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Phosphorus and Potassium Fertility Management for Maximizing Tart Cherry Fruit Quality and Productivity on Alkaline Soils

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PHOSPHOROUS AND POTASSIUM FERTILITY MANAGEMENT FOR MAXIMIZING TART

CHERRY FRUIT QUALITY AND PRODUCTIVITY ON ALKALINE SOILS

by

Sean D. Rowley

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ABSTRACT

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by

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Suitable orchard land in regions of high elevation, arid climates, and alkaline soil conditions is becoming more limited due to urban sprawl. With the loss of suitable farmland, increasing input costs, and the lack of sound fertility information for these regions, fruit growers face challenges in producing high quality fruit to meet local and general market demand. The question that arises is whether fruit growers can supply sufficient quantities of quality fruit to take full advantage of local and global demand. Government data for population, fruit production, and fruit consumption in Utah were reviewed to determine the potential size of the local market, and determine whether growers have opportunities to increase production to meet unsatisfied demand for high quality local produce. In addition to market analysis, fertility-based management strategies are needed to optimize yield and fruit quality in production areas of high elevation, arid climates, and alkaline soils. Three different approaches were used to investigate the effect of phosphorus (P) and potassium (K) on tart cherry fruit quality and yield at high elevations, arid climate conditions, and in alkaline soils. The approaches of this study include: a rate-response evaluation using the industry-standard Triple-16 fertilizer (16-16-16), and comparison of P and K fertilizer formulations to determine the most cost effective sources of these nutrients with regard to yield and fruit quality. Additions of P and K maintained adequate yield and fruit quality, but showed no significant difference among treatments, where historically aggressive nutrient management had been practiced. Fertilizer additions did result in a significant increase in yield and fruit quality where nutrient management programs were historically much less aggressive. There is no advantage of higher cost fertilizer formulations over standard low-cost sources (i.e.; Triple-16). Moreover, there is no significant advantage to splitting fertilizer application over time during the growing season. An analysis of government data indicates that, over the past 40 years, Utah has become a net importer of apples (1997), peaches (1987), and sweet cherries (2005), indicating increased local market opportunities. Increasing the fruit supply to the local market can best be accomplished by increasing yields and fruit quality on existing orchard acreage. Optimizing annual P and K nutrient management is an important key to maximizing yield and fruit quality. The results provide foundational guidelines of nutrient management for optimizing tart cherry production and fruit quality under regionally specific conditions.

(80 pages)

PUBLIC ABSTRACT

Phosphorous and Potassium Fertility Management for the Intermountain West

By: Sean D. Rowley

Suitable orchard land in regions of the Intermountain West is becoming more limited due to urban sprawl. With the loss of suitable farmland, increasing production costs, and the lack of sound fertility information for these regions, fruit growers face challenges to produce high quality fruit for market demand. Current standard management practices are not sufficient to optimize yield and fruit quality in the marginal farm land that is currently be used for fruit production. Fertility management of orchard trees is vital to tree health, yield, and fruit quality.

Three different approaches were used to investigate the effects of Phosphorus (P) and Potassium (K) nutrient additions on tart cherry yield and fruit quality, including: the correlation between fertilizer application rate and yield and fruit quality, the influence of different P and K nutrient sources on tree performance, and the relative importance of P or K on tree performance measures.

The rate that optimized yield was accomplished with rates between 0.45 and 0.91 kg/tree of 16-16-16 fertilizer. These rates produced optimum yields at sites with histories of moderate or not very aggressive nutrient management programs. For sites with a history of aggressive nutrient management there was no effect of rate on yield or fruit quality. The addition of K had larger effects on yield then the addition of P. No advantage of higher cost nutrient sources over standard low-cost sources was found. Furthermore, no advantage was observed from splitting fertilizer applications over time during the season.

Commercial orchard managers in the Intermountain West need information on optimum fertility management for their unique environment. Results from these studies were integrated in a series of grower recommendations contained in Chapter 4. Fertility management strategies in high elevation, arid climates, and alkaline soil conditions will provide benefits to fruit producers as well as fruit consumers. With fertility management strategies specific to the conditions of the Intermountain West, fruit growers will produce enough fruit that is high quality to take full advantage of local and global demand.

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Sean D. Rowley

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CHAPTER 1

INTRODUCTION

The commercial tree fruit industry in Utah has a total of 2,688 hectares in operation with an estimated utilized product value of $24 million (National Agricultural Statistics Service data for 2010) which accounts for about 11% of crop-related cash receipts in Utah, and is surpassed only by hay and wheat. Tart cherries are Utah's most important fruit crop with 1,335 producing hectares and a reported crop value of $9.18 million from the 2009 crop (NASS, 2010).

In Utah, agricultural land is very limited, with only 2.6% of the total land in irrigated agriculture (Hutson et al., 2005). Much of Utah's irrigated land is not suitable for fruit production because of unfavorable climate, insufficient water quantity or quality, and soils that are highly alkaline or saline (Gale et al., 2001). The land that is suitable for fruit production is also desired by home buyers. Urban growth in areas of prime fruit production is resulting in a rapid decrease in the amount of land that is suitable for fruit production. With the loss of prime fruit producing land, Utah fruit producers are forced to look elsewhere for diversification opportunities, and for technology to produce fruit on marginal land.

The demand for locally grown produce has increased significantly in recent years, just as the number of local consumers has increased. As the local food movement has gained national popularity, the question that arises is whether growers can supply sufficient quantities of high quality produce to support local demand. Since suitable orchard land in Utah is becoming more limited, increasing fruit supply to the local market could best be accomplished by increasing yields on existing orchard acreage. Government census reports indicate that both the Utah population and the estimated total fruit consumption have increased, while statewide fruit production has declined, shifting Utah from a net exporter of fresh fruit to a net importer (USDA-NASS, 2007). Over the last four decades Utah's population has tripled and is projected to continue that increase over the next decade (US Census Bureau, 2009). With the loss of prime farm land the number of fruit producing hectares has decreased dramatically. As the popularity of the local-food movement increases, questions arise as to the ability of individual states to generate sufficient produce for local demands.

This brings about both challenges and opportunities. The challenges that arise are producing fruit on more marginal sites including: challenging soil conditions as well as the lack of fertility information for high elevation, arid climates, and alkaline soil conditions, and increasing input costs. The most significant opportunity for local fruit producers is being able to supply sufficient amounts of locally grown fruit for the local market demand.

