A Comparative Analysis of Conventional, Genetically Modified (GM) Crops and Organic Farming Practices and the Role of Pesticides in Each

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April 2019

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This analysis was commissioned by the American Sugarbeet Growers Association in an effort to educate grower leaders about the similarities and differences between crop protection tools for various types of farming practices.

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The American public has the right to choose what type of food to eat from the three agricultural production categories, organic, conventional or GM-based food crops, all of which are sustainable. This paper was developed to help consumers understand the specifics behind food production so that their choice is based on facts, not fear or misconceptions stemming from partial information or inconclusive evidence. There are some differences in farming practices among conventional, GM and organic farming methods but there are many practices in common.

Key Takeaways From This Study:

- **Food products from conventional, GM crops and organic production practices are safe and are all highly regulated by various government agencies.**
- **Consumers have a variety of healthy and fresh food options from among the three production methods (conventional, GM or organic products) and should feel free to choose foods from among these different production strategies without social stigma or health concerns.**
- **Consumers are often willing to pay vastly higher prices for organic products even though they are not categorically more nutritious, healthier or better for the environment than their conventional or GM counterparts.**
- **Many consumers' preferences for organically produced foods are based on misconceptions about perceived benefits of organic foods compared to conventional or GM products**.

Questions Answered by This Study:

***Is organic food healthier than conventional food*?** No, nutritional content of food comparisons are confounded by many factors including plant varieties sampled and analytical techniques used. Some reports have found higher antioxidant levels in organic foods compared to conventional foods but other reports have found higher ascorbic acid (vitamin C) and tocopherols (vitamin E) in conventional foods when compared to organic foods. And some studies found no significant differences in nutrient status between organic and conventional food, and food from GM crops is equivalent in nutrition to its non-GM counterpart. What scientists do agree on is it is much more important to our health to eat an adequate portion of thoroughly washed fruits and vegetables daily than to omit them from our diet, *regardless* of how they were produced. (Washing minimizes threat of soil- or food-borne pathogens that cause food poisoning.)

None of the production methods is healthier than the other all of the time and they are generally equivalent to each other.

***Is organic production the better choice for environmental concerns*?** The answer is no.A common perception or myth is that pesticides and/or fertilizers are *not* used with organic farming practices. One may speculate about why this belief is widely held by consumers, but the truth is that pesticides and fertilizers are an integral part of successful certified organic farming businesses, just as they are for conventional farms and/or those who use GM crops. Just as we saw with nutritional considerations, with environmental impacts of agricultural practices there are important complex considerations to take into account; that is, there are trade-offs and there is not a straight-forward right or wrong answer to cover all situations. Organic production seems to produce a system that is higher in biodiversity than conventional farming. However, when yield is included, most conventional and GM cropping systems typically produce more per acre than their organic counterpart, thus use land more efficiently than most organic operations. Since we cannot 'develop' more land mass, perhaps land use efficiency begins to emerge as a top contender among the vast number of environmental factors in the environmental impacts 'trade-off' conversation. Projections of population increases require more food per arable acre which necessitates even greater land use efficiencies than we currently achieve. Greater output attained through increasingly efficient land use meets the emerging need for increased farming productivity and sustainability throughout the food value chain.

> **Each production method offers environmental advantages and drawbacks compared to one another. Organic production is not unconditionally better for the environment and requires more land to produce an equivalent amount of food as conventional or GM cropping methods.**

The overriding fact is **our food is safe regardless of how it is produced.** There is an extensive regulatory network of federal and state agency personnel who are constantly monitoring food in the U.S., **including imported food**. When a problem arises, they take action, as we have seen in recent times with contamination from food-borne pathogens.

Agriculture is a business and it takes many resources to produce the safe and healthy food available to all of us in the U.S. As Americans we have the right to choose what type of food we wish to consume. If we want to pay more for organic food, that is our right, but it is **not necessary** to purchase organic food to make healthy or environmentally responsible food choices. Is there room for improvement? Yes. Are science and technology driving factors in agriculture's quest for continual improvement? Yes. Across conventional, GM cropping and organic systems reliance on advances made through research and technologies helps us improve our ability to produce food and fiber in a safe and efficient manner to sustain life and promote a continually stronger and sustainable environment.

> **Food from conventional, GM crops and organic farming is safe and is closely regulated by a connected network of government agencies.**

Executive Summary

Agriculture is a complex industry that relies on advances in science and technology to remain sustainable, regardless if the business is managed under conventional methods and/or relies on genetically modified (GM) crops or follows certified organic standards. It is possible for the same producer, usually a large company, to have conventional crops and a certified organic operation for the same crops. Differences in some agricultural practices exist among the three agricultural business strategies mentioned above, but it may be surprising to realize how many techniques are common to all three approaches for producing food and fiber. Where the biggest divergence in practices exists among conventional, GM crops and organic farming is in the choices available for crop inputs, *i.e*., seeds, nutrient additions and pest management products.

Product Safety: Conventional and GM crop producers have access to approximately 13,600 registered synthetic pest management products that have been comprehensively reviewed by United States Environmental Protection Agency (EPA) scientists as delineated in the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and other federal laws. FIFRA requires that all synthetic crop protection products be registered after undergoing an extensive series of tests to ensure that registered products, when used according to label directions (the label is the law) are safe to human health and the environment. Most newer pesticides are less toxic than salt or vinegar.

In addition to adhering to federal laws and regulations for agricultural operations (there are many more than FIFRA), certified organic producers must also adhere to the U.S. Department of Agriculture's (USDA) National Organic Program (NOP) standards. The NOP allows most natural substances in organic farming, *e.g.,* fertilizers and approximately 1,385 pesticides, while prohibiting most, but not all, synthetic substances.

Pesticide Residues: FIFRA and many other laws require that the EPA establish tolerance limits for acceptable safe pesticide residues allowed on crops. Tolerance level setting requires risk assessments that consider the *potential* for exposure to a pesticide based on actual levels of pesticide residue detected, the amounts of foods consumed and the toxicity of individual pesticides. Tolerance level setting is a <u>very</u> conservative process that builds in multiple layers of safety factors (10 – 1000-fold) which consider susceptible populations such as infants, children and other sensitive subpopulations. To assure consumer safety a variety of state and federal agency personnel constantly sample food products for residue levels and have repeatedly found that **99% of the foods sampled are well below established tolerance levels.**

Organic Production Costs: In addition to the added expense in organic production that comes with hand labor typically used for weed control, yield is typically lower in an organic field than for a similar crop grown in a conventional or GM cropping system, thus more land is needed for organic production. Lower yields in organic production compared to conventional and GM practices are most likely attributed to losses due to pest pressures that occur. Yield losses are exacerbated by the limited number of pest control products available to certified organic producers, especially herbicides. Certified organic growers also incur expenses to achieve and maintain organic certification that conventional and GM growers do not have. Certification is obtained through USDA-accredited third-party certifiers who charge for their services.

Consumer Costs: An additional important reflection about the cost differential in organic foods compared to conventionally produced food is that some consumers are willing to pay more for 'natural' or organic foods. *Why*? According to recent research these consumers have accepted the organic industry's creation of a market perception of its products - that organic food is safer, healthier and/or better for the environment than conventionally or GM grown food - and are willing to pay double or more for organic food. As this paper will discuss, it is not necessary to purchase organic foodstuffs to maintain a healthy and nutritional diet or produce an environmentally responsible food chain.

Consumer Confidence: Now let's turn to what these agricultural business practices and tools may mean to us when we go into the grocery store. As consumers we are faced with a decision each time we purchase food for our families -- do we choose the more expensive organic product or the comparatively cost-effective conventionally or GM produced counterpart? *Do we purchase a basket of organic strawberries for $12/lb. or can we trust that the $4.50/lb. basket of conventionally grown strawberries is safe to consume?* The answer is "**Yes"**, we ***<u>can</u>*** trust that the $4.50 basket of berries is safe for our family. *Why*? Because tolerances levels of allowable pesticide residues, determined by EPA scientists, are established for synthetic pesticides to assure their safety to human health, and the mere presence of a residue <u>does not</u> equate to a risk. In this paper we will see that a teenager can consume 1,743 strawberries in a day with <u>no</u> concerns for a health risk. A final thought about food safety is that large-scale conventional, GM and organic producers are subject to the Food and Drug Administration's (FDA) Food Safety Modernization Act (FSMA) that requires extensive monitoring of all inputs to prevent contamination of food with human pathogens. Small grower operations are exempt from some segments of the rules. There are some concerns regarding possible contamination from human pathogens such as *Salmonella* and *E. coli 0157:H2* with grower's reliance on animal manures and composted materials, and FSMA is addressing these concerns.

Government personnel around the country are constantly monitoring the food supply to ensure all food safety standards are met. U. S. consumers can be assured their food is safe because federal and state laws exist to ensure our food is safe regardless of <u>how</u> or <u>where</u> it is produced.

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Key Points

Synthetic Pesticide use is governed by a myriad set of laws and regulations such as:

- Federal, Insecticide, Fungicide and Rodenticide Act (FIFRA) (https://www.epa.gov/laws-regulations/summary-federal-insecticide-fungicide-and-rodenticide-act)
- Food Quality Protection Act (FQPA) (https://www.epa.gov/laws-regulations/summary-food-quality-protection-act
- Food Safety Modernization Act (FSMA) (https://www.fda.gov/Food/GuidanceRegulation/FSMA/default.htm)
- Clean Water Act (https://www.epa.gov/laws-regulations/summary-clean-water-act)
- Clean Air Act (https://www.epa.gov/clean-air-act-overview)
- Endangered Species Act (https://www.fws.gov/endangered/laws-policies/)
- Numerous others

Genetically Modified (GM) Crops are regulated by United Stated Department of Agriculture (USDA), Federal Drug Administration (FDA) and US Environmental Protection Agency (EPA)

- Known as The Coordinated Framework
  - Each agency has a different role in determining and ensuring biotech crop safety (https://www.aphis.usda.gov/aphis/ourfocus/biotechnology/sa_regulations/ct_agency_framework_roles).
- USDA first determines that the GM crop is safe (as they oversee agriculture).
- EPA regulates the pesticidal substance produced = Plant-Incorporated Protectants (PIPs).
- FDA determines that crops do not present a human health risk.

Certified Organic Agriculture is governed by above and the Organic Food Protection Act and USDA's National Organic Program (NOP)

(https://www.ams.usda.gov/sites/default/files/media/Organic%20Foods%20Production%20Act%20of%201990%20(OFPA).pdf) & (https://www.ams.usda.gov/about-ams/programs-offices/national-organic-program)

- Three-year process to obtain organic certification of land.
- Certification maintained by third-party certifiers accredited through the USDA.

Established List of Approved and Prohibited Substances (National List) allowed in organic agriculture (https://www.ams.usda.gov/rules-regulations/organic/national-list)

- Approved substances must be derived from natural sources such as microbial or plant sources or mined minerals such as copper or sulfur.
- A few synthetic substances have been approved for organic use but they must appear on the National List, *e.g.,* Lime Sulfur Solution.

Registered/Approved crop protection products available:

- ~13,600$^+$ pesticides for conventional use (in CA ≈ U.S.) (https://www.cdpr.ca.gov/docs/label/actai.htm)
- ~ 1385 products available for certified organic use (https://www.omri.org/ubersearch/results?type[]=opd_listed_product&type[]=opd_prohibited_product&type[]=opd_removed_product&cl[]=16996&rb[]=17014&rb[]=17013)

FIFRA requires synthetic pesticides to be federally registered

- Up to 150 science-based tests required, more than for pharmaceuticals.
- May take up to 11 years from molecule discovery to product registration.
- Extensive/expensive R & D to determine 'go/no go' for development.
- Total costs are nearly $300M.
- All registered pesticides are required to undergo regular registration reviews at least every 15 years including input from the public (https://www.epa.gov/pesticide-reevaluation).

EPA and other agencies require tolerance levels be established

- Set strict limits on amount of pesticide residue (tolerance) that is safe to remain on crop.
- Tolerance set by risk assessments conducted by EPA scientists.
- Includes 10 – 1000-fold safety factor.
- Extensive network of regulatory officials continually test for residues.
- Residue presence **≠** automatic risk for health concern.

Risk Assessments consider *probability of* risk by accounting for:

- Actual levels of residue found,
- Possible exposure through dietary and other non-occupational means, and
- Toxicity.

Risk Assessments ≠ Hazard Assessments

- Alternatively, hazard assessments *look* for problems rather than consider *probability* of problems.

Established Tolerance Levels

- Provide statutory/regulatory assurance that our food supply is safe.
- Assure that domestically produced **and imported** food is safe.
- **99%** of the products tested had residues **below** EPA established tolerance levels in 2017.

Consider in one day: (even if the produce had the highest residues recorded by USDA)

- A **man** could consume **318 servings** of peaches without any effects.
- A **woman** could consume **529 servings** of apples without any effect.
- A **teen** could consume **1,743 servings** of strawberries without any effect.
- A **child** could consume **56,117 servings** of carrots without any effect.
  *Most newer pesticides are **less toxic** than table salt or vinegar*.

Agriculture is a business = there is a cost for the food it produces

- Organic crops are more intensively managed and have reduced yield than conventional or GM crops = higher costs (also perception of value).

Is there a right or wrong choice regarding organic and conventional production or GM cropping for human health and environmental concerns?

