12	8.4	0.7		
Fertilizer (B)	5	183.885	36.777	42.8328	0.0000 ***
L x B	10	19.983	1.998	2.3274	0.0173
A x B	10	9.679	0.968	1.1272	0.3511
L x A x B	20	33.682	1.684	1.9614	0.0169
Error	90	77.276	0.859		
Total	161	814.581			

Appendix 366: ANOVA for mineral N combined over sites at 20-45 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	466.085	233.042	330.1664	0.0000 ***
R(L)	6	8.505	1.417	2.0082	0.1432
MP (A)	2	22.914	11.457	16.2317	0.0004 ***
L x A	4	3.777	0.944	1.3377	0.3119
Error	12	8.47	0.706		
Fertilizer (B)	5	400.55	80.11	92.8659	0.0000 ***
L x B	10	22.358	2.236	2.5918	0.0083
A x B	10	10.418	1.042	1.2077	0.2969
L x A x B	20	34.256	1.713	1.9855	0.0153
Error	90	77.638	0.863		
Total	161	1054.971			

Appendix 367: ANOVA for soil bulk density combined over sites at 0-20 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.298	0.149	176.0788	0.0000 ***
R(L)	6	0.002	0	0.4083	
MP (A)	2	0.003	0.001	1.5188	0.2582 ns
L x A	4	0.003	0.001	0.8702	
Error	12	0.01	0.001		
Fertilizer (B)	5	0.008	0.002	1.6636	0.1515 ns
L x B	10	0.012	0.001	1.2646	0.2625
A x B	10	0.006	0.001	0.6115	
L x A x B	20	0.022	0.001	1.1565	0.3105
Error	90	0.084	0.001		
Total	161	0.447			

Appendix 368: ANOVA for soil bulk density combined over sites at 0-20 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.311	0.156	198.3041	0.0000 ***
R(L)	6	0.005	0.001	0.9764	
MP (A)	2	0.019	0.01	12.191	0.0013 ***
L x A	4	0.004	0.001	1.27	0.3349
Error	12	0.009	0.001		
Fertilizer (B)	5	0.039	0.008	7.4136	0.0000 ***
L x B	10	0.011	0.001	1.0937	0.3756
A x B	10	0.01	0.001	0.9477	
L x A x B	20	0.026	0.001	1.236	0.2450
Error	90	0.095	0.001		
Total	161	0.529			

Appendix 369: ANOVA for soil bulk density combined over sites at 0-20 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.321	0.161	154.4801	0.0000 ***
R(L)	6	0.005	0.001	0.8779	
MP (A)	2	0.072	0.036	34.815	0.0000 ***
L x A	4	0.004	0.001	1.0086	0.4409
Error	12	0.012	0.001		
Fertilizer (B)	5	0.094	0.019	15.175	0.0000 ***
L x B	10	0.014	0.001	1.1528	0.3332
A x B	10	0.01	0.001	0.7831	
L x A x B	20	0.027	0.001	1.0927	0.3712
Error	90	0.112	0.001		
Total	161	0.673			

Appendix 370: ANOVA for soil bulk density combined over sites at 0-20 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.342	0.171	165.3395	0.0000 ***
R(L)	6	0.006	0.001	0.9024	
MP (A)	2	0.182	0.091	87.9469	0.0000 ***
L x A	4	0.005	0.001	1.1439	0.3824
Error	12	0.012	0.001		
Fertilizer (B)	5	0.184	0.037	23.7028	0.0000 ***
L x B	10	0.013	0.001	0.8306	
A x B	10	0.016	0.002	1.0279	0.4268
L x A x B	20	0.033	0.002	1.0539	0.4112
Error	90	0.14	0.002		
Total	161	0.931			

Appendix 371: ANOVA for soil bulk density combined over sites at 20-45 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.268	0.134	156.8672	0.0000 ***
R(L)	6	0.005	0.001	0.8842	
MP (A)	2	0.001	0.001	0.594	
L x A	4	0.003	0.001	0.8279	
Error	12	0.01	0.001		
Fertilizer (B)	5	0.003	0.001	0.6692	
L x B	10	0.013	0.001	1.6042	0.1181
A x B	10	0.007	0.001	0.849	
L x A x B	20	0.019	0.001	1.2446	0.2385
Error	90	0.07	0.001		
Total	161	0.398			

Appendix 372: ANOVA for soil bulk density combined over sites at 20-45 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.264	0.132	99.7836	0.0000 ***
R(L)	6	0.007	0.001	0.8338	
MP (A)	2	0.003	0.002	1.2737	0.3151 ns
L x A	4	0.004	0.001	0.7927	
Error	12	0.016	0.001		
Fertilizer (B)	5	0.019	0.004	4.3671	0.0013 ***
L x B	10	0.017	0.002	1.9177	0.0527
A x B	10	0.011	0.001	1.3219	0.2310
L x A x B	20	0.019	0.001	1.1101	0.3539
Error	90	0.078	0.001		
Total	161	0.438			

Appendix 373: ANOVA for soil bulk density combined over sites at 20-45 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.262	0.131	97.1366	0.0000 ***
R(L)	6	0.009	0.002	1.1194	0.4069
MP (A)	2	0.038	0.019	14.0014	0.0007 ***
L x A	4	0.002	0.001	0.395	
Error	12	0.016	0.001		
Fertilizer (B)	5	0.072	0.014	14.7063	0.0000 ***
L x B	10	0.02	0.002	2.0027	0.0420
A x B	10	0.009	0.001	0.9064	
L x A x B	20	0.024	0.001	1.2488	0.2355
Error	90	0.088	0.001		
Total	161	0.54			

Appendix 374: ANOVA for soil bulk density combined over sites at 20-45 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.27	0.135	89.9102	0.0000 ***
R(L)	6	0.009	0.001	0.9981	
MP (A)	2	0.075	0.037	24.9879	0.0001 ***
L x A	4	0.004	0.001	0.5879	
Error	12	0.018	0.002		
Fertilizer (B)	5	0.147	0.029	24.5287	0.0000 ***
L x B	10	0.021	0.002	1.7802	0.0755
A x B	10	0.009	0.001	0.7841	
L x A x B	20	0.029	0.001	1.2028	0.2710
Error	90	0.108	0.001		
Total	161	0.689			

Appendix 375: ANOVA for AWHC combined over sites at 0-20 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	11112.207	5556.104	234.9646	0.0000 ***
R(L)	6	65.849	10.975	0.4641	
MP (A)	2	61.026	30.513	1.2904	0.3107 ns
L x A	4	87.327	21.832	0.9233	
Error	12	283.759	23.647		
Fertilizer (B)	5	128.625	25.725	1.3588	0.2474 ns
L x B	10	362.245	36.224	1.9133	0.0533
A x B	10	457.232	45.723	2.415	0.0136
L x A x B	20	351.404	17.57	0.928	
Error	90	1703.939	18.933		
Total	161	14613.613			

Appendix 376: ANOVA for AWHC combined over sites at 0-20 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	11088.996	5544.498	234.2338	0.0000 ***
R(L)	6	68.424	11.404	0.4818	
MP (A)	2	73.349	36.674	1.5494	0.2520 ns
L x A	4	92.088	23.022	0.9726	
Error	12	284.049	23.671		
Fertilizer (B)	5	297.36	59.472	3.1053	0.0124 *
L x B	10	361.916	36.192	1.8897	0.0568
A x B	10	457.027	45.703	2.3863	0.0147
L x A x B	20	352.694	17.635	0.9208	
Error	90	1723.673	19.152		
Total	161	14799.577			

Appendix 377: ANOVA for AWHC combined over sites at 0-20 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	11091.363	5545.681	236.7696	0.0000 ***
R(L)	6	68.336	11.389	0.4863	
MP (A)	2	183.473	91.737	3.9166	0.0491 *
L x A	4	90.175	22.544	0.9625	
Error	12	281.067	23.422		
Fertilizer (B)	5	561.402	112.28	5.8145	0.0001 ***
L x B	10	364.22	36.422	1.8861	0.0573
A x B	10	444.982	44.498	2.3044	0.0185
L x A x B	20	341.992	17.1	0.8855	
Error	90	1737.93	19.31		
Total	161	15164.94			

Appendix 378: ANOVA for AWHC combined over sites at 0-20 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	11000.158	5500.079	230.2874	0.0000 ***
R(L)	6	67.365	11.228	0.4701	
MP (A)	2	388.134	194.067	8.1256	0.0059 ***
L x A	4	87.68	21.92	0.9178	
Error	12	286.603	23.884		
Fertilizer (B)	5	894.596	178.919	9.2659	0.0000 ***
L x B	10	366.581	36.658	1.8985	0.0555
A x B	10	443.933	44.393	2.2991	0.0187
L x A x B	20	342.931	17.147	0.888	
Error	90	1737.846	19.309		
Total	161	15615.827			