Recent increases in fertilizer costs as well as an increase in demand for locally grown fruit have forced fruit producers to re-examine their fertility practices. In order to remain profitable, orchard managers need to determine the optimum and most cost effective method to reach proper fertility levels, while maintaining high quality fruit.

Fertility management is extremely important in tart cherry production. Not only does it ensure stable, high productivity but it affects fruit quality (sugar content, acidity, and color), and helps prolong tree health and longevity. By implementing a nutrient management program, tart cherry growers can improve productivity, and optimize fruit yield and quality. Tart cherry trees must have the correct ratio of leaves per fruit in order to produce the highest quality fruit. Determining the amounts of P and K in the leaves and fruit under a variety of conditions allows development of an economical and effective nutrient management plan specific to Utah conditions. The result is improved fruit for the consumer and increased profit for the tart cherry producers and processors. Current soil and plant tissue test interpretations and nutrient management guidelines used by Utah State University for tree fruit production are taken, primarily, from out-of-state research databases in the Pacific Northwest and the Eastern and Southeastern U.S. (James and Topper, 1993). Little published research has been done to evaluate and corroborate these guidelines for high elevation, alkaline soils and arid climate conditions.

Traditional soil tests typically indicate sufficient available phosphorus (P) and potassium (K) for fruit crops in Utah's orchard soils. However, since the time that these soil test recommendations were developed, improved orchard management practices have dramatically increased per-tree yields. In these high crop-load conditions, trees may occasionally exhibit nutrient deficiency symptoms. Recent preliminary comparisons (2009, unreplicated tests by author; data not cited) indicated that P and K additions may improve yield and fruit quality in high crop load situations. The fact that fruit quality (as defined by standards set largely by consumer preferences) affects profits to growers, has stimulated a great deal of research, both fundamental and applied, on the effect of various production practices and other factors on fruit quality, as well as total yield of orchard trees (Reuther et al., 1958).

Recent work with apples has shown that supplemental P and K improve fruit quality under high crop load conditions when conventional soil tests would indicate sufficiency. Phosphorus applications to mature trees showed an increase in fruit set and also higher levels of leaf and fruit tissue P concentrations. Fruit quality attributes were not directly affected by the P application. Application of K increased leaf and fruit K concentration, as well as fruit size and yield, fruit titratable acidity, and red coloration of the fruit (Fallahi et al., 2010). Older studies indicate that apple trees affected with "leaf-scorch," a symptom of potassium deficiency, produce fruit which do not color normally as they ripen. Potassium fertilization of such trees usually improves vigor, foliage condition, and markedly improves fruit color. In a field fertilizer experiment with apple trees, the interaction of potassium and nitrogen with fruit color was studied. The data showed that the best colored fruits were produced by low-nitrogen, high potassium treatments, and the poorest colored fruits were produced by high-nitrogen, low-potassium treatments (Boynton, 1954).

Phosphorus is a nutrient that needs to be applied to fruit trees generally. Phosphorus is not needed in large amounts in trees because it is used repeatedly and not very much is removed with the fruit (Westwood, 1988). This is through leaf and fruit decomposition each year after leaf shed. The uptake of P into the fruit usually follows the weight increase of the fruit and uptake continues until harvest. Phosphorus levels in apples have been positively correlated with fruit firmness and negatively correlated with low-temperature breakdown; therefore it is imperative to have sufficient P levels in the tree (Faust, 1989). Cherries usually do not respond to P fertilization; however, certain circumstances might indicate otherwise (Westwood and Wann, 1966). The circumstances under which cherries respond to P fertilization occur when other nutrients become immobilized and are not moving through the tree. Cherries need P in order to maintain a balance of micro nutrients within the tree. Research has shown that P fertilization in sweet cherries has also increased fruit firmness (Neilsen et al., 2007).

Potassium is also a nutrient that needs to be supplied to fruit trees in relatively large quantities. Fruits accumulate large amounts of K, so leaf symptoms are more likely and most severe as fruit approaches maturity during heavy crop years (Hanson, 1996). Fruit size, color, and acidity are positively related to K. Color development occurs when considerable quantities of sugars are present in the fruit. It is likely that insufficient K concentrations decrease photosynthesis of leaves; which in turn, lowers sugar concentrations (Faust, 1989). In peaches, K fertilization resulted in an increase in titratable acidity in the fruit (Hansen, 1980). Potassium fertilization also has a positive effect on fruit size and development. Fruit from potassium-deficient trees is smaller than normal, has dull surface color, and dull flavor from lack of acidity (Stiles, 1994).

Little research has been done on the effects P and K on tart cherries in the Intermountain West. Early research has shown that P and K added during the growing season had little to no effect on fruit quality. No definite conclusions can be drawn from the limited evidence available concerning the effect P nutrition has on color and other quality factors in deciduous fruits (Reuther et al., 1958). A survey of the limited data available does not reveal any clear-cut generalization concerning the effect of K level in deciduous fruit trees on such factors as firmness of flesh, total soluble solids, acid in the flesh, or time of ripening (Childers, 1954). However, when added with N, K has had positive effects on fruit quality (Wann, 1954). N fertilizer should be applied with the goal of achieving optimal yields as opposed to maximum yields and K fertilizer amounts should be applied to improve yield. Optimum yields in the case of fruit trees, are obtaining adequate yield levels while maintaining high quality fruit. Maximum yields are as much as the plant can produce. Maximum yields generally result in a decrease in fruit quality. Yield response to K uptake depends to a great extent on the level of N nutrition and the interaction is usually positive (Zhang et al., 2010). Research that has been done in apples suggests that P and K when added to apple trees during the early growing season will have a positive effect on fruit quality. Also, P and K play important roles during the early growing season in activating the enzymes that are involved in photosynthesis and respiration. The same study indicates that fruit size, acidity, and color are positively related to the application of P and K during the early growing season as well (Stiles and Reid, 1991).

Nutrient concentrations of leaves are an accurate indicator of the nutritional health of fruit crops. Plant tissue analysis is a very effective method used to diagnose deficiencies and monitor nutrient status so that problems are avoided (Roper, 1994). Leaf analysis should be an integral component of rate and formulation monitoring of nutrient sources to tart cherries (Callan and Westcott, 1996). To determine optimal nutrient rate application and formulations for beneficial results in tart cherry, frequent leaf tissue analysis should be part of nutrient management programs of tart cherry producers. The presence of nutrient deficiency symptoms indicate an acute shortage in the plant, and may reduce yield or fruit quality (Hanson and Proebsting, 1996). The nutrient deficiencies will most commonly present themselves first in the foliage of current season growth. Nutrients are not only required in a certain organ of the tree, but often must be present at a specific time in order to benefit the tree during the growing season (Faust, 1980). The objective is to determine which fertilizer treatments most efficiently improve nutrient status in tart cherry leaves and fruit.

