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The Effects of Seed Treatment, Sowing date, Cultivar and Harvest date on the Yield and Quality of Sugar Beet

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M.Agr.Sc 2002

The Effects of Seed Treatment, Sowing date, Cultivar and Harvest date on the Yield and Quality of Sugar Beet

A thesis submitted to the National University of Ireland in fulfilment of the requirements for the degree of Master of Agricultural Science

by

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February 2002

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Dedication

To John and Maura

Acknowledgements

Firstly I want to thank Dr. Paddy Barry, Lyons Estate Research Farm. I am forever grateful for his friendship, patience, and guidance in the long awaited preparation of this thesis.

Thanks to the staff in the Crop Science Department (1998) for help in the collation of data and harvesting of the crop especially John Mulhare M.Agr.Sc, Mark Plunkett M.Agr.Sc and Adrian Caufield M.Agr.Sc and the friendship of my colleagues, Tina Mc Grane M.Agr.Sc and Peter Malone M.Agr.Sc who put up with me.

I wish to thank Mr. Tony Harte, farm manager, Lyons Estate, Research Farm for the use of facilities and machinery.

Financial support by Irish Sugar Plc. (quality analysis) and Germain's U.K. (seed treatment and pelleting) is acknowledged and appreciated.

For their expertise and comments during the growing season, I thank Mr. Eugene Brennan and Mr. Noel Burke, Crop Technicians, Lyons Estate, Research Farm.

Sincere thanks to Garret Byrne M.Agr.Sc and Tony Mc Ivor M.Agr.Sc who went beyond the line of duty when hand-pulling the trials

By no means last, I want to express my sincere gratitude to my parents, John and Maura, and family who supported me all through and believed that education came first. And to my fiancée, Alison, thank you for helping me complete this thesis.

Glossary of Abbreviations

@	At
B	Boron
CO_2	Carbon dioxide
cm	Centimetre
^0C	Degrees Celsius
^0F	Degrees Fahrenheit
EMP	Diethyl Mercuric Phosphate
g	Gram
g/ ha	Grams per hectare
>	Greater than
ha.	Hectare
kg	Kilogram
kg/ha	Kilogram per hectare
LSD	Least Significant Difference
<	Less than
l/ha.	Litres per Hectare
m	Metre
m^2	Metres squared
mg	Milligram
mm	Millimetre
N	Nitrogen
%	Percent
P	Phosphorous
K	Potassium
Na	Sodium
S	Sulphur
t/ha.	Tonnes per hectare
W/m^2	Watts per metre squared
w/v	Weight per volume

1.0. Introduction

One of the problems associated with sugar beet growing in Ireland is that leaf development does not reach an optimal level until July. Thus large quantities of incident radiation are not utilised by sugar beet plants particularly during the months of May and June. Past solutions to the problem included transplanting and autumn sowing. These two options have lost popularity, due to excessive costs and a lack of true winter hardy varieties respectively. The remaining variable that can be manipulated to achieve a closed canopy earlier in the growing season is sowing date. Earlier sowing has been facilitated by improved varieties with greater bolting resistance and improved growth at low temperatures. However, successful early sowing is very much weather and soil dependant. Recent research in the U.K. has shown that sugar beet seed, when subjected to a series of wetting and heating treatments, is capable of germinating 4-5 days ahead of untreated seed and has also shown increased bolting resistance. In terms of yield this translated to 0.16 t/ha. increase of sugar due to the combined effect of possible earlier sowing and quicker emergence. The treatment has been commercially developed in the U.K. by Germain's U.K. as 'Advantage' seed.

To become widespread in its usage, 'Advantage' seed would have to show an economic return other than acting as an insurance policy for increased emergence and lower bolting. In Ireland, there has been limited research on 'Advantage' seed or on any seed advancement process. The effects of using 'Advantage' seed across sowing dates, cultivars and harvest dates are shown in this thesis.

2.0. Literature Review

The literature review is divided into four parts as follows:

2.1. Climate and yield of sugar beet.

2.2. Aspects of the agronomy of the sugar beet crop.

2.3. Seed advancement treatments

2.4. Quality parameters of sugar beet roots

2.1. Climate and yield of sugar beet:

Sugar beet is essentially a crop of temperate regions, the main area of production being between 30° and 60° N in Europe, Asia and North America (Cooke and Scott, 1993). Crombie (1949) stated that the sugar beet crop in Ireland is grown under climatic conditions that are different to most other beet growing countries. Loomis and Gerakis (1973) showed that maximum yields of sugar beet are obtained at latitudes between 30 ^{0} and 40 ^{0} and decline rapidly between 40 ^{0} and 55 ^{0}, where Ireland lies. With sugar beet, the plant continues to produce new leaves throughout the growing season and thus extends the period of light interception and crop photosynthesis (Sibma, 1977). This allows successful sugar beet growing in Ireland.

In a study of the effects of climatic influences on sugar beet, Gardiner (1972) concluded that even in the most favourable climatic areas of this country that the varietal constant for sugar beet will not be reached and that sugar beet is capable of responding to higher accumulated degree-day totals than is available in these areas. The sum of degree-days necessary for a particular crop variety to grow to maturity is termed the varietal constant. However, for spring wheat (grown in the same areas as the sugar beet) Gardiner (1972) showed that no significant differences in yields were due to climatic variations. This, he attributed to the fact that the varietal constant for wheat, of between 1900-2000 accumulated degree-days (using 42 ^{0}F base temperature) is reached in Ireland in the majority of years.

M^c Entee (1983) in a study of the effects of weather conditions on sugar beet yields in Ireland put forward some interesting discussion points. He used regression analysis to associate plant conditions with weather conditions. From his analysis, M^c Entee (1983) concluded that in April and May the significant effects of weather are those likely to reduce yield. Thus a bad spring has a greater proportionate effect than a good one. In March, which was assumed to equate to the pre-sowing period, he found that the balance between evaporation and rainfall significantly affected both yields of tops and roots. This he attributed to a positive evaporation to rainfall figure allowing the preparation of a good seedbed. This encouraged better establishment and higher plant populations. Heavy rain in the April/May period was deleterious to sugar yield as was drought conditions that damaged the emerging seedlings. Windy conditions in April were seen to affect both the yields of tops and roots, which M^c Entee (1983) reported was indicative of a lower percentage establishment. However windy conditions in May were seen to only affect the yield of roots through leaf damage. High daytime temperatures in May also lowered root yield and this was attributed to stomatal closure reducing photosynthesis and increasing respiration. The significant effects of favourable weather in the summer months (June, July and August) enhance yield. Towards the end of the growing season, the main influences of weather are more likely to have an adverse effect on yield. From this study it is obvious that anything, which can be done to counteract the effects of a bad spring i.e. to enhance the emergence and establishment phase of the sugar beet crop, would be of major benefit to final yields.

The most striking characteristic of our climate is the high rainfall averaging 1m, and reaching as high as 2m per year. The mean annual rainfall in the sugar beet areas ranges from 750 mm - 1250 mm, giving 200-270 rain days per year. A rain day is classified as a day when the total rainfall is not less than 0.2 mm. The high rainfall gives high air humidity (75-95 %), frequently clouded skies and restricted sunshine (Lee and Comerford, 1970). Our winters are mild (5-6 ^{0}C) and summers are cool (13-21 ^{0}C) due to the temperate influences of the Gulf Stream and southwesterly winds from the Atlantic.

2.1.1. Solar radiation:

The yield of sugar beet in the northern part of its cropping area is strongly correlated with the amount of solar radiation intercepted during the crop cycle (Scott and Jaggard 1978). In Ireland, Burke, Rice and Fruhlich (1985) demonstrated a linear relationship between the amount of radiation intercepted and both root and sugar yield. During the growing season, the growth rate of crops is determined ultimately by the amount of CO_2

fixed in photosynthesis per unit area of land. A measure of this is Leaf Area Index (L) which is the area of leaf over unit area of ground. Sugar beet crops need to produce a L value of 2.5 – 3 to cover the soil fully and intercept most of the incident solar radiation (Milford, Biscoe, Jaggard, Scott and Draycott, 1980). Leaf development does not reach an optimal level in Ireland until July and thus large quantities of incident radiation are not utilised by sugar beet plants particularly during the months of May and June (Gibbons, 1982; Burke, O'Connor and Herlihy, 1985).

Using gas exchange, Glauert (1983), demonstrated how CO_2 uptake and irradiance are closely related. When CO_2 was plotted against incident radiation over 24 hours, it was shown that CO_2 uptake increased over the whole range of incident radiation (0-800 W/m^2) but with a diminishing response. Over a longer period of time, mid June- mid December, he showed that the photosynthesis/light response curve was maintained in an essentially similar position until September. Glauert (1983) also showed that the daily increment in dry matter, estimated from the measured amount of CO_2 taken up by the crop during the day, is directly proportional to the amount of radiant energy intercepted by the foliage during that day. This correlation between calculated dry matter increment and intercepted radiation is constant over the time frame, and thus independent of temperature, plant size and age of the crop. From this, it is shown that biomass production is related directly to the amount of radiation intercepted by the foliage between sowing and harvest.

Insufficient light interception, especially in sugar beet, was found to be an important limitation to the growth rate in spring (Sibma, 1977). He showed that sugar beet only attained its maximum light interception when potential growth rate was decreasing, roundabout the end of June. Sibma (1977) concluded that the amount of potential production could not be altered. However an increase in the yield of beet is possible by bringing forward the time maximum light interception (closed canopy) is reached.

2.1.2. Temperature:

Work done in the UK by Hull and Webb (1970) and Scott, English, Wood and Unsworth (1973) on the yield of sugar beet in relation to growing season tried to plot yield of sugar per area and length of growing season. Each set of researchers found that at both ends of the growing season, i.e. for early sowing dates and late harvest dates that the relationship was not linear. Scott <u>et</u> <u>al</u> (1973) found that there were well-correlated relationships between yield and day-degrees; yield and incident radiation and yield and intercepted radiation. From these relationships he concluded that there was a close connection between radiation and temperature in determining yield. He also postulated that low temperatures early and late in the growing season affected the plant using the radiation available to it.

2.1.2.1. Temperature and seedling growth

The effect of soil temperature on early seedling growth was outlined by Gummerson and Jaggard (1984). They showed that seed kept below 3 ^{0}C would not germinate. Gummerson (1986), when reviewing the literature, cited other researchers who used 2.8 ^{0}C as the base temperature for sugar beet germination. In his work he used an equation to predict the time course of germination over a wide range of temperatures and potentials using the concept of hydrothermal time. This base temperature is not a critical temperature above, which all seeds will germinate and below which none will. Gummerson (1986) clearly pointed out that not all seeds would germinate even at a temperature of 5 ^{0}C after being left for 48 days with adequate water and aeration. Upping the temperature on this experiment to 18 ^{0}C, most of the un-germinated seeds then germinated. From his work he took 2.8 ^{0}C as the base value for germination of beet seed. He stated that the deviations he found in predicted germination and that measured in the field would probably not be noticed as germination near the base temperature is very slow and the seeds would germinate when the temperature rises.

The rate of emergence is also affected by temperature. Sugar beet seedlings require 80-day degrees above 3 ^{0}C to reach 50 % emergence sown at normal depth (about 30 mm) and in a good seedbed with adequate water. Therefore if the temperature was constant at 11 ^{0}C, 50 % emergence would occur after about 10 days but at 7 ^{0}C it would take 20 days (Gummerson and Jaggard, 1984). Delayed emergence also increases the time the seed and seedling are exposed to the risks of waterlogging, capping, pests and diseases. The ability to increase soil temperature directly is not a realistic possibility for the grower but by delaying sowing it can be achieved indirectly. However the cost of delayed sowing in terms of lost radiation interception (section 2.2.3.) is equally important in the sowing date decision. Gummerson and Jaggard (1984) concluded that once the criteria concerning bolting (section 2.2.2.) and yield loss are satisfied then there are too few good drilling days to allow a good seedbed to lie unsown because temperatures are too low. After emergence frost can seriously damage seedlings. Mild frost affects the seedlings by increasing the length of time they spend in the vulnerable stage, allowing adverse factors to attack them (Gummerson and Jaggard, 1984) but severe frost can kill the developing seedlings. The latter occurred in Ireland in 1998 when favourable weather in March prompted early drilling. A two week period of low temperatures and winds in April caused an estimated 10 % of the national crop to be drilled a second time due to poor plant populations caused by frost kill and wind damage (Grimes, 1998).

2.1.2.2. Temperature and leaf growth

The rate of early leaf growth was found to be sensitive to temperature by Terry (1968). Similar work by Thorne, Watson and Ford (1967) showed that cool temperatures typical of an early spring drilling situation will restrict leaf growth.

More detailed examination on the effects of temperature on leaf appearance and growth were carried out by Milford, Pocock and Riley (1985) using controlled environments. They showed a linear relationship between leaf appearance rate and temperature above a base temperature of 1 ^{0}C and found that the maximum rate of leaf appearance occurred above 20 ^{0}C. This is in agreement with Terry (1968) who found that it occurred in the range of 17 - 24 ^{0}C. When they examined the rate of leaf expansion Milford et al (1985) found that the rate of leaf expansion of the 5th leaf was linear with air temperature above a base temperature of 3 ^{0}C. Scott and Jaggard (1992) also concluded that the rate of canopy growth early in the season is related directly to temperature but once the crop is closed in, temperature does not affect growth rate. They quoted work done by Glauert (1983) where he found that only when the temperature in his gas exchange enclosures never exceeded 2 ^{0}C that the response to light was diminished.

2.1.2.3. Sucrose accumulation

In the literature there is conflicting views on the role of temperature on sucrose accumulation in the root. Ulrich (1952) showed that with beet grown under controlled climatic conditions, that the root underwent a ripening or ‘sugaring-up’ process, which is not a function of the age of the plant but is related to environmental changes such as nitrogen deficiency or a lowering of night temperatures. Low temperatures at night were also cited as a contributing factor to why inland areas in Ireland (with a greater diurnal temperature range) had higher sugar concentrations than coastal areas (Lee and O' Connor, 1976). However, Milford (1973) showed that sugar as a proportion of root dry matter reaches a maximum in early August and afterwards sugar and non-sugar dry matter are accumulated in parallel. This contradicts Ulrich's (1952) hypothesis, as sugar beet does not fulfil his ripening criteria.

2.2. Agronomy of the Sugar Beet Crop:

2.2.1 Genetic Composition:

In Ireland, cultivars have contributed substantially to sugar yield increase (O' Connor 1981). In 1960 the cultivars grown in Ireland were diploid multigerm. These were almost completely replaced by polyploid multigerm cultivars by 1962 as research showed that polyploid multigerm cultivars outyielded diploid varieties by 8 % for sugar productivity. The polyploid multigerm varieties were subsequently replaced by triploid monogerm varieties. European breeders considered that the development of triploid hybrids would be a quicker way to monogerm varieties with acceptable yield and quality characteristics than the development of conventional diploid or ansioploid first generation synthetics (Bosemark, 1993). These newer varieties had the dual advantage of being 3-4 % higher yielding over the polyploid multigerms (Comerford, and O' Connor, 1973) and also removed the need for hand singling. Since 1970, all seed used in Ireland has been monogerm pelleted seed sown to a stand (Grogan, 1997). The varieties used have been almost all triploid monogerm resulting from crossing monogerm diploid male sterile females with multigerm tetraploid pollinators. The varieties of today are thus widely different from the varieties 40 -50 years ago and have permitted growers and processors a much higher and more reliable level of sugar production than was earlier possible.

The reciprocal cross of using tetraploid male steriles and diploid pollinators to produce monogerm triploids took several years later to be tested on any reasonable scale (Bosemark, 1993). Work done in Ireland by Fitzgerald (1977) showed that the reciprocal cross would yield better than the same triploids borne on diploid male steriles. The main downfall with these triploids produced on tetraploid male steriles is that they do not give as good germination and field emergence and because of this it is unlikely that they will come onto the market (Bosemark, 1993). Since 1990, a number of monogerm diploids have been introduced to Ireland, which compare favourably with the existing triploid varieties (Grogan, 1997). One reason for the increased interest in diploids is that they give higher germination percentages and more even emergence than triploids (Kimber, 1990). At present there is much interest in the use of specific single-cross hybrids based on highly inbred diploid lines. These varieties have not got the genetic diversity of the triploid varieties or more broad-based diploids which adds variation to root size and shape as well as lowering the technological quality of the beet (Bosemark, 1993). In contrast to this, work done in the United States by Lasa, Romagosa, Hecker, and Sanz (1989) which compared a number of diploids and tetraploids as pollinators on a range of diploid cytoplasmic male sterile lines showed that the triploid hybrids had higher environmental stability than the diploid hybrids. Whether or not the specific diploids will take over from the broad-based triploids will depend on both breeder and grower accepting them. For the breeder they must be capable of producing high amounts of quality seed and for the grower they must have the same traditionally high degree of adaptability as the triploid varieties.

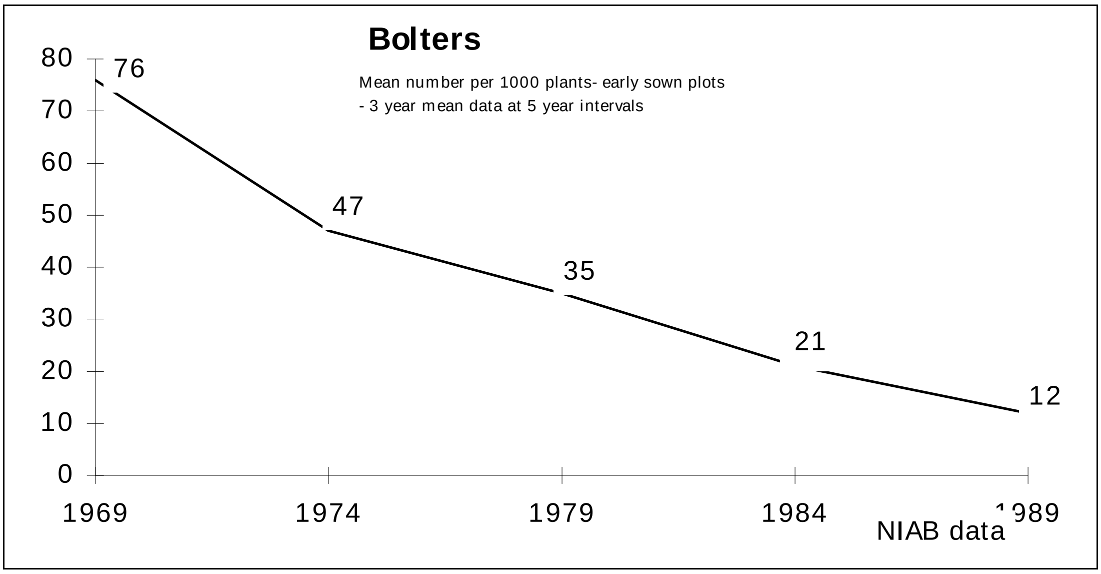
Three of the nine fully recommended sugar beet varieties for Ireland in 1998 were monogerm diploids with the remainder being monogerm triploids (Grogan, 1998)

With huge advances made in biotechnology and the advent of breeding new varieties by non-recombinant methods there are no limits to what is possible in the future for varieties. In a review of sugar beet breeding for the future, Johansson (1990) concluded that all new biotechnological advances would be used to incorporate relatively easy characters such as herbicide resistance, rhizomania resistance etc. into current varieties. For this material to be successfully reproduced, the use of a F_1 hybrid based on inbred lines would lessen the chances of the ‘new’ characteristic being lost in the commercialisation of the new variety. Johansson (1990) also remarked that the use of this new technology could be used to incorporate the genes for various beneficial characters from the wild Beta species into commercial varieties. Perhaps in the wake of resent controversy on the use of non-species genetic material in the make-up of Glyphosinate-resistant beet, that this latter option would be more acceptable to the general public, who will ultimately decide what variety, is grown in the fields. Maybe another way to use gene transfer in the make up of future varieties is to follow the lead of maize and find a non-food use (e.g. biodegradable plastic) for the end product (Laby, 1990).

2.2.2. Bolting

Sugar beet is a biennial plant and its complete lifecycle comprises of a period of vegetative growth, cold induced vernalisation, production of an upright extended flowering stem and seed production (Elliot and Weston, 1993). If sown sufficiently early in spring, the seeds and seedlings can receive sufficient cold stimulus to cause bolting in the first year of growth (Jaggard, Wickens, Webb and Scott, 1983). Bolters in sugar beet crops can (a) produce viable seeds which may result in a weed-beet infestation (Hornsey and Arnold, 1979) and (b) reduce yield (Longden, Scott and Tyldesley, 1975; Jaggard et al., 1983; Longden, 1989).

Control of bolting is complicated and under the influence of many factors with the three most important being: genetic effects; environmental effects on (i) the root crop and (ii) the seed crop (Longden, Clarke and Thomas, 1995). Several genes are involved in the so-called multigenic control of bolting in sugar beet (Longden et al., 1995). Campbell (1953) applied methods of selecting sugar beet varieties with bolting resistance, which were the basis for all other European sugar beet breeders (Bosemark, 1993). Improvements in bolting resistant varieties have been reported consistently over time in the U.K. by Jaggard et al. (1983); Kimber (1990); Durrant, Mash and Jaggard (1993) with each advocating earlier sowing dates. In the future, it may be possible to use genetic engineering to obtain bolting resistant varieties (Van Roggen, Thomas, Hedden, Phillips, Debenham, Scott and Mathews, 1997). The publication of a recommended list of sugar beet varieties was first introduced for Ireland in 1992. The 1998 recommended list for Ireland include two varieties safe to sow after mid. March and the remainder safe to sow after late March.



(after Kimber, 1990)

Whether or not a plant will set seed and bolt is dependant on the amount and level of cold it experiences after the seed has taken up water and become biochemically active (Longden et al., 1995). A very good relationship exists between percentage of plants bolting and the number of cool days (with a maximum temp. <12 °C) the crop experiences after sowing (Jaggard et al, 1983). Smit (1982) suggested that the greater part of the vernalisation process proceeds before or immediately after emergence. He made this assumption on the basis that the percentage of bolters correlated more to sowing date than to date of emergence in trials in the Netherlands between 1963-1976, (cv. Monohil). He also showed that high temperatures tended to counteract the previous cold treatment, especially soon after vernalisation.

The environment in which the seed crop is grown also affects the bolting of plants produced by that seed (Lexander, 1969; Wood, Scott and Longden, 1982). The warmer the temperatures experienced during ripening the more that bolting is reduced and as seed production has moved to the warmer areas of France and Italy this factor has declined in importance and is now small (Longden et al., 1995).

2.2.2.1. Loss of yield and quality due to bolters.

The presence of bolters in root crops decreases sugar yield by reducing both root weight and sugar percentage (Longden, Scott and Tyldesley, 1975). The reduction occurs because bolters use sugars for the production of the shoot and inflorescence and because, being tall, they shade the potentially productive, non-bolting plants within the crop (Jaggard et al., 1983). In field experiments in England every 1.0 percent of bolted plants in root crops reduced sugar yield by approx. 0.5 percent (Longden, 1989). Additionally, Longden and Scott (1980) have shown that a one percent level of bolters, in suitable weather, not controlled, could shed sufficient seed to cause a weed beet infestation. Successive generations of weed beet tend to become progressively more annual in habit and as such they produce small highly lignified roots with little sugar as they in turn become reproductive (Longden, 1989). Bolters thus create harvesting problems, are difficult to slice, and make dust in the pulp dryers, which can ignite spontaneously (Longden et al., 1995).