Appendix 379: ANOVA for AWHC combined over sites at 20-45 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	9461.363	4730.682	218.0183	0.0000 ***
R(L)	6	125.426	20.904	0.9634	
MP (A)	2	64.911	32.456	1.4958	0.2630 ns
L x A	4	13.926	3.481	0.1604	
Error	12	260.383	21.699		
Fertilizer (B)	5	230.28	46.056	2.0413	0.0803 ns
L x B	10	100.893	10.089	0.4472	
A x B	10	123.565	12.356	0.5477	
L x A x B	20	148.707	7.435	0.3296	
Error	90	2030.571	22.562		
Total	161	12560.024			

Appendix 380: ANOVA for AWHC combined over sites at 20-45 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	9504.167	4752.084	213.6706	0.0000 ***
R(L)	6	127.245	21.208	0.9536	
MP (A)	2	120.826	60.413	2.7164	0.1064 ns
L x A	4	14.234	3.558	0.16	
Error	12	266.883	22.24		
Fertilizer (B)	5	195.326	39.065	1.7049	0.1416 ns
L x B	10	104.571	10.457	0.4564	
A x B	10	122.939	12.294	0.5365	
L x A x B	20	147.781	7.389	0.3225	
Error	90	2062.258	22.914		
Total	161	12666.231			

Appendix 381: ANOVA for AWHC combined over sites at 20-45 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	9446.714	4723.357	216.0798	0.0000 ***
R(L)	6	125.225	20.871	0.9548	
MP (A)	2	240.273	120.137	5.4959	0.0202 *
L x A	4	14.644	3.661	0.1675	
Error	12	262.312	21.859		
Fertilizer (B)	5	247.437	49.487	2.1789	0.0634 ns
L x B	10	103.681	10.368	0.4565	
A x B	10	123.811	12.381	0.5451	
L x A x B	20	145.409	7.27	0.3201	
Error	90	2044.07	22.712		
Total	161	12753.576			

Appendix 382: ANOVA for AWHC combined over sites at 20-45 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	9460.807	4730.404	217.0775	0.0000 ***
R(L)	6	124.317	20.719	0.9508	
MP (A)	2	376.843	188.421	8.6466	0.0047 ***
L x A	4	17.695	4.424	0.203	
Error	12	261.496	21.791		
Fertilizer (B)	5	379.498	75.9	3.3021	0.0088 ***
L x B	10	102.904	10.29	0.4477	
A x B	10	131.796	13.18	0.5734	
L x A x B	20	140.14	7.007	0.3048	
Error	90	2068.695	22.985		
Total	161	13064.19			

Appendix 383: ANOVA for total N combined over sites at 0-20 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.822	0.411	104.2036	0.0000 ***
R(L)	6	0.02	0.003	0.8632	
MP (A)	2	0.15	0.075	18.9549	0.0002 ***
L x A	4	0.009	0.002	0.5525	
Error	12	0.047	0.004		
Fertilizer (B)	5	0.022	0.004	1.047	0.3952 ns
L x B	10	0.07	0.007	1.6693	0.1003
A x B	10	0.052	0.005	1.2431	0.2751
L x A x B	20	0.094	0.005	1.1229	0.3416
Error	90	0.376	0.004		
Total	161	1.661			

Appendix 384: ANOVA for total N combined over sites at 0-20 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.779	0.39	123.741	0.0000 ***
R(L)	6	0.035	0.006	1.8767	0.1664
MP (A)	2	0.383	0.191	60.7601	0.0000 ***
L x A	4	0.037	0.009	2.964	0.0645
Error	12	0.038	0.003		
Fertilizer (B)	5	0.063	0.013	2.6137	0.0297 *
L x B	10	0.053	0.005	1.1019	0.3695
A x B	10	0.043	0.004	0.8883	
L x A x B	20	0.077	0.004	0.8008	
Error	90	0.432	0.005		
Total	161	1.939			

Appendix 385: ANOVA for total N combined over sites at 0-20 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	2.102	1.051	258.3201	0.0000 ***
R(L)	6	0.054	0.009	2.2063	0.1147
MP (A)	2	0.669	0.335	82.2652	0.0000 ***
L x A	4	0.003	0.001	0.184	
Error	12	0.049	0.004		
Fertilizer (B)	5	0.223	0.045	14.436	0.0000 ***
L x B	10	0.028	0.003	0.9146	
A x B	10	0.033	0.003	1.0769	0.3883
L x A x B	20	0.094	0.005	1.5265	0.0917
Error	90	0.278	0.003		
Total	161	3.533			

Appendix 386: ANOVA for total N combined over sites at 0-20 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	2.049	1.024	182.6488	0.0000 ***
R(L)	6	0.006	0.001	0.178	
MP (A)	2	1.245	0.622	110.9543	0.0000 ***
L x A	4	0.031	0.008	1.3703	0.3015
Error	12	0.067	0.006		
Fertilizer (B)	5	0.524	0.105	28.3846	0.0000 ***
L x B	10	0.013	0.001	0.3635	
A x B	10	0.057	0.006	1.5345	0.1401
L x A x B	20	0.066	0.003	0.8929	
Error	90	0.332	0.004		
Total	161	4.389			

Appendix 387: ANOVA for total N combined over sites at 20-45 cm soil depth during Kharif 2006

S.O.V.	DF	SS	MS	F	P-value
Location	2	1.01	0.505	118.8811	0.0000 ***
R(L)	6	0.008	0.001	0.3284	
MP (A)	2	0.162	0.081	19.1149	0.0002 ***
L x A	4	0.01	0.003	0.6137	
Error	12	0.051	0.004		
Fertilizer (B)	5	0.017	0.003	0.7306	
L x B	10	0.065	0.006	1.4087	0.1893
A x B	10	0.051	0.005	1.1189	0.3571
L x A x B	20	0.133	0.007	1.4487	0.1211
Error	90	0.413	0.005		
Total	161	1.922			

Appendix 388: ANOVA for total N combined over sites at 20-45 cm soil depth during Rabi 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	0.817	0.408	59.2423	0.0000 ***
R(L)	6	0.06	0.01	1.4592	0.2715
MP (A)	2	0.186	0.093	13.4646	0.0009 ***
L x A	4	0.005	0.001	0.1682	
Error	12	0.083	0.007		
Fertilizer (B)	5	0.131	0.026	6.415	0.0000 ***
L x B	10	0.056	0.006	1.3744	0.2050
A x B	10	0.037	0.004	0.9026	
L x A x B	20	0.047	0.002	0.5768	
Error	90	0.367	0.004		
Total	161	1.788			

Appendix 389: ANOVA for total N combined over sites at 20-45 cm soil depth during Kharif 2007

S.O.V.	DF	SS	MS	F	P-value
Location	2	2.068	1.034	320.5441	0.0000 ***
R(L)	6	0.011	0.002	0.5836	
MP (A)	2	0.525	0.262	81.3035	0.0000 ***
L x A	4	0.004	0.001	0.3168	
Error	12	0.039	0.003		
Fertilizer (B)	5	0.19	0.038	7.6486	0.0000 ***
L x B	10	0.052	0.005	1.0489	0.4100
A x B	10	0.032	0.003	0.6384	
L x A x B	20	0.063	0.003	0.6308	
Error	90	0.448	0.005		
Total	161	3.432			

Appendix 390: ANOVA for total N combined over sites at 20-45 cm soil depth during Rabi 2008

S.O.V.	DF	SS	MS	F	P-value
Location	2	2.246	1.123	387.9443	0.0000 ***
R(L)	6	0.007	0.001	0.3803	
MP (A)	2	0.522	0.261	90.1858	0.0000 ***
L x A	4	0.015	0.004	1.3337	0.3133
Error	12	0.035	0.003		
Fertilizer (B)	5	0.432	0.086	20.1512	0.0000 ***
L x B	10	0.038	0.004	0.8744	
A x B	10	0.018	0.002	0.4179	
L x A x B	20	0.074	0.004	0.8632	
Error	90	0.386	0.004		
Total	161	3.772			

Appendix 391: ANOVA for Cumulative CO2 evolution during 2 days incubation combined over sites at the surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	16375.762	8187.881	83.7356	0.0000 ***
R(S)	6	317.369	52.895	0.5409	
MP (A)	2	67302.278	33651.139	344.1425	0.0000 ***
S x A	4	115.704	28.926	0.2958	
Error	12	1173.391	97.783		
Fertilizer (B)	5	120568.29	24113.658	636.8508	0.0000 ***
S x B	10	550.726	55.073	1.4545	0.1699
A x B	10	570.98	57.098	1.508	0.1495
S x A x B	20	1039.756	51.988	1.373	0.1572
Error	90	3407.751	37.864		
Total	161	211422.007			