Early work in cherry nutrition as well as more recent work indicates that nitrogen (N) sufficiency levels in leaf tissue should be between 2.0 and 3.5%, while levels that are less than 1.9% indicate deficiency. Phosphorus levels in leaf tissue should be between 0.1 and 0.4% to indicate sufficiency and values less than 0.08% indicate a deficiency. Potassium levels in leaf tissue should be between 1.0 and 3.0% to indicate sufficiency while levels less than 1.0% indicate deficiency (Shannon, 1954; Rom, 1994; Hanson, 1996).

Poll et al., 2003 reported that in heavy cropping blocks P and K additions may improve tart cherry productivity and fruit quality including soluble solids content, titratable acidity, color, and other measures. Other preliminary trials seem to confirm this (2009 unreplicated tests by author; data not cited). These preliminary results indicated that a detailed replicated study was needed to help develop the management guidelines that will allow Utah growers to fine tune their fertility management programs for optimum performance for high elevation, alkaline soils, and arid climate conditions. This thesis details the first phase of research designed to correlate tree fruit performance measures (both yield and fruit quality) to P and K application rate and formulation, particularly under high crop load conditions.

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CHAPTER 2

REVIEWING POTENTIAL LOCAL FRUIT MARKETS: A UTAH CASE STUDY[1]

Abstract

The demand for locally grown produce has increased significantly in recent years as the local food movement has gained national popularity. The question that arises is whether growers can supply sufficient quantities of produce to support local demand. Data for population, fruit production and fruit consumption were reviewed to determine the potential size of the local market in Utah, and determine whether growers can meet the demand for local produce. Trends indicate that both the Utah population and the estimated total fruit consumption have increased, while statewide fruit production has declined, shifting Utah from a net exporter of fresh fruit to a net importer. Since suitable orchard land in Utah is becoming more limited, increasing fruit supply to the local market could best be accomplished by increasing yields on existing orchard acreage.

On average, produce grown within the United States travels between 1640 and 3220 kilometers from farm to supermarket (11). For produce imported from other countries, this distance increases significantly. Produce travel distance, or "food miles," has become a concern for a growing number of people who refer to themselves as locavores. This term was first used in 2005 by four California women, and is defined as a person who purchases and eats only locally grown produce (2).

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[1]Coauthored by S.D. Rowley, T. Ernst, B.L. Black, and T.R. Roper
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The distance produce can travel and still be considered local varies. Often, local produce is defined as anything grown within 100 miles (161 km) of its market (2), or produce that is picked, packed, shipped and sold within 24 hours (1). For simplicity, local can also be defined as anything grown within the state in which it is sold (2). Farmers' markets and food co-operatives are both methods for facilitating sales of locally grown produce. In recent years, consumer attendance at farmers' markets and local food co-operatives has increased (6). A survey by the United States Department of Agriculture found that sales at farmers markets in the USA have increased from $888 million in 2000 to $1 billion in 2005 (1).

Shorter shipping distances are attractive to consumers interested in reducing their carbon footprint. A carbon footprint is an estimate of how much carbon (or greenhouse gas) a person produces in doing everyday tasks (11), and is one measure of the impact of activities on the environment (5). Another major reason for buying local fruits and vegetables is to help support the local economy (6).

While the locavore and "100-mile diet" concepts work well in California where there is a concentration of horticultural production and a relatively long growing season, other states within the USA may not have sufficient production to meet local needs. In Utah, agricultural land is very limited, with only 2.6% of the total land area in irrigated agriculture (4). Much of Utah's irrigated land is not suitable for fruit production because of unfavorable climate, insufficient water quantity or quality, or soils that are highly alkaline or saline (3). Utah orchards produce a variety of fruits including peaches, apples, and sweet and tart cherries.

As the popularity of the local-food movement increases, questions arise as to the ability of individual states to generate sufficient produce for local demands. The purpose of this study was to review data on population growth, fruit consumption and fruit production to determine the extent to which Utah's fruit industry can meet increasing demands for local produce.

Materials and Methods

State population and future population estimates were obtained from the U.S. Census Bureau (8). Fruit acreage estimates and statewide annual production from 1989 to 2009 were obtained from the Utah Agriculture Statistics and Utah Department of Agriculture and Food Annual Reports (7). Prior to 1989, acreage and production data were obtained from quinquennial Census of Agriculture reports (9). Per capita fruit consumption was obtained from United States Department of Agriculture – Economic Research Service reports (10), based on nationwide food disappearance estimates. Regression analysis was carried out using the curve-fitting feature of SigmaPlot (version X, Systat Software, Inc., San Jose, California, USA).

Results and Discussion

Population

Historically, the largest fruit producing area in Utah was along the Wasatch Front, encompassing Box Elder County on the north, Weber, Davis and Salt Lake counties, and extending through Utah County on the south. Other parts of Utah with commercial orchards included areas along the Colorado River in Grand County, and the Virgin River basin in Washington County. By the early 1970s, much of the suitable orchard ground in Weber, Davis and Salt Lake counties had become urbanized, and most fruit produced in Utah was from Utah County, with Box Elder County being the second largest production region (12).

Utah's population has steadily increased, with the last decade experiencing an annual growth rate of ≈2.48%, making Utah the fastest growing state in the USA. Predictions are that the state population will reach 3.08 million by 2020 (Table 2.1). In 2008 Utah County was the second fastest growing county in the state, and the 35th fastest growing county in the nation (8). The city of St. George in Washington County was ranked as the fastest growing metropolitan area in the USA as this area became a popular retirement community. Nearly all fruit production in Grand County also disappeared as this area became a popular vacation spot (centered around Moab).

Per capita consumption

For the purposes of this review, it is assumed that Utah per capita consumption mirrors national trends. Regression analysis indicates that per capita consumption for apple showed a significant quadratic trend, where peak consumption occurred in 1989, with consumption decreasing in recent years by ≈ 3.5% annually (Table 2.2). Per capita peach consumption also showed a significant quadratic relationship in time, with peak consumption in 1990, and a rate of decrease of ≈3.6% annually since 2005. However, cherry consumption has increased ≈6.3% annually in recent years (Table 2.2).