2.2.3. Sowing Date

To obtain high yields of sugar beet, it is important to have a full leaf cover established early in the growing season (Scott and Bremner 1966; Hull and Webb 1970). The yield of sugar beet in the northwestern part of its cropping area is strongly correlated with the amount of solar radiation intercepted during the crop cycle (Scott and Jaggard 1978). The rate of expansion of the leaf canopy is an important cause of variation in yield, because solar radiation is high in spring when the soil is not fully covered and because the rate of canopy expansion can vary greatly since it depends on temperature and crop establishment (Durr and Boffin 1995). The benefits of achieving a full leaf cover in the growing season are outlined in section 2.2.7.

Experiments in the U.K. (Hull and Webb 1970) and Ireland (O' Connor 1972), which compared sowing dates from late March to mid May, showed yields decreased 25-50 kg/ha. of sugar for each day's delay in sowing. Hull and Webb (1970) showed that when averaged over all sowing and harvest dates that, early sowings increased yield of roots by 19 % and increased yield of sugar by 18 % when compared to the latest sowing date. This effect became more pronounced the later the sowing dates as shown by Scott et al (1973). O' Connor (1981) showed that for a high quality sugar beet crop with optimum sugar yields and juice purities, the beet crop must be sown early. He showed in two consecutive years, 1977/78, that with later sown beet, yield of roots decreased significantly. He also showed that with progressively later sowing dates, sugar % decreased significantly for both years. Martens (1973) also showed that early sowing has been found to result in higher juice purities. Scott et al. (1973) showed that March sowings out yielded April sowings in 4 years out of 5 and postulated that newer varieties would be less susceptible to bolting and better able to grow at lower temperatures. These newer varieties would allow earlier sowing than then possible and thus would be beneficial to yield and sugar content.

Holmes and Adams (1966) showed that early sown beet increased in yield more in autumn than later sown beet. O’ Connor (1981) showed for earlier sown beet, that later harvesting dates significantly increased yield, but for later sown beet, the later harvesting had no significant effect on the yield of roots. He also showed that, on average, early April sowings gave rise to 2 % lower impurities i.e. potassium, sodium and harmful amino nitrogen than end of April/ early May sowings. The yield of white crystalline sugar was thus increased significantly for these earlier sowings. In Ireland, much of the sugar beet crop is sown in April with some sowings in March. This is because soil temperatures in March are low, causing delayed emergence and slow seedling growth (O’ Connor, 1981). Long-term experiments in the U.K. from 1963-1975 showed that there is a rapid fall in sugar yield from drillings after the end of March (Jarvis, 1997). The earliest drilling date for these experiments was usually middle March. More recent work carried out by British Sugar has examined using modern varieties and early drilling dates (1st week in March). These trials have demonstrated that there is no penalty to early drilling (Jarvis, 1997). Improved germination %, better bolting resistance and longer acting seed insecticides all contributes to achieving target plant populations even at these earlier sowing dates.

2.2.4. Harvesting Date

Studies carried out in sugar beet crops by Crombie (1949) in Ireland showed that yields increase from 2.0 to 4.5 tonnes per hectare during the mid October to mid December period. Holmes and Adams (1966) suggested that the yield of early-sown crops increased more during autumn than did late sown ones. In contrast, Draycott, Webb and Wright (1973) found evidence that late sown crops produced the largest increases. Hull and Webb (1970) showed that root yield increased by 6.25 tonnes per hectare in October and 2.5 tonnes per hectare in November at constant sugar percentage irrespective of sowing date. Scott et al (1973) showed similar gains in 1971 and related them to radiation intercepted between harvests. O’ Connor (1981) showed that a delay in harvesting increased root yield, sugar yield and extractable sugar yield in conformity with results obtained by Crombie (1949) and Hull and Webb (1970). Moraghan, Tiedeman and Torkelson (1973) gave data that showed that sugar yield increased fairly rapidly up to mid-November and then dropped off.

Ulrich (1955) suggested that sugar beet went through a specific process known as ‘sugaring up’. However, Milford (1973) showed that sugar as a percent of root dry matter reached a maximum in early August and afterwards increased in parallel with the non-sugar component of the dry matter. The currently held view is that sugar beet does not go through a specific ‘ripening’ period as it does not show evidence of a change in the sucrose concentration relative to the non- sucrose materials (Green, Vaidyanathan, and Ivins, 1986).

Glauert (1983) showed that the light response curve of the canopy remained constant until September and that from then on the canopy became less responsive to all light except dull light. He also showed that the crop continued to photosynthesise at temperatures as low as 1°C. However, with short, dull days and long warm nights in November and December, Glauert (1983) presented data that showed there are some winter nights that crop weight decreases and many winter days that crop yield does not increase in November/ December. With regard to the efficiency of radiation intercepted in the autumn, Jaggard et al (1983) showed that crops with sparse stands or diseased foliage either intercept little radiation or use it inefficiently resulting in small gains in autumn. He compared the yield gains increase through autumn of crops that were healthy and bolter free with crops that had gappy stands and > 5% bolters. Over the harvest times he showed significant differences of the good crops over the poor crops of 0.43 tonnes per hectare of sugar yield. When discussing juice purity, Kearney and O’ Connor (1973) demonstrated that harvest dates after the end of October did not change this parameter. Juice purity did increase rapidly in August and September however.

2.2.5. Length of growing season

Many experiments have shown that the yield of sugar beet is directly related to the amount of radiation intercepted during the growing season: Hull and Webb (1970); Scott et al (1973). The length of the growing season is limited by two factors:(i) date of drilling; (ii) date of harvesting (Jorritsma 1975).

He also presented data which showed that early drilling and early harvesting may give rise to the same length of growing period as late drilling and late harvesting but that the rate of growth from early drilling is more profitable than the rate of growth from later harvesting. Jorritsma (1975) divided two main categories of limiting factors for sowing date as being:

I. Fixed i.e. climate and soil (improved by liming and early ploughing)
II. Changeable i.e. cultivars, cultivation tools and techniques, crop protection, drills and seed types etc..

He postulated that the latter are becoming more important and that substantial progress could be obtained from seed treatments, bolting resistance, cold resistance, transplanting and from higher growth rates at lower temperatures. O' Connor (1981) found that early sowing and later harvesting gave the greatest amount of extractable sugar per ha. on average over various sowing date/ harvesting date combinations and over two consecutive years, 1977/'78. He showed a reduction of over 2.5 tonnes of sugar per ha. and a significant reduction in percent extractability for the shortest growing period relative to the longest growing period. Hull and Webb (1970) and Nilsson (1975) also presented results with the same conclusion. O' Connor (1981) also showed that an early start is more effective than the absolute length of the growing period. Work done in the U.K by Scott et al (1973) showed that days from sowing to harvest is not linear and that a quadratic function only accounted for 83 % of the variance. This was in close agreement with Hull and Webb (1970) who accounted for 80 % of the variance with regression analysis. Both Scott et al. (1973) and Hull and Webb (1970) indicated that in the early sowings, emergence and growth was slow. This is due to cold soils and that with later sowings the plants did not develop enough leaf area soon enough to take advantage of the solar radiation in the longest days of summer.

2.2.6. Seedling Emergence and Establishment

One hundred percent of the sugar beet crop in Ireland, United Kingdom and much of Western Europe is precision drilled with genetic monogerm seed (Maughan, 1977). This is known as drilling to a stand and requires a relatively weed free field and uniform seedling emergence (O' Connor, 1981). Jaggard (1979), when working with row widths of 50 cm. showed that yield is reduced when the distance between adjacent plants exceeds 40 cm. Scott and Durrant (1981) attributed losses in the region of 10 % to poor plant establishment. To minimise these gaps when drilling to a stand, there must be plants at over 70 % of the target positions. Sowing seeds closer together is an impracticable way to reduce the likelihood of such gaps as it reduces harvester efficiency (Harris, 1969). One possible way to sow more seeds is to keep the inter-seed spacing the same as used at present but to reduce row width and grow beet in a bed system as put forward by Jaggard (1980). This system has been tried in England and the successful mechanisation of these beds has been achieved but there has only been a small yield advantage over good but otherwise conventional husbandry (Scott and Jaggard, 1993). Durrant (1988) found that establishment in 69 crops surveyed in 1980 and 56 crops in 1981 was 64 % and 67 % respectively. This was a considerable improvement on the average of 56 % establishment in 254 experiments during 1970-77, discussed by Durrant, Dunning, Jaggard, Bugg and Scott (1988).

2.2.6.1. Plant Population:

For radiation interception to be maximised, it is crucial that establishment and spacing are correct (Scott and Jaggard, 1993). Scott (1964) showed that a plant population of 75,000 plants / ha., having reached the stage when leaf surface was maximal (late July/ early August) was intercepting 89 % of the incident radiation while plant populations of 37,000 plants / ha. at the same stage of development, were only intercepting 75 % of incident radiation. When taken to yield, Scott (1964) found that the yield differences between both populations were directly related to the amount of radiation intercepted by their respective canopies. O' Connor (1981) showed similar results with increasing plant stands of 50,000 - 100,000 plant / ha. Sugar content, percentage extractability and extractable sugar all increased while impurities of the root decreased. He also showed that the percentage of fanged roots decreased significantly with increasing plant population of 50,000 - 100,000 plants / ha. Goodman (1966) came to a similar conclusion when he suggested an optimum plant population of 75,000 plants / ha. to fill available space, without limiting water or nutrients, to give optimal yield. Draycott and Webb (1970) also gave an optimum of 80,000 plants per hectare but interestingly showed how by almost halving the plant population to 43,000 plants per hectare gave 95 % of the yield of roots. This was based on evenly spaced out plants. Smit (1993) when comparing later re-sowing dates with sub-optimal plant populations showed that the yield of sugar increased with increasing plant populations. He also showed that taken alone, emergence % did not have a significant influence on sugar yield. Smit et al (1995) discussed the negative effects of sowing elevated seeding rates to achieve target plant populations. He outlined the losses due to competition between the extra plants

and also the extra cost of seed. O' Connor (1975) presented data from a factory survey conducted in Ireland which looked at the relationship between plant population, sugar yield and sugar content. The survey was conducted on the number of roots delivered to the factories; the contract area and sugar yield of the growers involved. The results came to the same conclusion as in experimental trials in that 75,000 plants per hectare was the optimum plant population to achieve optimum yields and highest sugar contents. Yield differences in the survey were significant between plant populations.
Milford (1976) demonstrated how that the cell size of the cambium rings of the sugar beet root decrease with increasing plant density and thus the sugar concentration rises. Work done in New Zealand showed that purity of sugar increased with increasing plant populations (Mohammadkhani, Kemp and Millner, 1995). They showed that, for yield of sugar, there were no significant differences between plant populations of 80, 100, 120 and 140,000 plants.ha^{-1} but there was a trend for it to decrease. When both sugar purity and yield were taken into account they gave 100,000 plants.ha^{-1} as being the optimum plant population. Smit, Struik and Van Neijenhuis (1995) also showed that sugar content increased with plant density. When it fell from 75,000 to 55,000 plants/ha, fresh root yield fell by 3 % and sugar content fell by 1 %. From this work they came to a minimum plant density of 67,000 plants.ha^{-1} without yield losses. From the above information it would appear that plant population affects yield of extractable sugar more through sugar percentage and impurities than yield of roots when plant populations drop below 70,000-80,000 per hectare.

2.2.6.2. Seed Quality

Rapid establishment of uniform and vigorous sugar beet plants requires good quality seed, which germinates quickly and synchronously (Thomas, Gartland, Slater and Elliot, 1993). Durrant and Gummerson (1990) have reported increases in seed quality reflected by increased germination percentages. They showed that average field establishment increased from 60 % (approx.) in 1981 to 74 % in 1988. Average germination levels in the U.K. and Ireland have continued to improve and now average 96.5 %. These improvements are largely due to seed producers who concentrate seed growing in the most favourable regions and by processors who have to be more selective in producing the commercial grade (Kimber, 1990).

2.2.6.3. Variations in plant establishment

Durrant (1981) reviewed the problems associated with establishing an optimum plant density for maximum yield. In his paper Durrant (1981) cited a study in Sweden on the fate of 20,000 seeds sown between 1976 and 1979. This showed that 11,000 (55%) gave seedlings with the remainder examined under the microscope giving the following conclusions:

Observation	Proportion of the 9000 seeds which did not give plants (%)
I. Dead seed, abnormal seeds	9.7
II. 'Apparently healthy' seeds	3.4
III. Germinated seeds (reason for subsequent failure unknown)	75.8
IV. Dead seedlings (from damage due to Collembolla, Diptera, Symphla, etc.)	11.1

From this it can be seen that almost 90 % of the pre-emergence losses occurred after germination. Excavations for the possible causes of seedling death on these plots took place at least 10 days after the last seedling emerged. In a census of seedling establishment Durrant et al (1988) gave similar conclusions in that it was more common for seedlings to die after germination but before emergence than at any other stage. In their eight experiments, establishment figures of 70 % or greater were achieved in seven of the eight. The highest percentage of seedling loss was 12.4 % of seeds sown that germinated but died before emergence. Pre-emergence death of seedlings was attributed to dehydration, restriction under a stone or soil crust, pest damage, while water logging and herbicide damage were important causes in a few cases. Post-emergence death was mainly attributed to bird grazing. From these examinations and with weather and soil conditions data recorded at each site Durrant et al (1988) was able to propose possible explanations for seedling death. The results showed that seedlings were particularly vulnerable during the post germination/pre-emergence growth stage when up to 19 % of failures occurred and others sustained sub-lethal damage. Death due to pests and diseases accounted for about one quarter of the losses whilst extremes of water availability (water logging or dehydration) and deterioration in soil structure seemed to be associated with the rest. Cooke (1993) recommended that crops to be sown in fields that are at risk from pests such as springtails (*Onychiurus armatus*), wireworms (*Agriotes lineatus*) and leatherjackets (*Tipula paludosa*) should not be sown until the weather prospects favour rapid emergence and growth. The reason being that early sown crops often grow slowly during the first few weeks and remain longer in the susceptible seedling stage.

Durrant (1981) found that the spread of seedling emergence was uneven, with some of the variation persisting until harvest. Durrant and Mash (1990) showed an association between time to 50% emergence and establishment. Similar data presented by Durrant, Brown and Bould (1985) showed that germination percentage in the laboratory and establishment in the field are strongly related while Durrant and Gummerson (1990) showed that there is a clear association between germination percentage, true seed weight and rate of early growth. Quick early growth shortened the pre-emergence period and reduces the chance of lethal pest and disease attack, being waterlogged or caught beneath a soil cap (Durrant et al., 1988).

2.2.6.4. Soil moisture:

The establishment phase of the sugar beet crop is greatly affected by extremes of water availability (Durrant and Mash, 1992). Very dry conditions at sowing will delay germination and desiccate roots as they protrude, while wet conditions after germination will enhance growth but water-logging of seed soon after sowing is detrimental (Hadas and Russo, 1974; Hegarty, 1978). The effects of water-logging have been shown to be reduced by altering the type of pellet material used in the seed coat, with a more porous material being better than a clay material (Durrant and Loads, 1986). In lighter soils or in dry conditions sowing deeper to escape soil surface desiccation results in the seedling reaching the surface in a weakened state. Durr and Boffin (1995) when they measured the energy seedlings used up to reach the surface and emerge demonstrated this. In dry conditions, on lighter soils, the seedlings reached the surface at 100 - 110 day degrees (above a base temperature of $3^{o}C$). Soil crusting leads to emergence after 150-200 day degrees, which means that a high proportion of seedlings emerge during their third heterotrophic period, with a reduced relative growth rate (Durr and Boffin, 1995).

2.2.6.5. Possible improvements in plant establishment

From the above it is clear that the problems associated with losses from sowing to establishment are many and are seldom clear. Durrant (1988) from a survey of sugar beet fields in England demonstrated that there was need for improvements at every stage from sowing to establishment with each being small but the cumulative effect being worthwhile. Minimum passes of cultivation equipment in springtime reduce soil compaction as described by Jaggard (1984). The problems of soil pests attacking seedlings and their possible control are well researched and recommendations are available for the different pest situations (Cooke, 1993). Also advances have been made in the understanding of fertiliser placement at sowing and its effect on the establishment of seedlings (Draycott, Last and Webb, 1983). It is obvious that any process or husbandry method that promotes a rapid and even emergence of seedlings will increase plant establishment and improve plant population. Sowing later in the season, into warmer soils will do this but at the expense of a shorter growing season and reduced yields as discussed in section 2.2.3. A more novel approach is to somehow treat the seed so that it will germinate and emerge faster under the cold conditions normally associated with early sowing. This is expanded on further in section 2.3

2.2.7. Ground Cover

The formation of adequate leaf area is probably the most important factor determining dry matter production in agricultural crops (Watson, 1956). In sugar beet, early leaf cover must be established to maximise radiation interception in order to produce high sugar yields (Watson, 1952). Sibma (1977) demonstrated that by the time leaf canopy has reached its full size, around the last week of June, the potential production level will decrease, thus limiting actual growth more and more. The latter process cannot be changed, but the date, at which a closed canopy is attained in the field, can be influenced and advancing this date will affect the yield of beet favourably (Sibma, 1977). Much of the literature on ground cover has already been outlined in section 2.1.1.

Many agronomic methods of bringing forward the establishment of full leaf cover have been tried, e.g. closer spacing (Goodman, 1966), using large seed to produce faster growing seedlings (Scott, Harper, Wood and Jaggard, 1974; M^{c}. Lachlan, 1972), transplanting established seedlings (Scott and Bremner, 1966; Gibbons, 1982), fluid drilling (Currah, Gray and Thomas, 1974) and autumn sowing (Wood and Scott, 1975).

These treatments all increased dry matter production by varying amounts but had other undesirable effects, such as redistributing more of the dry matter to shoots at the expense of roots, or were unacceptable and uneconomic in practise.

2.3. Seed Advancement Treatments

2.3.1. Introduction:

The benefits of lengthening the growing season are defined (section 2.2.5). How this can be achieved has also been reviewed along with the problems associated with each method. In crops that rely on plant populations to achieve maximum yield and which do not have the ability to tiller, there have been various methods tried and researched to overcome these problems. This research is outlined below, some of which was carried out on crops the than sugar beet but carries relevance to the development of seed advancement treatments over the years. To keep a logical sequence, the important papers relating to the development of seed advancement treatments are presented in chronological order. Certain review papers are quoted with the important points outlined and direct reference is made to papers on sugar beet.

With reference to section 2.2.3, it is not recommended to sow sugar beet in Ireland before 20th. March. This is due to an increased risk of bolting and a delay in the time between sowing and plant emergence. In some years ground conditions are suitable for sowing in mid March and growers are faced with the dilemma of sowing into cold soils and accepting the risks associated with it (bolting and sparse plant stands) or delaying sowing until after 20th. March and accepting the loss of yield if conditions become wet and remain unsuitable for sowing for several weeks. Because of these problems there has been much research into developing seed treatments that will improve seedling vigour and allow earlier sowing without the risk of bolting and plant losses.

When the seed ripens, its water content is reduced to levels which a plant cannot tolerate. For the chemical reactions in the seed to start, which lead to germination, water must be taken up by the dry embryo. During germination water uptake occurs in three phases; with a static or lag phase separating two phases of rapid water uptake. The activities in the seed during germination and the role of water have been outlined by Ching (1972, 1973). The first phase is a physical process and occurs equally in live or dead seeds. However the amount of water depends on the seed and temperature (Mayer and Poljakoff-Mayber, 1975). The second phase is the synthesis of enzymes and organelles for the catabolism of seed reserves. The third phase is the synthesis of new cellular components and the emergence of the radicle by cell division and elongation from the seed. The water content of the embryo tissues must increase from 8-12 % of the dry seed to the 80-90 % of a plant so it can develop into a free seedling (Lexander, 1993).

Much of the basis of seed hydration techniques has been around since the 1800's as reviewed by Kidd and West (1919). They outlined the basic principles in their paper: that seeds swollen in water and sown still in the moist condition germinated more rapidly than untreated seeds; that seeds soaked in a 'minimum' amount of water and afterwards dried slowly at ordinary temperatures, imbibed water and developed more rapidly when again allowed to take up water and germinate than untreated seeds but that seeds dried rapidly after initial soaking germinated more slowly than untreated seeds. These points are fundamental to all other work on seed hydration treatments on a variety of species. Levitt and Hamm (1943) used the osmotic potentials of dextrose solutions, salt solutions and exposure to atmospheres of definite relative humidities to control the uptake of water in Kok-saghyz seeds. They wanted to overcome the inherent problems of a long drawn out germination phase of the Kok-saghyz seeds and speculated, that by increasing the moisture content of the seeds to permit necessary physiological changes to 'mature' the seeds but insufficient to permit germination, would achieve this. They then dried back the seeds to allow normal sowing. All methods were to hasten germination irrespective of 'wetting' method and the benefit was not affected by storage of up to 4 weeks after drying until sowing.

May, Milthorpe and Milthorpe (1962) reviewed the Russian work on seed hardening. Mainly concerned with trying to help plants become drought tolerant, they used different cycles of seed hydration in a restricted quantity of water followed by dehydration after a specified time. The Russian workers found that the greatest benefit in terms of drought tolerance was when the embryo was most advanced, however this was also the most likely stage of causing permanent injury to the embryo. The beneficial effect from the 'hardening' process was thought to be from the 'physio-chemical properties of the cytoplasm' leading to 'a greater ability to retain more water and a more efficient root system'. May et al (1962) presented data, which supported the claims by the Russian scientist Genkel that the treated plants retained the drought resistance properties throughout their growing season. He also concluded that an optimum time at which the seeds are dried back would require further work so as to induce the greatest degree of drought resistance with the minimum injury. The term seed 'priming' was used by Heydecker (1974) to describe a method of bringing seeds to the 'brink' of germination by using polyethylene glycol solutions.

Heydecker and Coolbear (1977), in a review of seed treatments, outlined the reported benefits of seed 'hardening' techniques but also raised questions about where the benefits came from; i.e. the wetting, the drying back or the addition of any chemical or hormonal additives. Heydecker and Coolbear (1977) cited Henckel and Ivanitskaya (1967) who reported that certain genes are depressed allowing plants to resist conditions of drought, heat, frost and salinity, all of which tend to dehydrate the protoplasm. The 'hardening' process initiates in the elasticity and viscosity of the protoplasm and encourages the formation of more high-energy compounds. Heydecker and Coolbear (1977) gave examples of work done on carrots by Austin et al (1969) and Hegarty (1970) on germination advantages produced by the 'hardening' method. The term 'hardening' seems to have been retained for historical reasons. The process, however, was more an advancement of germination. These workers could not specifically attribute the germination advantages to drought resistance.

Once a radical has protruded from the seed and DNA has started to replicate the seed cannot be dried back without injury (Milthorpe, 1950; Berrie and Drennan, 1971). May et al. (1962) quoting the Russian work on seed hardening, said that the latest time to dry back the seeds was at the time of radical emergence from the seed. Therefore the amount of water taken up by the pre-treatment must be carefully controlled. The problem of adding too much water in the pre-treatment process causes the seed to go too far in the germination process and will cause the seed to be damaged during the drying back phase. On the other hand, if too little water is added there are problems as described by Roberts and Roberts (1972). With not enough water added, the seeds deteriorate with time giving delayed germination, reduced seedling growth rates, decreased tolerance of adverse germination conditions and loss of germinabilitity (Hegarty, 1978; Delouche and Baskin, 1973). These all result from a general increase in hydrolytic activity in the seed during storage. Also aligned to these physiological problems, there has been evidence put forward of reduced seed vigour due to fungal activity during storage (Christensen, 1973).