Appendix 392: ANOVA for Cumulative CO2 evolution during 5 days incubation combined over sites at the surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	60130.396	30065.198	502.8961	0.0000 ***
R(S)	6	301.872	50.312	0.8416	
MP (A)	2	146363.195	73181.597	1224.0978	0.0000 ***
S x A	4	1432.476	358.119	5.9902	0.0069
Error	12	717.409	59.784		
Fertilizer (B)	5	181073.42	36214.684	477.9966	0.0000 ***
S x B	10	2185.528	218.553	2.8847	0.0036
A x B	10	608.742	60.874	0.8035	
S x A x B	20	1897.279	94.864	1.2521	0.2330
Error	90	6818.712	75.763		
Total	161	401529.03			

Appendix 393: ANOVA for Cumulative CO2 evolution during 10 days incubation combined over sites at the surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	71297.373	35648.686	324.4685	0.0000 ***
R(S)	6	1080.726	180.121	1.6394	0.2193
MP (A)	2	157181.41	78590.705	715.3197	0.0000 ***
S x A	4	274.969	68.742	0.6257	
Error	12	1318.415	109.868		
Fertilizer (B)	5	260602.082	52120.416	520.8647	0.0000 ***
S x B	10	4041.303	404.13	4.0387	0.0001
A x B	10	1056.065	105.607	1.0554	0.4049
S x A x B	20	2108.909	105.445	1.0538	0.4113
Error	90	9005.866	100.065		
Total	161	507967.118			

Appendix 394: ANOVA for Cumulative CO_2 evolution during 15 days incubation combined over sites at the surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	80390.268	40195.134	237.5266	0.0000 ***
R(S)	6	499.505	83.251	0.492	
MP (A)	2	164683.273	82341.637	486.5845	0.0000 ***
S x A	4	483.539	120.885	0.7143	
Error	12	2030.685	169.224		
Fertilizer (B)	5	270938.083	54187.617	602.7664	0.0000 ***
S x B	10	1770.143	177.014	1.9691	0.0460
A x B	10	674.199	67.42	0.75	
S x A x B	20	1567.959	78.398	0.8721	
Error	90	8090.838	89.898		
Total	161	531128.491			

Appendix 395: ANOVA for Cumulative CO_2 evolution during 2 days incubation combined over sites at the sub-surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	15954.414	7977.207	138.0674	0.0000 ***
R(S)	6	373.284	62.214	1.0768	0.4279
MP (A)	2	73874.33	36937.165	639.2988	0.0000 ***
S x A	4	198.989	49.747	0.861	
Error	12	693.331	57.778		
Fertilizer (B)	5	125087.955	25017.591	444.6424	0.0000 ***
S x B	10	580.798	58.08	1.0323	0.4233
A x B	10	362.972	36.297	0.6451	
S x A x B	20	848.609	42.43	0.7541	
Error	90	5063.807	56.265		
Total	161	223038.49			

Appendix 396: ANOVA for Cumulative CO_2 evolution during 5 days incubation combined over sites at the sub-surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	61287.496	30643.748	449.9826	0.0000 ***
R(S)	6	856.82	142.803	2.097	0.1295
MP (A)	2	129490.861	64745.43	950.7426	0.0000 ***
S x A	4	1134.031	283.508	4.1631	0.0242
Error	12	817.198	68.1		
Fertilizer (B)	5	187419.274	37483.855	586.3398	0.0000 ***
S x B	10	2750.053	275.005	4.3018	0.0001
A x B	10	974.641	97.464	1.5246	0.1436
S x A x B	20	1485.704	74.285	1.162	0.3057
Error	90	5753.569	63.929		
Total	161	391969.649			

Appendix 397: ANOVA for Cumulative CO_2 evolution during 10 days incubation combined over sites at the sub-surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	86938.673	43469.337	1000.4308	0.0000 ***
R(S)	6	651.397	108.566	2.4986	0.0835
MP (A)	2	143908.754	71954.377	1656.0036	0.0000 ***
S x A	4	1079.779	269.945	6.2127	0.0060
Error	12	521.407	43.451		
Fertilizer (B)	5	246985.415	49397.083	474.6279	0.0000 ***
S x B	10	1482.75	148.275	1.4247	0.1823
A x B	10	2075.44	207.544	1.9942	0.0430
S x A x B	20	1386.711	69.336	0.6662	
Error	90	9366.786	104.075		
Total	161	494397.112			

Appendix 398: ANOVA for Cumulative CO2 evolution during 15 days incubation combined over sites at the sub-surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	76874.348	38437.174	292.9827	0.0000 ***
R(S)	6	743.366	123.894	0.9444	
MP (A)	2	165063.844	82531.922	629.0896	0.0000 ***
S x A	4	435.602	108.9	0.8301	
Error	12	1574.312	131.193		
Fertilizer (B)	5	282855.873	56571.175	602.1036	0.0000 ***
S x B	10	983.4	98.34	1.0467	0.4118
A x B	10	802.698	80.27	0.8543	
S x A x B	20	1535.536	76.777	0.8172	
Error	90	8456.029	93.956		
Total	161	539325.006			

Appendix 399: ANOVA for Microbial biomass C combined over sites at the surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	93608.041	46804.02	603.974	0.0000 ***
R(S)	6	227.146	37.858	0.4885	
MP (A)	2	350608.951	175304.476	2262.185	0.0000 ***
S x A	4	1232.144	308.036	3.975	0.0280
Error	12	929.921	77.493		
Fertilizer (B)	5	231673.171	46334.634	920.0203	0.0000 ***
S x B	10	1120.171	112.017	2.2242	0.0230
A x B	10	429.928	42.993	0.8537	
S x A x B	20	963.573	48.179	0.9566	
Error	90	4532.636	50.363		
Total	161	685325.682			

Appendix 400: ANOVA for Microbial biomass C combined over sites at the sub-surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	95875.867	47937.933	753.9761	0.0000 ***
R(S)	6	160.794	26.799	0.4215	
MP (A)	2	329779.849	164889.924	2593.4173	0.0000 ***
S x A	4	1713.487	428.372	6.7375	0.0044
Error	12	762.962	63.58		
Fertilizer (B)	5	233344.693	46668.939	854.327	0.0000 ***
S x B	10	3330.421	333.042	6.0967	0.0000
A x B	10	975.108	97.511	1.785	0.0746
S x A x B	20	1292.041	64.602	1.1826	0.2878
Error	90	4916.39	54.627		
Total	161	672151.612			

Appendix 401: ANOVA for Microbial biomass N combined over sites at the surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	593.664	296.832	575.9483	0.0000 ***
R(S)	6	2.297	0.383	0.743	
MP (A)	2	1613.721	806.861	1565.5657	0.0000 ***
S x A	4	3.984	0.996	1.9326	0.1696
Error	12	6.185	0.515		
Fertilizer (B)	5	6737.839	1347.568	2514.4486	0.0000 ***
S x B	10	13.55	1.355	2.5283	0.0099
A x B	10	4.642	0.464	0.8662	
S x A x B	20	11.414	0.571	1.0649	0.3996
Error	90	48.234	0.536		
Total	161	9035.531			

Appendix 402: ANOVA for Microbial biomass N combined over sites at the sub-surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	608.363	304.182	425.5195	0.0000 ***
R(S)	6	3.59	0.598	0.8369	
MP (A)	2	1501.338	750.669	1050.1102	0.0000 ***
S x A	4	2.451	0.613	0.8573	
Error	12	8.578	0.715		
Fertilizer (B)	5	6934.451	1386.89	2687.2212	0.0000 ***
S x B	10	25.883	2.588	5.0151	0.0000
A x B	10	1.469	0.147	0.2846	
S x A x B	20	8.148	0.407	0.7894	
Error	90	46.45	0.516		
Total	161	9140.722			

Appendix 403: ANOVA for Mineralizable C combined over sites at the surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	5303.588	2651.794	324.5859	0.0000 ***
R(S)	6	80.346	13.391	1.6391	0.2194
MP (A)	2	11690.901	5845.451	715.497	0.0000 ***
S x A	4	20.462	5.116	0.6262	
Error	12	98.037	8.17		
Fertilizer (B)	5	19383.805	3876.761	521.0342	0.0000 ***
S x B	10	300.635	30.064	4.0405	0.0001
A x B	10	78.547	7.855	1.0557	0.4047
S x A x B	20	156.922	7.846	1.0545	0.4105
Error	90	669.646	7.441		
Total	161	37782.89			

Appendix 404: ANOVA for Mineralizable C combined over sites at the sub-surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	6466.489	3233.245	1002.8215	0.0000 ***
R(S)	6	48.475	8.079	2.5058	0.0828
MP (A)	2	10702.492	5351.246	1659.7396	0.0000 ***
S x A	4	80.305	20.076	6.2268	0.0060
Error	12	38.69	3.224		
Fertilizer (B)	5	18370.421	3674.084	474.5881	0.0000 ***
S x B	10	110.282	11.028	1.4245	0.1824
A x B	10	154.303	15.43	1.9932	0.0431
S x A x B	20	103.103	5.155	0.6659	
Error	90	696.747	7.742		
Total	161	36771.307			