Production area

Total Utah orchard land in apples, peaches, sweet and tart cherries increased from 3058 ha in 1969 to a maximum of 5694 ha in 1987. From 1987 to 2007 total fruit production area decreased by more than 50% to 2531 ha, the smallest area in 40 years (Figure 2.1).

The amount of land dedicated to apple production in the state increased from 1117 ha in 1969 to a peak of 2089 ha in 1987. From 1987 to 1989 apple production area dropped 28% to 1498 ha. After this sharp decline, production area has steadily declined to 567 ha in 2009. The decline in apple production area is likely due to a combination of factors, including the Alar controversy in 1989, increased foreign competition, and general loss of farmland to urban development.

Peach production area also increased from 1969 to 1987, reaching a peak of 1042 ha. Production area then declined to 405 ha in 1993, and has since increased to 607 ha in 2009. Sweet cherry production area has been decreasing ≈7.1% annually since 1969, reaching 203 ha in 2009. Some of the recent drop in sweet cherry area has been due to urban development on the best orchard sites. Many of the remaining orchard sites are more frost prone, making sweet cherry production less consistent, and less economically viable.

With the decline in apple acreage, and higher tolerance to fluctuating spring temperatures, tart cherry has recently become the state's most important fruit crop, with Utah ranking second behind Michigan in total tart cherry production. Tart cherry production is highly mechanized, and essentially all of the fruit is frozen for processing.

Since the focus of this paper is on local marketing of fresh produce, statistics on tart cherry acreage, production and consumption are not included in the following analyses.

Yields

Trends in fruit crop yields ($kg \cdot ha^{-1}$) are difficult to determine, because annual fluctuations exceed any apparent trend. These yield fluctuations are likely due to a combination of factors. The majority of Utah's commercial orchards are located in a relatively small geographic area, at elevations ranging from 1370 to 1550 m. This arid high-elevation area is prone to large diurnal temperature fluctuations in the spring, resulting in frequent loss of flower buds and blossoms to spring frosts. Regional frost events often affect a large portion of this primary fruit production region. In the case of apple, these frost events also synchronize biennial bearing.

Apple production technology and orchard management skills have improved significantly in the last 40 years. Many growers have moved to high density plantings on dwarfing rootstocks. However, some fruit growers have been much less aggressive in moving to modern systems, and continue to maintain old, lower-productivity orchards. Regression analysis showed no significant change ($P = 0.93$; $R^2 = 0.0066$) in apple yields from 1969 to 2009. However, any possible changes may have been masked by the large annual fluctuations due to freeze cycles and biennial bearing. Further, the lack of change may also be due to the mix of modern, high-density orchards and old, less-productive orchards.

Average sweet cherry yields showed equally variable results from year to year. Likewise, regression analysis showed no significant relationship between yield and time over the past 40 years. Modern sweet cherry orchards are also planted in higher densities, though not to the extent of apple or peach. Sweet cherry showed annual fluctuations similar to that of apple, with no detectable trend in per-hectare yields (P = 0.11; R^2 = 0.18).

Peach yields also showed significant annual fluctuation, but did show a significant curvilinear trend over the past 40 years (P = 0.028; R^2 = 0.268). The fitted regression curve ($y = 7.92x^2 – 31510x + 3134058$) indicated that yields have been increasing in recent years. Although older, less-productive peach orchards remain, many growers have moved to higher density orchards with quad-V training systems to improve crop yields.

Production totals

Production totals for the individual crops closely match the fluctuations in producing hectares. Statewide apple production ranged from 1.81 million kg in 1972 to a high of 30.9 million kg in 1987. Trend analysis predicted peak annual production in 1985 (Table 2.2).

Total peach production in the state ranged from a high of 8.18 million kg in 1976 to a low of 0.77 million kg in 1972. Quadratic trend analysis indicates that total peach production declined from 1969 to 1997 but has begun to rise in recent years to 4.54 million kg in 2009 (Table 2.2). Trend analysis of total Utah sweet cherry production shows that production has declined linearly since 1969 (Table 2.2).

The extremely low production of peaches in 1991; tart cherries, sweet cherries, and apples in 1971 and 2002; and sweet cherries in 2008 (Figures 2.2 to 2.4) are particularly noteworthy. Late spring frosts damaged flowers and reduced production in each of those years, nearly eliminating entire crops. General annual fluctuations are also apparent and can be attributed to smaller scale frost events that damaged part of the crop.

Statewide consumption

Although per capita consumption of apples and peaches has declined in recent years, the rapid population growth in Utah (Table 2.1) resulted in net increases in total statewide consumption of both crops. Statewide consumption of sweet cherries is increasing more rapidly than peach or apple (Table 2.2), due to increases in both population and per capita consumption.

Net exports

Based on trends in production and statewide consumption (population × per capita consumption), Utah became a net importer of apples in 1997 (Figure 2.2). In order for Utah producers to recapture 100% of the local market at current average yields, production area would need to increase by 800 ha, a 60% increase. Alternatively, average yields would need to increase to 21.0 $Mg{\cdot}ha^{-1}$. In 2005, statewide average yields were 26.7 $Mg{\cdot}ha^{-1}$. If this productivity were maintained across all apple orchards, 100% of total demands could be met. A more aggressive program of replacing old orchards with modern, high-density orchards could increase average annual yields per hectare.

From 1969 to 1987 total peach production decreased more rapidly than the population increased. As a result, Utah became a net importer of peaches in 1987 (Figure 2.3). However, since 1997 total statewide peach production has been increasing due to an increase in the production area (608 ha) and improved yields (Table 2.2). An additional 120 ha of producing orchards or a 16% increase in yields would meet current statewide demand.

Sweet cherry production has steadily decreased since 1969 while total consumption has increased. Trends indicate that Utah became a net sweet cherry importer in 2005 (Figure 2.4). To maintain local market share, producers will need to maintain or increase the producing sweet cherry hectares or move to a more aggressive program of orchard renewal and to more efficient orchard management systems on the most suitable orchard sites.

Conclusion

With continued increases in Utah's population and the growing local-food movement, demand for local fruit will continue to increase. For Utah growers to recapture local markets there needs to be an increase in production area, an increase in yields per hectare, or a combination of both. However, pressure from urban development in prime fruit growing regions is making expansion of the fruit production area economically unviable. Irrigation water is also being diverted for urban and suburban use, further limiting the amount of water available for agricultural production. Without more aggressive preservation of land for orchard use and greater allocation of water for food production, maintaining the existing orchard area will be challenging. Improving yields through increased orchard management skill and improved fruit production technology will be the primary avenues for growers to meet the increasing demand for local fresh fruit.