- It is not necessary to buy organic food to eat healthy or promote vigorous environment.
- Each production system has positive attributes and may have some negative impacts on the environment, meaning there are trade-offs to consider.
- Scientists report the need for additional studies that minimize variability of factors studied.
- It is after all, a matter of choice.

General Agreement Among Scientists:

- It is more important to eat the proper amount of fruits and vegetables daily for a healthy diet than to omit or intake fewer (which may be necessary due to higher cost of organics).

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Factor	Conventional	GM	Certified Organic
Perspective	Uses a variety of cultural practices, methods and tools to produce crops. May rely on cover crops and crop rotation, but monoculture is a common cropping strategy. Must adhere to laws governing pesticide use and environmental impacts of cultural practices.	Similar cultural practices and tools to conventional but several GM crops are developed for pest resistance or tolerance to certain pesticides, usually herbicides. Examples include GM crops, such as non-browning apples and potatoes, developed to reduce browning. Rainbow papayas were developed to have a resistance to ringspot virus and GM squash varieties were also developed to have a resistance to specific viruses. Must adhere to same laws and regulations as conventional systems. Subject to additional by USDA, FDA and EPA than conventional crops.	Cultural practices similar to conventional, but heavier reliance on crop rotation and cover crops. In addition to other laws, governed by USDA's National Organic Program (NOP) which sets strict standards defining organic practices.
Fertilizer Input	May use a variety of synthetic products plus those approved for organic production. May be applied in smaller amounts than products used in organic farming because fertilizers available are often more efficacious than those approved for organic production. Timing of application is important to minimize waste and possible run-off to surface water sources.	Similar to conventional.	May only use products that are approved for organic production. Heavy reliance on green and animal manures. Large quantities usually required to deliver adequate crop nutrition. Timing is important to assure nutrient availability matches crop needs, may also have surface water run-off concerns.
Soil Heath	Influenced by cropping system and may be compromised in monocultures and/or lack of cover crops. May rely on minimum or no-till practices which can help reduce soil erosion. The need to improve soil health is receiving increased attention in conventional farming as it can help improve soil structure, water infiltration and reduce soil erosion.	Agricultural practices may be influenced by the genetically modified trait incorporated into the plant. Because GM crops may require fewer pesticides, there may be fewer passes through the field which reduces the possibility of soil compaction as well as lowering the probability of pesticide impacts to the environment.	Reliance on cover crops, crop rotations, incorporation of compost and manures are all acceptable methods and collectively contribute positively to soil health through promoting a biodiverse root zone (microbes). Microbial activity can lead to increased soil particle aggregation which has a positive influence on soil structure and may reduce the potential for soil erosion and increase water infiltration.
Human Health	Products are heavily regulated and only registered for use once determined safe. Smaller farms may not require the same level of food safety inspection under FSMA.	Similar to conventional, must not have any new allergens or increased level of natural toxicants over conventional counterpart.	Products are allowed after review and determined safe for human health, or may not require registration. Smaller farms may not require the same level of food safety inspection under FSMA. Some concerns with use of manures and compost due to possible presence of human pathogens.

Factor	Conventional	GM	Certified Organic
Pest Management Inputs	Adoption of Integrated pest management (IPM) philosophy requires constant monitoring for pest detection. Once detected, growers will choose from a list of possible control mechanisms including reducing soil nutrient and water stress, release of predatory, sterile or other beneficial organisms, mechanical and physical controls and as a last resort, a registered synthetic or natural pesticide. **Note**: Pesticides approved for organic production are also used in some conventional systems.	Similar to conventional but may need less pesticides or narrower array of pesticides than conventional depending on the genetically modified trait incorporated into the plant.	Operates under the 'PAMS' strategy (Prevention, Avoidance, Monitoring and Suppression), as well as IPM. Limited access to pest management products, as the number of approved products is about 10% of those available for conventional or GM crops. Crop losses due to limited pest control options results in reduced yield compared to conventional and GM cropping systems.
Pesticide Resistance	Must be managed carefully through use of non-chemical practices and judicious use of chemicals from different chemical classes providing different modes of action for pest control.	Similar to conventional systems. Choice of chemical controls will be at least partially guided by genetically modified trait incorporated into the plant.	Lower potential for resistance development than in conventional and GM cropping systems because there is less reliance on chemical control.
Environmental Impact	Products are heavily regulated and only registered for use once determined they will have no or minimal impacts.	Similar to conventional but has additional regulatory oversight under the Coordinated Framework agreement.	Biodiversity frequently cited as higher in organic, but land use is significantly less efficient than in conventional systems.
Yield	Usually higher than in organic, allows for efficient land use.	Typically higher than conventional and organic counterparts.	Typically lower than conventional or GM due to pest pressures; and ~ 20 - 40% less efficient land use than conventional or GM crops.
Returns	Maximum yields possible allow greatest return on per acre basis.	Similar to conventional but may offer greater return on investment because it may require less pesticide use. However, seed costs are higher than conventional.	Reduced yield (typically), input costs, including certification, require higher price. Also, consumers willing to pay more for organic so returns may be higher.

*Inspired by: "S.K. Dara, 2018, *Safe, Profitable, and Practical Label for Sustainable Product and Food Security*, Progressive Crop Consultant, Nov/Dec 2018, pp 20-23.

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Background

Most communities in the United States (U.S.) have access to at least one grocery store that contains many food products which consumers may choose to purchase for themselves and their families. One of the many food choices we have as Americans is whether or not to use our sometimes scarce financial resources to purchase organically produced food (usually at a higher price) or the same (usually lower priced) conventionally produced item. For example, do we purchase a basket of California grown organic strawberries at $12/lb. or is it safe to select and should we put the basket of conventionally produced berries (from the same grower) in our shopping cart and spend only $4.50/lb.? This is a reasonable question - but the answer is complex. This paper will explore the shared, as well as the different practices found in conventional (and genetically modified (GM) crops) and certified organic agriculture that brings us these two baskets of strawberries. We will present the case that conventionally and GM produced food is a healthy and safe choice while acknowledging that some consumers *choose* organic foods, even with substantial costs differentials for the same product. They do this as a matter of preference perhaps due to *perceptions* and beliefs (Fess and Benedito 2018) they hold that may not be accurate across all circumstances. However, before we delve deeper into the specific issue of conventional (in this paper conventional agriculture will generally include GM-based crop production) and organic agriculture, let's look at the technologies and processes that brought us these two baskets of strawberries or any other agricultural food product.

Regardless of how a strawberry or any other crop is produced, it is the result of a complex and technologically advanced business known as **agriculture**. Defined by Merriam-Webster agriculture is: "*The science, art or practice of cultivating the soil, producing crops and raising livestock and in varying degrees the preparation and marketing of the resulting products." Ano*ther definition is: "*Agriculture is the art and science of growing plants and other crops and the raising of animals for food, other human needs, or economic gain."* (https:/www.cropsreview.com). Regardless of the approach taken to produce life-supporting materials, *e.g*., conventional, GM-based or certified organic, everyone involved in the production of food, feed, fiber, *etc*. is involved in agriculture. The agricultural community is very large and inclusive of many practices and business strategies, and how one produces strawberries, milk, beans, corn or any other agricultural product is largely the result of a business decision based on experience, past practices, available resources, knowledge, labor intensity, production and marketing risks, profitability and sometimes personal philosophy.

Practices in Common

To maintain sustainable operations, farmers face choices on a daily basis regarding matters that need action, sometimes immediate action, regardless of whether they are managing a conventional, GM crop or organic farm. During the course of their decision making, producers are determining how to allocate their resources, prioritizing those items which must be dealt with first, while not losing sight of their longer-term goals of producing food or fiber crops by the end of the season. In this manner, all viable producers act as economists, determining how and when to use their resources to ensure the sustainability of their agricultural business.

Annual cropping systems require land preparation which involves a series of cultivation practices such as tilling, chiseling, disking, *etc*. Farmers must also select the correct varieties to plant, take soil samples for nutritional analysis, and possibly provide some irrigation and weed control before planting. Once the crop is growing, farmers must monitor their crops carefully for nutritional and soil moisture status and possible pest invasions (including weeds). Again, all of these apply, regardless of how the crop is grown.

Many farms, irrespective of their size, are family-run operations and provide a living not only for family members but for their employees, and in indirect ways, for their community. These farm operations are no different than other commercial enterprises, and therefore make decisions that help them manage their respective organizations in a manner that ensures its sustainability over the long-term for future generations.

Significant Regulatory Requirements in Agriculture

In addition to the cultural practices already mentioned, farmers must be aware of technological advances such as precision agricultural tools that can help them make the most effective and efficient use of their resources as well as the myriad of federal and state regulatory mandates governing how they operate and affecting their bottom line. Regardless of whether they are operating under conventional, GM or certified organic standards they must comply with all relevant regulations to ensure the safety of the food product(s) they are producing as well as ensuring worker and environmental safety. Certified organic producers have more regulatory requirements than conventional and GM farmers which in part contribute to the increased costs of organic food.

The U.S. Environmental Protection Agency (EPA) administers many but not all of the federal standards governing food, worker and environmental safety regulations affecting all farming operations regardless of whether the farm relies on conventional, organic or GM technology. Sweeping environmental legislation such as the **Clean Water Air Act** (initially enacted in 1948 and substantially reorganized in 1972) sets pollution control standards for surface water and has far-reaching impacts on farm-related nutrient management decisions (https://www.epa.gov/laws-regulations/summary-clean-water-act). Similarly **The Clean Air Act**, with roots that go back to the 1960s, was passed in 1970 and amended in 1977 and 1990, was designed to protect human health and the environment from effects of air pollution from both stationary and mobile sources (https;//www.epa.gov/clean-air-act-overview). **The 1973 Endangered Species Act** was designed to protect critically imperiled species from extinction as a '*consequence of economic growth and development untampered by adequate concern and conservation*'. This Act is administered by the U.S. Fish and Wildlife Service and the National Marine Fisheries Service (https://fws.gov/endangered/laws-policies).

The federal government passes laws and develops regulations to protect the environment, but frequently the federal government delegates daily oversight and monitoring of these laws and regulations to the state level. States may develop their own laws and regulations that may be stricter than federal regulations but they cannot be weaker (https://leanweb.org/tools-resources/louisiana-citizens-guide-environmental-engagement/chapter-1-government-agencies-environmental-regulations/1-2-state/). Needless to say, compliance with federal and state environmental regulations can be difficult for agricultural operations, especially those operations managed by production-oriented employees.

Certified Organic Regulatory Requirements

In addition to the regulations mentioned above and many others entrusted to the EPA in their role overseeing agricultural practices in the United States, the **Organic Foods Production Act** of 1990 (OFPA) which established the National Organic Program (NOP) is housed in the U.S. Department of Agriculture (USDA) (https://www.ams.usda.gov/sites/default/files/media/Organic%20Foods%20Production%20Act%20of%201990%20(OFPA.pdf). The NOP develops rules and regulations for the production, handling, labeling, and enforcement of all USDA organic products (https://www.ams.usda.gov/about-ams/programs-offices/national-organic-program). In its rulemaking process, the USDA established the National Organic Standards Board (NOSB) which is an official federal advisory committee under the auspices of the USDA. The NOSB has 15 members, including scientists, policy experts and consumer-interest representatives from the public (non-government) sector. The NOSB advises the USDA on allowed and prohibited substances in organic production and handling. USDA scientists review the NOSB's recommendations and in a transparent manner, update The National List of Allowed and Prohibited Substances (aka National List) as appropriate (https://www.ams.usda.gov/rules-regulations/organic/national-list).

USDA organic regulations set out a description of organic agricultural practices including cultural, biological and mechanical practices to foster recycling of on-farm resources to maintain soil health, water quality and promote biodiversity. Acceptable pest management practices, an integral part of any farming business, are explicitly outlined in the NOP under what is known as the 'PAMS' strategy. This strategy involves: Prevention, Avoidance, Monitoring and Suppression and is spelled out as the manner in which certified organic farmers (in this paper we assume all organic producers are certified) must approach crop protection. As a last resort, organic producers may rely on an approved pesticide, *e.g*., a naturally occurring microorganism or a pesticide derived from naturally occurring plants (biopesticides). There are a few approved synthetic substances certified organic farmers may use, *e.g*., Lime Sulfur Solution, and these synthetic products approved for certified organic production are specified on the National List as determined by USDA's NOP (https://www.ams.usda.gov/about-ams/programs-offices/national-organic-program). The substances that appear on the National List must be necessary to production because of unavailability of natural or organic alternatives, and they must not be harmful to human health or the environment (https://ota.com/advocacy/organic-standards/national-list-allowed-and-prohibited-substances).

Genetically Engineered/Bioengineered/Modified Crops and Organic Agriculture

Interestingly, the 1990 OFPA did not mention biotechnology, genetic engineering (GE) or genetically modified organisms (GMO), but it did specifically prohibit synthetics (unless allowed) and allowed any natural substance (unless prohibited). (For the purpose of this paper, GMO/GM/GE and bioengineered will be used interchangeably.) In 2000 the NOP proposed a rule to exclude GMOs in organic production and handling. This prohibition stemmed from the fact that a variety of methods to genetically modify or influence growth and development of an organism are performed by means not possible under natural conditions or processes, and therefore not compatible with organic productions. Breeding which can include traditional plant breeding techniques for mutagenesis (treatment of plants with radiation or chemicals to induce random mutation), fermentation, hybridization, *in vitro* fertilization or tissue culture are allowed in organic production (McEvoy 2013). However, it is important to note that in a 2018 paper, the NOSB stated that it recognized "*the need to continually add methods to their list for review and to determine if the methods are or are not acceptable to organic agriculture*" (NOSB 2018).