Appendix 405: ANOVA for Mineralizable N combined over sites at the surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	828.64	414.32	514.1732	0.0000 ***
R(S)	6	3.146	0.524	0.6506	
MP (A)	2	1195.472	597.736	741.7928	0.0000 ***
S x A	4	2.666	0.666	0.827	
Error	12	9.67	0.806		
Fertilizer (B)	5	5216.538	1043.308	1486.1958	0.0000 ***
S x B	10	26.856	2.686	3.8256	0.0002
A x B	10	7.155	0.716	1.0192	0.4338
S x A x B	20	12.695	0.635	0.9042	
Error	90	63.18	0.702		
Total	161	7366.017			

Appendix 406: ANOVA for Mineralizable N combined over sites at the sub-surface soil

S.O.V.	DF	SS	MS	F	P-value
Season	2	882.151	441.076	445.2259	0.0000 ***
R(S)	6	7.402	1.234	1.2453	0.3503
MP (A)	2	1150.463	575.231	580.6441	0.0000 ***
S x A	4	3.945	0.986	0.9956	
Error	12	11.888	0.991		
Fertilizer (B)	5	5129.039	1025.808	1485.6266	0.0000 ***
S x B	10	16.246	1.625	2.3528	0.0161
A x B	10	4.732	0.473	0.6853	
S x A x B	20	10.629	0.531	0.7697	
Error	90	62.144	0.69		
Total	161	7278.639			

Appendix 407: ANOVA for Biological yield of wheat at site Guljaba during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	13224.704	6612.352	0.6465	
MP (A)	2	7150027.148	3575013.57	349.5475	0.0000 ***
Error	4	40910.185	10227.546		
Fertilizer (B)	5	42755823.48	8551164.7	911.2782	0.0000 ***
A x B	10	134767.741	13476.774	1.4362	0.2125
Error	30	281511.111	9383.704		
Total	53	50376264.37			

Appendix 408: ANOVA for Biological yield of wheat at site Guljaba during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	34748.778	17374.389	2.1912	0.2277
MP (A)	2	6688097.333	3344048.67	421.7417	0.0000 ***
Error	4	31716.556	7929.139		
Fertilizer (B)	5	36397936.17	7279587.23	537.7266	0.0000 ***
A x B	10	131294.667	13129.467	0.9698	
Error	30	406131.333	13537.711		
Total	53	43689924.83			

Appendix 409: ANOVA for Biological yield of wheat combined over years at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	1	76214.454	76214.454	8.3952	0.0200 *
R(S)	4	47973.481	11993.37	1.3211	0.3408
MP (A)	2	13816517.13	6908258.57	760.9603	0.0000 ***
S x A	2	21607.352	10803.676	1.19	0.3528
Error	8	72626.741	9078.343		
Fertilizer (B)	5	79004286.6	15800857.3	1378.6983	0.0000 ***
S x B	5	149473.046	29894.609	2.6084	0.0336
A x B	10	142208.093	14220.809	1.2408	0.2846
S x A x B	10	123854.315	12385.431	1.0807	0.3912
Error	60	687642.444	11460.707		
Total	107	94142403.66			

Appendix 410: ANOVA for Grain yield of wheat at site Guljaba during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	6597.37	3298.685	0.3527	
MP (A)	2	2046076.926	1023038.46	109.3828	0.0003 ***
Error	4	37411.296	9352.824		
Fertilizer (B)	5	10576120.32	2115224.06	325.6206	0.0000 ***
A x B	10	54492.185	5449.219	0.8389	
Error	30	194879.333	6495.978		
Total	53	12915577.43			

Appendix 411: ANOVA for Grain yield of wheat at site Guljaba during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	17446.037	8723.019	1.7125	0.2902
MP (A)	2	1528331.815	764165.907	150.0214	0.0002 ***
Error	4	20374.852	5093.713		
Fertilizer (B)	5	8995353.426	1799070.69	604.2617	0.0000 ***
A x B	10	21452.63	2145.263	0.7205	
Error	30	89319.111	2977.304		
Total	53	10672277.87			

Appendix 412: ANOVA for Grain yield of wheat combined over years at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	1	17176.333	17176.333	2.3779	0.1616 ns
R(S)	4	24043.407	6010.852	0.8322	
MP (A)	2	3518736.074	1759368.04	243.5695	0.0000 ***
S x A	2	55672.667	27836.333	3.8537	0.0673
Error	8	57786.148	7223.269		
Fertilizer (B)	5	19531541.3	3906308.26	824.7001	0.0000 ***
S x B	5	39932.444	7986.489	1.6861	0.1518
A x B	10	49654.593	4965.459	1.0483	0.4157
S x A x B	10	26290.222	2629.022	0.555	
Error	60	284198.444	4736.641		
Total	107	23605031.63			

Appendix 413: ANOVA for Straw yield of wheat at site Guljaba during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	3314.778	1657.389	0.5567	
MP (A)	2	1697848.444	848924.222	285.1503	0.0000 ***
Error	4	11908.444	2977.111		
Fertilizer (B)	5	10813976.44	2162795.29	407.507	0.0000 ***
A x B	10	70189.778	7018.978	1.3225	0.2636
Error	30	159221.444	5307.381		
Total	53	12756459.33			

Appendix 414: ANOVA for Straw yield of wheat at site Guljaba during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	16302.704	8151.352	0.6005	
MP (A)	2	1959567.815	979783.907	72.1773	0.0007 ***
Error	4	54298.741	13574.685		
Fertilizer (B)	5	9374746.093	1874949.22	248.9151	0.0000 ***
A x B	10	70872.852	7087.285	0.9409	
Error	30	225974.556	7532.485		
Total	53	11701762.76			

Appendix 415: ANOVA for Straw yield of wheat combined over years at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	1	24873.343	24873.343	3.0055	0.1212 ns
R(S)	4	19617.481	4904.37	0.5926	
MP (A)	2	3652005.13	1826002.57	220.641	0.0000 ***
S x A	2	5411.13	2705.565	0.3269	
Error	8	66207.185	8275.898		
Fertilizer (B)	5	20143956.6	4028791.32	627.5441	0.0000 ***
S x B	5	44765.935	8953.187	1.3946	0.2392
A x B	10	49654.537	4965.454	0.7734	
S x A x B	10	91408.093	9140.809	1.4238	0.1921
Error	60	385196	6419.933		
Total	107	24483095.44			

Appendix 416: ANOVA for Harvest index of wheat at site Guljaba during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.243	0.122	0.1818	
MP (A)	2	26.453	13.227	19.7659	0.0084 ***
Error	4	2.677	0.669		
Fertilizer (B)	5	102.357	20.471	40.0006	0.0000 ***
A x B	10	6.191	0.619	1.2097	0.3242
Error	30	15.353	0.512		
Total	53	153.275			

Appendix 417: ANOVA for Harvest index of wheat at site Guljaba during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.689	0.345	0.3915	
MP (A)	2	9.196	4.598	5.2239	0.0767 ns
Error	4	3.521	0.88		
Fertilizer (B)	5	84.194	16.839	70.3247	0.0000 ***
A x B	10	3.064	0.306	1.2797	0.2854
Error	30	7.183	0.239		
Total	53	107.848			

Appendix 418: ANOVA for Harvest Index of wheat combined over years at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	1	0.25	0.25	0.3232	
R(S)	4	0.933	0.233	0.301	
MP (A)	2	31.407	15.703	20.271	0.0007 ***
S x A	2	4.242	2.121	2.7382	0.1242
Error	8	6.197	0.775		
Fertilizer (B)	5	185.554	37.111	98.8011	0.0000 ***
S x B	5	0.997	0.199	0.5311	
A x B	10	7.115	0.712	1.8943	0.0636
S x A x B	10	2.14	0.214	0.5697	
Error	60	22.537	0.376		
Total	107	261.373			

Appendix 419: ANOVA for 1000- grain weight of wheat at site Guljaba during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.089	0.045	0.1198	
MP (A)	2	35.407	17.704	47.5379	0.0016 ***
Error	4	1.49	0.372		
Fertilizer (B)	5	207.248	41.45	119.7837	0.0000 ***
A x B	10	2.544	0.254	0.7352	
Error	30	10.381	0.346		
Total	53	257.159			

Appendix 420: ANOVA for 1000-grain weight of wheat at site Guljaba during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.947	0.474	2.5763	0.1910
MP (A)	2	35.529	17.765	96.6539	0.0004 ***
Error	4	0.735	0.184		
Fertilizer (B)	5	181.017	36.203	134.1238	0.0000 ***
A x B	10	4.642	0.464	1.7197	0.1220
Error	30	8.098	0.27		
Total	53	230.968			