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Table 2.1. Utah population and projected population. Data are from the United States Census Bureau.

Year	1960	1970	1980	1990	2000	2010	2020
Population (thousands)	891	1059	1461	1723	2244	2672	3084

Table 2.2. National trends in per capita consumption (10) and Utah state trends in total production (9) and consumption (10). The assumption is that Utah per capita consumption is the same as the USA average.

Crop	Regression equation	R^2	*P*-value	Peak	Recent trend
Per capita consumption					
Apple	$Y = -0.0036x^2 + 14.5x -14424$	0.44	<0.0001	1989	Decreasing
Peach	$Y = 0.0016x^2 + 6.37x - 6324$	0.32	0.0009	1990	Decreasing
Sweet Cherry	$Y = 0.0005x^2 - 1.92x + 1906$	0.53	<0.0001	---	Increasing
Total Utah production					
Apple	$y = -0.0319x^2 + 126.69x – 125738$	0.42	<0.0001	1985	Decreasing
Peach	$y = 0.0034x^2 - 13.58x + 13559$	0.22	0.0097	---	Increasing
Sweet Cherry	$y = -0.074x + 148.94$	0.38	<0.0001	---	Decreasing
Total Utah consumption					
Apple	$y = 0.33x - 632.53$	0.94	<0.0001	---	Increasing
Peach	$y = -0.002x^2 +7.96x - 7996$	0.83	<0.0001	>2009	Increasing
Sweet Cherry	$y = 0.0013x^2 - 5.09x + 5043$	0.79	<0.0001	---	Increasing

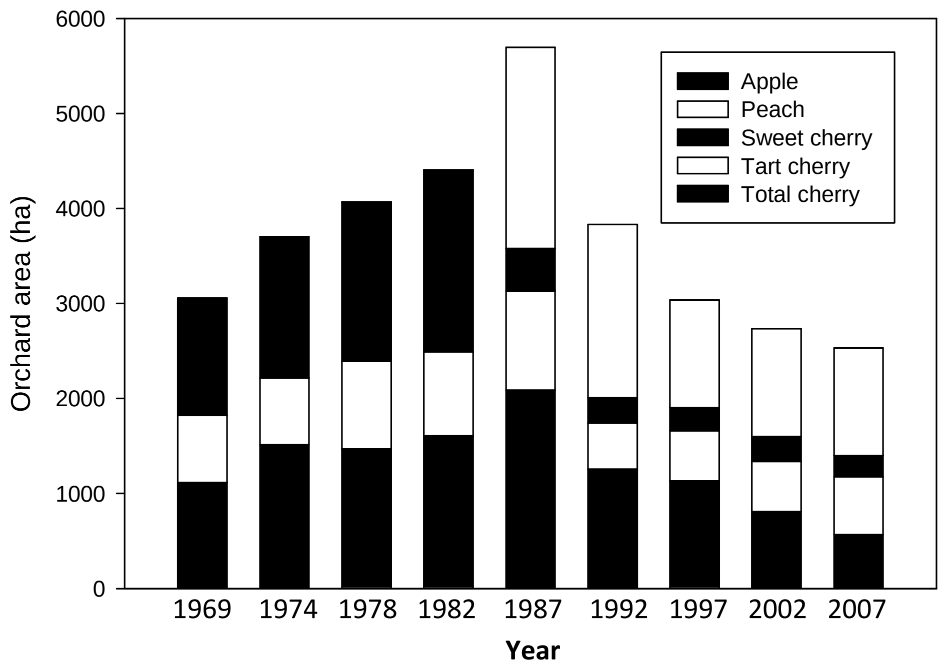

Figure 2.1. Total Utah orchard area for apple, peach, sweet and tart cherry. Data are from Census of Agriculture reports (9). Prior to 1987, sweet and tart cherry acreage were not reported separately.

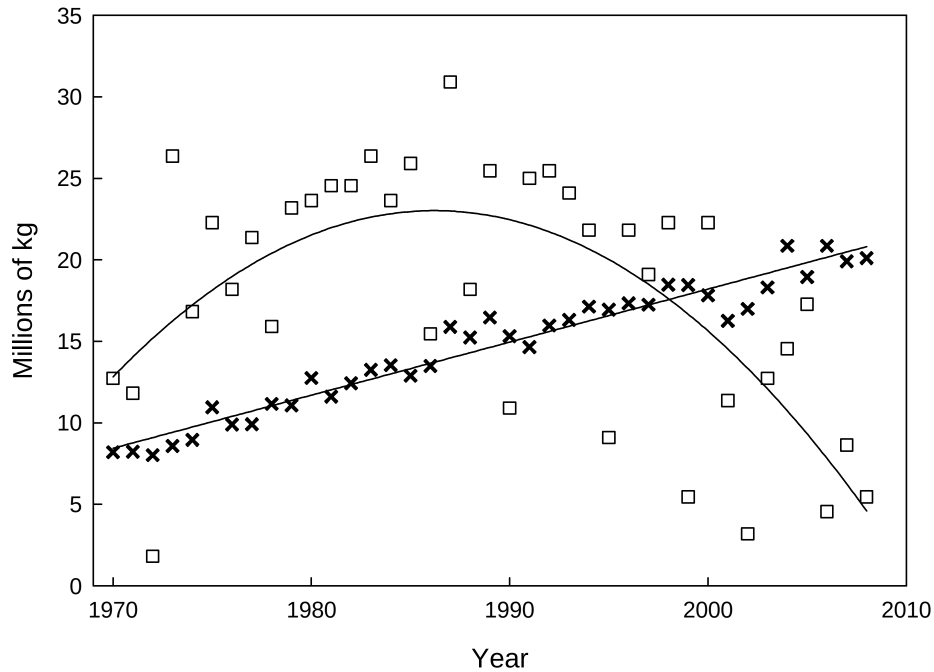

Figure 2.2. Trends in total statewide apple production (□) and consumption (×). Regression equations are shown in Table 2. Trend analysis indicates that Utah became a net importer of apples in 1997.