Heydecker and Coolbear (1977) highlighted the complexity of the problem of explaining the effects of the pre-treatment as they cited work on beetroot by Heydecker, Chetram and Heydecker (1971) and on sugar beet by Scott, Wood and Harper (1972). Both sets of workers attributed the germination advantage to the short term soaking removing the water-soluble inhibitor complex. Austin et al (1969) and Hegarty (1970) suggested the improvement in germination was from the enlargement of the embryo within the seed during treatment. Hegarty (1978) explained the benefits of the incompletely imbibed, non-dormant seeds by citing work from Salter and Darby (1976) on sugar beet. They used osmotic solutions to control water uptake by the seeds during their treatments. The treated seeds when re-hydrated gave a very rapid and even germination. From this, Hegarty (1978) concluded that the germination process in these seeds had proceeded via one route or another until a particular block was reached. He quoted work on various species of seeds in which certain substrates (mainly nucleic acids and enzymes) were found to be in higher concentrations in the treated seeds over the untreated seeds. On subsequent re-hydration of the treated seeds there was evidence of increased respiration over the untreated seeds. The rapid germination was explained to be partially due to changes in the physical structure of the seed and seed coat (Kidd and West, 1919 and Heydecker and Coolbear, 1977).

Seeds may be hydrated using the liquid or vapour phase of water. The vapour phase involves using exposure to periods of high relative humidity to sufficiently imbibe the seed to the level of hydration required. Varying reports of the success of this method have been reported in a review by Hegarty (1978). Some researchers reported deterioration of seeds in saturated atmospheres, others reported activation without germination and other researchers reported deterioration to some extent. Hegarty (1978) cited a number of possible reasons as to why results with this method are conflicting. The main causes are due to the problems of achieving uniformity of moisture content even in small samples of seed. Also it is very difficult to keep the temperature correct as not to allow condensation on the seed and hydration treatments seem to be particularly sensitive to concentrations of gases in the environment. However, it was reported by Owen (1952) that in very carefully controlled temperature conditions, seed activation and germination could occur over a range of water potentials.

Work done on carrots showed that by subjecting the seeds to one or more cycles of wetting and drying before sowing, seedlings were produced which imbibed water quicker, emerged faster, had larger embryos and more cells than conventional seed (Austin et al, 1969). It was postulated that this effect would benefit sugar beet because its yield depended greatly on the length of growing season (Goodman, 1966) as determined by sowing and harvesting dates.

2.3.2. Development of seed advancement techniques in sugar beet

Longden (1971) subjected natural sugar beet seed to various treatments of wetting and drying. He found that the optimum treatment was four cycles, in each of which equal weights of seed and water were mixed, enclosed in an airtight container for 24 hr and then spread out in a thin layer to dry for 48 hr. This increased cell numbers within the embryo by 229 % and seedling shoot weight by 31-53%. Also the seedlings from the treated seed emerged 2-5 days sooner than the seedlings from untreated seed. These experiments were not taken to yield but the positive effects on seedling development indicated the potential benefits for the UK crop if bolting could be controlled (Thomas, Jaggard, Durrant, Mash and Armstrong, 1993).

Longden, Johnson, Darby and Salter (1979) showed that untreated, advanced (three wetting/drying cycles) and polyethylene glycol "primed" seeds gave 78, 61 and 40 % establishment respectively. In sharp contrast to these results, Durrant, Payne and Mc Laren (1983) showed that advanced seed gave an increase in emergence of 9 % under controlled conditions and a 7 % increase under field conditions over untreated seed. They also showed that seed advancement reduced time to half final emergence. These results were based on 8 experiments over 5 years at Broom's Barn in the UK. When compared for sugar yields, Durrant et al. (1983) found that the advancement treatments used gave an increase of 0.36 t/ha of sugar but was not statistically significant from the control. They provided some evidence that seed advancement may help reduce the damage caused by field mice and the number of plants, which bolt. He also suggested that advanced seed would be of particular benefit in soils that are prone to capping due to its rapid emergence but that there would be a slightly increased risk of frost injury with early sowings. In lieu of these findings, a series of experiments was set up at Broom's Barn experimental station to develop a process which would both devernalise seed and increase establishment. Durrant and Jaggard (1988) showed that the best treatment for both improving establishment and decreasing bolting was steeping the seed in water for 3 hr at 25 ^{0}C, drying it to between 115 and 120 % of its original air-dry weight, storing it for 4 days at 25 ^{0}C and then air-drying it. This treatment decreased by nine days the time to half final emergence in early sowings.

It has been shown that increased cold temperatures experienced by the seed on the mother plant (Lexander, 1969) and before seedlings emerge above soil (Smit, 1982) can cause a sugar beet root crop to set seed and bolt. The decrease in bolting in advanced seed lots compared to untreated seed in experiments by Durrant and Jaggard (1988) and Durrant et al. (1983) was deemed to be from a devernalising effect caused by the seed advancement process (Durrant and Jaggard, 1988). Previous work had shown that the stimulus to bolt could only be modified after the four true leaf stage (Longden, Scott and Tyldesley, 1975). However, the devernalising process does not cancel cold stimuli received after sowing as was shown by Durrant and Jaggard (1988). Therefore the sugar beet plant does not have the capacity to store a warm experience to offset a subsequent cold experience as suggested by Purvis (1961).

Durrant and Mash (1990) assessed various seed treatments over a range of sowing dates for emergence, establishment and percentage bolters. The range of thermal time applied to their treatments was between 0 and 132-day degrees (d ^{0}C) above a base of 3 ^{0}C and between 0 and 60-day degrees above 15 ^{0}C. These base temperatures are considered appropriate for germination (Gummerson, 1986) and devernalisation (Durrant and Jaggard, 1988) respectively. The estimated time taken for the plant to emerge decreased with the thermal time experienced during seed treatment and with delayed sowing and within each sowing date there was an association between time to half final emergence and establishment (Durrant and Mash, 1990). It has been suggested that with early sowings i.e. before mid. March, that keeping the pre-emergence period as short as possible is an essential factor in successful establishment (Durrant and Mash, 1990). Durrant (1988) found a similar trend in a survey of crops in 1981 and 1982. A more rapid growth as shown by seed advancement treatments would allow the plant to overcome this vulnerable pre-emergence period.

With regard to devernalisation Durrant and Mash (1990) found that a thiram steep (0.2 % w/v for 12 hr at 25 ^{0}C) increased the percentage of bolters in the crop when sown in early March compared to a standard EMP steep for 20 minutes. The response was equivalent to the plant responding to 3 additional cool days (air max. >12 ^{0}C). However a more extensively advanced seed (four days at 25 ^{0}C) gave significantly less bolters than the EMP seed when sown in early March. The decrease was as if the plants responded to about seven less cool days. When weather data was taken into account, Durrant and Mash (1990) suggested that the sowing date for this extensively advanced seed could be brought forward to 15th March without the risk of bolters if soil conditions allowed. They postulated that both the Thiram-steep and the extensive advanced treatment make growth more rapid so plants become more sensitive to cold sooner than with EMP-steeped seed but the extensive treatment more than compensates for this by partially devernalising the seed.

When assessing the benefits that an advancement treatment may have under difficult sowing conditions, Durrant and Mash (1992) showed how at different levels of water availability the advanced seed outperformed the control seed except at intermediate water levels. In a depth of sowing trial, the advanced seed again gave better results over the untreated seed. These findings were repeated under field conditions also, where advanced seed reached half final emergence 2 days sooner. They proposed that an advancement treatment would not alter current sowing practises but would improve establishment even more. Taking this research further, Durrant et al (1993) took the most promising treatment of the 1990 trials and attempted to quantify the benefits of such a treatment in yield terms. They concluded that by using the treatment one could bring forward the sowing date by c. 10 days to the 10th March without the risk of causing a weed beet problem from bolters. This increased sugar yield on average by 0.35 t/ha. They found that the advanced seed emerged more rapidly than untreated seed, particularly in cold weather and early sowings. The advanced seed also had the benefits of having lower bolters when sown early (10th March) compared to the untreated seed. Durrant et al (1993) concluded that the untreated seed even with the benefits of newer varieties shouldn't be sown earlier than 20th March.

When discussing how the method of seed advancement could be made commercially viable, Durrant and Jaggard (1988) suggested that the process would require the calibration of individual seed lots and uniformity of moisture amongst individual seeds during treatment. By moisture control of the seed, one can expose it safely to longer periods at higher temperatures for devernalisation whilst accumulating little hydrothermal time (Gummerson, 1986).

In 1989 Germain's (UK) Ltd. began a major research project to bring this experimental work to a commercial reality. In trials from 1992-1997, an advancing treatment gave a more rapid emergence of seedlings. The yield benefits were difficult to distinguish in individual experiments but a yield increase was achieved that was independent of sowing and harvest date (Jarvis and Patchett, 1998). In 1995 the advancing treatment was offered commercially to UK farmers as 'Advantage'. The following year it was available to USA growers (Heyes, Osborne, Halmer and Hughes, 1997). In 1999, 'Advantage' treated seed became commercially available to Irish growers. Heyes et al (1997) showed a 1.8 % increase in yield of sugar from 'Advantage' across cultivars and sites. Fauchere (1997) showed that advanced seeds emerged 2 – 6 days quicker than the control seeds depending on sowing dates. Saunders (1998) when examining 'Advantage' seed and a range of starter fertilisers showed no yield benefit from 'Advantage' seed alone. However when used with starter fertilisers, yield increases were seen but not significantly so. He did show highly significant benefits in early season crop growth from combining a high Phosphorous starter fertiliser and 'Advantage' seed treatment.

2.4. Quality parameters for sugar beet roots

Beet quality is a combination of the entire chemical and physical aspects of the beet root which influence processing or which affect the yield of sugar or its by-products (Oldfield, 1974). Root quality is important to processors as the roots represent their major manufacturing cost. In its contract with growers the Irish Sugar Company stipulates that all sugar beet roots shall be topped squarely, immediately below where the lowest leaves on the crown have grown. The reason for this is that crown material relative to the main body of the root is known to be lower in sugar percentage and higher in impurities. These impurities are not removed easily, some not at all, causing a reduced yield of white crystalline sugar and increased production of molasses (O'Connor, 1981; Last, Draycott and Hull, 1976). The ideal position for separating whole beet into root and crown portions was put forward by Jorritsma and Oldfield (1969). At their demarcation point, the vascular bundles change from being irregular and corrugated to become concentric and parallel to the skin. This point corresponds closely to the position of the lowest leaf scar. Formulae for predicting the yield of white crystalline sugar from using laboratory data for K, Na, and Amino-N can only be used as indices of recoverable sugar yield. It is necessary to stimulate factory processes to achieve real root chemical quality (Harvey and Dutton, 1993).

2.4.1. Sugar Content

Oldfield (1974) pointed out that as the sugar content of beet increases, that labour, capital, transport costs and processing costs all decrease. This is reflected in the pricing structures of the sugar processors that the price paid per tonne of sugar increases as the sugar content of the root increases. Any factor that could increase sugar percentage effectively would be very worthwhile pursuing in a quota situation. The factors affecting sugar content relevant to this trial have already been reviewed in other sections.

2.4.2. Dirt Tare

Each year, extraneous material (mainly soil and stones) weighing 170,000- 190,000 tonnes is delivered to the two sugar beet processing factories in Ireland (Broderick, 1998). This constitutes 12.3 % - 13.7 % of the 1.38 million tonnes of beet processed annually in Ireland. At today's prices the cost of transporting this amount of dirt tare from grower to the processor is £1.64 million annually based on 32,800 hectares of beet at £1 to £1.20 / tonne over 1.38 million tonnes of clean beet (Broderick, 1998). This cost of transporting the dirt tare is totally borne by the grower. Obviously any saving in the amount of dirt tare delivered to the processor is a direct saving to growers.

At present much research is ongoing in Europe to reduce the amount of tare delivered to processors. In Denmark a three-year study was carried out by the Danisco Sugar Development Centre on all aspects of reducing soil tare (Fallesen and Van der Linden, 1997). Siucra Eireann has recently started a Quality Beet campaign with advice on all aspects of beet production to lower the delivery of tare to their factories (Broderick, 1998). The IIRB devoted its 47th conference to the subject of reducing tare through better harvesting and handling techniques. There have also been a number of promotions and changes to the payments systems by the processors. For example, the Dutch company Suiker Unie, have started to charge the growers on a per tonne of dirt tare delivered to the factory to encourage dirt removal on the farm (Harvey and Dutton, 1993). In Ireland there is a quality bonus scheme in place a number of years, which is referred to as the crown tare allowance. This is based on a quality payment equivalent of £1 per tonne of beet for crown tares under 7.99 % and a lesser amount for crown tares from 8 - 9 % (Broderick, 1998). In the future this is set to increase in an effort to again encourage growers to leave as much dirt and crown tare in the fields. Also there is and will be a significant element of the beet price formula that is associated with tonnes of clean beet delivered.

2.4.2.1. Problems associated with dirt tare

There are a number of well-known problems associated with dirt tare both to the grower and to the processor. To the grower the main problem is that excessive dirt during storage of beet in growers' clamps is the cause of 'hot-spots', which lead to increased losses due to over-heating. Also there are the sometimes forgotten losses of nutrients and organic matter from the topsoil (Harvey and Dutton, 1993).

Tops, dirt and trash accompanying beet to the factory are very harmful to the extraction process. Dirt that is not removed by the washing process goes through the extraction process where it will increase knife usage and if there is high clay content it will reduce sugar extraction in the carbonation stage (Harvey and Dutton, 1993). While the cost of removing and handling the dirt tare at the factories is a major concern, the environmental implications are now becoming increasingly important (Ryan, 1994). The amount of tare delivered to the processing plants in Ireland every year is enough to add 14-15 feet to an area of 1.6 hectares (Broderick, 1998). Today, processing factories will clean beet to a level of 0.2 - 0.5 % soil remaining on the roots (Fallesen and Van Der Linden, 1997). This results in using a large amount of wash water. In a study on the effects of soil on the performance of processing plants, Fallasen and Van Der Linden (1997) added soil (up to 1 %) to different lots of beet put through an experimental plant. Based on the amount of ash and sand (hydrochloric acid insoluble ash) allowed in fodder pills, 8 % and 2 % on a dry matter basis respectively, Fallasen and Van Der Linden (1997) concluded that 0.2 % soil on beet roots at processing would be the maximum permitted through a plant to achieve these parameters.

2.4.2.2. Reducing dirt tare

Work in the U.K. reported by Patchett and Bee (1997) showed that increasing plant populations significantly increased soil tare in each year of a 4-year trial as did Koch (1996). The reason given for the relationship was that at equivalent yields there is a greater surface area for soil to adhere to the smaller beet grown at higher plant populations. Smit et al (1995) also gave similar results when discussing trial work done in Holland. In the same years no relationship has been demonstrated between soil tare and root yield. Brown (1997) cited a uniform plant stand as a contributory factor in achieving low beet losses at harvest time. The possible sources for genetic variation in the modern varieties of sugar beet is limited due to selection in the past for internal root characteristics and yield.

Currently, there is work underway on reduced impact environmental beet as described by Elliot and Weston (1993). Meskin and Dieleman (1988) successfully crossed table beet with traditional beet varieties. They reported that this hybrid material had a much rounder shape without root groves, a narrower crown, less variations in crown height and required much less pulling power. However the yield and quality characteristics were less than what would be economically acceptable. Brussard (1996) reported similar findings and suggested that the tare unfriendly sugar beet has much potential for reducing production and processing costs. Patchett and Bee (1997) examined the effects of plant populations, variety and cleaning mechanisms on soil tare over 4 years in the U.K. They reported a cultivar 'Univers' giving lower soil tare than other cultivars on trial. Koch (1996) showed how choice of cultivar reduced soil tare by 20 % through different shaped roots and less variations in crown height.

In Ireland there is evidence that delaying harvesting contributes to increasing soil tare. Kenny (1999) reported 10.2%; 11.2%; and 13.1% average soil tares for the months October; November and December respectively over a period 1992-1996. Primarily this is a function of wetter conditions at time of harvest as wetter, more difficult conditions are more likely the later harvesting occurs. Also the type of beet harvester used mainly in Ireland is a belt lifter. This harvester requires good disease free leaves to lift the beet from the ground. Again, the later harvesting is delayed, the more likely frost damage and natural senescence to the leaves occurs and so the efficiency of the topping mechanism on the harvester is reduced thus increasing total tare.

3.0. Materials and Methods

3.1. Site and Location:

The trials were carried out on the University farm at Lyons Research Farm, Newcastle, Co. Dublin in a field known as Number 5. It is a level field with moderate drainage. The soil type is classed as a silty clay loam over a parent material of decalcified or decalcifying Calp limestone (Collins & Brickley, 1970).

3.2. Previous cropping history

This field had been in grazed grass for four years (1992-1996) and was sown to spring wheat in 1997.

3.3. Experimental Treatments:

3.3.1. Trial 1. (Time of sowing by seed treatment)

In trial one, a randomised complete block design with a factorial arrangement was used consisting of six treatments made up of two seed treatments and three sowing dates. The trial was replicated four times. The cultivar used was Libra, a triploid cultivar from Belgium breeders Strube-Dieckmann. It has very good root yield, average sugar content with good bolting resistance (Grogan, 1998). The seed treatments were named ‘Control’ for the untreated seed and ‘Advantage’ for the treated seed. The three sowing dates were as follows:

April 17th
April 24th
May 2nd

3.3.2. Trial 2. (Cultivar by seed treatment)

In trial two, a randomised complete block design with a factorial arrangement was used consisting of eight treatments made up of two seed treatments and four cultivars. The trial was replicated four times. The cultivars used were two diploids, Celt and Zulu and two triploids, Accord and Libra. The cultivar Celt has very even emergence under all conditions, average root and sugar yield with low impurities (Grogan, 1998). Zulu is described below. The cultivar Accord is classified as having reliable yields over many soil types, average sugar content with average bolting resistance (Grogan, 1998). The seed treatments were named ‘Control’ for the untreated seed and ‘Advantage’ for the treated seed.

3.3.3. Trial 3. (Time of harvest by seed treatment)

In trial three, a randomised complete block design with a factorial arrangement was used consisting of eight treatments made up of two seed treatments and four harvest dates. The trial was replicated four times. The cultivar Zulu, a diploid from Hilleshog, was used. It has average root yield and sugar content with bolting resistance. It generally gives good emergence and establishment (Grogan, 1998). The seed treatments were named ‘Control’ for the untreated seed and ‘Advantage’ for the treated seed.

The four harvest dates were as follows:

October 14th

October 21st

November 4th

November 18th

3.3.4. Trial 4

In trial four, a randomised complete block design was used consisting of three seed treatments. The trial was replicated four times. The cultivar Libra was used. The seed treatments were named ‘Control’ for the untreated seed, ‘Advantage’ for seed treated in a commercial manner by Germain’s, U.K. and ‘Experimental’ for seed that was advanced under an experimental process by Germain’s, U.K.

3.3.5. A typical trial layout.

Variety trial

Replication No. 2

Celt Advantage	Zulu Advantage	Libra Advantage	Accord Control	Libra Control	Accord Advantage	Zulu Control	Celt Control

3.3.5. Plot size and layout

All plots consisted of five rows, each being 56 cm apart and eight metres long. The trial area was the middle three rows of each plot with the end beet plants being discarded. The length of each plot was measured at harvest and recorded. From this and the inter-row spacing, a plot or trial area was calculated. Data on emergence, percentage ground cover, yield and quality are all from this trial area.

3.4. Cultural Treatments:

3.4.1. Seed source:

Seed of the sugar beet varieties Accord; Celt; Libra; and Zulu were sent to be advanced in the commercial manner by Germain's Ltd., King's Lynn, Norfolk, England. This advancement process is patented as 'Advantage' by Germain's U.K. Ltd. The process is based on work done at Broom's Barn, Norfolk, England. The optimum advancement process developed there was sugar beet seed steeped in water for a number of hours, partially dried back to 115% of the original weight and then treated for 4 days at 25^0C (Thomas et al., 1993). Seed from the same stock was used as the control seed in the four trials.

3.4.2. Cultivation:

The field was ploughed in the second week of December 1997 to a depth of 22 cm. Prior to sowing the field got two passes of a deep tine harrow and one or two passes of a rotary power harrow, depending on soil conditions. This cultivation produced a suitable seedbed for all the trials. In the time of sowing trial, the individual plots were power harrowed just prior to sowing to avoid a crust developing. In all cases machinery passes were kept to a minimum. There were no further inter-row passes by machinery after sowing.

3.4.3. Fertilisation:

The trial field received 0.86 t/ha. of beet compound fertiliser No. 1 from Irish Sugar. The compound was in the following ratio - 112 kg N : 34 kg P : 120 kg K : 50 kg Na : 26 kg S : 2.8 kg B. The compound was spread conventionally between the first and second passes of a deep tined harrow. No further applications of granular fertiliser were deemed necessary based on soil analysis and place in rotation.

3.4.4. Sowing:

All the trials were ‘drilled to a stand’ using a conventional Armer-Salmon five row precision seeder. The seeder had ridging bodies in front of the seed boxes and also had a granule applicator for insecticides at sowing. The seed spacing for all the trials was 56 cm between drills and 17.0 cm within drills. This gave a seeding rate of 107,000 seeds per ha. with a target final plant population of 75,000 plants /ha. .

Due to adverse weather and the heavy nature of the soil in March and the first half of April, drilling did not commence until April 17th with the drilling of the first time of sowing of Trial 1. Trial 2 and Trial 3 were drilled on the 18th April 1998. The second time of sowing in Trial 1 and all of Trial 4 were drilled on the 24th April 1998 while the final time of sowing of Trial 1 was drilled on the 2nd May 1998.

Observations – soil conditions on all sowing dates were good. Very heavy rain after sowing on the 24th April caused a slight crust to form on the seedbed.

3.5. Chemical treatments:

3.5.1. Fungicides:

An application of foliar elemental sulphur was made in the variety, harvest date and experimental trials on 24th August to control Powdery mildew (*Erysiphe polygoni*). No further fungicides were applied as it was thought it would bias the later harvest dates over earlier harvest dates.

3.5.2. Weed control:

The main weed species in the field were : Black Bindweed (*Fallopia convolvulus*); Common Chickweed (*Stellaria media*); Common Orache (*Atriplex patula*); Fat Hen (*Chenopodium album*); Knotgrass (*Polygonum aviculare*); Red Dead Nettle (*Lamium purpureum*); and Shepherd’s Purse (*Capsella bursa pastoris*).

The same chemicals were applied to all plots in three splits as follows: -

Timing	Chemical (active ingredient)	Rate
T. 1	Betanal-Progress (Phenmedipham, Desmedipham, Ethofumesate)	1.0 l/ha.
	Goltix (Metamitron)	0.5 kg/ha.
T. 2	Betanal-Progress	2.0 l/ha.
	Goltix	1.0 kg/ha.
	Mineral oil	0.25 l/ha.
T. 3	Betanal-Progress	3.0 l/ha.
	Goltix	1.5 kg/ha.
	Mineral oil	0.4 l/ha.

The harvest date, variety and experimental treatment trials were sprayed perpendicular to the direction of sowing with a tractor-mounted Berthound sprayer. In the case of the sowing date trial, the plots were sprayed separately using an Azo plot sprayer. Each of the three times of sowing had to be sprayed separately for the first two spray dates. For T3 all four trials were sprayed using the tractor-mounted sprayer. It was not deemed necessary to treat the advanced seed treatments differently from the control seed treatments with regard to weed control.

Observations - at T1 and T2 the beet plants in 'Advantage' treatments looked noticeably more advanced in growth than the control treatments of the same sowing date. No record was made of beet vigour after the times of spraying but treatments were not any more 'checked' than would be expected. Weed control was good in all four trials.