The NOP addresses inadvertent contamination from a GMO of an organic product through testing procedures in the certification process, but does not establish GMO tolerance levels as they do for the trace level presence of residue from a registered pesticide (discussed below), which is set at 5% of a specific residue. According to USDA's webpage "Organic 101: Can GMOs Be Used in Organic Products?" "Any certified organic operation found to use prohibited substances or GMOs may face enforcement actions, including loss of certification and financial penalties. However, unlike many pesticides, there aren't specific tolerance levels in the USDA organic regulations for GMOs. As such, National Organic Program policy states that trace amounts of GMOs don't automatically mean the farm is in violation of the USDA organic regulations." (https://www.usda.gov/media/blog/2013/05/17/organic-101-can-gmos-be-used-organic-products)

Regulation of GM crops with pesticidal traits in the U.S. is overseen by three different federal agencies known as The Coordinated Framework: EPA, USDA and the Food and Drug Administration (FDA), (https://www.aphis.usda.gov/aphis/ourfocus/biotechnology/sa_regulations/ct_agency_framework_roles). The FDA consults with other agencies to determine the safety of GM crops (with pesticidal traits) are as safe as their conventional counterparts, ensuring no new allergens or increased levels of natural toxicants exist in GM crops. The USDA has general responsibility to ensure the safety of agriculture, and therefore must make a determination that a GM crop is not a plant pest. Before that determination takes place, the USDA strictly controls interstate movement, importation restrictions and environmental release. The EPA regulates the pesticidal substance produced and the genetic material necessary for its production in the plant. EPA nomenclature for this type of GM crop is 'plant-incorporated protectants' or PIPs. The EPA has continual oversight over GM crop use and conducts periodic reviews of the technology (Mendelsohn, *et.al*. 2003).

It is interesting to point out that many of the GM crops grown in the U.S. are those that have been engineered to help plants be resistant to either a specific pest, *e.g*., Bt corn (*Bacillus thuringiensis*) which is resistant to corn earworm and other lepidopterous larval (worm) pests or be able to tolerate specific pesticides, usually herbicides such as glyphosate or dicamba. These genetic modifications help growers reduce their reliance on some specific pesticides or at a very minimum reduce the spectrum of pesticides needed in their pest management program. In other words, they make the case for the potential of reduced exposure to pesticides for humans and the environment than might be possible in non-GM cropping scenarios.

Pesticides (Regulatory Overview)

Perhaps the most impactful federal regulations under EPA's purview with direct implications to farming stem from **The Federal Insecticide, Fungicide and Rodenticide Act** (FIFRA) first passed in 1947 and significantly updated in 1972 (https://www.epa.gov/laws-regulations/summary-federal-insecticide-fungicide-and-rodenticide-act). FIFRA gives the EPA authority to regulate the registration, distribution, sale and use of all pesticides. According to FIFRA a pesticide is:

- Any substance or mixture of substances intended for preventing, destroying, repelling or mitigating any pest,
- Any substance or mixture of substances intended for use as a plant regulator, defoliant or desiccant, and
- Any nitrogen stabilizer.

Furthermore, FIFRA gives the EPA authority (both intrastate and interstate commerce) to regulate all types of pesticides including:

- insecticides,
- herbicides,
- fungicides,
- rodenticides,
- anti-microbials (*e.g.,* household bleach), and
- devices.

Pesticides have two major types of ingredients: the active ingredient (AI) - the ingredient with the mode of action that provides pest control, and the inert or inactive ingredients, those used in the formulation of a final pesticide product. Regardless of whether synthetic pesticides are intended for conventional or organic farming (sometimes both), most must be registered by the EPA and state regulatory agencies before they can be sold anywhere in the U.S. The pesticide registration process for synthetic products requires a series of up to ~150 science-based studies which are reviewed by EPA scientists to determine the product's safety to human health and the environment when used according to the label (*the label is the law*!). **In fact, more tests are required for pesticides than for pharmaceuticals** (Winter 2018a). It can take up to **10 or 11 years** from discovery to final registration and sales for a single pesticide. To help put this timeline into perspective, consider that it took **five years** to build the Hoover Dam, and it takes approximately **seven years** to become a lawyer (McDougall 2016). The federal registration process itself takes 24 months for a new active ingredient with a food use and has a registration fee of $627,568 for conventional products and 19 months and a fee of $51,053 for federal registration of biopesticides including organic products. Pesticides must also be registered in each state before they can be offered for sale, and this additional step in the overall registration process can take one to two years, or more in some states like California.

Before a pesticide, both conventional and organic, ever gets to the point of the aforementioned federal registration application, it has undergone a very extensive and expensive series of tests by the company developing it. Frequently a conventional synthetic pesticide is tested for three or four (or more) years by a company before they consider submitting it to the EPA for registration. Needless to say the processes for conventional synthetic pesticide development and registration require years of scientific research and millions of dollars. Safety and efficacy testing can involve up to $250M (or more) of private investment with an additional $33M$^+$ required for registration, bringing the total close to $300M (McDougall 2016). It may be more than 10 years from initial discovery of a promising molecule to the point of it becoming a viable, registered commercial pesticide. McDougall (2016) surveyed major crop protection manufacturers and reported that in 2014 the ratio of molecules discovered to pesticides registered was ~ 159,574 to1! Organic pesticide product development and registration can take more than three years for the full process and requires between $500K - $1M (or more) of private investment. This information should dispel any notion that just because a company develops a promising molecule, it will *automatically* find its way to the market as crop protection product.

The federal registration process is a transparent one that relies on the most up-to-date science available as well as input from the public. As a part of the registration process, the EPA establishes a maximum legal residue limit of the pesticide (tolerance) allowed to remain on a harvested crop. Established tolerance levels ensure that the food will be safe and apply to food grown in the U.S. and to imported food. In addition, all registered pesticides must undergo a registration review by EPA a minimum of every 15 years that assesses changes since the last review, conducts new assessments as needed, includes input from the public and consults with regulatory partners (https://www.epa.gov/pesticide-reevaluation/reregistration-and-other-review-programs-predating-pesticide-registration).

Setting Tolerance Limits

EPA scientists set tolerances when they find that a pesticide can be used with "*reasonable certainty of no harm*". In addition to the EPA, the USDA and FDA consult with EPA personnel regarding standards for the level of pesticide residue that is allowed in or on crops. Residues are measureable traces of pesticides on harvested crops (Winter 2018b). Tolerances for each crop use of a pesticide are set after the EPA develops a risk assessment that considers:

- The aggregate, non-occupational exposure from the pesticide (exposure through diet, drinking water and pesticides used around the home),
- The cumulative effects from exposure to pesticides that have a common mechanism of toxicity (two or more pesticides) with a common mode of action,
- Whether there is an increased susceptibility to infants and children or other sensitive (elderly) subpopulations from exposure to pesticides, and
- Whether the pesticide produces an effect in people similar to an effect produced by a naturally occurring estrogen or produces other endocrine disruption-effects.

Stated more simply, dietary risk assessments conducted for establishing tolerance levels consider the *probability* of risk which takes into account: actual level of pesticides detected, amounts of foods consumed and the toxicity of the individual pesticide (Winter 2018c). (Note: tolerances may also be referred to maximum residue limits (MRLs) in some references or in different countries.)

University of California, Davis, Food Scientist and Toxicology expert, Dr. Carl Winter (2018a), noted that "*Most pesticides today are less toxic than table salt or vinegar."* To help put the discussion about tolerance limits and the safety they provide into an even greater context regarding health, some examples developed by Dr. Robert Krieger, former head of University of California, Riverside, Personal Chemical Exposure Program, are shown below. Please keep in mind, these are examples* of the amount of food one would have to eat in one day and still not reach a level of concern about adverse effects from pesticide residues, even if the crop had the highest level of pesticide residues recorded by the USDA for that crop:

- A **man** could consume **318 servings of peaches** in one day without any effect
- A **woman** could consume **529 servings of apples** in one day without any effect
- A **teen** could consume **1,743 servings of strawberries** in one day without any effect
- A **child** could consume **56,117 servings of carrots** in one day without any effect (*Excerpted from: Winter 2014 & MacDonald 2016)

The EPA sets tolerance limits to protect the public health. These limits incorporate safety factors, or added margins of safety to protect sensitive populations including infants, children and the elderly. Federal and state regulatory agencies across the country routinely sample food products for the presence of pesticide residues (Brooks 2014). The USDA's 2017 Pesticide Data Program (PDP 2017) reported that residue sampling tests showed that **99% of the products tested had residues below the EPA benchmark levels** (tolerances) established by the EPA. Tests were conducted on fresh and processed foods as well as milk, honey and bottled water. These tests put a strong emphasis on foods that are consumed by infants and children (USDA 2018). The FDA is responsible for enforcing EPA tolerances, and if new scientifically obtained data reveal a problem the EPA removes from the market any pesticide that is determined not safe for human consumption. Results from the PDP are also used in other important ways to inform and improve agricultural practices, improve IPM objectives as well as to protect consumers' health (PDP 2017 & USDA 2018).

The Food Quality Protection Act (FQPA, 1996) requires the EPA to ensure that all pesticides used on food in the U.S. meet the FQPA stringent safety standards, especially for children (https://www.epa.gov/laws-regulations/summary-food-quality-protection-act). The FQPA requires EPA to determine that a pesticide's use on food is safe for children and other sensitive subpopulations and includes an additional safety factor, tenfold, unless data show a different factor to be protective, to account for uncertainty in data relative to children. The FQPA contains a requirement that pesticides be reviewed within a 10-year period following initiation of FQPA with the most toxic chemicals first. Generally the public can take heart that EPA's continued reevaluation (considering new data) of registered products in addition to strict FQPA requirements and significant and continual improvements in science (including detection abilities) combined with the increased use of safer, less toxic pesticides has led to an overall trend of reduced risk from pesticide use (https://www.epa.gov/safepestcontrol/food-and-pesticides).

As with environmental legislation mentioned previously, pesticides must be consistent not only with federal laws but also with state and tribal laws and regulations which can vary (significantly) across the country. Generally states have primary authority with their state for compliance monitoring and enforcement against the use of pesticides in violation of labeling requirements (https://www.epa.gov/sites/production/files/2014-01/documents/1983frnotice.pdf).

The Food Safety Modernization Act (FSMA) passed in 2011 is under the purview of the FDA. The Act enables FDA to protect public health by strengthening the food safety system. FDA personnel are able to focus on *preventing* food safety problems rather than relying on *reacting* to problems after they occur. FSMA provides FDA with new enforcement authorities designed to achieve higher rates of compliance with prevention- and risk-based food safety standards as well as to be able to respond better to problems when they occur. This law also gives the FDA tools to enforce **the same safety standards on imported foods as domestic foods**. A major goal of FSMA is to have FDA build an integrated national food safety system in partnership with state and local officials (https://www.fda.gov/newsevents/publichealthfocus/ucm239907.htm).

Highlights of FSMA's authorities and mandates include (but are not limited to):

- Mandatory preventive controls for food facilities – Facilities must have written preventive control plans,
- Mandatory produce safety standards – FDA must establish science-based, minimum standards for the safe production and harvesting of fruits and vegetables. These standards must consider naturally occurring hazards as well as those introduced (intentionally and unintentionally) and include soil amendments such as compost,
- Authority to prevent international contamination through regulations that protect against the intentional adulteration of food,
- Mandated inspection frequency by FDA and access to records, and
- Testing by accredited laboratories to ensure that food testing meets high-quality standards.

Role of Crop Protection Inputs in Conventional, GM and Certified Organic Production

There are over 30,000 weed species, nearly 15,000 types of insects and thousands of microbial organism that threaten crop health during the growing season, as well as rodents and other animals. We should also consider that stored crops are vulnerable to damage done by insects and disease agents as well as by rodents (Winter 2018d). Use of pesticides and other crop inputs is perhaps the point where the largest bifurcation of agricultural practices takes place among conventional, GM and organic farming strategies. **A common perception or myth is that pesticides and/or fertilizers are *not* used with organic farming practices (Wilcox 2011). One may speculate about why this belief is widely held by consumers, but the truth is that pesticides and fertilizers are an integral part of successful**

certified organic farming businesses, just as they are for conventional farms and/or those who use GM crops.

Before they turn to pesticides, most farmers regardless of how they grow their crops adhere to the principles of Integrated Pest Management (IPM) for their pest control strategies and will choose mechanisms to help *preven*t pests when possible including choosing the optimum planting dates and variety selections, crop rotations when possible, assuring adequate soil nutrient and moisture status, among other management practices. Generally producers turn to pesticides as a last resort.

Most farmers embrace the concept of IPM because by definition it helps them allocate their pest control resources in the most judicious manner possible. The University of California, Davis (UCD) defines IPM as *"An ecosystem-based strategy that focuses on long-term prevention of pests or their damage through a combination of techniques such as biological control, habitat manipulation, modification of cultural practices (including mechanical and physical controls) and the use of resistant varieties*. *Pesticides are used only after monitoring indicates they are needed according to established guidelines and treatments made with the goal of removing only the target organism. Pest control materials are selected and applied in a manner that minimizes risks to human health, beneficial and non-target organisms and the environment." (*UCD, What is IPM*?)* In essence, IPM practitioners look for long-term pest control solutions and rely on a combination of methods that work better together than they do separately; *synergy at its best*.