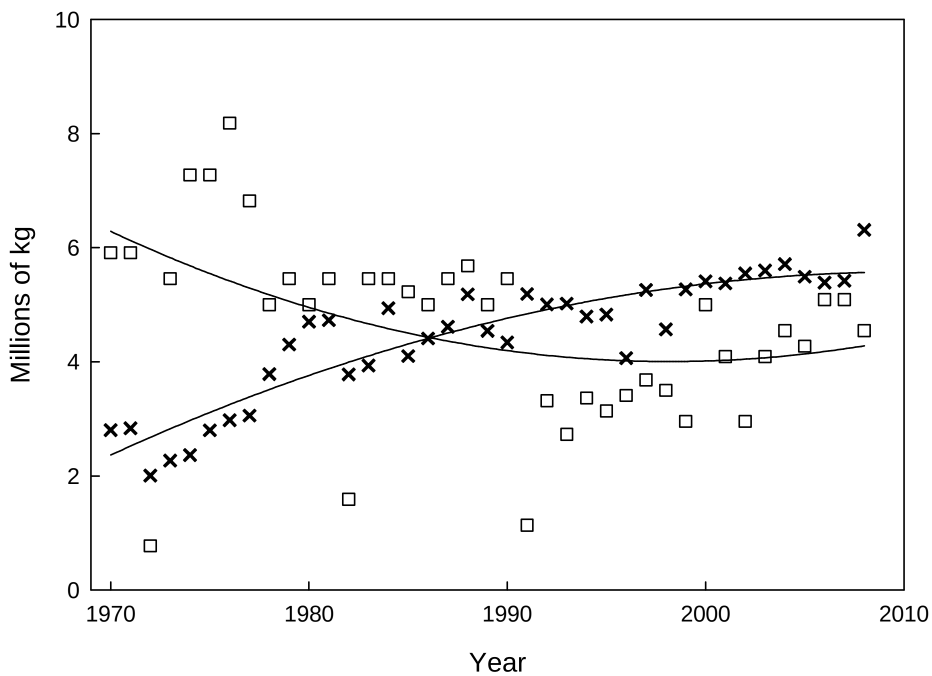

Figure 2.3. Trends in total statewide peach production (□) and consumption (×). Regression equations are shown in Table 2. Trend analysis indicates that Utah became a net importer of peaches in 1987.

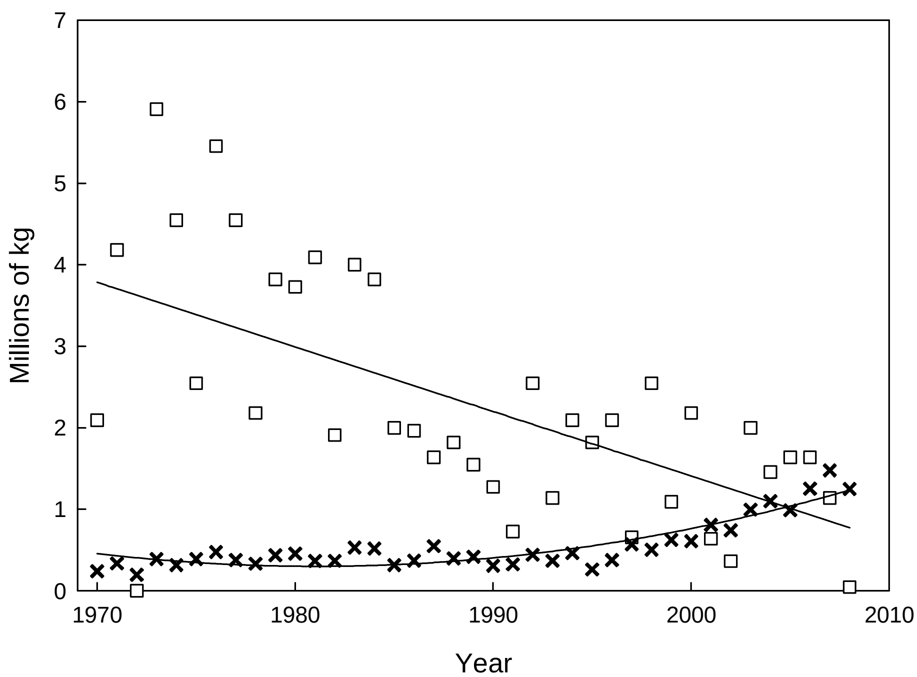

Figure 2.4. Trends in total statewide sweet cherry production (□) and consumption (×). Regression equations are shown in Table 2. Trend analysis indicates that Utah became a net importer of sweet cherries in 2005.

CHAPTER 3

P AND K FERTILITY MANAGEMENT FOR OPTIMIZING TART CHERRY YIELD AND FRUIT QUALITY ON ALKALINE SOILS

INTRODUCTION

Fertility management is an important part of producing tart cherries (*Prunus cerasus*, 'Montmorency'). In order to produce quality fruit, the trees must have adequate amounts of nutrients available. Utah tart cherry growers rely heavily on recommendations from Michigan and the Pacific Northwest for fertility requirements. Utah soils and water quality are drastically different from areas where recommendations have been developed (James and Topper, 1993). Thus, there is a need for recommendations that will better suit grower needs at high elevations, in arid climates, and alkaline soil conditions.

Utah is the second leading tart cherry producer in the United States, behind Michigan. Over the past three years, tart cherry production in Utah has fluctuated significantly. The 2009 crop was the largest that has been recorded, with total production of 21,319 metric tons (47.0 million pounds); the last record was in 1992 with total production of 13,608 metric tons (30.0 million pounds). This number drastically exceeded previous production years. The large crop was associated with a dramatic decrease in fruit quality, mainly soluble solids and acidity. The large crop coupled with the less than desirable fruit quality, was impetus for this research to determine optimal fertilizer rates and formulations for increasing yield and fruit quality. It is imperative to find fertilizer rates and formulations that will maintain both high yield and high fruit quality.

Fertility management research has been most active over the past 25 to 30 years. As recently as the 1950's, horticultural experts noted that no generalizations had been drawn regarding specific P and K requirements for fruit trees (Childers, 1954). More recently however, sufficiency levels of P and K to maintain high fruit quality levels have been observed (Faust, 1980). This research indicated that P and K are very important contributors to fruit quality and that P and K needs to be added regularly to maintain sufficiency for long term fruit quality (Faust, 1989). Size, color, and acidity have all been shown to be positively related to the additions of P and K to tree fruits (Stiles and Reid, 1991). In Utah, 80% of all tart cherries produced are marketed as a dried product, 10 -15% are used for juice concentrate, and the other 5-10% used for pie fill and other cherry baked goods. It is necessary to maintain high levels of soluble solids (sugar) as well as acidity in order for a dried product to be top quality. The high fruit quality desired can be maintained with nutrient additions among other factors.