Appendix 421: ANOVA for 1000-grain weight of wheat combined over years at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	1	9.363	9.363	33.6686	0.0004 ***
R(S)	4	1.036	0.259	0.9316	
MP (A)	2	70.895	35.447	127.4613	0.0000 ***
S x A	2	0.042	0.021	0.0749	
Error	8	2.225	0.278		
Fertilizer (B)	5	386.821	77.364	251.1975	0.0000 ***
S x B	5	1.444	0.289	0.938	
A x B	10	3.369	0.337	1.0938	0.3815
S x A x B	10	3.817	0.382	1.2394	0.2854
Error	60	18.479	0.308		
Total	107	497.491			

Appendix 422: ANOVA for Biological yield of wheat at site Gado during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	17172.111	8586.056	0.2373	
MP (A)	2	10282174.78	5141087.39	142.0866	0.0002 ***
Error	4	144731.111	36182.778		
Fertilizer (B)	5	48746255.56	9749251.11	1020.0139	0.0000 ***
A x B	10	195011	19501.1	2.0403	0.0642
Error	30	286738.778	9557.959		
Total	53	59672083.33			

Appendix 423: ANOVA for Biological yield of wheat at site Gado during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	8266.333	4133.167	0.4719	
MP (A)	2	10211176.33	5105588.17	582.8741	0.0000 ***
Error	4	35037.333	8759.333		
Fertilizer (B)	5	54298616.22	10859723.2	716.5974	0.0000 ***
A x B	10	111454.778	11145.478	0.7355	
Error	30	454637	15154.567		
Total	53	65119188			

Appendix 424: ANOVA for Biological yield of wheat combined over years at site Gado

S.O.V.	DF	SS	MS	F	P-value
Season	1	153680.333	153680.333	6.839	0.0309 *
R(S)	4	25438.444	6359.611	0.283	
MP (A)	2	20469102.06	10234551	455.45	0.0000 ***
S x A	2	24249.056	12124.528	0.5396	
Error	8	179768.444	22471.056		
Fertilizer (B)	5	102909600.7	20581920.1	1665.7	0.0000 ***
S x B	5	135271.111	27054.222	2.1895	0.0671
A x B	10	153727.611	15372.761	1.2441	0.2827
S x A x B	10	152738.167	15273.817	1.2361	0.2874
Error	60	741375.778	12356.263		
Total	107	124944951.7			

Appendix 425: ANOVA for Grain yield of wheat at site Gado during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	35662.111	17831.056	2.4766	0.1996
MP (A)	2	2229456.333	1114728.17	154.8275	0.0002 ***
Error	4	28799.222	7199.806		
Fertilizer (B)	5	12379621.06	2475924.21	568.0289	0.0000 ***
A x B	10	87428.778	8742.878	2.0058	0.0688
Error	30	130764	4358.8		
Total	53	14891731.5			

Appendix 426: ANOVA for Grain yield of wheat at site Gado during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1432.259	716.13	0.3127	
MP (A)	2	2419566.259	1209783.13	528.1956	0.0000 ***
Error	4	9161.63	2290.407		
Fertilizer (B)	5	13572966.15	2714593.23	705.2554	0.0000 ***
A x B	10	67903.074	6790.307	1.7641	0.1117
Error	30	115472.778	3849.093		
Total	53	16186502.15			

Appendix 427: ANOVA for Grain yield of wheat combined over years at site Gado

S.O.V.	DF	SS	MS	F	P-value
Season	1	48344.676	48344.676	10.1883	0.0128 *
R(S)	4	37094.37	9273.593	1.9543	0.1948
MP (A)	2	4645553.574	2322776.79	489.5099	0.0000 ***
S x A	2	3469.019	1734.509	0.3655	
Error	8	37960.852	4745.106		
Fertilizer (B)	5	25915151.27	5183030.25	1262.9381	0.0000 ***
S x B	5	37435.935	7487.187	1.8244	0.1217
A x B	10	71343.648	7134.365	1.7384	0.0928
S x A x B	10	83988.204	8398.82	2.0465	0.0438
Error	60	246236.778	4103.946		
Total	107	31126578.32			

Appendix 428: ANOVA for Straw yield of wheat at site Gado during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	3713.444	1856.722	0.2824	
MP (A)	2	2849355.444	1424677.72	216.7158	0.0001 ***
Error	4	26295.778	6573.944		
Fertilizer (B)	5	12465422.83	2493084.57	617.963	0.0000 ***
A x B	10	83392.556	8339.256	2.0671	0.0608
Error	30	121030.778	4034.359		
Total	53	15549210.83			

Appendix 429: ANOVA for Straw yield of wheat at site Gado during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	4975.815	2487.907	0.9373	
MP (A)	2	2602100.259	1301050.13	490.1676	0.0000 ***
Error	4	10617.185	2654.296		
Fertilizer (B)	5	13650880.37	2730176.07	281.3065	0.0000 ***
A x B	10	65595.963	6559.596	0.6759	
Error	30	291160.333	9705.344		
Total	53	16625329.93			

Appendix 430: ANOVA for Straw yield of wheat combined over years at site Gado

S.O.V.	DF	SS	MS	F	P-value
Season	1	48344.676	48344.676	10.4775	0.0119 *
R(S)	4	8689.259	2172.315	0.4708	
MP (A)	2	5429870.13	2714935.07	588.3971	0.0000 ***
S x A	2	21585.574	10792.787	2.3391	0.1585
Error	8	36912.963	4614.12		
Fertilizer (B)	5	26078258.94	5215651.79	759.2088	0.0000 ***
S x B	5	38044.269	7608.854	1.1076	0.3660
A x B	10	88480.87	8848.087	1.288	0.2579
S x A x B	10	60507.648	6050.765	0.8808	
Error	60	412191.111	6869.852		
Total	107	32222885.44			

Appendix 431: ANOVA for Harvest index of wheat at site Gado during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	2.327	1.164	11.6784	0.0214
MP (A)	2	12.784	6.392	64.156	0.0009 ***
Error	4	0.399	0.1		
Fertilizer (B)	5	151.901	30.38	94.9931	0.0000 ***
A x B	10	4.396	0.44	1.3746	0.2390
Error	30	9.594	0.32		
Total	53	181.401			

Appendix 432: ANOVA for Harvest index of wheat at site Gado during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.078	0.039	0.2381	
MP (A)	2	19.384	9.692	59.07	0.0011 ***
Error	4	0.656	0.164		
Fertilizer (B)	5	150.237	30.047	62.5454	0.0000 ***
A x B	10	6.456	0.646	1.3439	0.2532
Error	30	14.412	0.48		
Total	53	191.223			

Appendix 433: ANOVA for Harvest Index of wheat combined over years at site Gado

S.O.V.	DF	SS	MS	F	P-value
Season	1	0.623	0.623	4.7219	0.0615 ns
R(S)	4	2.405	0.601	4.5604	0.0327
MP (A)	2	31.816	15.908	120.6488	0.0000 ***
S x A	2	0.352	0.176	1.3343	0.3162
Error	8	1.055	0.132		
Fertilizer (B)	5	301.01	60.202	150.4632	0.0000 ***
S x B	5	1.127	0.225	0.5635	
A x B	10	3.801	0.38	0.95	
S x A x B	10	7.051	0.705	1.7624	0.0876
Error	60	24.007	0.4		
Total	107	373.247			

Appendix 434: ANOVA for 1000-grain weight of wheat at site Gado during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.518	0.259	1.2996	0.3674
MP (A)	2	58.694	29.347	147.2118	0.0002 ***
Error	4	0.797	0.199		
Fertilizer (B)	5	332.079	66.416	213.53	0.0000 ***
A x B	10	3.149	0.315	1.0123	0.4562
Error	30	9.331	0.311		
Total	53	404.568			

Appendix 435: ANOVA for 1000-grain weight of wheat at site Gado during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.083	0.041	0.1665	
MP (A)	2	45.318	22.659	91.3807	0.0005 ***
Error	4	0.992	0.248		
Fertilizer (B)	5	237.968	47.594	168.528	0.0000 ***
A x B	10	4.155	0.416	1.4713	0.1986
Error	30	8.472	0.282		
Total	53	296.988			

Appendix 436: ANOVA for 1000-grain weight of wheat combined over years at site Gado

S.O.V.	DF	SS	MS	F	P-value
Season	1	5.245	5.245	23.4502	0.0013 ***
R(S)	4	0.601	0.15	0.6715	
MP (A)	2	103.576	51.788	231.5496	0.0000 ***
S x A	2	0.436	0.218	0.9754	
Error	8	1.789	0.224		
Fertilizer (B)	5	565.209	113.042	380.9685	0.0000 ***
S x B	5	4.837	0.967	3.2606	0.0114
A x B	10	3.352	0.335	1.1298	0.3559
S x A x B	10	3.951	0.395	1.3317	0.2349
Error	60	17.803	0.297		
Total	107	706.8			