IPM practitioners turn to pesticides as a *last* resort, not as the automatic 'go-to' pest control method, and they often refer to their pest management 'tool box' that includes a combination of the practices listed above and others, along with pesticides when needed. When a farmer who follows IPM practices turns to a pesticide, one can be reasonably certain that the pesticide used will be among the more recent, 'safer' pesticides as designated by the EPA. It is even possible or probable that at least one of the pesticides used during the course of the growing season of conventional or GM crops may be the same one used by certified organic farmers, *e.g*., Spinosad or Dipel, insecticides registered for control of worms and other pests on many crops including vegetables.

Pesticides in Conventional, GM and Organic Farming

Essentially it is the <u>source or origin</u> of a pesticide that determines a pesticide's applicability to certified organic farming. As mentioned, pesticides are defined broadly by the EPA and anything used to control a pest (weed, insect, rodent, bacteria, fungus or virus, *etc*.) is considered a pesticide by <u>definition</u>, regardless of whether it's used as a conventional, GM crop or an organic pest management tool. Most organic pesticides are derived from natural sources, *e.g*., mined sulfur or copper and naturally occurring microbes are examples of such sources, but others are included. These natural pesticide sources are usually subjected to some sort of process, for example, crushing, emulsifying or fermenting to convert or formulate them into a material that can be applied in a reasonable manner for pest control.

Synthetic pesticides used in conventional agricultural operations are those developed in a laboratory by scientists who specialize in chemistry, biochemistry and/or plant and animal physiology. Today's research does not look for broad spectrum pesticides. Rather, the trend has been to look for safer products with smaller environmental impacts with particular target sites or modes of action in mind. Active ingredients (AI) found in synthetic pesticides are usually designed to be used in very small quantities, usually only ounces per acre in a final, formulated product, *e.g*., on average, 360 ml of a pesticide or approximately the size of a soda can is needed to spray one acre of crops (MacDonald 2016). An example of this is the AI, chlorantraniliprole (Coragen) used to control worms on broccoli, cauliflower and cabbage. It is used at 0.098 lb. AI per acre, applied in a formulation at 7.5 fl. oz. per acre. That's half of the pint-size soda bottle for an entire acre of crop, or put another way, on an area almost the size of a football field, goal line to goal line.

In general, a synthetic pesticide's half-life (50% of product still on site) is measured in days, not hours, which means its field efficacy is increased over many of the substances found in natural organic products. The natural insecticide pyrethrin which is derived from the chrysanthemum plant is used for worm control in organic crops. It has a half-life of about 12 hours with less than 3% remaining on plant leaves after five days. Scientists using the pyrethrin structure, developed a synthetic pyrethrin (pyrethroid) that has a half-life of three - five days. That means 50% of the pyrethroid is still providing worm control five- ten times longer than the natural pyrethrin. For every one application of a pyrethroid, four - five applications of natural organic pyrethrin would have to be made to achieve the same control. That's not just savings in product applied, but it also reduces mixer/loader/applicator exposure and resources involved with the spray application.

Most pesticides used in agricultural production are reviewed by the EPA and for certified organic farming, the USDA's NOP program. Many pesticides must go through the federal registration process mentioned previously, but there are some exceptions known as Minimum Risk Pesticides (MRP). These pesticides are those which the EPA has determined pose little risk to human health or the environment. These products (many may be used in both organic and conventional agriculture) must meet strict guidance regarding the allowed AI and inert ingredients. Active ingredients must be contained on the FIFRA-designated 25(b) list and inert ingredients must be classified as those contained on the NOP's List 4A "Inert Ingredients of Minimal Concern". Minimum Risk Pesticides are exempt from the requirements of tolerance setting, and the EPA has strict requirements for claims that can be made for these products. Even though federal registration of MRPs is not required, many states require that they be registered (https://www.epa.gov/minimum-risk-pesticides/minimum-risk-pesticide-definition-and-product-confirmation & https://www.epa.gov/minimum-risk-pesticides/conditions-minimum-risk-pesticides).

Although the EPA reviews many pesticides used in organic farming, many of them do not require the establishment of a tolerance (Roseboro 2017). Spinosad, a pesticide derived from soil bacteria, reviewed by the NOSB, is approved for organic (and conventional) farming and does have an established tolerance. Most other crop protection products used in organic agriculture are exempt from the requirements of tolerance setting. It's interesting to note that most of the pesticides used in organic farming are used on fruit and vegetables while pesticide use is less common in organic grain production (Roseboro 2017).

As already stated, one of the main differences in pesticides allowed in certified organic agriculture from those used in conventional production is that the source of an organic product is a natural source, such as neem oil, diatomaceous earth and pepper among others. There are some synthetic products used in organic production, *e.g.*, alcohols, copper sulfate and hydrogen peroxide (Roseboro 2017), but they must be reviewed by the NOSB for recommendation to be included, or not, on the National List. The NOSB reviews substances on the National List every five years in a 'sunset' review and the frequency of these reviews provides a mechanism for the NOP to stay current with the latest information and innovations in organic agriculture.

There are significantly fewer approved pesticides for organic production than for conventional and GM cropping systems. The Organic Materials Review Institute (OMRI) lists approximately 1,385 crop protection products approved for organic production in the U.S. (https://www.omri.org/ubersearch/results?type[]=opd_listed_product&type[]=opd_prohibited_product&type[]=opd_removed_product&cl[]=16996&rb[]=17014&rb[]=17013). Many of the pesticides on OMRI's list are biopesticides which are derived from naturally occurring agents such as bacteria, animals, plants and some minerals (Brooks 2014), and as stated earlier they must be registered under FIFRA. According to the California Department of Pesticide Regulation (CDPR) (https://www.cdpr.ca.gov/docs/label/actai.htm & https://www.cdpr.ca.gov/docs/pressrls/dprguide/chapter3.pdf) in 2016 there were approximately 13,600^{+} pesticides registered (in CA) most of them for use in conventional farming and on GM crops. The CDPR list also includes products approved for organic production. California product registration statistics can be considered representative of those products registered federally.

Pesticides and Human Health Considerations

The presence of a pesticide residue (measurable traces of pesticides on food crops) does not in itself represent a risk to a human health (Winter 2018b). Allowable pesticide residues (tolerance) are strictly governed and monitored by federal and state agencies. As discussed, allowable tolerance levels are set by the regulations overseeing tolerance limits which consider what level of residues can be safely consumed on a daily basis over a course of a lifetime. Tolerance limits comprise this consumption consideration and then include a 10 – 1000-fold safety factor to take sensitive populations into consideration. Tolerance limit setting is a very conservative process - tightly overseen by the EPA, USDA and FDA, and monitored by state and federal officials.

Detection technologies used in monitoring pesticide residues continually advance as scientists develop new methodologies and equipment. It is now commonly possible to detect resides in the parts per billion (PPB) (Miller 2018) where just a generation ago, detection limits were commonly reported in the parts per million (PPM) range. Because of continual advances in detection capabilities it is even more important to remember that detection of a pesticide residue alone does not equal risk.

Dr. Carl Winter and a graduate student found that "*consumer exposure to the most frequently detected pesticides on the (*Environmental Working Group's*) 2010 "Dirty Dozen" commodities were extremely low and well below the reference dose in all cases. Reference Dose (RfD) represents levels not considered to pose any health concern for consumers.*" They further stated that, "*In 75% of the cases in their review exposure was well below 0.01% of the Rfd, representing exposures at least* ***one million times lower than those that do not demonstrate any toxicological effects (threshold level) in laboratory animals exposed to the pesticides on a daily basis throughout their lifetimes****."* (Winter 2018c)

Cancer
As mentioned above, pesticides, including those approved for organic agriculture, are any product or device intended to control, mitigate, prevent, repel or kill a pest (weeds, rodents, insects, fungi, bacteria, nematodes, *etc*.). By definition, pesticides are intended to provide pest control, per its Latin roots:

'pestis' = deadly, contagious disease
'*cide*' = killer.

The public is often confused by news reports that sometimes (loosely) link pesticide exposure to different human health risks including cancer. In today's 24/7 news cycle, it can appear that we are hearing of these connections more frequently than in the past. According to Dr. Winter (2018e) cancer is becoming more common for several reasons including improvements in medical care that allow us to live longer, technologies that provide improved diagnoses and lifestyle choices. The primary causes of cancer are generally those over which we have a behavioral choice, including smoking, drinking, obesity and lack of exercise. A few potent infections caused by microbial pathogens may also contribute to the risk of certain types of cancer such as the human papillomavirus, hepatitis B and C, HIV and Epstein-Barr viruses.

The EPA requires extensive testing of each pesticide AI [based on internationally accepted guidelines, (Winter 2018a)] with regard to cancer and other human health concerns to determine if an AI may damage cells or lead to tumors in laboratory animals. These tests are conducted at exposure levels that the general population, including farm workers, would **never experience** under normal conditions. Using very high doses when a test is conducted allows EPA and other regulatory agency scientists to build in the 10 - 1000-fold safety factors for safe use of a pesticide. Additionally, results from these tests help guide label directions regarding use patterns and volume as well as personal protective equipment needed to be worn by agricultural workers.

Glyphosate, the AI in Roundup and other herbicides has come under close scrutiny in the press recently. Ian Musgrave, senior lecturer in Pharmacology, Univ. of Adelaide in Australia cited The Agricultural Health Study from 2018 which was carried out for more than 10 years on 50,000 farm workers. The report found that this population with the highest exposure to glyphosate showed that if there is any risk of cancer from glyphosate products, the risk is exceedingly small (Musgrave 2018). In his article, Musgrave also made the interesting observation "*juries don't decide science*" in reference to the recent lawsuit regarding glyphosate, and he further stated that the court case did not reveal any new scientific data. Dr. Winter (2018e) also referenced this same epidemiological study of more than 50,000 farmers that showed no statistically significant increase in any cancer from glyphosate use.

The International Agency for Research on Cancer (IARC) an intergovernmental agency operating under the World Health Organization through the United Nations, identified glyphosate as a 'probable' carcinogen to humans by means of a 'hazard assessment'. A hazard assessment differs from a risk assessment in that the process does not assess whether an agent is *likely* to cause cancer because a hazard assessment does not take *exposure* into account unlike a risk assessment. To put these IARC results into a different perspective, IARC reviewed nearly 1000 factors and only one has been determined not to be 'non-carcinogenic'. IARC's list of known, probable and possible carcinogens includes: sunshine, mobile phones, alcoholic beverages, coffee, working as a hairdresser, hot yerba mate tea and a number of other equally innocuous, common items encountered on a daily basis (Genetic Literacy Project 2018).

Because of its close scrutiny and oversight of pesticides in the U.S., the EPA acts as a watch dog to provide a regulatory safety net through its routine periodic re-evaluation process necessary for a pesticide to maintain its registration. When potential risk factors are identified, the EPA requires pesticide manufacturers to conduct additional scientific tests and submit results from these tests to the EPA for their review and consideration. If and when warranted, the EPA works in a transparent manner to inform the public about any safety concerns and takes appropriate action regarding the registration status of the product it is reviewing.

Confusion and concerns over the impact of pesticide residues to their health have led some consumers to eat only organically produced food. These consumers choose to do this and are willing to pay more for organic food because they have accepted the organic industry's contention that organic food is safer and/or healthier than conventional food (Wilconx 2011, Watson 2012, McFadden & Huffman 2017). Going back to the strawberry example at the beginning of this paper, if some consumers choose only organic produce they may be forced to reduce their overall consumption of fresh fruit and vegetables because of personal financial constraints. Dr. Winter concluded (2018c), "*Strong science . . . . . . indicates that all conventionally produced fruits and vegetables should be a part of a healthy diet, and those singled out as 'dirty' based upon arbitrary and methodologically unsound approaches can and should be consumed without stress or fear."*

Nutritional Considerations

Some consumers believe that organic food is more nutritious than conventionally or genetically engineered crops used to produce food (Wilsox 2011), but scientists' opinion vary regarding the significance of nutritional differences among the production methods. Many factors impact results of studies comparing nutritional values among different production systems (Fess and Benedito 2018, Barański, *et al*. 2014), and FDA reports that foods from genetically engineered plants are generally as nutritious as foods from comparable traditionally bred plants (https://www.fda.gov/food/ingredientspackaginglabeling/geplants/ucm346030.htm).

Fess and Benedito (2018) conducted a comprehensive analysis of many facets of organic and conventional cropping systems including nutritional information. They state "*that crop quality is a complex term that integrates several physiological (firmness, dry matter content) and biochemical (nutritional and sensory) factors, creating great difficulty to generically compare products from conventional and organic systems*." Studies covering different global locations and soil types as well as crop varieties complicate comparisons in different cropping systems. They also point out that other factors such as poor experimental design, lack of consistency in the techniques used for measuring nutrient components and even a lack of consistency of a definition of organic can confuse results. To minimize variability of results their review of nutritional studies attempted to compare only those with similar and/or consistent methods. They reported that some foods from organic production systems may have higher concentrations of antioxidants and vitamins than those from conventional systems, while tocopherols (vitamin E) and ascorbic acid (vitamin C) were greater in some crops under conventional management. But results from different studies and researchers were not consistent, even within the same vegetable or fruit type. Interestingly, Fess and Benedito (2018) referred to a study that found sensory qualities (taste, feel) of strawberries produced under different cultivation systems varied most due to genotype (varieties).