Crop load also affects fruit quality where crop load is inversely proportional to fruit quality. As crop load increases, nutrient deficiencies become more apparent and fruit quality tends to decrease (Hanson, 1996). Fruit trees also tend to have cyclic production (alternate years, one year a heavy crop the next year a smaller crop, see Figures 2.2, 2.3, and 2.4). This would indicate that adequate nutrition in high load years may have a significant impact on following years.

Fruit trees will produce buds 12 to 16 months prior to those buds maturing into fruit. Bud formation and development depends largely on tree health as well as environmental conditions. Fruit bud development can be influenced by crop load. According to Hanson and Proebsting (1996) nutrient deficiencies in sweet cherry trees will decrease fruit set (a component of yield). In order to maintain high levels of fruit set, nutrient needs must be met annually. Phosphorus and potassium nutrients are particularly essential to produce fruit. Cherry fruits accumulate large amounts of K during the time of maturation. In heavy crop load situations large amounts of K are transported into the fruit, and hence with harvest comes the loss of large amounts of K from the tree (Hanson, 1996). When P and K are added with nitrogen, positive effects on fruit quality have been observed for mature tart cherry trees (Wann, 1954).

Leaf tissue samples are the most effective way to determine nutrient sufficiency levels in fruit trees. Published optimal timing for tissue sampling for nutrient analysis is generally 1 July to 15 July. Recommendations are that tissue samples should be taken from the current season's growth, and must be fully expanded leaves (Roper, 1994). Sufficient foliar nutrient values for tart cherries vary slightly from other fruit crops (Table 3.1) and it is important to maintain sufficiency levels to optimize yield and fruit quality. Values noted in Table 3.1 are derived, however, from major fruit producing regions throughout the U.S., and have not been fully corroborated for Utah conditions (Shannon, 1954 and Rom, 1994).

This chapter presents work designed to address three primary objectives:

- First determine the correlation between fertilizer application rate and yield and fruit quality. Based on research previously cited, we hypothesize that increasing fertilizer rate will have a positive effect on yield and fruit quality.
- Second, determine the influence of different P and K nutrient sources on tree performance. This allows for a comparison of the cost effectiveness of different formulations and the effects on nutrient management programs. We hypothesize that our detailed research will show that there is no effect of nutrient source on tree performance.
- Third, determine the relative importance of P or K on tree performance measures. Based on our own preliminary research, K is more influential on yield and fruit quality than P in high elevations, arid climate conditions, and alkaline soils typical of Utah. We hypothesize that K is more important to yield and fruit quality than P.

MATERIALS AND METHODS

The study was conducted at five different sites all in commercial tart cherry orchards in southern Utah County. Three sites (A, B, and C) are located in Santaquin, UT, USA. Two sites (D and E) are located in West Payson, UT. USA.

Treatment blocks at all sites were selected based on past production, tree uniformity, and nutrient management history. Each site consisted of mature producing tart cherry trees. Past production, tree uniformity, and nutrient management history varied among sites. Two sites (A and B) were used in 2010 and 2011, and three sites (C, D, and E) were only used in 2011. Sites A and B had similarly designed treatment blocks, and treatments at sites C, D, and E were similarly designed.

Site A:

Site Description:

Site A (39.58 N latitude, 1481 m elevation) consisted of trees planted in 1993 oriented north to south, with a tree spacing of 4.3 x 5.5 m. This site has a soil classification of Pleasant Vale loam and Lakewin gravelly fine sandy loam with a pH of 7.6 and 3.5% organic matter. The average annual production of these trees is between 50-100 kg/tree depending on growing conditions each year. The trees are large (5-6 m tall and 4 m wide) and each tree filled the space provided. There were no visible differences in bloom density among treatment plots in either 2010 or 2011. In 2010, approximately 80% of each tree was in full bloom on 10 May. Conditions in 2011 were similar and 90% of each tree was in full bloom around 10 May.

Cultural management at site A included annual applications of necessary nutrients for optimal tree and fruit growth, and competition management between the trees and understory was maintained using an herbicide strip free of weeds and an alleyway planted with a grass cover crop. Prior to this experiment, annual applications of N were applied at 317 g/tree, and for two years prior to the experiment applications of P and K were added at 72.6 g/tree P_2O_5 and 72.6 g/tree K_2O. Nutrients were applied by banding, within the herbicide strip, and in quantities sufficient for optimum tree growth and health. Application of nutrients typically occurred in the winter and early spring, depending on the crop load for the upcoming growing season.

Design specifics:

The experimental design at site A was a randomized block design with six replications. Ten treatments were applied within each replication. Four treatments were designed to test yield and fruit quality response to the rate of application of both P and K together and thus addressed the first objective of this study. Six additional treatments designed to determine the influence of different P and K formulations on the performance of the trees addressed the second objective of the project. One treatment was a control that received no additional nutrients.

The first treatment applications in 2010 were made from 24-27 May and were applied prior to a rain storm. The second treatment application was made 22 June 2010 and applied prior to a scheduled irrigation. Applications made in 2011 were first applied between 20-23 May just prior to a rainstorm. The second application was made 9 June 2011 prior to a scheduled irrigation (Table 3.2).

The four rate-response treatments consisted of four different rates of 16-16-16 fertilizer applied to large enough plots (23 trees) to obtain a full tank of harvested fruit that was tracked through commercial harvest and packing. The per-tree rates applied to each treatment were 0.23 kg, 0.45 kg, 0.91 kg, and 0.45 kg applied twice during the growing season. The six additional treatments employed various commercially-available P and K fertilizer formulations applied to six-tree plots at the currently recommended application rate of P and K (0.45 kg/tree). This entire study block at site A required 18 rows of trees (two rows of 23-tree plots, and one row of six-tree plots per replicated block).

Site B:

Site Description:

Site B (39.57 N latitude, 1524 m elevation) is an orchard oriented east to west, with a tree spacing of 4.3 x 5.5 m. The soil classification is Welby silt loam and Lakewin gravelly fine sandy loam with a pH of 7.9 and 2.0% organic matter. This orchard was planted in 1995. The trees are large (5 m tall and 4 m wide) and each tree has filled the space provided. The average annual production of these trees is between 30-75 kg/tree. The bloom density for this orchard in 2010 was about 75% of each tree in full bloom on 10 May and there were no visible differences among treatment plots. Crop year 2011 was similar with full bloom around 10 May and 85% of each tree in full bloom. There were no visible bloom differences in 2011 between treatment plots.