Weed Control Timings

Spray Timing	Plant Growth Stage	Trial Plots sprayed
T.1 15 May 1998	Flat Cotyledon	Trial 1 - First time of sowing Trial 2 - All plots Trial 3 - All plots
T. 1 23 May 1998	Flat Cotyledon	Trial 1 - Second time of sowing Trial 4 - All plots
T. 1 29 May 1998	Flat Cotyledon	Trial 1 - Third time of sowing
T. 2 20 June 1998	Four True Leaves	Trial 1 - First time of sowing Trial 2 - All plots Trial 3 - All plots Trial 4 - All plots
T. 2 30 June 1998	Four True Leaves	Trial 1 - Second time of sowing
T. 2 5 July 1998	Four True Leaves	Trial 1 - Third time of sowing
T. 3 29 July 1998	6-8 True Leaves	Trial 1 - All plots Trial 2 - All plots Trial 3 - All plots Trial 4 - All plots

3.5.3. Insecticides:

A granular application of Yaltox-Combi (a.i. carbofuran-isofenphos), placed around the seed, was used at sowing in all trials mainly for the control of leatherjackets (*Tipula paludosa*) and wireworms (*Agriotes lineatus*).

An aphicide, Sumi-Alpha (Esfenvalerate) was applied to the crop on 19th June. A second aphicide, Decis (Deltamethrin) was applied on 9th July. Both applications were to control black-bean aphids (*Aphis fabae*).

3.5.4. Trace Elements:

One foliar spray of ‘Mantrac’ containing 500 g/ha. of manganese was applied to all plots on the 19th June as the soil is known to be deficient in manganese. No obvious symptoms of manganese deficiency were evident in the crop.

3.6. Experimental Recordings and Calculations.

3.6.1. Emergence and Establishment

Emergence counts were made on all plots in Trial 1 and Trial 4. Emergence counts were also made on three replications of Trial 3 and randomly selected plots of Trial 2. A plant was considered emerged once its hypocotyl could be seen with the naked eye after it had come over ground level. No record of emerged plants killed due to abiotic or biotic factors was made. These recordings were made on the middle three rows of each plot. Target establishment figures were calculated from inter-seed spacing and plot length as follows:

$$\frac{\text{Plot length}}{\text{Inter-seed spacing}} = \text{Number of seeds per row}$$

Number of seeds per row X number of rows = number of seeds sown per plot.

The number of seeds sown per plot was assumed to be equivalent to 100 % establishment of the plot. A final count of the number of roots at harvest gave a final establishment count.

Observations – emergence in all trials was excellent with final plant populations >70,000 plant /ha. Some minor pest damage was seen in a small number of plots but was not specific to any one treatment or plot.

3.6.2. Percentage ground cover measurement

The development of the crop canopy from emergence to full leaf cover was assessed by determining the percentage of ground cover achieved by the plants at a particular time relative to full ground cover. This was measured in all plots of Trial 1 and Trial 4. It was also measured in three replications of Trial 3 and randomly selected plots of Trial 2. At each assessment two randomly taken measurements were taken per plot from the middle three rows of each. The percentage ground cover was determined with the aid of a perspex sheet measuring 56 cm wide and 88 cm long. These measurements correspond to the space occupied by 5 plants evenly spaced by the spacing arrangement used in the trial plots. The perspex sheet was sub-divided by a marker into 100 boxes 5.6 cm x 8.8 cm. The perspex sheet was held by hand over the plot and the number of ‘full’ or ‘empty’ boxes was counted.

3.6.3. Harvesting :

The four trials were harvested by hand starting on the 7th October and the last being 18th.November. The loose dirt was shaken off the roots after pulling. The beet plants in the trial area were topped by hand through the lowest leaf scar as described by O’ Connor (1981). The roots taken from each plot were weighed separately from the crowns using electronic scales. The number of beet plants per plot was also recorded at harvest. From the plots, 20 roots were randomly selected by hand, bagged and stored in a refrigerated room at 3 ^{o}C, until they were sent to the laboratory to be analysed

Observations – Conditions at all harvest times were dry and cool. Both tops and crown were in good condition, which also facilitated easier hand pulling and crowning.

3.6.4. Soil Tare analysis:

In all four trials a soil tare assessment was carried out. A sub-sample from each plot was weighed, cleaned using a knife and weighed again. From this, the soil tare percentage was calculated.

3.6.5. Quality Analysis

In all four trials, a random sample of roots from the plots was bagged and stored in a refrigerated room at 3 ^{o}C. These samples were sent to the laboratory at Irish Sugar Plc., Carlow for quality analysis.

Figures received for sugar percentage were used to calculate total sugar yield per hectare as follows:

Yield of clean Beet (t/ha.) X sugar % = yield of sugar/ha. (t/ha.)

Readings for Potassium (K), Sodium (Na) and Amino-N were expressed in mg per 100g sugar.

These were then used to calculate the Summation value for Impurity Index as follows:

$$\frac{\mathbf{1(1.9\ K + 2.3\ Na + 10\ amino\text{-}N)}}{\mathbf{Sugar\ \%}} = \mathbf{Sum\ I.I.} \quad \text{(Kearney, 1971)}$$

Percentage extractability was expressed as follows:

$$\mathbf{100\text{-}(\frac{1.9\ Sum\ I.I.}{1000})} = \mathbf{\%\ Extractability} \quad \text{(Kearney, 1971)}$$

Extractable sugar per hectare (t/ha.) was expressed as follows:

$$\frac{\mathbf{Yield\ of\ sugar/ha.\ X\ \ \%\ Extractability}}{\mathbf{1000}}$$

3.6.6 Statistical analysis

The data for all measurements was subjected to standard analysis of variance as described by Snedecor and Cochran (1967). The computer package MSTAT was used for this purpose.

4.0. Results

The results of the four trials are presented below. Each trial is presented separately and the analysis of the data can be seen in the appendices. Graphs are used to illustrate trends over a period of time that might not be clear from the tables.

4.1. Time of sowing by seed treatment trial (Trial 1)

4.1.1. Emergence

4.1.2. Ground Cover

4.1.3. Yield & Quality

4.2. Cultivar by seed treatment trial (Trial 2)

4.2.1. Emergence

4.2.2. Ground Cover

4.2.3. Yield & Quality

4.3. Time of harvest by seed treatment trial (Trial 3)

4.3.1. Yield & Quality

4.4. Experimental treatment trial (Trial 4)

4.4.1. Emergence & Ground Cover

4.4.2. Yield & Quality

4.1. Time of sowing by seed treatment trial (Trial 1).

4.1.1 Emergence

Figure 1. Effect of 'Advantage' seed on the emergence percentage of sugar beet for first sowing date (17/4/98).

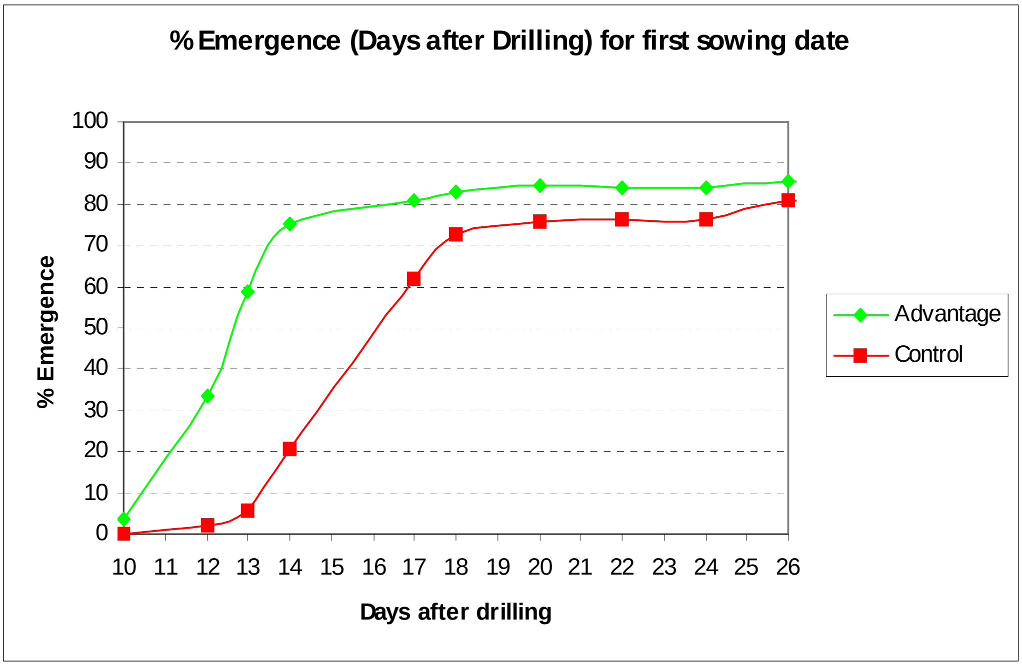


Table 1. Effect of 'Advantage' seed on the emergence percentage of sugar beet for first sowing date (17/4/98).

	Days after Drilling					
	10	**12**	**13**	**14**	**17**	**18**
Seed Treatment						
Control	0.0	2.2	5.4	20.7	61.8	72.6
Advantage	3.8	33.5	58.9	75.4	81.0	82.8
LSD 5 %	0.81	0.84	0.7	0.88	0.74	0.28
LSD 1 %	1.49	1.53	1.29	1.61	-	-

Advantage seed was significantly ($p<0.01$) better than the control for percentage emergence up to 14 days after drilling (first sowing date) and was significantly better ($p<0.05$) up to 18 days after drilling (first sowing date). There was no significant difference in emergence percentage beyond 18 days after drilling (first sowing date).

At 50 % emergence there were 4 days between the 'Advantage' and the control.

(See Appendix 1)

Figure 2. Effect of ‘Advantage’ seed on the emergence percentage of sugar beet for second sowing date (24/4/98).

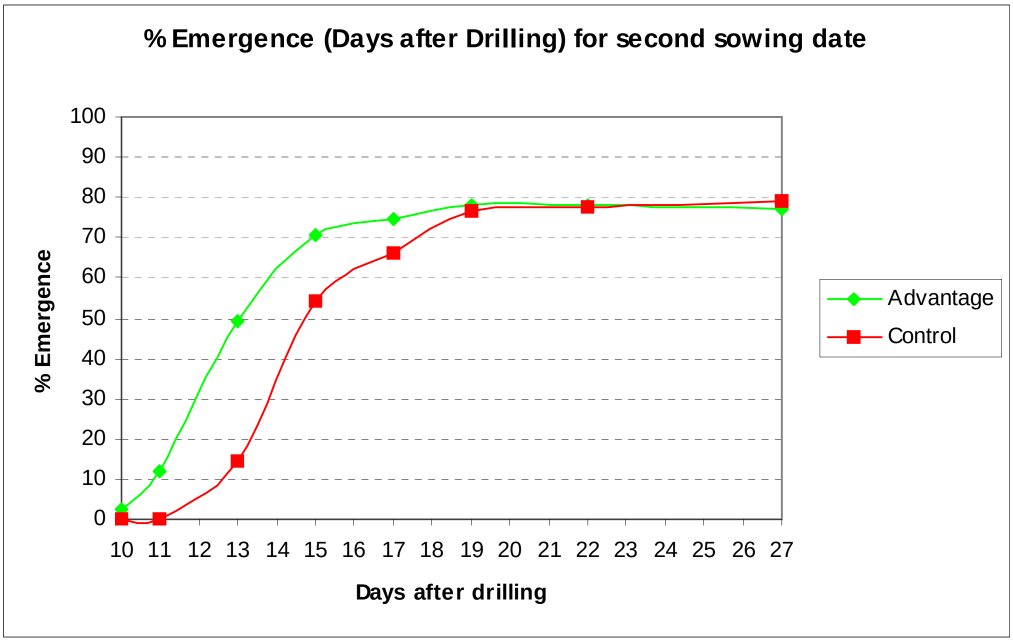


Table 2. Effect of ‘Advantage’ seed on the emergence percentage of sugar beet for second sowing date (24/4/98).

Days after drilling					
	10	**11**	**13**	**15**	**17**
Seed Treatment					
Control	0	0	14.7	54.0	65.9
Advantage	2.5	12.1	49.5	70.8	74.5
LSD 5 %	0.48	0.49	0.82	0.34	0.47
LSD 1 %	0.88	0.91	1.52	0.63	-

Advantage seed was significantly ($p<0.01$) better than the control for percentage emergence up to 15 days after drilling (second sowing date) and was significantly better ($p<0.05$) up to 17 days after drilling. There was no significant difference in emergence percentage beyond 17 days after drilling. At 50 % emergence there were 2 days between ‘Advantage’ and the control.

(See Appendix 2)

Figure 3. Effect of 'Advantage' seed on the emergence percentage of sugar beet for third sowing date (2/5/98).

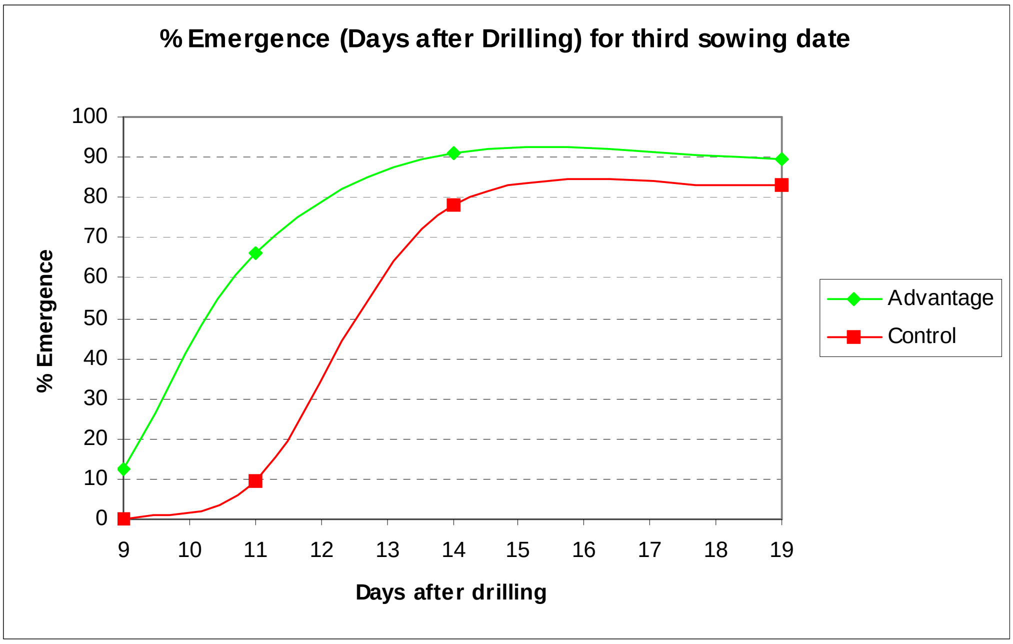


Table 3. Effect of 'Advantage' seed on the emergence percentage of sugar beet for third sowing date (2/5/98).

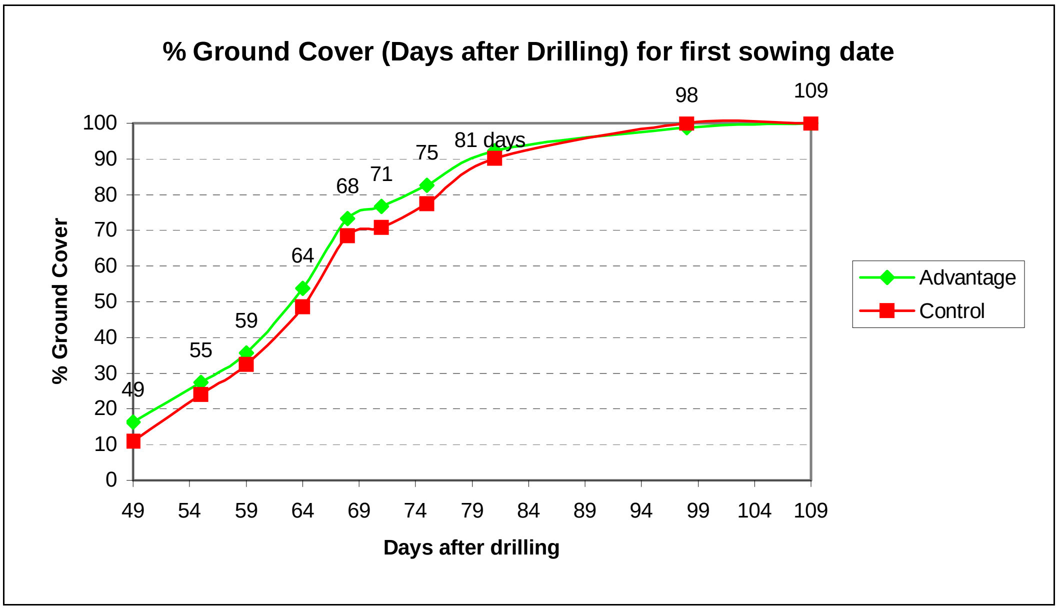
	Days after Drilling		
	9	**11**	**14**
Seed Treatment			
Control	0	9.4	78.3
Advantage	12.5	65.9	90.9
LSD 5 %	0.54	0.53	0.39
LSD 1 %	0.99	0.97	-

Advantage seed was significantly ($p<0.01$) better than the control for percentage emergence up to 11 days after drilling (third sowing date) and was significantly better ($p<0.05$) up to 14 days after drilling. There was no significant difference in emergence percentage beyond 14 days after drilling. At 50 % emergence there were 2 days between the 'Advantage' and the control.

(See Appendix 3)

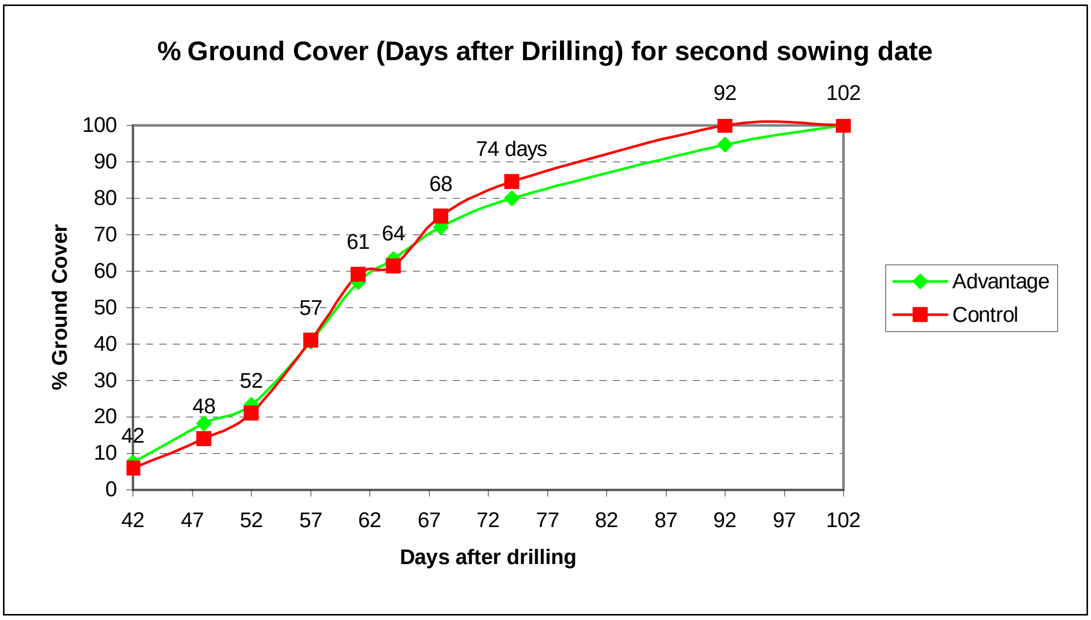
4.1.2. Ground Cover

Figure 4. Effect of 'Advantage' seed on percentage ground cover for first sowing date (17/4/98).



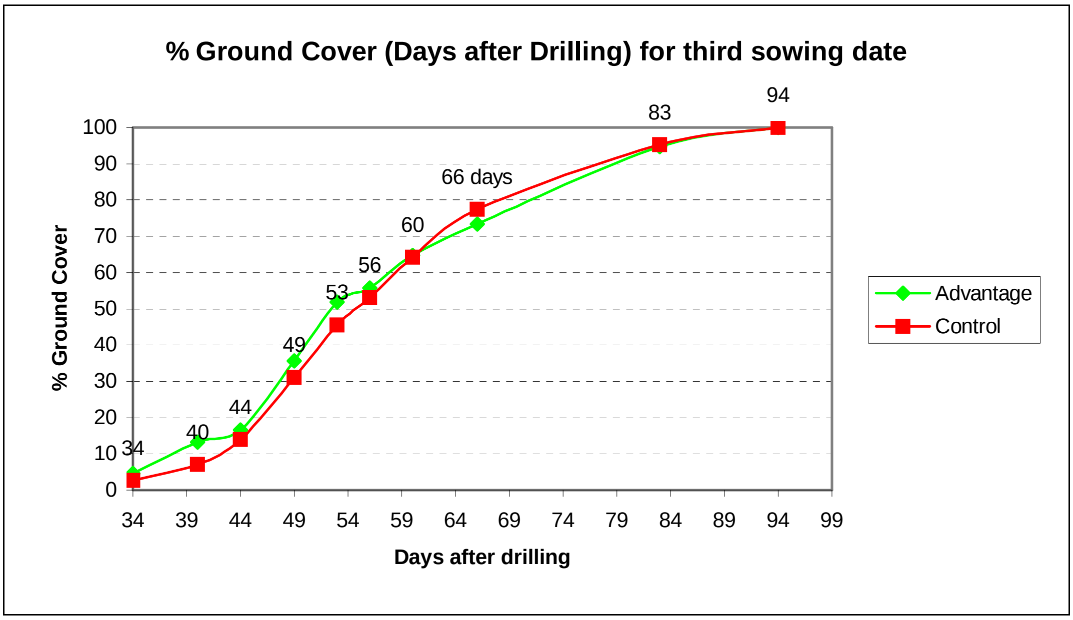
There was little difference in treatment in % ground cover except that 'Advantage' seed treatment gave better ground cover than the control only at the 49 (LSD 5% = 3.25) and 71 (LSD 1% = 4.77) day measurement times. (See Appendix 4)

Figure 5. Effect of 'Advantage' seed on percentage ground cover for second sowing date (24/4/98).



Seed treatment had no significant effect on percentage ground cover for the second sowing date. (See Appendix 5)

Figure 6. Effect of 'Advantage' seed on percentage ground cover for third sowing date (2/5/98).



There was little difference in % ground cover between the seed treatments with the 'Advantage' seed treatment giving better cover than the control at only the 40 day measurement (LSD 5% = 4.03).

(See Appendix 6)

4.1.3. Yield & Quality

Table 11. Effect of sowing date and the use of 'Advantage' seed on the yield of clean beet (t/ha.) and percentage tare.

Sowing date	Yield of clean beet (t/ha.)	% Tare
First	66.89	10.42
Second	61.47	10.83
Third	57.98	13.08
LSD 5%	3.52	-
LSD 1%	3.98	-
Seed Treatment		
Control	61.52	11.09
Advantage	62.71	11.79
LSD 5%	-	-

Yields of clean beet declined as sowing date was delayed with the first date of sowing yielding significantly ($P<0.01$) greater than the second and third dates.

Neither sowing date nor seed treatment significantly affected percentage tare on the roots. (See Appendices 7 and 8)

Table 12. Effect of sowing date and the use of 'Advantage' seed on percentage sugar in the roots and percentage sugar extractability in the roots.