Mayo Clinic staff (2018) also found a small or moderate increase in flavonoids and Omega-3 fatty acids in organic foods compared to conventional foods, and similar findings were reported by Barański, *et al*. (2014) and Benbrook, *et al*. (2013). A study conducted by Stanford researchers in 2012 reached similar conclusions regarding Omega-3 fatty acids, as well as reporting higher phosphorus levels (required for bone and teeth formation, https://medlineplus.gov/ency/article/002424.htm) in organic food compared to conventional. However overall, the Stanford researchers **found very little differences in nutritional content between organic and conventionally produced food** (Watson 2012). As an aside, these same Stanford researchers found that food poisoning bacteria were equally present in organic and conventionally produced food, and readers may recall incidents in December 2018 of food-borne pathogens on romaine lettuce.

It seems fair to say that when it comes to comparing nutritional values among organic, conventional and GM food crops, the body of scientific evidence points to the need for future studies to focus on understanding the interactions between the environment (soil/location) and crop genetic factors responsible for composition differences between organic and conventional crops (Barański, *et al*. 2014). Additionally researchers need to ensure they are comparing the same crop varieties, as varietal differences may matter, and using identical analytical methods in their investigations.

A mutual point of agreement among scientists is that **eating fruit and vegetables is good for you, regardless of how they are produced**. Research published in 2014 showed that people who consume large amounts of fruits and vegetables on a daily basis have the lowest risk of dying from any cause (Miller 2018). In this same article, Ms. Miller, a registered nurse and registered dietician, also cited a 2016 study that claimed people who consume lots of fruits and vegetables enjoy better emotional health than those who don't. She recommends that we increase our consumption of all forms of fruit and vegetables regardless of how they are grown. It is important to state that scientists consistently caution that in order to minimize possible contamination from harmful soil- or food-borne pathogens that can cause food poisoning we should thoroughly wash all fresh produce before consuming it. And although a health risk of pesticide residues on produce is very small, a thorough washing of the surface should alleviate concerns (Winter 2018f).

In closing the discussion about nutritional considerations of consuming fruit and vegetables '*buying local'* is a factor that can help assure the freshness of the produce purchased (Watson 2018) which is most likely harvested more recently, and thus has better flavor, consistency and nutritional value than store-purchased produce. An additional benefit of '*buying local'* is that it can help build confidence in our food selections, regardless of how the food is grown (Wilcox 2011). Talking directly with the farmer who produces some of the foods we eat, will most likely build a connection to our food that can give us confidence to know we are providing healthy food choices for our family.

Environmental Considerations

Agriculture, which has been practiced in some form for nearly 12,000 years, has allowed advancement of the human population. Agriculture by its very nature is the manipulation of the natural landscape to enhance the environment for plant and/or animal adaptation and production which in turn, provides needed food and fiber (Stoney Brook University, NY ~ 2013). Advances in agriculture, even primitive ones through the ages, allowed for human exploration and settlement into areas with arable land and access to water. In the past 100 years or so, science has played a major role in the evolution of agriculture allowing advances in plant breeding, development of efficient and safe crop inputs and technologies that have been developed to allow for 'as-needed' irrigation, fertilizer and precision pest management tools.

Regardless of the farming strategy, conventional, GM crops or certified organic, many agricultural practices are needed to *prevent* problems and produce a crop. Some of the common practices we've mentioned include crop rotation, selection of planting dates, mixed plantings, maintenance and improvement of soil health, and the release of beneficial, predatory and/or sterile insects for pest management as well as judicious pesticide applications. It's worth repeating, in all farming strategies most farmers rely on pesticides as a last resort to control pests. There are multiple costs associated with pesticide applications including those for the product itself, the labor, time and equipment and energy necessary for application. Why would any good business person (farmer) apply a pesticide if not necessary?

Sustainability
All farmers who are concerned about the long-term capabilities of their operations embrace **sustainability**. Agricultural sustainability is not easily defined but in this paper we consider the tenets of sustainability to be: an agricultural production scheme that provides **food, fiber or other societal necessary materials** over the long-term, implements **practices that reduce their impact to the environment** and **maintains economic viability** of the business (Fess & Benedito 2018). There does not appear to be agreement regarding a defined set of characteristics to use to define environmental sustainability, however soil fertility management is certainly a consideration in any farming plan. Organic farming fertility practices rely on the use of green and/or animal manures, compost incorporation and crop rotations. However, some conventional farmers also use these techniques in addition to synthetic fertilizers which are prohibited in organic production. In their comprehensive review of the literature on this topic, Fess and Benedito (2018) reported that in general, fields under organic fertility management had higher soil microbial biodiversity than conventional fields which can affect the nitrogen (N) mineralization cycle. Inorganic N in organic fields was generally found in greater proportion as ammonium (NH_4^+) vs. nitrate (NO_3^-) compared to conventional fields, thus organic fields may have a lower potential for N leaching than conventional fields. They point out that the <u>source</u> of manure influences its leaching potential as poultry litter has three times as much NO_3^- than manure from sheep or horses, and thus poultry manure has a higher possibility for pollution than other sources of manure. Timing of manure application is also an important consideration since the nutrients contained in it may not be immediately available for crop use.

Nutrient inputs usually differ in conventional and organic cropping systems since conventional systems may use green or livestock manure as organic farms do, but they also rely on synthetic fertilizers. Synthetic fertilizers can be applied in a form that is available for crop use when the crop needs it, whereas manures usually need to undergo environmental and biological degradation to release available nutrients, therefore nutrients may not be as available for immediate crop use as with synthetic products (Ritchie 2017). Excess nutrients from any type of fertilizer source may be susceptible to leaching or run-off, posing pollution concerns to ground and/or surface water sources. In essence, there is a potential for pollution especially to water sources from either conventional or organic farming practices so timing of nutrient/fertilizer inputs is critical.

Cover crops are commonly used in annual conventional, organic and GM crop production and are known to improve soil health through various mechanisms. Leguminous cover crops have the potential of providing increased soil N, and most cover crops can provide the benefit of reducing the risk of soil erosion. In the past several years research has focused on other favorable outcomes that cover crops provide (Nickel 2018). Cover crop root systems act as an anchor for soil particles thus reducing the risk of soil erosion from wind and water and also increase soil structure by fostering an environment in the root zone for a diverse population of soil microbes that play an essential role in soil particle aggregation, leading to improved soil structure. Improved soil structure can lead to increased water penetration and infiltration through the soil profile, and root channels made by cover crops can provide a mechanism for increased rooting depth, thus a healthier plant for the subsequent cash crop (Nickel 2018). Regardless of the farming system cover crops are for the most part, a win-win for their overall impact on the environment.

Greenhouse gas emissions (GHGE) also present a mixed picture in terms of environmental impacts of the three farming systems. Ritchie (2017) stated that results are very crop-dependent and in a comparison of GHGE from various food types, fruits, cereals, pulses, vegetables and animal products, sources of GHGE tended to cancel each other out. An example of this is that GHGE through synthetic fertilizer production and application is largely balanced by NO_3^- emissions from manure applications (Ritchie 2017).

Energy use (direct and indirect) can be higher in a conventional system than in an organic system when the energy (indirect) required for manufacturing synthetic crop inputs is considered. Direct energy use refers to the use of fossil fuels, oils, electricity, *etc.*, and indirect use involves the manufacturing and distribution of agricultural products (Fess and Benedito 2018). Fess and Benedito caution that many studies do not make the distinction between the two types of energy uses which can be misleading and give rise to conflicting results. Furthermore, Richie (2017) points out energy requirements are crop-dependent and in vegetable production especially, energy use may be higher in organic than in conventional systems, mainly due to the need for alternative weed controls (propane-fueled flame weeding). In addition, no till or minimum till cropping systems common to conventional and GM productions reduce reliance on energy with fewer passes over the field than an organic system that relies on mechanical weed control.

Biodiversity is another metric of environmental health that has been assessed recently. According to EPA, "*Biodiversity is the variety of all forms of life and it is essential to the environments in which species can exist; these include ecosystems of all types and sizes, rare ecosystems, and corridors between habitats." (*https://www.epa.gov/enviroatlas/enviroatlas-benefit-category-biodiversity-conservation*).* Although there still is room for additional studies comparing various agricultural practices' impacts on biodiversity, many researchers find that biodiversity is greater in organic farming systems than in conventional and/or GM cropping systems. Biodiversity is affected by many agricultural practices common to any farming system such as cultivating and tilling, habitat disruption and crop protection inputs. The scale tips in favor of organic systems over conventional systems when measuring biodiversity, but the potential for an impact on biodiversity also exists in organic farming systems (Ritchie 2017) and yield should be factored into this discussion and is mentioned below.

Pesticides have generally been considered to have a negative impact on the environment when their ecotoxicity has been examined over the years so most consider organic farming to be more positive in this area of concern. However, this viewpoint does not reflect the *actual risk* of a negative ecotoxic effect of many of the recently registered 'safer' pesticides. **Many of the the1960s, Silent Spring-era crop protection products have been removed from the market and replaced by modern-day products that may be less harmful than numerous household products found under the typical kitchen sink** (Ruishalme 2016). Any synthetic and many natural-based pesticides on the market today have undergone a series of tests examining their toxicity to mammals, non-target organisms as well as their environmental fate. The rules governing how they may be used consider environmental impacts and worker safety, and label use directions reflect these elements. Adoption of state-of-the-art crop protection products registered as 'safer' products by the EPA has reduced the risk of environmental damage (when used as directed) much more than earlier, first-generation products. Ruishalme (2016) draws a remarkable conclusion that we sometimes overlook: "***The environment does not in fact differentiate between a harmful impact from a 'natural source' (however that may be defined) and a 'non-natural' one**."* And as EPA points out, their continuous reevaluation of registered pesticides, major improvements in science, and increases in the use of safer, less toxic pesticides, has led to an overall trend of reduced risk from pesticides (https://www.epa.gov/safepestcontrol/food-and-pesticides).

Conventional and GM crop farming systems compared to organic systems generally have a reduced environmental impact when we consider the amount of land needed to produce similar yields in the different systems (Ritchie 2017). Steven Novella (2017) stated that organic farming can use as much as 20 - 40% more land than conventional farming, and that the use of GM crops is a positive factor regarding land use, especially as technologies allow for genetic modifications that promote more efficient photosynthesis, water use efficiency or development of increased number of varieties that can fix their own N, *etc*. As we stated earlier, GM crops are banned in organic production. According to Novella, about 40% of the Earth's land is used for farming and this amount represents nearly all of the arable land available. A review article written by Ruishalme (2016) stated that trying to assess the environmental impacts of one system over another is not necessarily a 'one plus one' metric as we must consider many factors such as size of the farming area, and how the impacts of agricultural practices are measured. Ritchie (2017) also pointed out that the type of crop and location must be factored into environmental impact assessments of different farming systems. There is general agreement that to produce the same quantity of food, organic systems require a larger land area than conventional crops (Ritchie 2017). Ruishalme further stated that in part, because of the judicious use of pesticides, conventional farming uses land more optimally producing more yield on less land than organic farming.

Genetically modified crops (prohibited in organic farming) may provide additional benefits to the environment to those discussed above, as many GM crops help farmers reduce their reliance on pesticides (Brookes and Barfoot 2014), may allow for more adoption of a no-till or low-till system which reduces fuel and energy usage, GHGE and may help reduce run-off and soil erosion (Ruishalme 2016). The scientific literature provides mixed conclusions about possible effects of genetically modified crops on soil microbial ecosystems which can influence soil health and nutrient availability (Brolsma *et al*. 2015, Guan *et al.* 2016, Wolmarans & Swart 2016). Most researchers found that many factors affect soil microbiota including: location, soil type, organic matter content, depth, moisture, pH and clay content; all of these soil parameters may have more influence on the dynamics of soil microbial activity than the effect of genetically engineered plant traits. Wolmarans & Swart (2016) state that the utilization of cultural and management practices that increase availability of soil nutrients should be encouraged to facilitate optimal GM crop production.

When trying to balance the relative importance of the environmental impacts of farming systems, we must consider that some factors may be more important in the overall global picture than others, *i.e*., trade-offs in environmental impacts of various farming practices must be put into context. Is energy consumption which is generally lower in organic than in conventional cropping systems more important than total land needed for food production? What about GHGE and pollution potentials from the different sources of nutrients in the various farming systems? When considering environmental impacts how do we determine which choices to make regarding the best farming system to use? Perhaps the impact on land use is the most important factor to consider since we cannot develop more land mass. Is it possible that a hybrid approach, one that utilizes the positive attributes from each farming system using scientific and technological advances judiciously, is the solution to the way we should move forward to a sustainable agricultural future?

Conclusions

Many of the articles reviewed for this paper did not conclusively point to one farming system as clearly advantageous over another for all circumstances. In most articles the various authors pointed to caveats, such as crop type, location, methodologies employed, *etc*. that needed to be considered when comparing results from different studies. The debate over the benefits of one farming system compared to another (organic vs. conventional for example) is needlessly polarized in our opinion. The misconceptions that organic farming has less environmental impacts than conventional systems is not true over all metrics, especially in one that may be the most important of all, land use efficiency. After all, we cannot develop more land mass so using the arable land we have most efficiently may just be the most important environmental factor to consider.