Appendix 437: ANOVA for Biological yield of wheat at site Kotlai during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	35385.481	17692.741	0.7894	
MP (A)	2	9498233.926	4749116.96	211.8821	0.0001 ***
Error	4	89655.852	22413.963		
Fertilizer (B)	5	54923770.09	10984754	1009.391	0.0000 ***
A x B	10	137834.741	13783.474	1.2666	0.2924
Error	30	326476.667	10882.556		
Total	53	65011356.76			

Appendix 438: ANOVA for Biological yield of wheat at site Kotlai during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	61153.37	30576.685	1.605	0.3078
MP (A)	2	9794197.37	4897098.69	257.0578	0.0001 ***
Error	4	76202.296	19050.574		
Fertilizer (B)	5	52516777.93	10503355.6	732.3579	0.0000 ***
A x B	10	173721.741	17372.174	1.2113	0.3233
Error	30	430255	14341.833		
Total	53	63052307.7			

Appendix 439: ANOVA for Biological yield of wheat combined over years at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	1	135044.08	135044.083	6.5137	0.0341 *
R(S)	4	96538.85	24134.713	1.1641	0.3945
MP (A)	2	19277151.9	9638575.95	464.907	0.0000 ***
S x A	2	15279.39	7639.694	0.3685	
Error	8	165858.1	20732.269		
Fertilizer (B)	5	107339680.4	21467936.1	1702.2	0.0000 ***
S x B	5	100867.6	20173.528	1.5995	0.1741
A x B	10	117603.8	11760.376	0.9325	
S x A x B	10	193952.7	19395.272	1.5378	0.1485
Error	60	756731.7	12612.194		
Total	107	128198708.6			

Appendix 440: ANOVA for Grain yield of wheat at site Kotlai during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	5604.778	2802.389	0.7099	
MP (A)	2	2451045.444	1225522.72	310.4467	0.0000 ***
Error	4	15790.444	3947.611		
Fertilizer (B)	5	14112367.5	2822473.5	457.779	0.0000 ***
A x B	10	75715.222	7571.522	1.228	0.3137
Error	30	184967.444	6165.581		
Total	53	16845490.83			

Appendix 441: ANOVA for Grain yield of wheat at site Kotlai during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	6031	3015.5	0.4086	
MP (A)	2	2586236.778	1293118.39	175.214	0.0001 ***
Error	4	29520.889	7380.222		
Fertilizer (B)	5	13440408.83	2688081.77	530.7306	0.0000 ***
A x B	10	75691.889	7569.189	1.4944	0.1900
Error	30	151946.111	5064.87		
Total	53	16289835.5			

Appendix 442: ANOVA for Grain yield of wheat combined over years at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	1	13333.333	13333.333	2.3541	0.1635 ns
R(S)	4	11635.778	2908.944	0.5136	
MP (A)	2	5028545.056	2514272.53	443.9106	0.0000 ***
S x A	2	8737.167	4368.583	0.7713	
Error	8	45311.333	5663.917		
Fertilizer (B)	5	27537219.56	5507443.91	980.8054	0.0000 ***
S x B	5	15556.778	3111.356	0.5541	
A x B	10	45523.389	4552.339	0.8107	
S x A x B	10	105883.722	10588.372	1.8857	0.0650
Error	60	336913.556	5615.226		
Total	107	33148659.67			

Appendix 443: ANOVA for Straw yield of wheat at site Kotlai during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	22047.148	11023.574	1.8251	0.2734
MP (A)	2	2463340.481	1231670.24	203.9202	0.0001 ***
Error	4	24159.852	6039.963		
Fertilizer (B)	5	13355893.7	2671178.74	499.1251	0.0000 ***
A x B	10	68732.63	6873.263	1.2843	0.2830
Error	30	160551.667	5351.722		
Total	53	16094725.48			

Appendix 444: ANOVA for Straw yield of wheat at site Kotlai during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	57534.704	28767.352	5.1022	0.0793
MP (A)	2	2500122.481	1250061.24	221.7101	0.0001 ***
Error	4	22553.074	5638.269		
Fertilizer (B)	5	13108726.82	2621745.36	429.5309	0.0000 ***
A x B	10	100500.63	10050.063	1.6465	0.1411
Error	30	183112.222	6103.741		
Total	53	15972549.93			

Appendix 445: ANOVA for Straw yield of wheat combined over years at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	1	46542.259	46542.259	7.9708	0.0224 *
R(S)	4	79581.852	19895.463	3.4073	0.0659
MP (A)	2	4957221.556	2478610.78	424.4839	0.0000 ***
S x A	2	6241.407	3120.704	0.5344	
Error	8	46712.926	5839.116		
Fertilizer (B)	5	26420025.89	5284005.18	922.5302	0.0000 ***
S x B	5	44594.63	8918.926	1.5571	0.1860
A x B	10	103573.889	10357.389	1.8083	0.0785
S x A x B	10	65659.37	6565.937	1.1463	0.3445
Error	60	343663.889	5727.731		
Total	107	32113817.67			

Appendix 446: ANOVA for Harvest index of wheat at site Kotlai during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.27	0.135	0.3888	
MP (A)	2	28.454	14.227	40.9743	0.0022 ***
Error	4	1.389	0.347		
Fertilizer (B)	5	203.628	40.726	83.3341	0.0000 ***
A x B	10	9.986	0.999	2.0433	0.0638
Error	30	14.661	0.489		
Total	53	258.388			

Appendix 447: ANOVA for Harvest index of wheat at site Kotlai during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.174	0.587	1.7735	0.2809
MP (A)	2	31.108	15.554	46.9748	0.0017 ***
Error	4	1.324	0.331		
Fertilizer (B)	5	192.755	38.551	81.785	0.0000 ***
A x B	10	10.066	1.007	2.1354	0.0530
Error	30	14.141	0.471		
Total	53	250.568			

Appendix 448: ANOVA for Harvest Index of wheat combined over years at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	1	0.03	0.03	0.0885	
R(S)	4	1.444	0.361	1.0647	0.4334
MP (A)	2	59.227	29.614	87.3128	0.0000 ***
S x A	2	0.335	0.167	0.4939	
Error	8	2.713	0.339		
Fertilizer (B)	5	395.943	79.189	164.9637	0.0000 ***
S x B	5	0.44	0.088	0.1833	
A x B	10	13.859	1.386	2.8872	0.0052
S x A x B	10	6.192	0.619	1.2898	0.2569
Error	60	28.802	0.48		
Total	107	508.987			

Appendix 449: ANOVA for 1000-grain weight of wheat at site Kotlai during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.345	0.172	0.2711	
MP (A)	2	63.205	31.602	49.6878	0.0015 ***
Error	4	2.544	0.636		
Fertilizer (B)	5	364.692	72.938	318.7661	0.0000 ***
A x B	10	2.209	0.221	0.9652	
Error	30	6.864	0.229		
Total	53	439.859			

Appendix 450: ANOVA for 1000-grain weight of wheat at site Kotlai during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.108	0.054	0.2513	
MP (A)	2	44.084	22.042	102.7876	0.0004 ***
Error	4	0.858	0.214		
Fertilizer (B)	5	304.124	60.825	128.3728	0.0000 ***
A x B	10	1.444	0.144	0.3049	
Error	30	14.214	0.474		
Total	53	364.833			

Appendix 451: ANOVA for 1000-grain weight of wheat combined over years at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	1	1.638	1.638	3.8517	0.0853 ns
R(S)	4	0.453	0.113	0.2661	
MP (A)	2	106.394	53.197	125.1006	0.0000 ***
S x A	2	0.896	0.448	1.0532	0.3926
Error	8	3.402	0.425		
Fertilizer (B)	5	666.548	133.31	379.4594	0.0000 ***
S x B	5	2.268	0.454	1.2913	0.2797
A x B	10	1.82	0.182	0.518	
S x A x B	10	1.833	0.183	0.5218	
Error	60	21.079	0.351		
Total	107	806.33			

Appendix 452: ANOVA for Plant-N concentration by wheat at site Guljaba during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.037	0.019	0.7256	
MP (A)	2	13.068	6.534	256.1129	0.0001 ***
Error	4	0.102	0.026		
Fertilizer (B)	5	26.683	5.337	138.8709	0.0000 ***
A x B	10	0.355	0.035	0.9231	
Error	30	1.153	0.038		
Total	53	41.398			

Appendix 453: ANOVA for Plant-N concentration by wheat at site Guljaba during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.181	0.09	2.5614	0.1922
MP (A)	2	18.553	9.276	262.7516	0.0001 ***
Error	4	0.141	0.035		
Fertilizer (B)	5	27.84	5.568	153.9558	0.0000 ***
A x B	10	0.527	0.053	1.4566	0.2044
Error	30	1.085	0.036		
Total	53	48.327			