Sowing date	% Sugar	% Sugar extractability
First	17.48	92.45
Second	17.00	92.22
Third	16.88	91.97
LSD 5%	-	-
Seed Treatment		
Control	16.91	91.94
Advantage	17.33	92.49
LSD 5%	-	-

The first sowing date gave the highest % sugar but it was not significantly different from the two other sowing dates. 'Advantage' seed gave higher sugar but it was not significantly different from the control.

Sowing date did not affect percentage extractability of the sugar but Advantage seed gave a higher value than the control (p=0.07). (See Appendices 9 and 10)

Table 13. Effect of sowing date and the use of 'Advantage' seed on the yield of sugar (t/ha.) and yield of extractable sugar (t/ha.).

Sowing date	**Yield of sugar (t/ha.)**	**Yield of extractable sugar (t/ha.)**
First	11.69	10.82
Second	10.45	9.64
Third	9.76	9.00
LSD 5%	0.86	0.84
LSD 1%	1.19	1.16
Seed Treatment		
Control	10.41	9.57
Advantage	10.88	10.07
LSD 5%	-	-

The first sowing date had a significantly higher yield of sugar than the third (P<0.01) and second (P<0.05) sowing dates. Yield of sugar was higher from the 'Advantage' seed over the control but not significantly so. The first sowing date had a significantly (P<0.01) higher yield of extractable sugar than the first and second sowing dates.
(See Appendices 11 and 12)

Table 14. Effect of sowing date and the use of 'Advantage' seed on number of plants/Ha.('000) (prior to harvest) and on yield of tops (t/ha.).

Sowing date	Number of plants/Ha. ('000)	Yield of tops (t/ha.)
First	76.47	47.34
Second	73.49	43.99
Third	81.53	44.26
LSD 5%	4.74	-
LSD 1%	6.56	-
Seed Treatment		
Control	75.69	44.52
Advantage	78.63	45.87
LSD 5%	-	-

The third sowing date had a significantly higher percentage final plant establishment than the second (P<0.01) and first (P<0.05) sowing dates. The first sowing date gave the highest yield of tops but it was not significantly different from the second and third sowing dates.

'Advantage' seed gave a higher yield than the control but not significantly so. (See Appendices 13 and 14)

4.2. Cultivar by seed treatment trial (Trial 2)

4.2.1. Emergence

Figure 7. Effect of 'Advantage' seed on percentage emergence of the cultivar Accord.

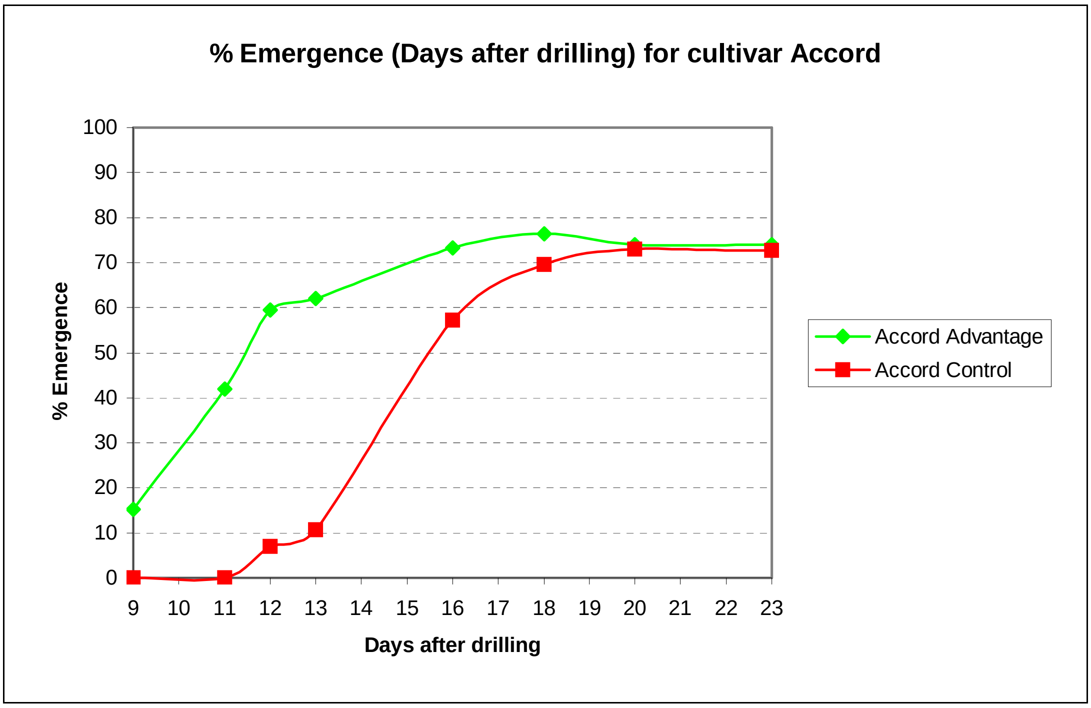


Figure 8. Effect of 'Advantage' seed on percentage emergence of the cultivar Celt.

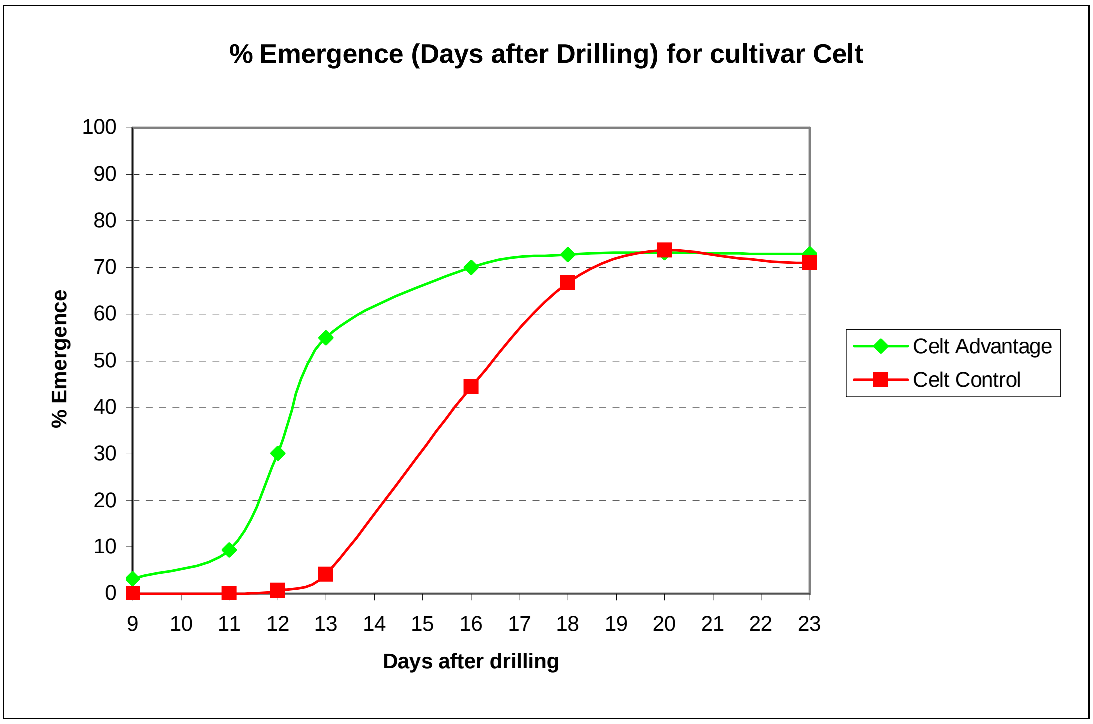


Figure 9. Effect of 'Advantage' seed on percentage emergence of the cultivar Libra.

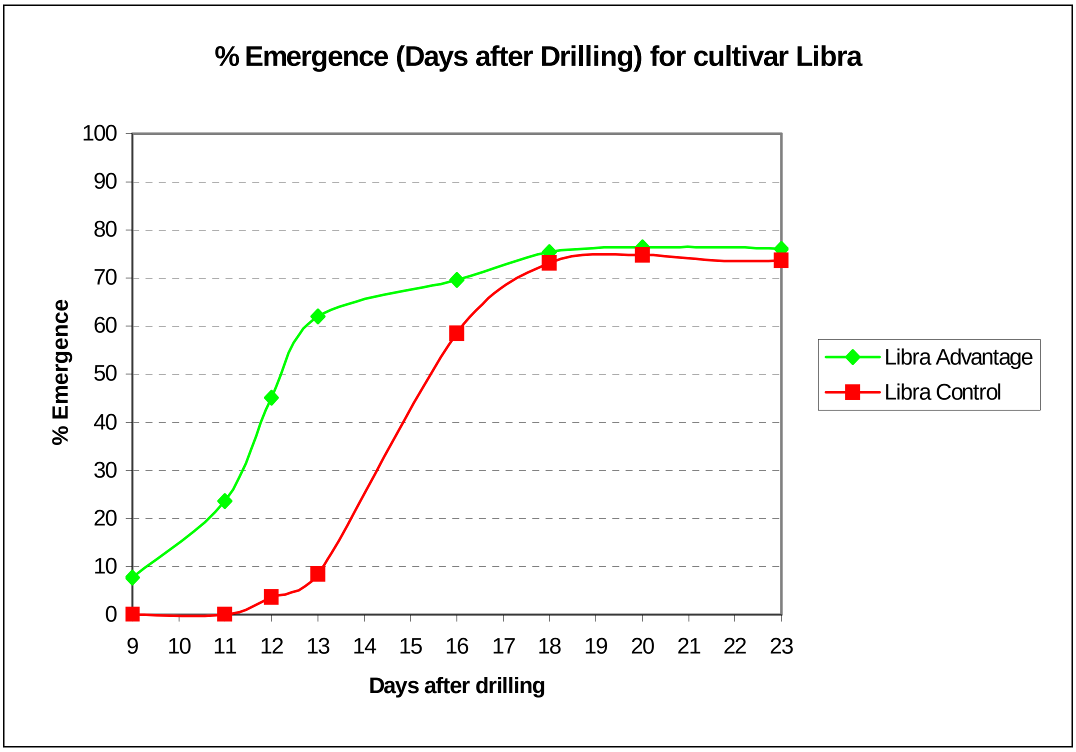


Figure 10. Effect of 'Advantage' seed on percentage emergence of the cultivar Zulu.

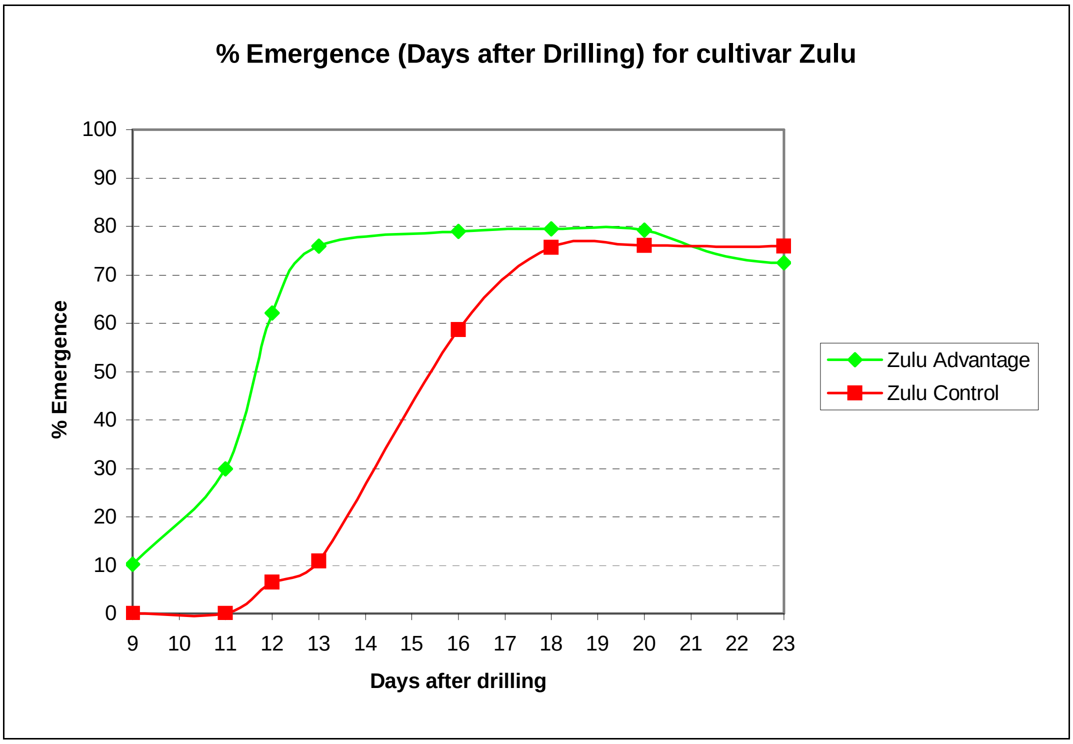


Table 7. Effect of cultivar and the use of 'Advantage' seed on the percentage emergence of sugar beet.

% Emergence (Days after Drilling)									
Cultivar	**9**	**11**	**12**	**13**	**16**	**18**	**20**	**23**	**33**
Accord	7.6	21	33.2	36.4	65.2	72.9	73.3	73.3	74.4
Celt	1.6	4.7	15.5	29.5	57.3	69.7	72	72	73.2
Libra	3.9	11.8	24.4	35.3	64	74.3	74.9	74.9	77.2
Zulu	5.1	15	34.3	43.4	68.9	77.5	74.2	74.2	79.5
LSD 5 %	2.2	5.4	9.1	7.3	-	-	-	-	-
LSD 1 %	3.0	7.5	12.6	10.0	-	-	-	-	-
Seed Treatment									
Control	0	0	4.5	8.5	54.7	71.3	73.3	73.3	76.9
Advantage	9.1	26.3	49.2	63.7	72.9	76	73.9	73.9	75.2
LSD 5 %	1.5	3.8	6.4	5.2	6.6	-	-	-	-
LSD 1 %	2.1	5.3	8.9	7.1	8.9	-	-	-	-

Cultivar had a significant effect on percentage emergence on 4 assessment dates after drilling viz. 9, 11, 12 and 13. Accord had the highest % emergence on days 9 and 11 while Celt had the lowest. Accord and Zulu were the highest at days 12 and 13 and Celt the lowest.

Advantage seed gave a significantly ($p<0.01$) greater percentage emergence than the control up to 16 days after drilling. However on 9,11 and 12 days after drilling, there was a significant interaction between cultivar and seed treatment.

(See Appendix 15)

4.2.2.Ground Cover

Figure 11. Effect of 'Advantage' seed on percentage ground cover for the cultivar Accord.

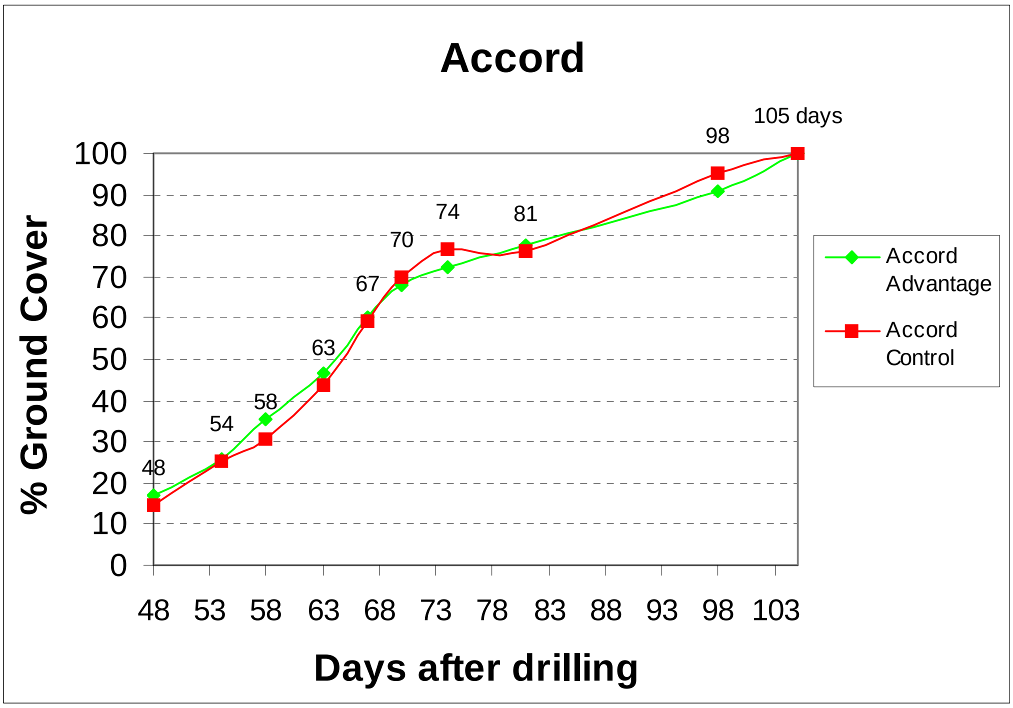


Figure 12. Effect of 'Advantage' seed on percentage ground cover for the cultivar Celt.

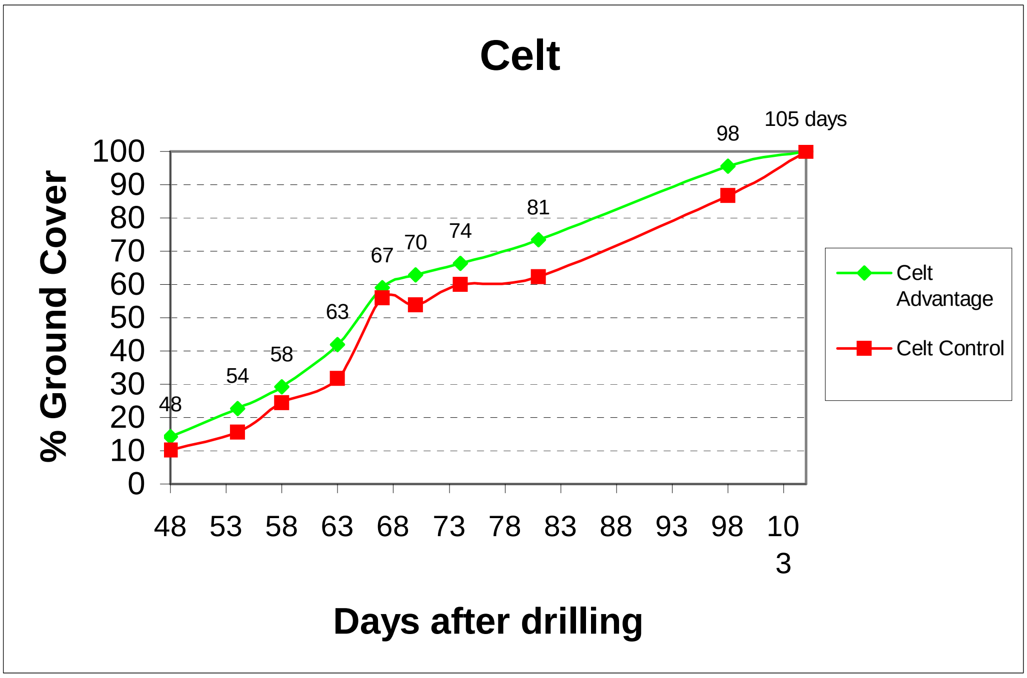


Figure 13. Effect of 'Advantage' seed on percentage ground cover for the cultivar Libra.

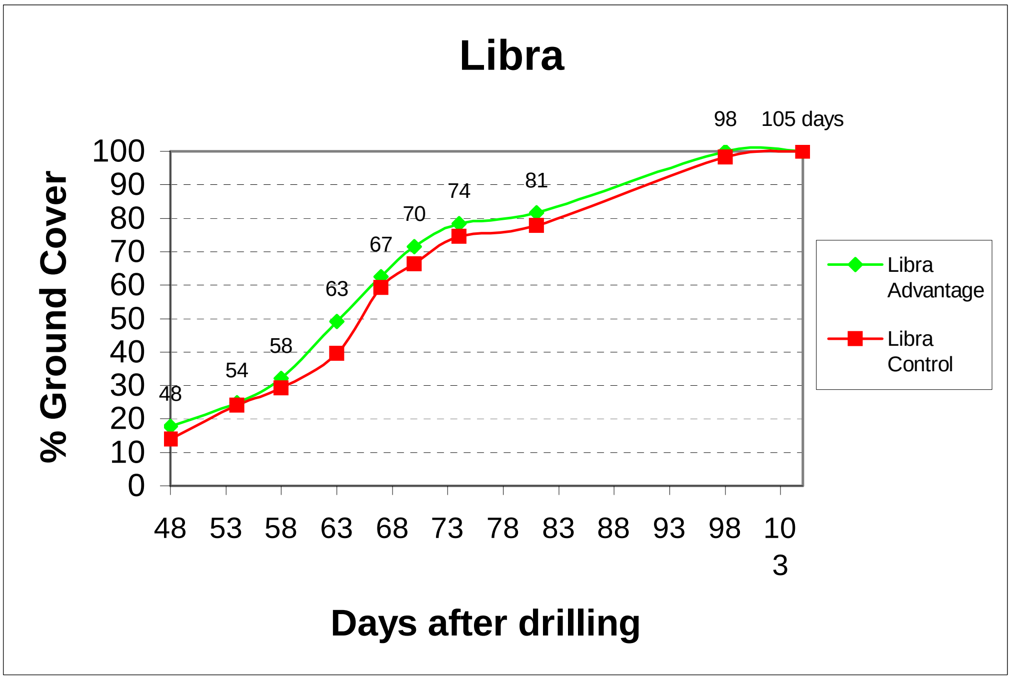


Figure 14. Effect of 'Advantage' seed on percentage ground cover for the cultivar Zulu

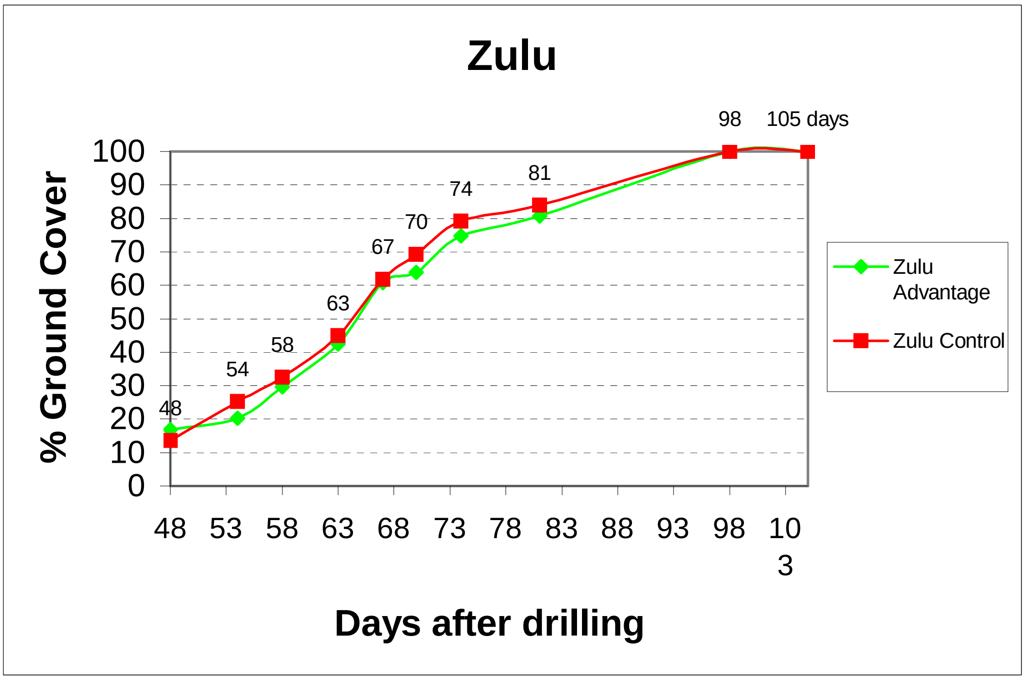


Table 8. Effect of cultivar and the use of 'Advantage' seed on percentage ground cover of sugar beet.