The perception that organic food is healthier and more nutritious than food produced in conventional or GM cropping systems does not hold across all food types or under all situations. There is evidence that some organic fruits and vegetables may have higher antioxidant content than conventionally grown produce, but then some conventional foods have more vitamin C and vitamin E than organic produce. The point really is that regardless of how the produce is grown, **it is more important to our health to eat an adequate amount of fruit and vegetables daily, than to omit them from our diet.** Higher price points for organic food compared to conventionally grown food can be a deciding factor in this debate. We consider it an unnecessary consideration since we can rely on the extensive regulatory system to ensure that **our food supply is safe regardless of the production system used.**

Concern about the presence of a pesticide residue ignores the fact that its presence alone does **not** equal a risk. In the previous discussion of the tolerance setting process we highlighted the rigorous standards of risk assessments that must be met to establish a tolerance limit of an allowable pesticide residue. *Remember how many strawberries a teen could eat in a day and still not have a risk to their health?* (**1,743!**) The agricultural regulatory system across the U.S. provides a safety net of monitoring and enforcement services carried out by various state and federal governmental agencies. And these **stringent standards exist for conventionally produced as well as organically produced food imported into the U.S.** The USDA through its Agricultural Marketing Service (AMS) Division ensures that all food products imported into the U.S., organic and conventionally produced, meet the same safety standards set by the EPA and other agencies for food produced in the U.S. (https://www.ams.usda.gov/sites/default/files/media/Importing%20Organic%20Products%20Factsheet.pdf).

The American public has the right to choose what type of food to eat from the three production strategies, organic, conventional or GM-based food crops. This paper was developed to help consumers understand the specifics behind food production so that their choice is based on facts, not fear or misconceptions stemming from partial information or inconclusive evidence. There are some differences in farming practices among conventional, GM and organic farming methods but there are many practices in common. Anytime we do something to the environment there is a potential for impact of that action, no matter whether in a conventional or organic farming system. "*The environment does not in fact differentiate between a harmful impact from a 'natural source' (however that may be defined) and a 'non-natural' one."* There are trade-offs and as consumers we need to have the facts so we know which trade-offs may be more consequential in the big picture than others.

Farmers who are in this industry for the long-term think about the **sustainability** of their business and make choices to ensure its continuing existence. All farmers and their families eat the same food, drink the same water and breathe the same air as the general public and farmers especially have more exposure to crop protection products than the general public -- *why would they not take precautions to protect themselves, their families and the environment to preserve the way they make a living?* Food producers make choices about the practices they follow on their farms - sometimes the same producer chooses different farming systems for business reasons. Regardless of whether they follow conventional or organic farming practices or grow GM crops, the food produced by these various approaches is safe because we have a very rigorous regulatory system that ensures the safety of our food web, and we can't imagine any farmer would knowingly choose an unsafe or unnecessary action in their food production business. **Our food is safe**. *Now let's look at those two baskets of strawberries again* . . . . . .

Strawberry Case Study

Land Preparation, Pest Management and Soil Fertility

Conventional and Organic: Proper land preparation is an important factor in strawberry production regardless of the farming approach taken. Disking, chiseling, soil sampling for nutrient status, and pre-plant irrigation and fertilizer/compost applications are routine land preparation practices; in conventional plantings, a soil fumigating agent is used prior to planting (discussed below). Beds/rows are shaped and black plastic mulch along with drip irrigation tape is placed in the field in preparation for planting.

Pest management is very intensive in a strawberry crop, regardless of how it is grown, and one decision open to both organic and conventional cropping systems is choosing resistant varieties which should result in reduced disease pressure from some fungal organisms. Perhaps the biggest disparity in the manner in which strawberries are grown under conventional compared to organic practices is the use of a very expensive pre-plant soil fumigant in conventional systems. Fumigation controls soil-borne pests such as weed seeds, arthropods, nematodes and diseases and allows for continual planting of a high value crop like strawberries (usually on very expensive land) for several years without having to rotate to a different crop. Because of the intense pressure from weeds, insects and diseases, organic strawberry growers usually rotate their crop annually with another to reduce losses from various pests. Finding a field that can be used for organic strawberry production also presents a challenge for organic growers as any field used for organic production must be free from conventional chemical use for a period of three years. All growers can help avoid some pest pressures through irrigation timing that can also reduce dust (which promotes mites) and by providing adequate plant nutrition. Both farming strategies can make use of sulfur and copper (for organic farmers, those approved for organic production) for insect or disease control and conventional producers have access to registered synthetic and natural crop protection products. Both systems rely on the use of biological controls, *i.e.,* release of predatory insects for worm or mite control and both can turn to Bt (*Bacillus thuringiensis*) products for worm control (for organic producers the product must be approved for organic production). Hand culling of damaged/diseased plants is also possible, but this practice is very intensive and expensive and if used, it will usually be in an organic crop.

Both conventional and organic strawberry growers plant into heavy black plastic mulch which is slotted to allow planting. This plastic row cover helps with weed control in the rows as well as preserving precious soil moisture. Weed control presents many challenges to organic producers as there are few approved, efficacious crop protection products. Organic producers rely on mechanical cultivation, hand-hoeing, and some may use a torching system, whereas conventional growers may use cultivation as well, but also have access to registered herbicides.

Organic strawberry producers generally use compost or approved liquid and foliar fertilizers, frequently applied through the drip irrigation system (known as 'fertigation'). Some of the approved foliar sprays are made of seaweed and calcium. As we saw with pest management, conventional growers can rely on a large array of fertilizers to ensure their crops are getting the nutrition they need to thrive.

Harvest

Conventional and Organic: Strawberry harvest (in CA) occurs from approximately April through October and takes place about two times weekly. Peak harvest is from June through August, depending on the location and varieties grown. Harvest is a labor-intensive enterprise and harvest crews may double from 30 to 60 harvesters during the peak season, depending on the size of the operation. In addition to the labor, trays to hold the berries, trucks, pallets and access to coolers are also needed.

Yield

Conventional and Organic: Yields vary by variety and location, but average yields for organic production range from 3,500 – 5,000 trays/acre. Yields for conventional production vary more widely than for organic production and range from 4,000 -10,000 (or more) trays per acre, depending on variety. In general, trays weigh eight pounds but variability in fruit exists and trays may weigh up to 10 pounds. Fruit must be transported quickly to coolers to preserve freshness.

References

2014 Sample Costs to Produce Organic Strawberries, Central Coast Region, Univ. of CA Cooperative Extension.

2016 Sample Costs to Produce and Harvest Strawberries, Central Coast Region, Univ. of CA Cooperative Extension.

K. Klonsky, 2012, Comparison of Production Costs and Resource Use for Organic and Conventional Production Systems, Univ. of CA Cooperative Extension.

Comparison of Agricultural Practice & Cost
Organic vs. Conventional Strawberries on a Per Acre Basis

Operation	Organic	Conventional
Soil preparation, irrigation, misc. costs	$841.00	$2,200.00
Drip Tape	$365.00	$1,638.00
Plants and runner	$4,607.00	$4,607.00
removal	$1,642.00	$1,642.00
Fertilizer	$1,869.00	$698.00
Pest Control (Insecticide, Fungicide)	$966.00	$1,766.00
Lygus Vac	$1,101.00	$0.00
Weed Control, Hand Hoe	$2,474.00	$0.00
Fumigate	$0.00	$3,600.00
Total Cultural Cost	**$13,865.00**	**$16,151.00**
Harvest	$28,673.00	$44,809.00
Total Operating Cost	**$42,538.00**	**$60,960.00**
Return	$63,750.00	$70,000.00
	4,250 trays @ $15.00/tray Break Even 4,250 trays @ $10.00/tray	7,000 trays @ $10.00/tray Break Even 7,000 trays @ $ 8.71/tray

Alfalfa Case Study (In California's Central Valley**)**

Alfalfa ranks fourth among all crops grown in the United States, especially in the West, behind corn, soybeans and wheat, but the amount of acreage has declined by approximately 40% over the last half century. Alfalfa is a perennial crop with stand productivity of approximately three – four years and is grown primarily as a livestock feed crop for domestic consumption and export. Alfalfa may be planted in the spring or fall - this example assumes a fall planting in California's San Joaquin Valley.

Certified organic alfalfa producers have many regulatory requirements with which they must abide starting with ensuring that production takes place on certified organic land. Additionally, farmers may use only allowed substances including seed, and they must take precautions against pesticide drift and other sources of prohibited contaminants. Organic producers must also ensure they use hay handling equipment and storage areas that are designated for organic production, or that the equipment and storage area is properly cleaned between conventional/GE and organic crop handling. Everything requires documentation and third-party certification.

Stand Establishment

Land Preparation

<u>Certified, GE and Certified Organic</u>: Residue from previous crop is disked in followed by chiseling to a depth of 18 – 24 inches to improve root penetration and water infiltration. Field is rolled and then laser-leveled. Seed bed preparation usually requires disking and harrowing with a ring roller as well as building borders, typically at 60-ft intervals; however, furrow irrigation is also common. Organic producers may spread chicken manure over the ground and incorporate it with the second disking before laser leveling to remove surface unevenness. It is very important to do everything possible to get good stand establishment because the young, organic crop will compete with weeds and insects and pest management tools for certified organic production are very limited, especially for weed control.

Fertilization

<u>Conventional and GE</u>: Pre-plant soil testing is recommended to check for phosphorus (P) and potassium (K) especially, depending on location and field conditions. Nitrogen (N) and P and possibly sulfur (S) are applied at appropriate levels in early fall prior to final disking.
<u>Certified Organic</u>: Soil samples are recommended to help determine crop needs so that the grower can incorporate the appropriate amount of manure (for adequate N) or they may use other approved substances. Organic alfalfa may need supplemental P, K and S, depending on soil fertility. If needed, composted chicken manure may be applied prior to planting which can supply sufficient amounts of P, K and S for several years of production. No additional N is applied because alfalfa fixes its own N through nitrogen fixation process associated with Rhizobium bacterial inoculation. Tissue sampling in subsequent years of production will help determine if additional nutrient amendments will be needed.

Planting

<u>Conventional and GE</u>: RoundUp Ready seed is typically used and planted with a seeder ¼ - ½ inch deep due to small seed size, typical seeding rates range from 15 - 25 lbs. per acre. Seed is generally planted in late September or October (depending on location). After sprouting, seedlings are relatively weak and must be protected from weeds. Once the 'crown' is developed, plants are more vigorous which allows the plants to re-grow many times, thus allowing for multiple cuts each year of production. Mature plants have a vigorous tap root which may grow to a depth of eight to ten feet deep or more.
<u>Certified Organic</u>: Producers are encouraged to purchase certified organic seed for appropriate pest resistance in the grower's respective area. Selecting seed with the appropriate fall dormancy for the grower's area is also recommended. If certified seed is not available, conventionally produced seed may be used, but the grower must ensure (and have documentation) that it is not from a genetically engineered source. The seed should be inoculated with the appropriate organically approved nitrogen-fixing bacteria (Rhizobium) if alfalfa has not been grown in the area in the past ten years. Ideal planting time in the San Joaquin Valley is in early fall. Higher seeding rates than for conventional production may help ensure stand density and help young alfalfa seedlings compete against weeds. Stand life may be up to four years.

Irrigation

Conventional, GE and Certified Organic: Immediately after planting sprinkler irrigation is frequently used during stand establishment for organic and conventional or GE production. Once the stand is established growers may use border or furrow irrigation during production seasons, and in some areas, growers use sprinkler or drip irrigation.

Pest Management

Conventional and GE: During stand establishment, it is important to monitor the young crop carefully for both nutrient and possible pest problems. The crop is carefully monitored to help prevent pest infestation using practices outlined under Integrated Pest Management (IPM) guidelines. IPM tactics include use of biological control achieved using natural enemies, modified cutting schedules, use of pest-resistant varieties and pesticide applications as needed. During stand establishment it is especially critical to correctly identify and effectively control weeds as weeds may have the biggest impact on crop yield and quality of all the pests commonly found in alfalfa fields. Pre-emergent herbicides may be required.
Certified organic: Producers will follow above practices (except pre-emergent herbicides) but have only a limited number of allowed organic products to combat pests and have no efficacious herbicides. Pre-irrigation followed by cultivation can help reduce weed density in seedling alfalfa but with no herbicides the grower's best defense is to do what he can to foster a strong stand to help suppress weed competition. If weeds overtake an organic field, a grower may resort to periodic light grazing with sheep on dry fields or cut early to allow sunlight to reach young plants so they can compete better with weeds.

Production Years

Irrigation

Conventional, GE and Certified Organic: During production years the stand is usually irrigated using border or furrow irrigation, however as noted, there are areas where sprinkler and drip irrigation systems are used. Actual amount of water applied will be dependent on environmental conditions including evapotranspiration requirements; in calculating the amount of irrigation water needed, a 75% application efficiency is generally adequate.

Fertilization

Conventional, GE and Certified Organic: After stand establishment it is recommended that annual plant tissue samples be taken either in spring or fall to determine nutrient requirements. Focus of these tissue samples is usually on P and K so that appropriate adjustments can be made including micronutrients using appropriate materials.

Pest Management

Conventional and GE: Pesticides may be applied through irrigation water (chemigation) or may be applied by tractor/boom/sprayer or other machinery. Some growers use aerial applicators for delivery of foliar applications. It is important to select pesticides that are relatively safe to natural enemy species and to honeybees while controlling the target pests.

In older stands, weeds may impact yield and quality more than other pests. After establishment, weeds are controlled with broad spectrum herbicides, frequently RoundUp, especially with a RoundUp Ready crop. Other products, particularly those that are more selective than RoundUp are also recommended for herbicide-resistance management purposes. Older stands may be over-seeded with other forages (grasses or legumes) to help extend crop productivity and prevent further weed infestations. For all pests, rotation of pesticides with different modes of action is highly recommended to prevent pests from developing resistance to individual products or a shift to different weed or other pest species.