Appendix 454: ANOVA for Plant-N Concentration by wheat combined over years at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	1	3.142	3.142	103.3133	0.0000 ***
R(S)	4	0.218	0.054	1.7913	0.2238
MP (A)	2	31.38	15.69	515.9701	0.0000 ***
S x A	2	0.241	0.121	3.9633	0.0637
Error	8	0.243	0.03		
Fertilizer (B)	5	54.405	10.881	291.7352	0.0000 ***
S x B	5	0.118	0.024	0.6341	
A x B	10	0.269	0.027	0.7208	
S x A x B	10	0.613	0.061	1.6428	0.1164
Error	60	2.238	0.037		
Total	107	92.866			

Appendix 455: ANOVA for Plant-P concentration by wheat at site Guljaba during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.015	0.007	9.6138	0.0297
MP (A)	2	0.005	0.003	3.4422	0.1351 ns
Error	4	0.003	0.001		
Fertilizer (B)	5	6.362	1.272	170.3046	0.0000 ***
A x B	10	0.043	0.004	0.5702	
Error	30	0.224	0.007		
Total	53	6.653			

Appendix 456: ANOVA for Plant-P concentration by wheat at site Guljaba during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.011	0.005	0.618	
MP (A)	2	0.019	0.01	1.1389	0.4060 ns
Error	4	0.034	0.009		
Fertilizer (B)	5	7.011	1.402	211.0489	0.0000 ***
A x B	10	0.034	0.003	0.5129	
Error	30	0.199	0.007		
Total	53	7.308			

Appendix 457: ANOVA for Plant-P Concentration by wheat combined over years at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	1	0.552	0.552	118.6864	0.0000 ***
R(S)	4	0.025	0.006	1.3695	0.3259
MP (A)	2	0.005	0.003	0.5821	
S x A	2	0.019	0.01	2.0805	0.1873
Error	8	0.037	0.005		
Fertilizer (B)	5	13.362	2.672	378.6587	0.0000 ***
S x B	5	0.011	0.002	0.3044	
A x B	10	0.037	0.004	0.5182	
S x A x B	10	0.04	0.004	0.5683	
Error	60	0.423	0.007		
Total	107	14.513			

Appendix 458: ANOVA for Grain-N concentration by wheat at site Guljaba during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.335	0.167	0.2351	
MP (A)	2	138.638	69.319	97.345	0.0004 ***
Error	4	2.848	0.712		
Fertilizer (B)	5	255.463	51.093	172.861	0.0000 ***
A x B	10	3.841	0.384	1.2995	0.2751
Error	30	8.867	0.296		
Total	53	409.992			

Appendix 459: ANOVA for Grain-N concentration by wheat at site Guljaba during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.641	0.321	1.6507	0.3001
MP (A)	2	204.149	102.074	525.619	0.0000 ***
Error	4	0.777	0.194		
Fertilizer (B)	5	242.043	48.409	154.6519	0.0000 ***
A x B	10	4.822	0.482	1.5405	0.1737
Error	30	9.39	0.313		
Total	53	461.822			

Appendix 460: ANOVA for Grain-N Concentration by wheat combined over years at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	1	142.692	142.692	314.8902	0.0000 ***
R(S)	4	0.976	0.244	0.5385	
MP (A)	2	339.263	169.632	374.3401	0.0000 ***
S x A	2	3.524	1.762	3.8882	0.0661
Error	8	3.625	0.453		
Fertilizer (B)	5	496.11	99.222	326.0736	0.0000 ***
S x B	5	1.396	0.279	0.9174	
A x B	10	4.465	0.446	1.4672	0.1743
S x A x B	10	4.198	0.42	1.3796	0.2117
Error	60	18.258	0.304		
Total	107	1014.506			

Appendix 461: ANOVA for Grain-P concentration by wheat at site Guljaba during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.004	0.002	0.1497	
MP (A)	2	0.008	0.004	0.2681	
Error	4	0.059	0.015		
Fertilizer (B)	5	9.279	1.856	198.3212	0.0000 ***
A x B	10	0.116	0.012	1.2441	0.3047
Error	30	0.281	0.009		
Total	53	9.747			

Appendix 462: ANOVA for Grain-P concentration by wheat at site Guljaba during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.048	0.024	2.6433	0.1855
MP (A)	2	0.026	0.013	1.4353	0.3390 ns
Error	4	0.036	0.009		
Fertilizer (B)	5	9.867	1.973	403.3331	0.0000 ***
A x B	10	0.122	0.012	2.4917	0.0260
Error	30	0.147	0.005		
Total	53	10.246			

Appendix 463: ANOVA for Grain-P Concentration by wheat combined over years at site Guljaba

S.O.V.	DF	SS	MS	F	P-value
Season	1	1.723	1.723	145.0227	0.0000 ***
R(S)	4	0.053	0.013	1.1069	0.4164
MP (A)	2	0.02	0.01	0.833	
S x A	2	0.014	0.007	0.5992	
Error	8	0.095	0.012		
Fertilizer (B)	5	19.048	3.81	534.6665	0.0000 ***
S x B	5	0.098	0.02	2.7498	0.0266
A x B	10	0.172	0.017	2.4085	0.0176
S x A x B	10	0.067	0.007	0.9364	
Error	60	0.428	0.007		
Total	107	21.716			

Appendix 464: ANOVA for Plant-N concentration by wheat at site Gado during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.104	0.052	8.0886	0.0393
MP (A)	2	18.736	9.368	1454.5094	0.0000 ***
Error	4	0.026	0.006		
Fertilizer (B)	5	35.632	7.126	154.7211	0.0000 ***
A x B	10	0.37	0.037	0.8025	
Error	30	1.382	0.046		
Total	53	56.249			

Appendix 465: ANOVA for Plant-N concentration by wheat at site Gado during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.208	0.104	2.0855	0.2397
MP (A)	2	17.412	8.706	174.8334	0.0001 ***
Error	4	0.199	0.05		
Fertilizer (B)	5	33.469	6.694	146.1257	0.0000 ***
A x B	10	0.364	0.036	0.795	
Error	30	1.374	0.046		
Total	53	53.026			

Appendix 466: ANOVA for Plant-N Concentration by wheat combined over years at site Gado

S.O.V.	DF	SS	MS	F	P-value
Season	1	0.377	0.377	13.4035	0.0064 ***
R(S)	4	0.312	0.078	2.773	0.1025
MP (A)	2	36.108	18.054	642.0623	0.0000 ***
S x A	2	0.04	0.02	0.7177	
Error	8	0.225	0.028		
Fertilizer (B)	5	68.708	13.742	299.16	0.0000 ***
S x B	5	0.393	0.079	1.7102	0.1461
A x B	10	0.376	0.038	0.8186	
S x A x B	10	0.358	0.036	0.7789	
Error	60	2.756	0.046		
Total	107	109.653			

Appendix 467: ANOVA for Plant-P concentration by wheat at site Gado during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.019	0.01	1.2005	0.3905
MP (A)	2	0.034	0.017	2.1056	0.2373 ns
Error	4	0.032	0.008		
Fertilizer (B)	5	6.501	1.3	222.7195	0.0000 ***
A x B	10	0.042	0.004	0.7202	
Error	30	0.175	0.006		
Total	53	6.802			

Appendix 468: ANOVA for Plant-P concentration by wheat at site Gado during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.025	0.012	1.0372	0.4336
MP (A)	2	0.002	0.001	0.1024	
Error	4	0.048	0.012		
Fertilizer (B)	5	6.47	1.294	177.7814	0.0000 ***
A x B	10	0.066	0.007	0.9082	
Error	30	0.218	0.007		
Total	53	6.83			

Appendix 469: ANOVA for Plant-P Concentration by wheat combined over years at site Gado

S.O.V.	DF	SS	MS	F	P-value
Season	1	0.357	0.357	35.8202	0.0003 ***
R(S)	4	0.044	0.011	1.1025	0.4181
MP (A)	2	0.018	0.009	0.8935	
S x A	2	0.018	0.009	0.9148	
Error	8	0.08	0.01		
Fertilizer (B)	5	12.962	2.592	395.2793	0.0000 ***
S x B	5	0.009	0.002	0.2829	
A x B	10	0.023	0.002	0.3454	
S x A x B	10	0.085	0.009	1.3036	0.2494
Error	60	0.393	0.007		
Total	107	13.989			

Appendix 470: ANOVA for Grain-N concentration by wheat at site Gado during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.17	0.085	0.3095	
MP (A)	2	178.316	89.158	323.8251	0.0000 ***
Error	4	1.101	0.275		
Fertilizer (B)	5	258.788	51.758	230.404	0.0000 ***
A x B	10	4.524	0.452	2.0139	0.0677
Error	30	6.739	0.225		
Total	53	449.639			