% Ground Cover (Days after Drilling)										
Cultivar	**48**	**54**	**58**	**63**	**67**	**70**	**74**	**81**	**98**	**105**
Accord	15.8	25.3	33.2	45.3	59.7	68.8	74.4	77.0	86.5	95.0
Celt	12.2	19.1	26.8	36.8	57.5	58.3	63.2	67.9	87.8	98.1
Libra	15.9	24.5	30.8	44.3	60.9	68.9	76.4	79.8	95.0	98.1
Zulu	15.2	22.8	31.1	43.8	61.3	66.5	76.9	82.3	97.5	100
LSD 5 %	-	-	-	4.7	-	6.0	7.0	7.1	-	-
LSD 1 %	-	-	-	-	-	-	9.8	-	-	-
Seed Treatment										
Control	13.1	22.5	29.3	40.0	59.1	64.8	72.5	75.1	93.4	99.4
Advantage	16.6	23.3	31.7	45.1	60.6	66.5	72.9	78.4	89.9	96.3
LSD 5 %	2.6	-	-	3.8	-	-	-	-	-	-
LSD 1 %	-	-	-	-	-	-	-	-	-	-

Celt developed ground cover slower than the other three cultivars and significantly so at the 63, 70, 74, and 81 day measurement times. Up to 81 days after drilling, Advantage seed gave a greater percentage ground cover than the control, significantly so at the 48 and 63 days after drilling times.

(See Appendix 16)

4.2.3. Yield & Quality

Table 15. Effect of cultivar and the use of 'Advantage' seed on yield of clean beet (t/ha) and percentage tare.

Cultivar	Yield of clean beet (t/ha.)	% Tare
Accord	65.07	8.50
Celt	61.05	9.78
Libra	66.58	9.74
Zulu	62.54	10.22
LSD 5%	4.13	-
Seed Treatment		
Control	63.09	9.43
Advantage	64.54	9.69
LSD 5%	--	-

Choice of cultivar significantly (P<0.05) improved the yield of clean beet (t/ha.). Libra had a significantly (P<0.05) greater yield of clean beet (t/ha.) than Celt. Seed treatment had no significant effect on yield of clean beet. Neither choice of cultivar nor seed treatment had a significant effect on percentage tare. (See Appendices 17 and 18)

Table 16. Effect of cultivar and the use of 'Advantage' seed on percentage sugar in the roots and percentage sugar extractability.

Cultivar	% Sugar	% Sugar extractability
Accord	18.41	93.31
Celt	17.81	92.68
Libra	18.10	92.78
Zulu	17.99	92.71
LSD 5%	-	-
Seed Treatment		
Control	18.08	92.76
Advantage	18.07	92.98
LSD 5%	-	-

Neither choice of cultivar nor seed treatment significantly affected percentage sugar in the roots or sugar extractability in the roots. (See appendices 19 and 20)

Table 17. Effect of cultivar and the use of 'Advantage' seed on yield of sugar (t/ha.) and yield of extractable sugar (t/ha.).

Cultivar	Yield of sugar (t/ha.)	Yield of extractable sugar (t/ha.)
Accord	11.98	11.17
Celt	10.86	10.07
Libra	12.05	11.18
Zulu	11.25	10.44
LSD 5%	0.72	0.67
LSD 1%	0.98	0.92
Seed Treatment		
Control	11.41	10.59
Advantage	11.66	10.82
LSD 5%	-	-

The cultivars Accord and Libra had a significantly higher yield of sugar and extractable sugar than the cultivars Celt ($P<0.01$) and Zulu ($P<0.05$). (See Appendices 21 and 22)

Table 18. Effect of cultivar and the use of 'Advantage' seed on numbers of plants/Ha. ('000) (prior to harvest) and on yield of tops (t/ha.).

Cultivar	Number of plants/Ha. ('000)	Yield of tops (t/ha.)
Accord	72.16	50.57
Celt	74.53	48.61
Libra	76.14	46.97
Zulu	79.93	39.66
LSD 5%	-	4.39
LSD 1%	-	5.98
Seed Treatment		
Control	76.75	46.88
Advantage	74.62	46.02
LSD 5%	-	-

Neither choice of cultivar nor seed treatment affected final plant counts.

The cultivar Zulu had a significantly ($P<0.01$) lower yield of tops than Accord, Celt or Libra. (See Appendices 23 and 24)

4.3. Time of harvest by seed treatment trial (Trial 3)

4.3.1. Yield & Quality

Table19. Effect of harvest date and the use of 'Advantage' seed on the yield of clean beet (t/ha.) and percentage tare.

Harvest Date	Yield of clean beet (t/ha.)	% Tare
First	55.16	5.56
Second	58.32	8.84
Third	61.14	11.48
Fourth	62.81	11.63
LSD 5%	3.32	1.93
LSD 1%	4.52	2.64
Seed Treatment		
Control	58.14	9.61
Advantage	60.57	9.15
LSD 5%	2.35	-

Yield of clean beet increased as harvest date was delayed. The fourth harvest date had a significantly higher yield of clean beet than the first harvest date ($P<0.01$) and the second harvest date ($P<0.05$) while the third harvest date had a significantly higher yield of clean beet than first harvest date ($P<0.01$).

The seed treatment 'Advantage' had a significantly ($P<0.05$) higher yield of clean beet than the control.

Percentage tare increased as harvest date was delayed. The fourth and third harvest dates both had significantly ($P<0.01$) higher percentage tare than the first and second harvest dates while the second harvest date had a significantly ($P<0.01$) higher percentage tare than the first harvest date.

(See Appendices 25 and 26)

Table 20. Effect of harvest date and the use of 'Advantage' seed on percentage sugar in the roots and percentage sugar extractability.

Harvest Date	% Sugar in the roots	% Sugar extractability
First	17.39	93.21
Second	17.24	92.54
Third	17.26	92.36
Fourth	17.78	92.91
LSD 5%	0.40	-
Seed Treatment		
Control	17.47	92.77
Advantage	17.37	92.72
LSD 5%	-	-

The fourth harvest date had a significantly ($P<0.05$) higher percentage sugar than the second or third harvest dates. Neither harvest date nor seed treatment significantly affected % sugar extractability of the roots. (See Appendices 27 and 28)

Table 21. Effect of harvest date and the use of 'Advantage' seed on the yield of sugar (t/ha.) and yield of extractable sugar (t/ha.) in the roots.

Harvest Date	Yield of sugar(t/ha.)	Yield of extractable sugar (t/ha.)
First	9.58	8.93
Second	10.05	9.30
Third	10.55	9.75
Fourth	11.16	10.37
LSD 5%	0.54	0.50
LSD 1%	0.73	0.68
Seed Treatment		
Control	10.15	9.42
Advantage	10.52	9.75
LSD 5%	-	-

Yield of sugar increased as harvest date was delayed. The fourth harvest date had a significantly higher yield of sugar than the first ($P<0.01$), second ($P<0.01$) and third ($P<0.05$) harvest dates. The third harvest date had a significantly ($P<0.01$) higher yield of sugar than the first harvest date. Yield of sugar was higher (P=0.06) for the 'Advantage' seed treatment than the control.

Yield of extractable sugar increased as harvest date was delayed. The fourth harvest date had a significantly higher yield of extractable sugar than the first (P<0.01), second (P<0.01) and third (P<0.05) harvest dates. The third harvest date had a significantly (P<0.01) higher yield of extractable sugar than the first harvest date. Yield of extractable sugar was higher (P=0.06) for the 'Advantage' seed treatment than the control. (See Appendices 29 and 30)

Table 22. Effect of harvest date and the use of 'Advantage' seed on number of plants/Ha. (Prior to harvest) and on yield of tops (t/ha.).

Harvest Date	Number of plants/Ha. ('000)	Yield of tops (t/ha.)
First	82.58	46.77
Second	77.37	40.41
Third	80.87	40.41
Fourth	77.56	37.48
LSD 5%	-	4.40
LSD 1%	-	5.99
Seed Treatment		
Control	78.22	38.93
Advantage	80.97	43.61
LSD 5%	-	3.11
LSD 1%	-	4.23

Neither harvest date nor seed treatment significantly affected final plant establishment.

The first harvest date had a significantly (P<0.01) higher yield of tops than the subsequent harvest dates.

The seed treatment 'Advantage' had a significantly (P<0.01) higher yield of tops than the control. (See Appendices 30 and 31)

4.4. Experimental seed treatment trial (Trial 4)

4.4.1. Emergence

Figure 15. The effect of seed treatments on emergence percentage of sugar beet.

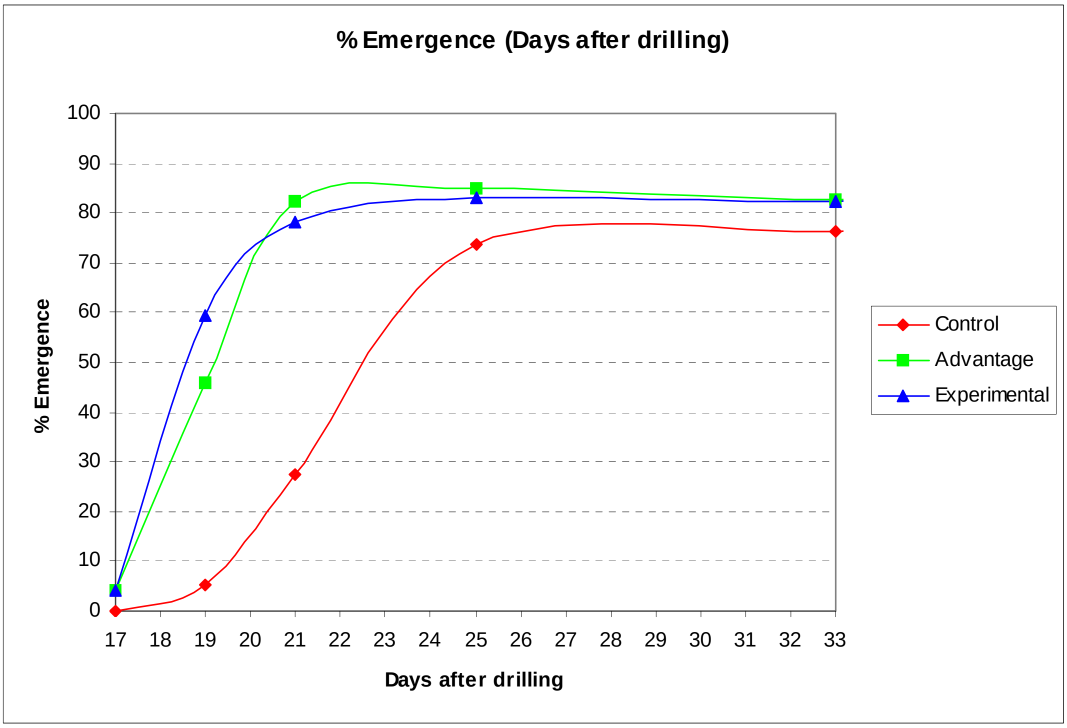


Table 9. The effect of seed treatments on percentage emergence of sugar beet.

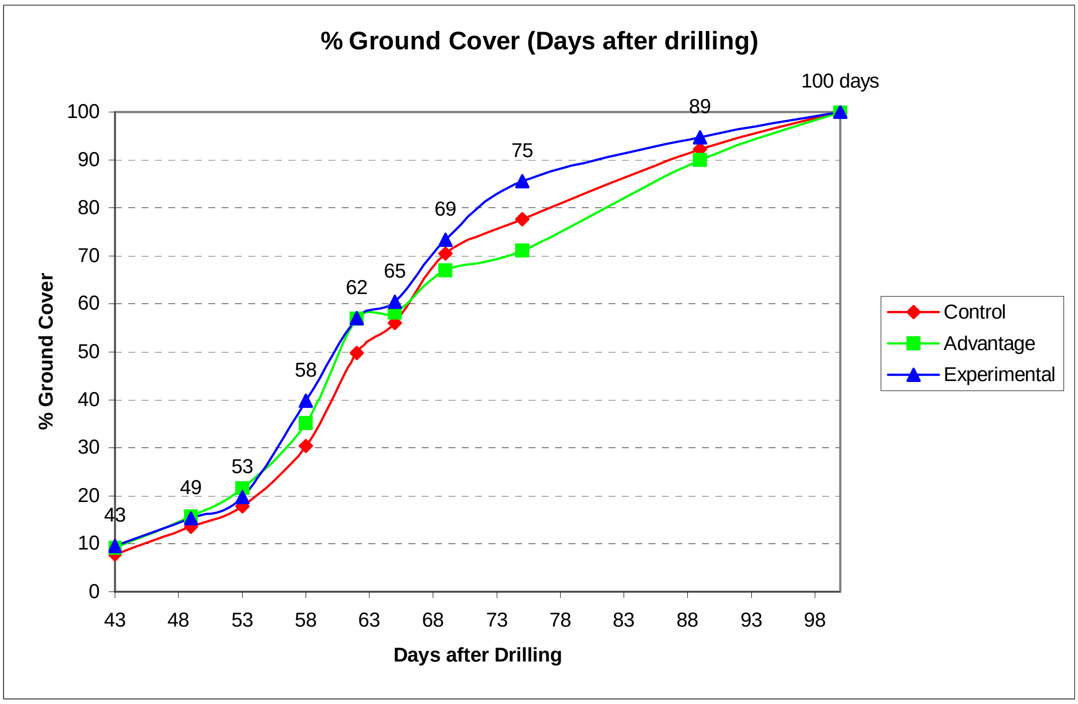
	Percentage emergence (Days after drilling)	
Seed Treatment	**19**	**21**
Control	5.2	27.4
Advantage	45.9	82.4
Experimental	59.3	78.3
LSD 5 %	11.4	12.3
LSD 1 %	17.3	18.6

Seed treatment had a significant ($P<0.01$) effect on emergence percentage at 19 and 21 days after drilling. At these dates, both ‘Advantage’ and the experimental treatment increased significantly ($P<0.01$) the percentage emergence over the control. At day 19, the experimental treatment had a significantly ($P<0.05$) higher percentage emergence than ‘Advantage’. Overall the percentage emergence in the control was lower (n.s.) than other treatments.

(See Appendix 33)

4.4.2. Ground Cover

Figure 16. The effect of seed treatments on percentage ground cover of sugar beet.



There was little difference in ground cover achieved except at 58 days after drilling, the experimental treatment had significantly higher % ground cover than 'Advantage' (LSD 5% = 4.0) and control (LSD 1% = 6.1). On the same date 'Advantage' had significantly higher % ground cover than the control ($P<0.05$).

At 75 days after drilling, the experimental treatment had a significantly higher % ground cover than 'Advantage' (LSD 1% = 12.3).

(See Appendix 34)

4.4.3. Yields & Quality

Table 23. Effect of seed treatments on the yield of clean beet (t/ha.) and percentage tare.

Seed treatment	Yield of clean beet (t/ha.)	% Tare
Control	54.79	3.78
Advantage	56.46	4.98
Experimental	57.07	4.98
LSD 5%	-	-

There were no significant differences in the yield of clean beet or percentage tare due to seed treatment.
(See Appendices 35 and 36)

Table 24. Effect of seed treatments on percentage sugar in the roots and percentage sugar extractability in the roots.

Seed treatment	% Sugar in the roots	% Sugar extractability
Control	17.78	94.14
Advantage	17.75	94.05
Experimental	17.75	94.17
LSD 5%	-	-

There were no significant differences in percentage sugar or percentage extractability due to seed treatment.
(See Appendices 37 and 38)

Table 25. Effect of seed treatments on the yield of sugar (t/ha.) and yield of extractable sugar (t/ha.) in the roots.

Seed treatment	Yield of sugar (t/ha.)	Yield of extractable sugar (t/ha.)
Control	9.74	9.17
Advantage	10.02	9.42
Experimental	10.13	9.53
LSD 5%		-

There were no significant differences in the yields of sugar or extractable sugar due to seed treatment.

(See Appendices 39 and 40)

Table 26. Effect of seed treatments on number of plants per hectare ('000) (prior to harvest) and on the yield of tops (t/ha.)

Seed treatment	Plants per hectare ('000)	Yield of tops (t/ha)
Control	81.06	45.08
Advantage	77.84	44.81
Experimental	87.12	45.88
LSD 5%		-

There were no significant differences in the final plant establishment due to seed treatment and there were no significant differences in the yield of tops due to seed treatment.

(See Appendices 41 and 42)

5.0. Discussion

5.1 Time of Sowing by Seed Treatment Trial

Emergence & Establishment:

At all three times of sowing, excellent plant populations (>80,000 plants /ha.) were achieved for both the treated ‘Advantage’ seed and the untreated control seed. Once visible to the eye, plants were considered as emerged. At harvest time the number of roots per plot was counted. Again all three times of sowing had very good numbers of roots (>70,000 roots /ha.) for both ‘Advantage’ and control plots. Due to poor weather the first sowing date could not be drilled until April 17^{th}. Soil temperatures at 10 cm in the week preceding drilling were on average 5 ^{0}C. At the first drilling soil temperatures were 7 ^{0}C.

Gummerson and Jaggard (1984) suggested that sugar beet seeds require about 80 day degrees above a base of 3 ^{0}C to reach 50 % emergence when sown at normal depth (about 30 mm) in loose soil with adequate water. Using 3 ^{0}C as base, the ‘Advantage’ plots of the first drilling reached 50 % emergence after 13 days or 74.4-day degrees. The control plots of the same drilling reached 50 % emergence 3 days later or 94.3-day degrees. For the second sowing date, the ‘Advantage’ plots reached 50 % emergence 13 days after drilling or 80.6 day degrees, while the control plots reached 50 % emergence 2 days later or 95.3 day degrees. The third drilling had a similar pattern with the ‘Advantage’ plots reaching 50 % 10 days after drilling or 73 day degrees and the control 2 days later (92.2-day degrees).

Taking a target plant population of 75,000 plants /ha. to achieve maximum sugar production (Scott, 1964), the ‘Advantage’ plots reached this 14 days after the first drilling date with the control 6 days later. The ‘Advantage’ plots reached 75,000 plants /ha. 17 days after the second drilling with the control 2 days later. For the third drilling date the ‘Advantage’ plots reached 50% emergence 10 days after sowing with the control plots 3 days later. These results agree with Longden (1971) who reported that the emergence from an advancement treatment was 2-5 days quicker than that from untreated seeds. Durrant, Payne and Mc Laren (1983) showed how an advancement treatment gave an average 4 days quicker interval to half final emergence than untreated seeds in 8 experiments over 5 years. Durrant and Jaggard (1988) when comparing different seed treatments, showed a decrease of nine days to half final emergence from an advanced seed treatment over untreated seed. Durrant and Mash (1992) showed that advanced seed reached half final emergence two days sooner than control seed across a range of sowing depths. Fauchere (1997), Jarvis and Patchett (1998) and Saunders (1998) also showed similar benefits from using ‘Advantage’ treated seed. The late dates of sowing made the differences between ‘Advanatge’ and the control treatment small for 50% emergence and full emergence as evident by the declining difference as time of sowing was delayed.

Number of Bolters at Harvest:

Due to the later than usual sowing date, the crop experienced few cool days (with a max. temp. <12 ^{0}C). Jaggard et al (1983) and Longden et al (1995) showed this to be the critical environmental factor, which affects the numbers of plants that bolt. No bolters were recorded during the year or at harvest.

Percentage Ground Cover:

Even though the percentage ground cover was greater at the different dates of sowing for the ‘Advantage’ treated seed over the control, it was seldom significantly different. This probably meant that early radiation interception was not very different, between plots. Thomas et al. (1993) showed that the ability to sow earlier due to an advancing treatment gave an increase in percentage leaf cover of between 1% and 6%. However this was measured between seed treatments sown on different dates. In this trial there was little difference shown between ‘Advantage’ treated seed and control seed in terms of percentage ground cover. Sowing date had a much greater influence on percentage ground cover than seed treatment.

This carried through to yield data, which was expected as the interception of light energy, is directly related to sugar yields in a healthy, stress-free crop (Burke, Rice and Fruhlich, 1985). Reducing the time taken to maximum light interception (closed canopy) increases yield of beet (Sibma, 1977). In this trial there was a period of eighteen days corresponding to that time when percentage ground cover measurements were not taken. However if we take the date 28th June 1998, on which a leaf cover measurement was taken, the first sowing date had 90% ground cover the second had 80-85% ground cover and the third had 75-80% ground cover. There was no difference between seed treatments on this date. Durrant et al (1993), showed very good correlation between the extra light intercepted and increases in sugar yield between earlier sowings made possible due to seed treatment. From the data in this trial one could conclude that the extra yield was from the light intercepted due to sowing date and not due to seed treatment, and that this was evident from field measurements during the growing season. The sowing date in this trial would be considered later than normal as an average of sowings since 1990 in Ireland. The real benefits of ‘Advantage’ as seen from the literature are best expressed under difficult conditions experienced by the developing seedling. Some of these benefits were shown in this trial as improved seedling vigour and accelerated ground cover to a certain stage. One may only postulate the benefits of ‘Advantage’ over non-treated seed in an early (mid March), sown trial that suffered cold conditions afterwards. This would merit further work across a range of soil types and years before definite conclusions could be drawn.

Yield of Roots:

The sowing dates in this trial were at one-week intervals and would be considered to be average over a number of year’s sowings. Even still the trend of earlier sowing giving higher yields was statistically evident ($p<0.01$). Hull and Webb (1970) showed a 19% increase in yield of roots between the first and last sowing dates. O’ Connor (1981) showed similar results. This trial showed a 15% increase in yield of roots between the first and third date of drilling. No increase was seen from using the seed treatment ‘Advantage’. There was however a trend of higher yields from this treatment across the three sowing dates in the order of 1.9%. This is in agreement with Jarvis and Patchett (1998) who reported an increase of almost 1-% in root yield with Advantage treated seed across drilling and harvest dates

Soil Tare %:

Soil tare% was not significantly affected by sowing date. In the literature soil tare is not reported on as a parameter in assessing sowing date trials. Seed treatment had no effect on soil tare.

Percentage Sugar in the Roots:

As sowing dates were delayed, % sugar in the roots decreased but not statistically so. This is in agreement with Durrant et al. (1993). Hull and Webb (1970), over 5 years data, got inconsistent results regards time of sowing and sugar percentage. O’ Connor (1981) showed a steady decrease in % sugar in the roots as sowing was delayed which was significant for the two years 1977 and 1978 bar two drillings in 1977. ‘Advantage’ seed also gave higher % sugar in the roots but not significantly so. This was also shown by Durrant et al. (1993) with their advancing treatment. Saunders (1998) showed no increase in sugar % in the roots due to 'Advantage'

Percentage Sugar Extractability:

Sowing date did not affect % sugar extractability but there was a trend for this value to decrease as sowing date was delayed. This is to be expected as % sugar extractability is closely correlated to % sugar in the roots due to the figure for % sugar being used in the Summation Index calculation and this in turn being used in the % sugar extractability calculation. O' Connor (1981) showed a significant difference between sowing dates for % sugar extractability in the roots. The later the sowing was delayed, the lower % sugar extractability became. 'Advantage' seed gave a higher value than control seed for this parameter, which was just outside significance at the 5% level ($p=0.07$). Durrant et al. (1993) and Saunders (1998) found no effect of advanced seed lots on impurities.