Certified Organic: As with conventional and GE alfalfa, certified organic producers must monitor their fields carefully and take every precaution possible to prevent pest invasions. They follow IPM practices and if they must resort to a pesticide, it must be one allowed for organic production. If insect pressure is high, growers may only attain 60 – 70% pest control with approved products. As noted earlier, there are no effective approved herbicides for organic production, so careful stand management is extremely important or yield and quality may suffer.

Harvest
Conventional, GE and Certified Organic: Crop is harvested using a swather, dried in windrows and when hay reaches the appropriate moisture content, it is baled and compressed it into ~125-lb. bales or into rolls weighing as much as 1600 lbs. (As noted earlier, certified organic producers must ensure that all harvest equipment is either designated for organic handling or properly cleaned prior to using it.) Bales may range in weight from 50 pounds to nearly one ton and are usually rectangular, but they may also be shaped into round bales as noted above. Smaller bales may be lifted by hand, but commercial bales are moved by bale wagons from the field to a different location where they are stacked. In the San Joaquin Valley conventional and GE alfalfa producers may get up to ten cuts each season. Organic producers typically expect only up to seven cuts per season due to losses from pest pressures, especially weeds. Alfalfa is frequently sold as hay but may be used as silage where it undergoes a fermentation process during storage or it may be produced as pellets or cubes which facilitates transportation of the crop for export.

Yield
Conventional and GE: In the San Joaquin Valley yield is typically 10 tons per acre at 90% dry matter; annual yields may range from 8 – 11 tons per acre. First and second cuttings are generally the largest where mid-summer cuttings may be the lowest among the total annual harvests.
Certified Organic: Yields range from five – seven tons per acre with three to seven cuttings per year, depending on location and alfalfa variety. Seven tons per acre over seven cuttings each year is common in the California Central Valley's organic alfalfa production area. Yield is lower than conventional production yield due to pest pressures and possible nutrient deficiencies.

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Alfalfa Stand Establishment
Comparison of Agricultural Practice & Cost
Organic vs. Conventional

Operation	Organic	Conventional
Fertilizer	$67.00	$74.00
Custom Field Operation (chisel, disc, ridge)	$307.00	$348.00
Seed/Plant/Irrigate	$117.00	$221.00
Irrigation	$87.00	$87.00
TOTAL OPERATING COST	**$578.00**	**$730.00**

Conventional Cost > Organic Cost
Roundup Ready Seed + Herbicide Application after new seedlings established

Comparison of Agricultural Practice & Cost
Organic vs. Conventional Alfalfa

Operation	Organic	Conventional
Fertilizer	$69.00	$86.00
Insecticides	$101.00	$41.00
Herbicides	$0.00	$94.00
Irrigation (7xOrganic, 10xConventional)	$507.00	$725.00
Misc.	$0.00	$20.00
Harvest (7xOrganic, 10xConventional)	$350.00	$463.00
TOTAL PRODUCTION COSTS	**$1,027.00**	**$1,429.00**

Yield (Ton / Acre)	7 Ton	10 Ton
Cross Return	$1,820.00*	$2,500.00**
Net (Per Acre)	$793.00	$1,071.00
Net at Conventional Price ($250)	$723.00	
Break Even Harvest Ton/Acre	**4 Tons***	**5.7 Tons****
	*At $260.00/Ton	**At $250.00/Ton

Corn Case Study

Corn, an annual crop, is primarily grown in the Midwestern United States which claim about 90% of the annual production in the U.S. The midwestern portion of the U.S. has approximately 70 million acres of corn and is the largest contiguous corn growing area in the world. Needless to say corn is an extremely important part of the economy to that region and to the country. Corn is primarily grown as a feed crop for livestock but is also used as a biofuel and in food as well as sweeteners (high fructose corn syrup). It can be grown in rotation with soybeans, wheat or sorghum, but it also may be grown several years in a row in the same field (monoculture) in conventional and GE cropping systems. Approximately 93% of the corn grown in the U.S. is genetically engineered with either a single trait incorporated, such as herbicide tolerance or insect resistance. More and more, 'stacked' traits, herbicide tolerance and insect resistance are incorporated together into corn.

The U.S. is the largest producer and exporter of corn in the world; however, to meet demand for organic corn, the U.S. imports nearly one-half its supply of organic corn as only 1% of the corn grown in the U.S., mostly in the Midwest, is organic. Most of the U.S.-produced organic corn is for livestock feed, especially for organic dairy cattle and poultry feed. The majority of organic corn production in the U.S. is in Wisconsin, Iowa, Minnesota, Michigan and New York but organic corn is grown in 36 states and is the second largest organic grain/seed crop behind organic wheat grown in the U.S.

Land Preparation

<u>Certified, GE and Certified Organic</u>: Conservation tillage is used on 65% of corn with 27% of that no-till. No till varies by region with 34% in Northern Great Plains, 49% in the Prairie States and 53% in the South. 'Conservation Tillage' refers to a range of reduced tillage systems with no-till or zero-till being the extreme. Typical conventional land preparation involves chiseling in the fall or winter to a depth of 18 inches which helps improve root penetration and water infiltration. In spring, fields are disked two times. Beds are listed (30-inch beds) and shaped, usually in one pass in the spring, but this may happen in the fall prior to planting.

Fertilization-

<u>Conventional and GE</u>: A starter fertilizer with appropriate nitrogen (N), phosphorous (P) and potassium (K) is applied beneath the seed during planting. A little later in the season, usually May, a side-dressing of N may be applied. During the season, an additional three applications of N will be applied with irrigations in June and July. Much of the corn in the Northern Great Plains depends upon rainfall for crop development. Under these conditions most of the fertilizer needs are met at planting or side-dress prior to row closure.

<u>Certified Organic</u>: Corn is a moderate to heavy user of most nutrients, especially N. Using legumes, especially alfalfa that is in the ground for two years in a crop rotation plan is required to provide some residual, biologically fixed N for the growing corn crop's demands. Animal manure should be incorporated into the soil to prevent losing some of its N to the atmosphere. Nutrients from manures are released in a slower manner than those from a synthetic fertilizer source. Supplementary N fertilizers may include approved sources of cottonseed meal, feather meal, blood meal or fish meal. Liming minerals may be used to supply calcium and magnesium if needed. Supplementary forms of P may be obtained by using approved sources of rock phosphate. Potassium may be supplied through sulfate of potash-magnesium or mined potassium sulfate, or sources of fly ash in blended organic fertilizers.

Planting

<u>Conventional and GE</u>: RoundUp Ready seed or perhaps 'stacked'-incorporated traits seed is planted in March – May depending on geographical location, or when the soil is ready (>50ºF) at approximately 33,000 seed per acre on 30-inch spacing, but spacing may be 38-inches. Seed is generally planted at two-inch depth. Earlier plantings when the soil is cool and damp may promote seedling disease.

<u>Certified Organic</u>: Producers are encouraged to purchase certified organic seed for appropriate pest resistance in the grower's respective area.

Irrigation
Conventional, GE and Certified Organic: A pre-plant irrigation is applied in March or April and will be followed by regular irrigations as needed, depending on environmental demands. Fertilizer may be applied with irrigation water. Areas of the East, Upper Midwest, South and parts of the Southwest are dependent upon rainfall for crop growth. Most of the irrigated corn is in the prairie states of KS, MO, SD, ND, NE, the mountain states of CO, UT, CA, AZ and southwestern/southern states of NM, TX and OK.

Pest Management
Conventional and GE: Several insects and spider mites, especially in dry conditions, are common pests in corn. Plants with resistance to lepidopteran (worm) pests can be expected to need less insecticide sprays than conventional crops. However, growers of Bt (*Bacillus thuringiensis)* corn are encouraged to plant approximately 5% - 30% of non-GE corn to help manage resistance building up in the corn worm pests. When pesticide applications are necessary, they are generally applied with a tractor and spray boom over the top of plants. Use of pesticides with different modes of action is recommended throughout the season for resistance management purposes. Early weed control may be achieved with mechanical cultivation, however, during the growing season, weeds are generally controlled with herbicides usually RoundUp if RoundUp Ready seed is used or other broad spectrum products, post emergence. Growers are encouraged to contact their local experts for advice for appropriate control measures. Diseases can be controlled with registered fungicides.
Certified organic: Insect pests can be a major problem to organic corn producers since they are prohibited from using Bt (worm-resistant) varieties achieved through genetic engineering. Crop rotation to non-susceptible hosts is one mechanism to try to avoid some pests. Field sanitation is also required to remove possible refuge for harboring corn pests. Field sanitation will be mostly effective at reducing potential for early infestation but since insects may migrate into the organic crop from neighboring fields, later season infestations will not be avoided by field sanitation between harvests. Some natural parasites such as *Trichogramma* wasps may help control some corn pests. Organic growers are also encouraged to foster an environment that is favorable to predator insects such as damsel bugs, mantids and assassin bugs to help control corn pests. Use of biological controls requires careful monitoring and release of the biological control at the right time to maximize control. There are some approved Bt products organic growers may use for worm pests as well. Use of resistant varieties is highly recommended. No-till is even more challenging in organic systems because organic-compliant seed treatments to protect seedlings from insects and diseases are limited and organic-compliant herbicides are expensive to use on a broad scale. They are also less effective than conventional herbicides.

Weeds are a problem due to lack of efficacious herbicides and are generally managed by cultivation. Use of mulches or cover crops may help suppress weed growth. The majority of organic corn producers in the Midwest rely on tillage operations to manage weeds. They use rotary hoes or harrows for over-the-row weed management and row cultivators for between-row management. Successful weed management is especially critical for organic farmers. Cover crops serve a role in weed control by outcompeting weeds and as an added benefit, by providing nutrients for the crop as they can be plowed under prior to planting or terminated without tillage in reduced tillage or no-till operations.

Harvest
Conventional, GE and Certified Organic: Once mature, the corn grain is allowed to dry down in the field to approximately15% moisture before harvest. A combine is used to harvest the crop separating the ear and grain from the stalk and spreading the remaining plant material over the field where it will begin to decompose and is generally tilled in. Grain is typically stored in environmentally controlled elevators before sale. Organic producers must ensure that harvest and storage equipment meet organic standards.

Yield
Conventional and GE: Yields range from five to six tons per acre at approximately 15% moisture.
Certified Organic: Average yield can be expected to be approximately 80 – 85% of conventional/GE corn yield, but may vary significantly due to environmental conditions. According to USDA data for 2014, organic corn for grain yield was 35% less than conventional and corn silage yielded 20% less than conventional.

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Comparison of Agricultural Practice & Cost
Organic vs. Conventional Corn

OPERATION	ORGANIC COST/ACRE	CONVENTIONAL COST/ACRE
Soil preparation/plant/cultivate/harvest	$110.00	$83.00
Fuel	$38.00	$17.00
Labor	$65.00	$21.00
Seed Fertilizer	$60.00	$114.00
Fertlizer	$58.00	$110.00
Chemicals (Insecticides/Herbicides)	$10.00	$47.00
Total Non Land Cost/Acre	**$341.00**	**$392.00**
Revenue Organic (116 bu @ $8.87/bu)**	**$1,029.00 / Acre	* $441.00 / Acre
Revenue Conv. (180 bu @ $3.80/bu)	- -	$684.00 / Acre

**Organic prices over past 8 years average $5-$10 per/bu ($8.80-$13.80/bu), higher than conventional.

*Revenue Organic at current conventional price of $3.80/bu

Apple Case Study

Apples are grown commercially in 36 states in the United States with Washington being the top apple producing state. Orchards can be expected to be productive for 20 – 30 years, depending on cultivars, environment, *etc*. To ensure harvest is extended over the season several cultivars should be planted which will also help facilitate pollination. Organic and conventional practices are similar except for nutrient and pest management inputs as well as the need for designated organic harvest/storage conditions. Differences are mentioned below. Apple production is one of the most challenging crops to manage organically due to heavy pest pressures and limited products to control apple pests.

Orchard Establishment
The ideal site is one with rolling hills or land with a four – eight percent slope to promote air drainage especially during spring frosts. The best soils for orchard establishment are those that are well drained to promote healthy root growth. Soil should be plowed and leveled so that the orchard floor is even to reduce the possibility of standing water. A level orchard floor will also aid in cultural practices and harvest. Soil samples should be taken prior to planting to determine soil fertility as well as to test for nematode presence (root pathogens). Results from these soil tests will help guide any soil amendments that may be needed such as lime and/or fertilizer prior to planting. If nematodes are present it is important to take control measures as nematode damage can stunt or kill trees before they even have a chance to produce fruit leading to an uneven stand of mature trees. Trees should be planted in rows that are as evenly spaced as possible which will aid in cultural practices and harvest. Maximum size of the trees determines distance between rows and between trees. If possible early blooming varieties should be planted in a location in the orchard that is the least susceptible to frost.

Rootstock and Cultivar Selection and Pollination
Rootstock selection is important as it will determine tree size. Most orchards are now planted on dwarfing or semi-dwarfing stock which facilitates cultural practices and harvest as well as decreases time to first harvest (may be able to harvest in second or third season vs. fifth season for standard trees). Depending on the stock selected trees may require support for their branches. Cultivar selection will be based on location and intent for the fruit, *e.g.,* fresh market vs. processing. One apple has been bioengineered, known as Arctic, which has a reduced browning trait; at least three different varieties of Arctic apples are available on the market. Selection of varieties resistant to apple scab which can be a serious problem is especially recommended for organic growers. Growers are encouraged to select multiple cultivars which will not only encourage pollination but help extend the harvest season. Bees are considered essential to ensure pollination and the usual recommendation is for one hive per acre.