Appendix 471: ANOVA for Grain-N concentration by wheat at site Gado during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.583	0.791	4.4459	0.0963
MP (A)	2	202.092	101.046	567.5969	0.0000 ***
Error	4	0.712	0.178		
Fertilizer (B)	5	251.011	50.202	175.1441	0.0000 ***
A x B	10	3.025	0.302	1.0552	0.4247
Error	30	8.599	0.287		
Total	53	467.021			

Appendix 472: ANOVA for Grain-N Concentration by wheat combined over years at site Gado

S.O.V.	DF	SS	MS	F	P-value
Season	1	16.372	16.372	72.2275	0.0000 ***
R(S)	4	1.753	0.438	1.9338	0.1982
MP (A)	2	379.437	189.719	836.9594	0.0000 ***
S x A	2	0.971	0.485	2.1413	0.1800
Error	8	1.813	0.227		
Fertilizer (B)	5	509.149	101.83	398.339	0.0000 ***
S x B	5	0.65	0.13	0.5083	
A x B	10	5.521	0.552	2.1598	0.0330
S x A x B	10	2.027	0.203	0.793	
Error	60	15.338	0.256		
Total	107	933.032			

Appendix 473: ANOVA for Grain-P concentration by wheat at site Gado during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.003	0.001	0.2537	
MP (A)	2	0.003	0.001	0.2726	
Error	4	0.021	0.005		
Fertilizer (B)	5	9.617	1.923	196.1715	0.0000 ***
A x B	10	0.107	0.011	1.0955	0.3966
Error	30	0.294	0.01		
Total	53	10.045			

Appendix 474: ANOVA for Grain-P concentration by wheat at site Gado during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.025	0.013	3.1111	0.1531
MP (A)	2	0.006	0.003	0.6957	
Error	4	0.016	0.004		
Fertilizer (B)	5	10.425	2.085	303.8312	0.0000 ***
A x B	10	0.052	0.005	0.7519	
Error	30	0.206	0.007		
Total	53	10.729			

Appendix 475: ANOVA for Grain-P Concentration by wheat combined over years at site Gado

S.O.V.	DF	SS	MS	F	P-value
Season	1	0.05	0.05	10.6932	0.0114 *
R(S)	4	0.028	0.007	1.4932	0.2912
MP (A)	2	0.008	0.004	0.8704	
S x A	2	0	0	0.0419	
Error	8	0.037	0.005		
Fertilizer (B)	5	19.972	3.994	479.3204	0.0000 ***
S x B	5	0.07	0.014	1.6748	0.1545
A x B	10	0.052	0.005	0.6194	
S x A x B	10	0.107	0.011	1.2886	0.2575
Error	60	0.5	0.008		
Total	107	20.824			

Appendix 476: ANOVA for Plant-N concentration by wheat at site Kotlai during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.074	0.037	6.6344	0.0537
MP (A)	2	18.006	9.003	1614.0406	0.0000 ***
Error	4	0.022	0.006		
Fertilizer (B)	5	30.169	6.034	149.7202	0.0000 ***
A x B	10	0.662	0.066	1.6439	0.1418
Error	30	1.209	0.04		
Total	53	50.142			

Appendix 477: ANOVA for Plant-N concentration by wheat at site Kotlai during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.008	0.004	0.1873	
MP (A)	2	15.341	7.671	344.5877	0.0000 ***
Error	4	0.089	0.022		
Fertilizer (B)	5	33.239	6.648	191.6147	0.0000 ***
A x B	10	0.342	0.034	0.9868	
Error	30	1.041	0.035		
Total	53	50.061			

Appendix 478: ANOVA for Plant-N Concentration by wheat combined over years at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	1	0.454	0.454	32.5959	0.0004 ***
R(S)	4	0.082	0.021	1.4791	0.2949
MP (A)	2	33.283	16.642	1195.5926	0.0000 ***
S x A	2	0.064	0.032	2.2967	0.1629
Error	8	0.111	0.014		
Fertilizer (B)	5	63.266	12.653	337.4426	0.0000 ***
S x B	5	0.143	0.029	0.7604	
A x B	10	0.493	0.049	1.3137	0.2441
S x A x B	10	0.512	0.051	1.3661	0.2180
Error	60	2.25	0.037		
Total	107	100.657			

Appendix 479: ANOVA for Plant-P concentration by wheat at site Kotlai during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.005	0.002	2.5934	0.1896
MP (A)	2	0.003	0.001	1.5428	0.3187 ns
Error	4	0.004	0.001		
Fertilizer (B)	5	7.396	1.479	230.3333	0.0000 ***
A x B	10	0.048	0.005	0.7505	
Error	30	0.193	0.006		
Total	53	7.648			

Appendix 480: ANOVA for Plant-P concentration by wheat at site Kotlai during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.002	0.001	0.0541	
MP (A)	2	0.031	0.016	1.0376	0.4335 ns
Error	4	0.06	0.015		
Fertilizer (B)	5	8.158	1.632	248.0776	0.0000 ***
A x B	10	0.076	0.008	1.1551	0.3575
Error	30	0.197	0.007		
Total	53	8.524			

Appendix 481: ANOVA for Plant-P Concentration by wheat combined over years at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	1	0.318	0.318	39.6577	0.0002 ***
R(S)	4	0.007	0.002	0.2049	
MP (A)	2	0.025	0.013	1.5633	0.2672 ns
S x A	2	0.009	0.005	0.5718	
Error	8	0.064	0.008		
Fertilizer (B)	5	15.511	3.102	477.3166	0.0000 ***
S x B	5	0.042	0.008	1.3057	0.2737
A x B	10	0.054	0.005	0.8276	
S x A x B	10	0.07	0.007	1.0828	0.3896
Error	60	0.39	0.006		
Total	107	16.49			

Appendix 482: ANOVA for Grain-N concentration by wheat at site Kotlai during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.572	0.286	1.0568	0.4281
MP (A)	2	185.76	92.88	342.9439	0.0000 ***
Error	4	1.083	0.271		
Fertilizer (B)	5	247.436	49.487	131.9868	0.0000 ***
A x B	10	6.754	0.675	1.8014	0.1037
Error	30	11.248	0.375		
Total	53	452.854			

Appendix 483: ANOVA for Grain-N concentration by wheat at site Kotlai during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	1.214	0.607	3.0864	0.1546
MP (A)	2	0.482	0.241	1.2261	0.3843 ns
Error	4	0.787	0.197		
Fertilizer (B)	5	262.322	52.464	173.2121	0.0000 ***
A x B	10	5.744	0.574	1.8963	0.0857
Error	30	9.087	0.303		
Total	53	279.636			

Appendix 484: ANOVA for Grain-N Concentration by wheat combined over years at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	1	116.127	116.127	496.7307	0.0000 ***
R(S)	4	1.787	0.447	1.9108	0.2021
MP (A)	2	91.924	45.962	196.6008	0.0000 ***
S x A	2	94.319	47.159	201.7221	0.0000
Error	8	1.87	0.234		
Fertilizer (B)	5	507.018	101.404	299.2002	0.0000 ***
S x B	5	2.74	0.548	1.6167	0.1694
A x B	10	7.286	0.729	2.1499	0.0338
S x A x B	10	5.212	0.521	1.5378	0.1485
Error	60	20.335	0.339		
Total	107	848.617			

Appendix 485: ANOVA for Grain-P concentration by wheat at site Kotlai during 2006-2007

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.016	0.008	1.7026	0.2918
MP (A)	2	0.027	0.013	2.8318	0.1713 ns
Error	4	0.019	0.005		
Fertilizer (B)	5	8.929	1.786	164.4234	0.0000 ***
A x B	10	0.125	0.012	1.1496	0.3609
Error	30	0.326	0.011		
Total	53	9.441			

Appendix 486: ANOVA for Grain-P concentration by wheat at site Kotlai during 2007-2008

S.O.V.	DF	SS	MS	F	P-value
Replication	2	0.011	0.006	0.374	
MP (A)	2	0.011	0.005	0.3466	
Error	4	0.061	0.015		
Fertilizer (B)	5	7.98	1.596	150.2716	0.0000 ***
A x B	10	0.053	0.005	0.4986	
Error	30	0.319	0.011		
Total	53	8.434			

Appendix 487: ANOVA for Grain-P Concentration by wheat combined over years at site Kotlai

S.O.V.	DF	SS	MS	F	P-value
Season	1	0.006	0.006	0.5649	
R(S)	4	0.027	0.007	0.6879	
MP (A)	2	0.014	0.007	0.7235	
S x A	2	0.023	0.011	1.1442	0.3656
Error	8	0.08	0.01		
Fertilizer (B)	5	16.863	3.373	313.9958	0.0000 ***
S x B	5	0.046	0.009	0.8578	
A x B	10	0.118	0.012	1.0943	0.3812
S x A x B	10	0.06	0.006	0.5612	
Error	60	0.644	0.011		
Total	107	17.881			