Yield of Sugar:

This was significantly higher for the first sowing over the second and third dates. This in agreement with Durrant et al. (1993), Jaggard et al. (1983), O' Connor (1981), Hull and Webb (1970) and Holmes and Adams (1966). The increase in yield of sugar per day from this experiment was 0.14t/ha./day. This is higher than the 0.03 t/ha./day which was the mean of 13 crops as outlined by Durrant et al. (1993) when reviewing relevant literature. These were based on mid to late March drilled crops versus early April sown crops. In this trial a mid April crop was compared with an early May crop. Hull and Webb (1970) found that progressively later sowing dates would result in greater yield losses as did Scott et al. (1973). This would explain some of the greater yield penalties found in this trial from later sowings.

'Advantage' seed did give higher yield of sugar over the control but not significantly so. This is in agreement with Durrant et al. (1993) who used a similar seed treatment and found increases from 'advanced' seed over Thiram treated seed in 7 out of 8 experiments but not at the 5% probability level in individual comparisons. Saunders (1998) found no significant differences in yield of sugar between seed treatments.

Yield of Extractable Sugar:

This parameter decreased as sowing was delayed. This was to be expected as yield of sugar and % extractability followed the same pattern. Delaying sowing gave significantly ($p<0.01$) lower yields of extractable sugar. This is in agreement with O'

Connor (1981). Durrant et al (1993) found that neither sowing date nor seed treatment had an effect on sugar % (or impurities) and did not discuss extractable sugar. Saunders (1998) found similar results. In this trial there was no significant difference found between 'Advantage' and control.

Yield of Tops:

In the literature, there is little significance given to yield of tops and little references. In this trial no significant differences were found for the two parameters discussed

Number of Roots at Harvest

There were significantly a greater number of roots from the third sowing date than the other two dates. As sowing date is delayed, conditions become more favourable to the developing seedling and thus higher plant populations (Gummerson and Jaggard, 1984). O' Connor (1981) also showed higher final plant populations as sowing was delayed. Seed treatment gave no significant difference for number of roots at harvest. All plots gave greater than 70,000 plants/ha. which is required for maximum yield (Goodman,1966). In all cases, there was a loss of plants over the growing season.

5.2 Cultivar By Seed Treatment Trial

Emergence & Establishment:

All four cultivars had good plant populations (>70,000 plants/ha) for both the 'Advantage' and control seed. Once visible to the eye, the plants were considered as emerged. Again at harvest time good plant populations were recorded across both cultivar and seed treatment (>70,000 plants/ha). As in the sowing date trial, 'Advantage' seed gave faster emergence than the control, which was significant ($p<0.01$) up to 16 days after drilling

The length of time taken to 50 % emergence was on average three days shorter with the 'Advantage' treatment across the four cultivars. In this trial, there were two diploid cultivars (Celt and Zulu) and two triploids (Accord and Libra). From the literature, Kimber (1990) and Grogan (1997), the diploids are noted for even emergence and higher germination percentages. However in this trial, Celt showed very poor germination characteristics and was the worst recorded variety at all dates. From figure 8, it is clear that the treated seed of Celt was the culprit. One would have to conclude that the batch of 'Advantage' seed had poor vigour. One of the benefits of the

‘Advantage’ treatment quoted in the literature is that it ‘evens up’ a batch of seed, i.e. allows seeds of poor vigour to catch up with seeds of better vigour (Heyes et al, 1997). This is shown with the ‘Advantage’ seed 15 days after drilling.

Number of Bolters at Harvest:
No bolters were recorded during the year or at harvest.

Percentage Ground Cover:
As with the time of sowing trial the ‘Advantage’ seed treatment showed a slightly higher percentage ground cover over the control treatment up to 81 days after sowing. The differences were small and were significant on only two dates. From this data, one would not have expected significant differences in the radiation intercepted and this is borne out in the yields obtained. In the literature there is very little data on cultivar by seed treatment trials. However, patterns did emerge among the cultivars where Celt followed on its performance as the worst variety for seed vigour with the worst figures for percentage ground cover also. Celt had the lowest values for percentage ground cover up to 81 days after emergence
From the literature Grogan (1997) described the diploids as having upright, erect leaves as compared to the triploids with more prostate leaves but this would not explain the poor performance of Celt especially as Zulu is also a diploid.

In this trial ground cover percentage was measured by holding a perspex sheet just over the crop canopy and counting the number of ‘full’ or ‘empty’ boxes. Upright leaves could be biased against even though they may be intercepting a large proportion of the incident radiation, especially as the sun only shines down directly from above for a small proportion of the day. The sun during this short period would mimic our counting. As the sun is reaching the highest point in the sky in the morning and on the decline in the afternoon, one could expect upright leaves to be intercepting sunlight in the same manner as ‘prostate’ leaves. The variety ‘Zulu’ is also a diploid, but showed no differences in percentage ground cover from the two triploid varieties. There was no interaction between seed treatment and cultivar. However, from the graph, Celt benefited more from the ’Advantage’ treatment than the other three cultivars at all measurement days.

Yield of Roots:

As expected from the percentage ground cover data, Celt had the lowest yield of clean beet. This agrees with Burke et al (1985), Sibma (1977) and Glauert (1983). It also demonstrates that the method of assessing light interception was not unfairly biased against the upright leaves of the diploid, Celt. There was a trend for the triploids to have a higher yield of roots compared to the diploids. Diploids are noted for their even emergence and bolting resistance in the case of Celt (Grogan, 1998). The results here mirror the yield data of the recommended list 1998 (Appendix). This trial was designed to identify any interactions between cultivar choice and seed treatment. No such interactions occurred for yield of roots.

As in the time of sowing trial, seed treatment had no effect on yield of roots. The trend was for higher yields of roots for 'Advantage' over the control in the order of 2% which is almost identical to the results in the time of sowing trial (1.9%). Again this is in agreement with Jarvis and Patchett (1998). However it must be pointed out that the results were not significant

Note:

One replication of this trial was sown seven days later than the other three replications due to weather. This accounts for the statistically significant variation in replications in Appendices 19, 21, 22, and 25. This later sown replication was not analysed for emergence or ground cover. Again this demonstrates that time of sowing was more critical to yield and quality parameters than seed treatment.

Soil Tare Percentage:

From the recommended list, 1998, there is no variety identified as having lower soil tare. There is a lack of genetic variation amongst modern beet varieties due to breeders and growers putting emphasis on yield and quality parameters (Bosemark, 1993). In this trial, there was no variation in soil tares between cultivars. This trial was harvested by hand for logistical reasons and tare was assessed by hand cleaning. By its very nature hand pulling gives lower soil tares than a mechanical harvester and this is shown in the average tare figure of 9.6% across cultivars. This is much lower than the 12.3 – 13.7% average tare recorded by the two processing factories in Ireland (Broderick 1998). Seed treatment had no effect on soil tare. Koch (1996) and Patchett and Bee (1997) reported that the final plant population at harvest affected soil tares. Further work on a bigger scale, with mechanical harvesting is required to identify soil tare effects due to cultivar based on this principal.

Percentage Sugar in the Roots:

Cultivar had an effect on sugar percentage that was marginally outside significance (p=0.06). Accord recorded the highest whilst Celt had the lowest percentage sugar. This is in agreement with Grogan (1998). This is also in agreement with our ground cover assessments.

Seed treatment had no effect on percentage sugar in the roots. This is in agreement with Saunders (1998).

Percentage Sugar Extractability:

The cultivars ranked the same for this parameter as for percentage sugar in the roots with Accord having the highest figure and Celt the lowest. Neither cultivar nor seed treatment had a significant effect on sugar extractability.

Yield of Sugar:

Cultivar was highly significant for this trait. The triploids had higher yields of sugar over the two diploid cultivars. The ranking of the cultivars for this trait is in agreement with the recommended list (Grogan 1998). No interaction occurred between seed treatment and cultivar. Seed treatment had no effect on yield of sugar. This is in agreement with Durrant et al (1993) and Saunders (1998).

Yield of Extractable Sugar:

Again the cultivars were ranked in the same order as for yield of sugar. The greater yield of clean roots for the cultivar Libra more than compensated for its lower percentage sugar and sugar extractability as shown by its number one ranking for this trait. The results here are in agreement with the recommended list of cultivars (Grogan, 1998). Seed treatment had no effect on this parameter. Saunders (1998) showed no effect by the seed treatment ‘Advantage’ on extractable sugar.

Yield of Tops:

In this trial, cultivar was highly significant for this trait with Zulu having a lower yield of tops than the other three cultivars. No specific reason can be given for this and no field observations indicate that a disease or pest problem specifically affected this cultivar. This trait is not measured in the recommended list. The lower weight of tops for Zulu did not effect its yield data as it had better yield figures than the Celt plots while Celt had very high yields of tops.

Number of Roots at Harvest:

All treatments had greater than 70,000 roots/ha. which is required for maximum yield (Jaggard, 1973). Neither cultivar nor seed treatment had any effect on this parameter. There was a trend for the diploids to have slightly more plants at harvest over the triploids when averaged together. This is in agreement with Grogan (1998).

5.3 Time of Harvest by Seed Treatment Trial

Emergence & Establishment:

As this trial was primarily to see the effects of progressively later harvest dates on the seed treatment 'Advantage', this parameter was not scrutinised closely. The cultivar used in this trial, Zulu, was assessed for emergence and establishment in the cultivar trial. There were excellent (>75,000) plant populations recorded in all plots with high final plant counts recorded. The figures reflect the later than usual sowing date and excellent seed vigour characteristics of the cultivar Zulu.

Number of Bolters at Harvest:

No bolters were recorded during the year or at harvest.

Yield of Roots:

There is agreement in the results shown by Hull and Webb (1970), Scott et al (1973) and O' Connor (1981) that a delay in harvesting increased root yield. In this trial, yield of roots increased as harvest date was delayed. However, the percentage increase from later harvest dates declined from 5.7% $\rightarrow$ 4.8% $\rightarrow$ 2.7%. Scott et al (1973) related the extra yield from later harvest dates to radiation intercepted between the harvest dates. Glaurt (1983) showed that the light response curve of the canopy remained constant until September and then fell away. The data shown here suggests that the response to incident radiation and the incident radiation both diminished as harvest date was delayed.

Jarvis and Patchett (1998) showed an increase of 1% from 'Advantage'. Durrant et al (1993) showed that advanced seed plots did not increase yield over standard seed in individual experiments. However, when they pooled their results with two large trials from Durrant and Mash (1992 a), ‘Advantage’ did significantly increase yield at the 5% level. Seed treatment had a significant effect on yield of roots across harvest dates in this trial. ‘Advantage’ seed gave an increase of 4.2% for yield of roots over standard seed. Based on the response to seed treatment shown in this trial, the extra cost of ‘Advantage’ was recouped.

Soil Tare Percentage:

As harvest date was delayed, soil tare percentage increased significantly. From field notes, the weather was not particularly bad on any harvest date. One possible reason for the increased soil tare could be due to the poorer quality tops for the later harvest dates. Poorer quality tops make it harder to pull the beet ‘cleanly’ out of the ground. This results in having to dislodge the beet by foot or spade and doesn’t allow the ‘knocking together’ of two beet by hand thus more soil adheres to the beet. The increase in soil tare due to harvest date was more than the average increase shown by Kenny (1999). The effect of poor quality tops is more pronounced using belt-type lifters than wheel type lifters. Seed treatment had no effect on the soil tare percentage.

Percentage Sugar in the Roots:

The effect of harvest date on percentage sugar in the roots is inconsistent and largely determined by changes in soil moisture affecting the water content in the roots (Hull & Webb, 1970). Green et al, (1986) and Milford (1973) demonstrated that beet does not ripen as its sugar content as a percentage of root dry matter is constant from early August onwards. In this trial the effect of harvest date was inconsistent with the last harvest date having a higher percentage sugar than the second or third harvest date. Hull & Webb (1970) and O’ Connor (1981) showed that the early October harvest date had a higher sugar percentage in the roots than an early December date. However, both sets of researchers placed more significance on total yield of sugar.

Seed treatment had no effect on percentage sugar in the roots.

Percentage Sugar Extractability:

Harvest date did not affect percentage sugar extractability in agreement with Kearney and O’ Connor (1973) who presented data which showed that juice purity did not vary after the end of October. Seed treatment did not affect percentage sugar extractability.

Yield of Sugar:

Results shown in this trial are in agreement with Holmes and Adams (1966), Hull and Webb (1970), Scott et al (1973) and O' Connor (1981) that a delay in harvesting increased sugar yield. The rate of increase was linear at 4.9% up to the third date of harvest and increased to 5.7% between the third and fourth date. Yields of sugar increased by 0.24 t/ha/week up to the third harvest date. This figure agrees with Scott et al (1973) who showed an average increase in sugar yields of 0.245 t/ha/week averaged over four years in the period 7th October to 10th November. O' Connor (1981) compared yields of sugar from October and November harvest dates relative to a end of September harvest date. He showed a 9.93% increase in yield of sugar for that comparison. In this trial, the percentage increase from mid November relative to early October was 16.5%. A further two harvest dates in late November and early December would be needed to clarify the trends shown here. However from the two authors quoted, the effect of later harvesting peaked around mid November and dropped off after that date. One would have expected similar findings based on the yield of roots data in this trial.

Seed treatment had an effect on yield of sugar that was just outside significance (p=0.06). The percentage increase in yield of sugar was 3.6% or 0.37 t/ha. Saunders (1998) showed an increase in yield of sugar from 'Advantage' but not enough to be significant at the 5% level. Jarvis and Patchett (1998) showed an increase (1%) in yield of sugar from 'Advantage'. Heyes et al (1997) reported a 1.8% increase from 'Advantage' across varieties and sites. No detailed emergence data was recorded for this trial so the emergence data from Zulu in the cultivar trial has been used instead as both trials were drilled on the same date. The time taken to half final emergence was shortened by 4 days. This is equal to 0.09 t/ha/day based on a yield response from 'Advantage' of 0.37 t/ha. Durrant et al (1993) showed an increase in yield of sugar of 0.19 t/ha and reduction in time to half final emergence of 4 days giving a yield benefit of 0.048 t/ha/day from 'Advantage'. Further large-scale trials are required to see if the benefits shown here can be repeated in Ireland.

Yield of Extractable Sugar:

Both Hull & Webb (1970) and Scott et al (1973) did not discuss extractable sugar. O' Connor (1981) showed that the yield of extractable sugar increased with later harvesting dates relative to the first harvest date. In this trial, yield of sugar increased as harvest date was delayed. Yield of extractable sugar for the 'Advantage' seed was 3.5% higher than for the control. This was just outside significance (p=0.06) and almost identical to the effect of 'Advantage' on yield of sugar, which was 3.6%. One can conclude that 'Advantage seed treatment had no effect on impurity levels. Saunders (1998) showed no effect on impurity levels or on yield of extractable sugar from 'Advantage'.

Yield of Tops:

The first harvest date had a higher yield of tops than later dates. This was probably due to natural leaf deterioration from frost and disease. The later harvest date treatments were not sprayed with a fungicide, as would be the norm, if a grower were planning a late harvest. While the effect of leaf deterioration was not evident in yield or quality readings, it does have an effect on the efficiency of belt type lifters. Brown (1998) noted these types of lifters as the worst for root losses under all conditions.

Seed treatment 'Advantage' significantly increased yield of tops. Other authors whom trialled seed advancing techniques or 'Advantage' did not discuss this parameter. Further work with mechanical harvesting is needed to show if the increase in yield of tops shown here improves the efficiency of belt type lifters for root losses in the field.

5.4 EXPERIMENTAL SEED TREATMENT TRIAL

In this trial, an experimental treatment called 'Experimental' was compared with the commercially available 'Advantage' and seed that was not put through on advancing process 'Control'. 'Experimental' is another advancing process developed by Germain's U.K. Ltd.

Emergence & Establishment:

Very good plant populations were recorded in all plots. 'Experimental' reached 50% emergence one day sooner than 'Advantage', while 'control' plots did not reach 50% emergence until four days after 'Experimental'. These results agree with Durrant et al (1983) Durrant and Jaggard (1988), Durrant and Mash (1992) and Saunders (1998). From this data, 'Experimental' had much the same emergence curve as 'Advantage' and at only one date was it significantly better than 'Advantage' for this trait.

Number of Bolters at Harvest:

No bolters were recorded during the year or at harvest.

Percentage Ground Cover:

As in the other three trials, there were only slight differences between the ‘Advancing’ treatments and ‘Control’ seed. From day 62 after drilling until complete cover was achieved, the ‘control’ plots had higher ground cover than ‘Advantage’ plots. At all dates, however, ‘Experimental’ had greater ground cover than ‘control’. Significant differences between the treatments existed at two dates only but no pattern emerged.

Yield of Roots:

No significant effect on yield of roots due to seed treatment showed up in this trial. The trend was for the two ‘Advancing’ treatments to have higher yields than the ‘control plots.

Soil Tare Percentage:

In this trial no variation existed among seed treatments for soil tare. This agrees with the results shown in the other three trials.

Percentage Sugar in the Roots and Percentage Sugar Extractability:

Figures for these two parameters were almost identical across seed treatments. This agrees with findings by Saunders (1998). Authors who looked at seed advancement techniques such as Durrant et al (1993), Durrant and Mash (1992) and Fauchere (1997) showed no variation in sugar percentage or juice purity due to seed advancement.

Yield of Sugar and Extractable Sugar:

No significant differences occurred between seed treatments for either parameter. Yield of sugar was increased by 2.8% for ‘Advantage’ over the control. This agrees with results from the time of sowing trial and cultivar trial. ‘Experimental’ showed a 4 % increase for this parameter over control. Yield of extractable sugar followed an identical pattern to yield of sugar. These findings agree with Durrant et al (1993) and Saunders (1998)

Yield of Tops:

Seed treatment had no effect on yield of tops.

6.0. Summary and Conclusions

Trials were carried out at Lyons Estate Research Farm during 1998 on sugar beet (*Beta Vulgaris*). The commercially available seed treatment 'Advantage' was tested across 3 sowing dates, 4 commercially available cultivars and 4 harvest dates. Trials were carried out in a factorial arrangement and subject to standard statistical analysis. Data on emergence, ground cover, yield and quality was analysed.

Percentage emergence of seed was satisfactory in all experiments. The benefit of 'Advantage' treatment during the emergence stage of growth was clearly seen in all trials. On average 'Advantage' seed emerged 2-3 days earlier than untreated seed and reached the target population (>75,000 plants/ha 4 days sooner than the control seed. During the growing season, ground cover was measured until complete cover was reached. In the trials it was less clear as to the benefits of using the treatment 'Advantage', as it was seldom statically different from control seed. As yields can be related to the radiation intercepted, it is not surprising that there were not large differences in yields.

Delaying sowing date resulted in decreased yields of clean beet, sugar and extractable sugar. The two triploid varieties, Libra and Accord gave better yields of clean beet, sugar and extractable sugar than the two diploid cultivars Zulu and Celt. Delaying harvesting gave increased yields of clean beet, sugar and extractable sugar. The 'Experimental' seed treatment was not superior to the 'Advantage' treatment.

In only one of the experiments was 'Advantage' better than the control treatment in respect of yield of clean beet, in the time of harvest trial. This was not reflected in yield of sugar or extractable sugar. In all other situations, there were no differences between 'Advantage' and the control treatments. There was no benefit from using 'Advantage' seed in the current experiments. However earlier sowing dates require investigation with pre-treated seed.

7.0. Bibliography

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<u>**Appendix 1**</u>

Analysis of variance for **percentage emergence** for **seed treatment X time of sowing** trial (1st. sowing date)

Source of variation	**d.f.**	**Mean squares (days after drilling)**											
		10	**12**	**13**	**14**	**17**	**18**	**20**	**22**	**24**	**26**	**29**	**34**
Replication	3	0.13	0.321	0.123	0.227	0.108	0.09	0.057	0.038	0.037	0.075	0.028	0.035
Seed treatment	1	7.22	36.551	56.18	34.445	2.645	0.605	0.5	0.387	0.396	0.151	0.211	0.211
Error	3	0.13	0.138	0.097	0.152	0.108	0.015	0.97	0.073	0.074	0.025	0.045	0.071
Total	7	-	-	-	-	-	-	-	-	-	-	-	-
F-ratio	-	55.54	265.02	581.17	227.11	24.42	40.33	5.17	5.29	5.35	6.15	4.74	2.96
Probability	-	0.005	0.0005	0.0002	0.0006	0.0159	0.0079	0.1075	0.105	0.1038	0.0892	0.1177	1.2
Coefficient of variation (%):		***18.49***	***8.05***	***5.18***	***5.12***	***3.49***	***1.25***	***3.12***	***0.72***	***2.73***	***1.55***	***2.09***	***2.64***

Appendix 2

Analysis of variance for **emergence %** for **seed treatment X time of sowing** trial (2nd.sowing date)

Source of variation	d.f.	Mean squares (days after drilling)							
		10	**11**	**13**	**15**	**17**	**19**	**22**	**27**
Replication	3	0.045	0.048	0.358	0.268	0.115	0.048	0.044	0.037
Seed treatment	1	4.961	24.151	20.801	2.42	0.5	0.011	0.002	0.02
Error	3	0.045	0.048	0.135	0.023	0.043	0.038	0.033	0.017
Total	7								
F-ratio	-	111.28	504.03	154.56	103.71	11.54	0.3	0.05	1.2
Probability	-	0.0018	0.0002	0.0011	0.002	0.0426	0.6238	0.8307	0.3534
Coefficient of variation (%):		***11.81***	***8.0***	***5.7***	***1.72***	***2.22***	***1.99***	***1.86***	***1.31***

Appendix 3

Analysis of variance for **emergence %** for **seed treatment by time of sowing** trial (3rd.sowing date)

Source of variation	d.f.	Mean squares (days after drilling)			
		9	**11**	**14**	**19**
Replication	3	0.058	0.071	0.081	0.068
Seed treatment	1	24.851	51.511	0.911	0.245
Error	3	0.058	0.055	0.031	0.048
Total	7				
F-ratio	-	429.09	943.72	29.16	5.07
Probability	-	0.0002	0.0001	0.0124	0.1098
Coefficient of variation (%):		***8.71***	***3.55***	***1.74***	***2.14***

Appendix 4

Analysis of variance for **percentage ground cover** for **seed treatment X time of sowing** trial (1st. sowing date)

Source of variation	**d.f.**	**Mean squares (days after drilling)**									
		49	**55**	**59**	**64**	**68**	**71**	**75**	**81**	**98**	**109**
Replication	3	2.708	21.281	9.365	0.708	138.458	13.5	26.115	41.865	3.125	0
Seed treatment	1	60.500	22.781	19.531	55.125	50.0	72.0	52.531	9.031	3.125	0
Error	3	2.083	6.615	7.198	11.708	7.5	1.333	23.115	13.615	3.125	0
Total	7										
F-ratio	-	29.04	3.44	2.71	4.71	6.67	54.00	2.27	0.66	1.00	-
Probability	-	0.0125	0.1605	0.1981	0.1185	0.0816	0.0052	0.2288	0.4750	-	-
Coefficient of variation:		***10.59***	***10.01***	***7.88***	***6.69***	***3.86***	***1.57***	***6.01***	***4.05***	***1.78***	***0***

Appendix 5

Analysis of variance for **percentage ground cover** for **seed treatment X time of sowing** trial (2nd. sowing date)

Source of variation	**d.f.**	**Mean squares (days after drilling)**									
		42	**48**	**52**	**57**	**61**	**64**	**68**	**74**	**92**	**102**
Replication	3	3.583	6.458	11.375	15.542	63.531	27.198	20.375	12.031	15.458	o
Seed treatment	1	6.125	36.125	10.125	0.125	9.031	7.031	18.000	42.781	55.125	o
Error	3	1.208	28.458	10.875	21.708	39.365	102.281	63.583	33.865	15.458	o
Total	7										
F-ratio	-	5.07	1.27	0.93	0.01	0.23	0.07	0.28	1.26	3.57	-
Probability	-	0.1098	0.3419	0.4058	0.9443	0.6647	0.8101	0.6316	0.3428	0.15	-
Coefficient of variation:		***16.29***	***33.08***	***14.90***	***11.40***	***10.81***	***16.23***	***10.83***	***7.07***	***4.04***	***o***

Appendix 6

Analysis of variance for **percentage ground cover** for **seed treatment X time of sowing** trial (3rd. sowing date)

Source of variation	d.f.	Mean squares (days after drilling)									
		34	**40**	**44**	**49**	**53**	**56**	**60**	**66**	**83**	**94**
Replication	3	0.875	6.208	11.948	46.875	7.615	13.615	18.583	85.781	6.333	0
Seed treatment	1	8.000	78.125	13.781	40.500	81.281	13.781	0.500	34.031	0.500	0
Error	3	1.417	3.208	2.615	8.917	34.281	75.531	25.083	41.281	10.167	0
Total	7										
F-ratio		5.65	24.35	5.27	4.54	2.37	0.18	0.02	0.82	0.05	-
Probability		0.0979	0.0160	0.1054	0.1229	0.2212	0.6981	0.8967	0.4308	0.8387	-
Coefficient of variation:		***32.83***	***17.69***	***10.65***	***8.95***	***12.03***	***15.96***	***7.76***	***8.52***	***3.36***	***0***

Appendix 7

Analysis of variance for **yield of clean beet (t/ha.)** for **seed treatment X time of sowing** trial.