Blossom and Fruit Thinning, Pruning and Training
Blossom and fruit thinning is usually accomplished with growth regulators for conventional growers during and just after bloom. Omitting blossom thinning may lead to alternate-year production. Once fruit has set, fruit thinning is necessary to help ensure maximum marketable fruit size and quality. In some locations it is natural for the trees to experience ‘June Drop’ three to four weeks after bloom. If hand thinning, as is commonly practiced in organic orchards, doing so after ‘June Drop’ makes the task easier and helps ensure highest fruit quality by spacing fruit on the limb and removing damaged or diseased fruit. Organic growers may also rely on a lime-sulfur product for thinning.

Many different pruning and training (determines the tree shape) systems exist and which systems are used will be guided in part by the chosen rootstocks and cultivars. Regardless of the training system, pruning will be necessary, usually in late winter before trees leaf out. Some growers may also prune in the summer to allow sunlight to penetrate the canopy to improve fruit color.

Fertilizer and Pest Management
Soil samples collected prior to orchard establishment will guide the early years of the orchard’s production cycle. As trees grow, their nutrient requirements vary. Apple trees generally need Nitrogen (N), phosphorus (P) and potassium (K) but they also need adequate levels of calcium (Ca), boron (B), copper

(Cu) and zinc (Zn) to maintain healthy trees and good fruit production. Soil tests and leaf analyses are recommended approximately every three years (depending on environmental conditions and tree growth). Organic producers rely on cover crops to provide N; cover crops are planted during the establishment year.

Apple pests including weeds, insects, diseases and rodents will vary according to location and cultivar. As noted above, some cultivars are resistant to apple scab and disease pressure from fungi and bacteria are likely to be less in arid western regions of the country than in the humid East and Mid-West. Codling moth is probably the most common apple insect pest, but it is widely studied and growers use a 'degree day' modeling system to help guide their pest management decisions for this pest. Trapping and monitoring is critical to any codling moth management program. Additionally, growers may use pheromone emitters for mating confusion/disruption, parasitic wasps and sterile males to disrupt growth cycle, but these techniques usually just reduce, not eliminate fruit damage. Many products are available to assist with codling moth control for conventional growers. However, organic producers have a limited number of products that can be used outside of the biologicals. Both copper and narrow-range mineral oils have organic approval and do provide insect and disease control. Conventional growers also have a fairly large arsenal of crop protection chemicals to choose from. Organic growers, however, are severely limited in the products they may use for other insects such as aphids, spider mites or other arthropods that can be a serious pest on apples. Growers need to consult local authorities to determine best control strategies.

Fire blight, a bacterial disease, is perhaps the most dangerous disease in apples as it is very difficult to control. Infections often occur on blossoms after petal-fall. If fire blight is noticed in the orchard it will become a source of infection and infected areas need to be removed from the orchard and burned. Orchard floor sanitation is essential to help reduce the spread of fire blight. There are various products available to help with control but control is variable and a challenge for both conventional and organic producers. Cutting out diseased wood and treatment with Bordeaux or approved fixed-copper materials are the only acceptable control method for organic growers. Conventional growers have the advantage of also being able to use streptomycin sulfate for fire blight control.

Weeds are a problem for any grower, especially an organic grower. Blooming weeds are a problem because they are a source of competition for pollinating insects (as well as water and nutrients), and all weeds present potential problems for harboring other pests and causing safety hazards for workers and/or machinery. A variety of herbicides are available for conventional growers including residual and contact products. No efficacious herbicides exist for organic apple production so growers resort to mechanical means (tractor and flail mower) followed by disking.

Harvest and Storage

Harvest can begin as early as July and extend through October or November, depending on variety and location. Apples are hand-picked by crews on ladders and placed into bags and then into field bins that vary in size from 20 – 25 bushels each. Workers need to be very careful not to damage fruit, especially fruit intended for the fresh market; damaged fruit will not command a premium. Tractors move the filled bins to storage areas away from the field. If the production is a certified organic business, harvest equipment and storage areas must be designated for organic or properly cleaned to meet organic standards. Orchard floor sanitation after harvest is very important, especially in organic orchards, to help prevent an overwintering refuge for pests.

Yield

Yields vary according to cultivar, location and local pest pressures, and regardless of production method, yield will vary from year to year in the same orchard. Average yield for conventional orchards ranges from 20 – 25 tons per acre. Average yield for organic orchards ranges from 10 - 20 tons per acre.

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Comparison of Agricultural Practice & Cost
Organic vs. Conventional Apples

OPERATION	ORGANIC COST/ACRE	CONVENTIONAL COST/ACRE
Orchard Activities		
Prune/Train/Thin	$1,450.00	$1,260.00
Pesticide	$1,540.00	$1,150.00
Fertilizer	$419.00	$251.00
Bee hives (per hive)	$110.00	$110.00
General Farm Labor	$430.00	$430.00
Irrigation	$335.00	$335.00
Harvest Activities		
Picking, Hauling	$2,550.00	$2,242.00
Warehouse Pack Charges	$11,529.00	$12,490.00
Maintenance & Repair		
Maintenance & Repair	$202.00	$202.00
Fuel & Lube	$210.00	$180.00
Other Variables		
Crop Insurance	$190.00	$190.00
Overhead 5% of Variable Costs	$949.00	$950.00
Interest 5% of Variable Costs	$747.00	$740.00
Total Variable Costs	**$20,661.00**	**$20,530.00**
Total Fixed Cost*	$4,767.00	$4,184.00
Total Cost	**$25,428.00**	**$24,714.00**
Net Production Revenue	**$36,240.00**	**$27,560.00**
Net Return	**$10,812.00**	**$2,846.00**

Organic = 48 bins/A @$775/bin
Break even price = $530/bin

Conventional = 52 bins/A @ $530/bin

*Fixed Costs=Depreciation, Interest, Other

Dairy Case Study

In 2015 and 2016 California was the number one dairy producing state followed by Wisconsin, New York Idaho, and Texas making up the remaining top five dairy producers in the U.S. during this time period. Dairy products are large contributors to these states' economies (https://www.statista.com/statistics/194968/top-10-us-states-by-milk-production/). Demand for organic milk has increased significantly over the past decade and estimates are that at least 5% of all milk products sold in 2016 were organic, and as with other organic foods, the price for organic milk can be as much as two times that for conventional milk. In 2016 California produced nearly 800M pounds of milk, representing 20% of the organic milk produced in the U.S. Texas, Wisconsin, Oregon and New York were also major organic milk producers in that same time period (Ag Marketing Resource Center 2019).

One of the major characteristics of organic compared to conventional dairies is the size of the operation. Organic dairies tend to have smaller herd sizes than nonorganic dairies, and the USDA reported that in 2009 87% of organic dairies in the U.S. milked less than 100 cows (McBride & Greene 2009). Large organic dairies are those with 200 or more cows and tend to be located in the West (California and Oregon) rather than in the Upper Midwest or Northeast where more of the smaller organic dairies are located (McBride and Greene 2009). Of course some organic dairies have 1000 – 2000 cows, but those dairies are fewer in numbers than smaller organic operations and tend to be located in western states. Conventional dairies usually have more than 150 cows, and therefore may rely on and economically benefit from technology more than organic dairies. Organic dairies tend to be dependent on (sometimes unpaid) labor contributed by the dairy owner/producer (McBride & Greene 2007 & 2009).

Many organic dairies operating today started out as conventional dairies, but transitioned to organic for economic purposes (McBride & Greene 2007). Generally organic milk prices are at least two times higher than and tend to be more stable than conventional milk prices which fluctuate significantly month to month and year to year (McBride & Greene 2007, Tranel 2017). Larger operations benefit from economies of scale regardless of production system, however, smaller organic dairies (<190 cows) can be competitive with nonorganic dairies that have up to 500 cows (Nehring, *et al*. 2012). Tranel (2017) reported that there is as much variability from dairy to dairy as there is between the two dairy systems which can confound comparisons between the two dairy systems.

Organic dairy herds tend to be crossbred cows because of their perceived greater survival and fertility rates (https://extension2.missouri.edu/g3052) while conventional dairy herds are typically purebred Holstein-Friesian (aka Holstein) cows because of their high capacity for milk production (Sorge *et al*. 2016). The National Organic Program (NOP) prohibits tail docking for organic dairy cows (https://www.ams.usda.gov/sites/default/files/media/Dairy%20-%20Guidelines.pdf) whereas conventional dairy cows' tails are usually docked.

Another difference between organic dairy and conventional dairy production practices is their respective feeding systems (McBride & Greene 2007). Starting in 2010, the NOP required that organic dairy cows receive at least 30% of their dry matter intake from pasture grazing for at least 120 days during the grazing season (McBride & Greene 2009, Sorge, *et. at*. 2016). The requirement for pasture grazing by the NOP is known as the 'pasture rule' (Sorge*, et.al*. 2016). Additionally everything organic cows eat (dry feed/forage, *etc*.) must be from a certified organic source which means no synthetic chemicals can be used on organic feed (McBride and Greene 2009). Conventional dairy cows may have access to pasture but will generally be fed a ration of high quality dry forage of alfalfa, barley, corn and/or grass hay, as well as silage (fermented feed) and possibly protein and vitamin supplements based on a nutritionist's recommendation.

Organic dairy producers cannot use any antibiotics (except to treat sick cows), and therefore rely on preventive practices for herd health (Sorge, *et al*. 2016), while conventional dairy cows receive routine veterinary services and approved medicines when necessary. Once an organic cow is treated with an antibiotic she must be removed from the herd and none of her milk or meat can ever be sold as organic (Sorge, *et al.* 2016). Similarly organic dairy cows cannot receive any hormones however some conventional dairy producers (less than 20%) administer the FDA-approved growth hormone, rbST (recombinant bovine somatotropin) to improve milk production.

For background purposes, rbST is based on the somatotropin naturally produced in cattle. Somatotropin is a protein hormone produced in the pituitary gland of animals, including humans, and is essential for normal growth, development and health maintenance. When produced for commercial dairy application using biotechnology, the hormone is called rbST and is known as 'recombinant' bST or 'rbST'. This process is also advantageous for producing a more consistent and purified source of bST. The FDA approves an animal drug only after studies show that the food (in this case, milk and meat) from treated animals is safe for people to eat, and that the drug does not harm treated animals, or the environment (FDA, https://www.fda.gov/animalveterinary/safetyhealth/productsafetyinformation/ucm055435.htm).

Production Practices

Organic- If a dairy is transitioning from a conventional to an organic operation, pastures and any cropland providing feed for cattle must be managed under organic rules for 36 months before it can be certified and all feed must meet organic standards. NOP rules require that the herd must receive organic health care for at least 12 months for herd certification, and all animals over six months of age must have access to pasture for grazing.

Organic cows are generally milked two times daily (https://www.uaex.edu/4h-youth/activities-programs/docs/dairy%20facts.pdf) and produce milk approximately 305 days each year. Average daily milk production varies from cow to cow and year to year, but organic dairy producers can expect about 13,600^{+} pounds of milk per cow annually which translates into approximately 45 pounds or a little over 5.2 gallons daily (McBride & Green 2007, Nehring, *et al*. 2012, https://wcroc.cfans.umn.edu/organic-profits).

Conventional – Cows under this type of operation generally receive daily rations of feed as referenced above and may or may not have access to pasture. A small percentage (approximately 17%) of conventional dairy cattle is given rbST (McBride & Greene 2007) to increase milk production over those not receiving rbST. Regardless of whether conventional cows are given rbST or not, they usually produce more milk than organic cows and are generally provided more veterinary services than organic cows, perhaps because of their increased milk production (McBride & Greene 2007).

Conventional cows are milked two to three times daily for approximately 305 days each year. Typical milk production per cow varies as it does with organic cows but is nearly 21,000 pounds annually or an average of 72 pounds or a little over eight gallons of milk daily on a per cow basis (Nehring, *et al*. 2012).

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Comparison of Agricultural Practice & Cost/Returns
Organic vs. Conventional Dairy

OPERATING COSTS	ORGANIC COST/CWT*	CONVENTIONAL COST/CWT
Feed, purchased & homegrown, graze	$15.66	$9.14
Veterinary & medicine	$0.56	$0.78
Fuel, lube, electricity	$1.05	$0.50
Other, bedding, litters, custom services	$3.41	$1.64
Total Operating Costs:	**$20.68**	**$12.06**
Allocated Overhead		
Hired Labor	$2.83	$1.80
Opportunity cost, unpaid labor	$5.80	$1.26
capital recovery machinery/equipment	$4.43	$3.78
Other	$2.27	$0.68
Total Allocated Overhead:	**$15.33**	**$7.52**
Total Costs Listed	**$36.01**	**$19.58**
Gross Value Production:		
Milk sold	$35.06	$16.22
Cattle/calves sold (per lb.)	$2.56	$1.99
Total Sales	**$37.65**	**$18.21**
Value of Production less Operating Costs	**$16.97**	**$6.15**
Value of Production less Total Costs	**$1.64**	**-$1.37**

Average Organic Milk Prices $31-$38/cwt	Organic	Conventional
	14,214 lbs/cow	22,052 lbs/cow
*cwt = 100 weight	83 cows/farm	270 cows/farm

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