Source of variation	**d.f.**	**Mean square**	**F-ratio**	**Probability**
Replication	3	44.927	4.0957	0.0261
Time of sowing	2	161.419	14.7152	0.0003
Seed treatment	1	8.437	0.7692	
TOS * ST	2	16.535	1.5074	0.2532
Error	15	10.969		
Total	23			

Coefficient of variation: 5.33 %

Appendix 8

Analysis of variance for **percentage tare** for **seed treatment X time of sowing** trial.

Source of variation	**d.f.**	**Mean square**	**F-ratio**	**Probability**
Replication	3	26.642	4.0047	0.028
Time of sowing	2	16.457	2.4738	0.1179
Seed treatment	1	2.884	0.4335	
TOS * ST	2	0.686	0.103	
Error	15	6.653		
Total	23			

Coefficient of variation: 22.54 %

Appendix 9

Analysis of variance for **percentage sugar** for **seed treatment X time of sowing** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	0.23	0.3919	
Time of sowing	2	0.808	1.376	0.2827
Seed treatment	1	1.042	1.7748	0.2027
TOS * ST	2	0.122	0.061	0.104
Error	15	8.804	0.587	
Total	23			

Coefficient of variation: 4.48 %

Appendix 10

Analysis of variance for **percentage sugar extractability** for **seed treatment X time of sowing** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	1.807	3.8577	0.0315
Time of sowing	2	0.459	0.9799	
Seed treatment	1	1.826	3.8978	0.0671
TOS * ST	2	0.308	0.6582	
Error	15	0.468		
Total	23			

Coefficient of variation: 0.74 %

Appendix 11

Analysis of variance for **yield of sugar (t/ha.)** for **seed treatment X time of sowing** trial.

Source of variation	**d.f.**	**Mean square**	**F-ratio**	**Probability**
Replication	3	0.877	1.3468	0.2968
Time of sowing	2	7.512	11.5334	0.0009
Seed treatment	1	1.354	2.0785	0.1699
TOS * ST	2	0.63	0.9677	
Error	15	0.651		
Total	23			

Coefficient of variation: 7.58 %

Appendix 12

Analysis of variance for **yield of extractable sugar (t/ha.)** for **seed treatment X time of sowing** trial.

Source of variation	**d.f.**	**Mean square**	**F-ratio**	**Probability**
Replication	3	0.597	0.96	
Time of sowing	2	6.786	10.9187	0.0012
Seed treatment	1	1.51	2.4295	0.1399
TOS * ST	2	0.605	0.9739	
Error	15	0.622		
Total	23			

Coefficient of variation: 8.03 %

Appendix 13

Analysis of variance for **final plant establishment ('000/Ha.)** for **seed treatment by time of sowing**

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	60.114	3.0348	0.0619
Time of sowing	2	132.409	6.6846	0.0084
Seed treatment	1	51.715	2.6108	0.127
TOS * ST	2	17.662	0.8896	
Error	15	19.808		
Total	23			

Coefficient of variation: 5.77 %

Appendix 14

Analysis of variance **for yield of tops (t/ha.)** for **seed treatment X time of sowing** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	106.056	8.3241	0.0017
Time of sowing	2	27.673	2.172	0.1485
Seed treatment	1	10.962	0.8604	
TOS * ST	2	15.476	1.2147	0.3244
Error	15	12.741		
Total	23			

Coefficient of variation: 7.9 %

Appendix 15

Analysis of variance for **percentage emergence** for **seed treatment X cultivar** trial

Source of variation	**d.f.**	**Mean squares (days after sowing)**								
		9	**11**	**12**	**13**	**16**	**18**	**20**	**23**	**33**
Replication	2	3.08	18.26	16.82	21.23	21.95	0.57	36.22	36.30	35.27
Cultivar (C)	3	38.07	276.20	463.40	194.70	140.84	63.44	9.32	9.30	47.70
Seed treatment (ST)	1	492.32	4142	1024	18267	1998.40	133.48	1.76	1.71	18.41
C X ST	3	38.07	276.2	210.23	65.99	57.53	6.65	10.77	10.62	45.27
Error	14	3.02	19.02	53.88	49.81	79.65	60.56	53.02	52.99	35.58
Total	23	-	-	-	-	-	-	-	-	-
F-value (C)	-	12.62	14.52	8.60	3.91	1.77	1.05	0.17	0.17	1.34
F-value (ST)	-	163.24	217.76	223.18	366.95	25.09	2.20	0.03	0.03	0.5
F-value (C X ST)	-	12.62	14.52	3.90	1.32	0.72	0.11	0.20	0.20	1.27
Prob. (C)	-	0.000	0.000	0.002	0.032	0.202	0.40	-	-	-
Prob. (ST)	-	0.000	0.000	0.000	0.000	0.000	0.11	-	-	-
Prob. (C X ST)	-	0.000	0.000	0.032	0.306	-	-	-	-	-
Coefficient of variation: (%)		***38.34***	***33.20***	***27.35***	***19.55***	***13.98***	***10.57***	***9.90***	***9.89***	***7.84***

Appendix 16

Analysis of variance for **percentage ground cover** for **seed treatment X cultivar** trial

Source of variation	**d.f.**	**Mean squares (days after sowing)**									
		48	**54**	**58**	**63**	**67**	**70**	**74**	**81**	**98**	**105**
Replication	2	7.3230	22.625	7.9480	54.573	35.385	81.073	68.167	28.344	568.71	36.458
Cultivar (C)	3	18.760	46.094	41.903	89.181	17.306	150.12	250.84	236.52	232.46	34.375
Seed treatment (ST)	1	68.344	3.760	35.042	155.04	13.500	19.260	0.8440	66.677	98.000	78.125
C X ST	3	0.8440	37.205	19.736	55.569	5.5830	63.038	45.927	54.417	136.00	51.042
Error	14	8.7630	14.625	14.650	19.144	30.278	31.740	43.107	43.594	85.589	26.339
Total	23	-	-	-	-	-	-	-	-	-	-
F-value (C)	-	2.141	3.152	2.860	4.658	0.572	4.730	5.819	5.426	2.716	1.305
F-value (ST)	-	7.798	0.257	2.392	8.099	0.446	0.607	0.019	1.529	1,145	2.966
F-value (C X ST)	-	0.096	2.544	1.347	2.903	0.184	1.986	1.065	1.248	1.589	1.938
Prob. (C)		0.141	0.058	0.075	0.018	-	0.017	0.008	0.011	0.071	0.299
Prob. (ST)		0.014	-	0.144	0.013	-	-	-	0.237	0.297	0.099
Coefficient of variation: (%)		***20.04***	***16.67***	***12.57***	***10.29***	***9.20***	***8.58***	***9.03***	***8.60***	***10.09***	***5.25***

Appendix XX

Analysis of variance for percentage ground cover for seed treatment by cultivar trial 48 days after sowing

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	2			
Cultivar	3			
Seed treatment	1			
V * ST	3			
Error	14			

Total	23

Coefficient of variation:

Appendix XX

Analysis of variance for percentage ground cover for seed treatment by cultivar trial 54 days after sowing

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	2			
Cultivar	3			
Seed treatment	1			
V * ST	3			
Error	14			
Total	23			

Coefficient of variation:

Appendix XX

Analysis of variance for percentage ground cover for seed treatment by cultivar trial 58 days after sowing

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	2			
Cultivar	3			
Seed treatment	1			
V * ST	3			

Error	14
Total	23

Coefficient of variation:

<u>Appendix XX</u>

Analysis of variance for percentage ground cover for seed treatment by cultivar trial 63 days after sowing

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	2			
Cultivar	3			
Seed treatment	1			
V * ST	3			
Error	14			
Total	23			

Coefficient of variation:

<u>Appendix XX</u>

Analysis of variance for percentage ground cover for seed treatment by cultivar trial 67 days after sowing

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	2			
Cultivar	3			

Seed treatment	1			
V * ST	3			
Error	14			
Total	23			

Coefficient of variation:

Appendix XX

Analysis of variance for percentage ground cover for seed treatment by cultivar trial 70 days after sowing

Source of variation	**d.f.**	**Mean square**	**F-ratio**	**Probability**
Replication	2			
Cultivar	3			
Seed treatment	1			
V * ST	3			
Error	14			
Total	23			

Coefficient of variation:

Appendix XX

Analysis of variance for percentage ground cover for seed treatment by cultivar trial 74 days after sowing

Source of variation	**d.f.**	**Mean square**	**F-ratio**	**Probability**
Replication	2			

Cultivar	3
Seed treatment	1
V * ST	3
Error	14
Total	23

Coefficient of variation:

Appendix XX

Analysis of variance for percentage ground cover for seed treatment by cultivar trial 81 days after sowing

Source of variation	**d.f.**	**Mean square**	**F-ratio**	**Probability**
Replication	2			
Cultivar	3			
Seed treatment	1			
V * ST	3			
Error	14			
Total	23			

Coefficient of variation:

Appendix XX

Analysis of variance for percentage ground cover for seed treatment by cultivar trial 98 days after sowing

Source of variation	**d.f.**	**Mean square**	**F-ratio**	**Probability**

Replication	2			
Cultivar	3			
Seed treatment	1			
V * ST	3			
Error	14			
Total	23			

Coefficient of variation:

Appendix XX

Analysis of variance for percentage ground cover for seed treatment by cultivar trial 105 days after sowing

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	2			
Cultivar	3			
Seed treatment	1			
V * ST	3			
Error	14			
Total	23			

Coefficient of variation:

Appendix 17

Analysis of variance for **yield of clean beet (t/ha.)** for **seed treatment X cultivar** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	52.165	3.3151	0.0397
Cultivar	3	49.383	3.1383	0.047
Seed treatment	1	16.936	1.0763	0.3113
C * ST	3	9.47	0.6018	
Error	21	15.735		
Total	31			

Coefficient of variation: 6.22 %

Appendix 18

Analysis of variance for **percentage tare** for **seed treatment X cultivar** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	6.481	0.7799	
Cultivar	3	4.393	0.5287	
Seed treatment	1	0.536	0.0645	
C * ST	3	1.347	0.1621	
Error	21	8.31		
Total	31			

Coefficient of variation: 30.15 %

Appendix 19

Analysis of variance for **percentage sugar** for **seed treatment X cultivar** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	0.287	1.671	0.2037
Cultivar	3	0.501	2.9199	0.0579
Seed treatment	1	0.001	0.0047	
C * ST	3	0.122	0.7091	
Error	21	0.172		
Total	31			

Coefficient of variation: 2.29 %

Appendix 20

Analysis of variance for **percentage sugar extractability** for **seed treatment X cultivar** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	3.047	9.0563	0.0005
Cultivar	3	0.697	2.0712	0.1347
Seed treatment	1	0.396	1.1773	0.2902
C * ST	3	0.107	0.3177	
Error	21	0.336		
Total	31			

Coefficient of variation: 0.62 %

Appendix 21

Analysis of variance for **yield of sugar (t/ha.) for seed treatment X cultivar** trial.

Source of variation	**d.f.**	**Mean square**	**F-ratio**	**Probability**
Replication	3	2.098	4.2946	0.0164
Cultivar	3	2.645	5.4663	0.0062
Seed treatment	1	0.505	1.0438	0.3186
C * ST	3	0.316	0.6534	
Error	21	0.484		
Total	31			

Coefficient of variation: 6.03 %

Appendix 22

Analysis of variance for **yield of extractable sugar (t/ha.)** for **seed treatment X cultivar** trial.

Source of variation	**d.f.**	**Mean square**	**F-ratio**	**Probability**
Replication	3	2.256	5.3582	0.0067
Cultivar	3	2.473	5.8787	0.0045
Seed treatment	1	0.52	1.2355	0.2789
C * ST	3	0.293	0.6957	
Error	21	0.421		
Total	31			

Coefficient of variation: 6.06 %

Appendix 23

Analysis of variance for **final plant establishment (‘000/Ha.)** for **seed treatment X cultivar** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	15.639	0.4802	
Cultivar	3	85.218	2.6167	0.0778
Seed treatment	1	36.317	1.1151	0.3030
C * ST	3	10.012	0.3074	
Error	21	32.567		
Total	31			

Coefficient of variation: 7.54 %

Appendix 24

Analysis of variance for **yield of tops (t/ha.)** for **seed treatment X cultivar** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	29.854	1.6722	0.2034
Cultivar	3	181.314	10.1559	0.0002
Seed treatment	1	5.96	0.3338	
C * ST	3	17.411	0.9752	
Error	21	17.853		
Total	31			

Coefficient of variation: 9.1 %

Appendix 25

Analysis of variance for **yield of clean beet (t/ha.)** for **seed treatment X time of harvest** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	25.996	2.5524	0.0829
Time of harvest	3	90.105	8.8469	0.0005
Seed treatment	1	47.021	4.6167	0.0435
TOH * ST	3	13.806	1.3555	0.2836
Error	21	10.185		
Total	31			

Coefficient of variation: 5.38 %

Appendix 26

Analysis of variance for **percentage tare** for **seed treatment X time of harvest** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	4.369	1.2597	0.3137
Time of harvest	3	64.961	18.7296	0.0000
Seed treatment	1	1.711	0.4934	
TOH * ST	3	2.327	0.6709	
Error	21	3.468		
Total	31			

Coefficient of variation: 19.86 %

Appendix 27

Analysis of variance for **percentage sugar** for **seed treatment X time of harvest** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	0.238	1.6205	0.2147
Time of harvest	3	0.498	3.3847	0.0372
Seed treatment	1	0.069	0.4717	
TOH * ST	3	0.083	0.5643	
Error	21	0.147		
Total	31			

Coefficient of variation: 2.20 %

Appendix 28

Analysis of variance for **percentage sugar extractability** for **seed treatment X time of harvest** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	1.294	2.6746	0.0735
Time of harvest	3	1.173	2.4244	0.0942
Seed treatment	1	0.035	0.0725	
TOH * ST	3	0.447	0.9327	
Error	21	0.484		
Total	31			

Coefficient of variation: 0.75 %

Appendix 29

Analysis of variance for **yield of sugar (t/ha.)** for **seed treatment X time of harvest** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	0.356	1.3296	0.2914
Time of harvest	3	3.662	13.6716	0.0000
Seed treatment	1	1.074	4.0103	0.0583
TOH * ST	3	0.358	1.3354	0.2897
Error	21	0.268		
Total	31			

Coefficient of variation: 5.01 %

Appendix 30

Analysis of variance for **yield of extractable sugar (t/ha.)** for **seed treatment X time of harvest** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	0.222	0.9658	
Time of harvest	3	3.053	13.2777	0.0000
Seed treatment	1	0.905	3.9342	0.0605
TOH * ST	3	0.278	1.2073	0.3315
Error	21	0.23		
Total	31			

Coefficient of variation: 5.00 %

Appendix 31

Analysis of variance for **final plant establishment('000/Ha.)** for **seed treatment X time of harvest** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	92.555	2.4078	0.0958
Time of harvest	3	52.331	1.3614	0.2818
Seed treatment	1	60.253	1.5675	0.2243
TOH * ST	3	4.814	0.1252	
Error	21	38.439		
Total	31			

Coefficient of variation: 7.79 %

Appendix 32

Analysis of variance for **yield of tops (t/ha.)** for **seed treatment X time of harvest** trial.

Source of variation	d.f.	Mean square	F-ratio	Probability
Replication	3	334.932	18.7187	0.0000
Time of harvest	3	122.977	6.873	0.0021
Seed treatment	1	174.939	9.777	0.0051
TOH * ST	3	3.245	0.1814	
Error	21	17.893		
Total	31			

Coefficient of variation: 10.25 %

Appendix 33

Analysis of variance for **percentage emergence** for **experimental seed treatment** trial

Source of variation	**d.f.**	**Mean squares (days after drilling)**					
		17	**19**	**21**	**25**	**33**	**39**
Replication	3	4.036	26.07	29.75	11.42	67.06	33.14
Seed treatment	2	21.201	3165.7	3755.3	142.38	54.58	68.47
Error	6	4.346	43.63	50.23	70.96	17.21	14.78
Total	11	-	-	-	-	-	-
F-ratio	-	4.877	72.55	74.76	2.006	3.172	4.631
Probability	-	0.055	0.0001	0.0001	0.215	0.115	0.061
Coefficient of variation (%):		***78.43***	***17.96***	***11.31***	***10.45***	***5.15***	***4.62***

Appendix 34

Analysis of variance for **percentage ground cover** for **experimental seed treatment** trial

Source of variation	**d.f.**	**Mean squares (days after drilling)**									
		43	**49**	**53**	**58**	**62**	**65**	**69**	**75**	**89**	**100**
Replication	3	2.632	14.806	7.417	16.18	41.75	51.28	41.74	13.94	64.89	0
Seed treatment	2	3.396	5.146	14.06	90.25	68.42	19.15	40.720	199.94	22.58	0
Error	6	1.84	2.868	2.979	5.333	40.14	15.09	20.33	22.05	16.47	0
Total	11	-	-	-	-	-	-	-	-	-	-
F-ratio	-	1.845	1.794	4.720	16.92	1.71	1.269	2.006	9.07	1.37	0
Probability	-	0.237	0.245	0.058	0.003	0.260	0.347	0.215	0.015	0.32	0
Coefficient of variation (%):		***15.43***	***11.35***	***8.74***	***6.57***	***11.61***	***6.68***	***6.41***	***6.02***	***4.40***	***0***

Appendix 35

Analysis of variance for **yield of clean beet (t/ha.)** for **experimental seed treatment** trial.

Source of Variation	d.f.	Mean Square	F-ratio	Probability
Replication	3	17.033	3.0626	0.113
Seed treatment	2	5.605	1.0079	0.4194
Error	6	5.561		
Total	11			

Coefficient of variation: 4.2 %

Appendix 36

Analysis of variance for **percentage tare** for **experimental seed treatment** trial.

Source of Variation	d.f.	Mean Square	F-ratio	Probability
Replication	3	2.938	0.4976	
Seed treatment	2	4.865	0.8239	
Error	6	5.905		
Total	11			

Coefficient of variation: 49.46 %

Appendix 37

Analysis of variance for **percentage sugar** for **experimental seed treatment** trial.

Source of Variation	d.f.	Mean Square	F-ratio	Probability
Replication	3	0.079	3.1776	0.1061
Seed treatment	2	0.001	0.0336	
Error	6	0.025		
Total	11			

Coefficient of variation: 0.89 %

Appendix 38

Analysis of variance for **percentage sugar extractability** for **experimental seed treatment** trial.

Source of Variation	d.f.	Mean Square	F-ratio	Probability
Replication	3	1.294	2.6746	0.0735
Seed treatment	2	0.035	0.0725	
Error	6	0.484		
Total	11			

Coefficient of variation: 3.83 %

Appendix 39

Analysis of variance for **yield of sugar (t/ha.)** for **experimental seed treatment** trial.

Source of Variation	**d.f.**	**Mean Square**	**F-ratio**	**Probability**
Replication	3	0.345	2.3593	0.1707
Seed treatment	2	0.164	1.123	0.3852
Error	6	0.146		
Total	11			

Coefficient of variation: 3.84 %

Appendix 40

Analysis of variance for **yield of extractable sugar (t/ha.)** for **experimental seed treatment** trial.

Source of Variation	**d.f.**	**Mean Square**	**F-ratio**	**Probability**
Replication	3	0.255	1.9814	0.2183
Seed treatment	2	0.142	1.1056	0.3902
Error	6	0.129		
Total	11			

Coefficient of variation: 3.83 %

Appendix 41

Analysis of variance for **percentage final plant establishment (‘000/Ha.)** for **experimental seed treatment** trial.

Source of Variation	**d.f.**	**Mean Square**	**F-ratio**	**Probability**
Replication	3	49.799	0.662	
Seed treatment	2	88.849	1.1812	0.3694
Error	6	75.222		
Total	11			

Coefficient of variation: 10.58 %

Appendix 42

Analysis of variance for **yield of tops (t/ha.)** for **experimental seed treatment** trial.

Source of Variation	**d.f.**	**Mean Square**	**F-ratio**	**Probability**
Replication	3	81.69	4.8785	0.0475
Seed treatment	2	1.231	0.0735	
Error	6	16.745		
Total	11			

Coefficient of variation: 9.04 %

Appendix 43

Mean Dry bulb temperatures (deg C) Casement Aerodrome April/May 1998 and calculation of day-degrees (above 3C)

Date	April	Day-degrees (Above 3C)		May	Day-degrees (Above 3C)
1	8.8	5.8		9.3	6.3
2	9.1	6.1		8.9	5.9
3	8.2	5.2		10.4	7.4
4	8.2	5.2		10.7	7.7
5	7.7	4.7		9.7	6.7
6	7.7	4.7		10.8	7.8
7	8.0	5		11.4	8.4
8	5.8	2.8		10.4	7.4
9	3.7	0.7		10.3	7.3
10	1.4	-1.6		8.8	5.8
11	3.0	0		10.2	7.2
12	1.5	-1.5		10.5	7.5
13	2.0	-1.0		11.7	8.7
14	2.2	-0.8		14.0	11.0
15	3.1	0.1		14.3	11.3
16	4.2	1.2		13.1	10.1
17	6.1	3.1		13.4	10.4
18	7.9	4.5		14.1	11.1
18	7.7	4.7		15.8	12.8
20	8.8	5.8		16.8	13.8
21	10.1	7.1		13.1	10.1
22	10.5	7.5		12.1	9.1
23	9.6	6.6		13.1	10.1
24	11.1	8.1		13.1	10.1
25	8.7	5.7		12.5	9.5
26	7.2	4.2		9.7	6.7
27	6.9	3.9		8.7	5.7
28	7.9	4.9		10.0	7.0
29	8.8	5.8		11.3	8.3
30	8.9	5.9		12.1	9.1
31	--	--		12.8	9.8