Cultural management at site B was moderate nutrient management (annual N application, occasional P and K application), competition management between the trees and understory was maintained by using an herbicide strip free of weeds, and a conservative alleyway planted with a grass cover crop. Prior to this experiment annual N applications were applied at 317.5 g/tree no prior P and K applications were made. Nutrients were been applied by banding within the herbicide strip, and in quantities sufficient to maintain tree growth and health. Application of nutrients generally occurs in the winter and early spring depending on the crop load.

Design Specifics:

The experimental design at site B was a randomized block design with eight replications. Ten treatments were applied within each replication. Five treatments were designed to test yield and fruit quality response to the rate of application of both P and K together, addressing the first objective of the study. Five additional treatments were designed to determine the influence of different P and K formulations on the performance of the trees addressed the second objective of the project. One treatment was a control receiving no additional P and K.

Rate-response treatments which consisting of five rates of 16-16-16 fertilizer were applied to eight-tree plots. The per-tree rates applied to each treatment were 0.23 kg, 0.45 kg, 0.91 kg, and 0.45 kg applied twice during the growing season. The five additional treatments employed various commercially-available P and K fertilizer formulations applied to eight-tree plots at the currently recommended application rate of P and K (equivalent to 0.45 kg/tree of 16-16-16). This entire study required 16 rows of trees (eight replicated blocks, with two rows of trees per replicated block).

The first treatment applications in 2010 were made from 24-27 May and were applied prior to a rain storm. The second treatment application was made 22 June 2010 and applied prior to a scheduled irrigation. Applications made in 2011 were first applied between 20-23 May just prior to a rainstorm. The second application was made 21 June 2011 prior to a scheduled irrigation (Table 3.2).

Site C:

Site Description:

Site C (39.59 N latitude, 1465 m elevation) is an orchard planted in 1997 on 4.3 X 5.5 m spacing. The soil classification is Keigley silty clay loam with a pH of 7.9 and 3.5% organic matter. The orchard is oriented north to south. The trees are of moderate size (3.5-4.5 m tall and 3 m wide) and are still growing to fill the space provided. The annual production for this orchard is between 30-50 kg/tree. The average bloom density for each tree at this site in 2011 was 90% full bloom around 10 May, with no visible bloom density differences among treatments.

Cultural management at site C included applying nutrients for tree growth when deficiency symptoms were visible (N only), competition management between the trees and understory was maintained by using an herbicide strip free of weeds, and an alleyway planted with a grass cover crop. Previous N additions were applied only when deficiency symptoms were present and were applied at 208.7 g/tree. Nutrients were applied by banding within the herbicide strip and in quantities necessary when tree health showed signs of decline. Application of nutrients generally occurs in the winter and early spring depending on tree need.

Design Specifics:

The experimental design at site C was a randomized block design with four replications. Eight treatments were applied within each replication. Two treatments were P and K sources applied separately, and five treatments of P and K fertilizer combined to meet the analysis ratio of 0-16-16 were applied at five different rates. The rates applied to each tree within each plot were 0.23 kg of 0-16-16, 0.45 kg, 0.91 kg, 0.45 kg applied twice, and 0.91 kg applied twice during the growing season. All plots, including the control plots, received 0.32 kg nitrogen (N).

The eight treatments were designed to test yield and fruit quality response to P and K application rate, as well as determine the influence of P and K applied alone, on the performance of the trees. The eight treatments were applied to 16-tree plots. The first treatments were applied on 20 May 2011 prior to a rainstorm. The second application of the two split treatments was applied on 22 June 2011 prior to a scheduled irrigation (Table 3.2).

Site D:

Site Description:

Site D (40.07 N latitude, 1393 m elevation) is an orchard planted in 1996 on 4.3 X 5.5 m spacing. The soil classification is Sanpete gravelly fine sandy loam with a pH of 8.5 and 1.5% organic matter. The orchard is oriented north to south. The trees are moderate in size (4-5 m tall and 3 m wide) and are managed to fill the space between the trees, but not the space between the rows. The annual production for this orchard is between 40-75 kg/tree. The average bloom density for each tree at this site in 2011 was 90% full bloom around 10 May, with no visible bloom density differences among treatments.

Cultural management at site D was moderate nutrient management (annual N application, occasional P and K application), competition management between the trees and understory was maintained by using an herbicide strip free of weeds, and an alleyway planted with a grass cover crop. Previous annual nutrient additions included: 453.6 g/tree N and 59.0 g/tree P_2O_5. Nutrients were been applied by banding within the herbicide strip, and in quantities sufficient to maintain tree growth and health. Application of nutrients generally occurs in the winter and early spring depending on the crop load.

Design Specifics:

The experimental design at site D was a randomized block design with four replications. Eight treatments were applied within each replication. Two treatments were P and K sources applied separately, and five treatments of P and K fertilizer combined to meet the analysis ratio of 0-16-16 were applied at five different rates. The rates applied to each tree within each plot were 0.23 kg 0-16-16, 0.45 kg, 0.91 kg, 0.45 kg applied twice, and 0.91 kg applied twice during the growing season. All plots, including the control plots, received 0.32 kg nitrogen (N).

The eight treatments were designed to test yield and fruit quality response to P and K application rate, as well as determine the influence of P and K applied alone, on the performance of the trees. The eight treatments were applied to 18-tree plots. The first treatments were applied on 20 May 2011 prior to a rainstorm. The second application of the two split treatments was applied on 22 June 2011 prior to a scheduled irrigation (Table 3.2).

Site E:

Site Description:

Site E (40.04 N latitude, 1393 m elevation) is an orchard planted in 1997 on 4.3 X 5.5 m spacing. The soil classification is Taylorsville silty clay loam with a pH of 8.2 and 2.0% organic matter. The orchard is oriented north to south. The trees are moderate in size (3-4 m tall and 3 m wide) and are still growing to fill the space provided. The annual production for this orchard is between 25-35 kg/tree. The average bloom density for each tree at this site in 2011 was 70% full bloom around 10 May, with no visible bloom density differences among treatments. However, the low bloom density can be attributed to the trees' competition for nutrients with the weeds and grass growing in the tree row and alleyway together over the life of the orchard.

The nutrient management history at this site has been very minimal over the lifetime of the trees. There have been no additions of N, P, or K prior to this study. Also, prior to this experiment there has been minimal understory management. The herbicide strip has a relatively large population of weeds which compete for nutrients. However, this year the management practices were adjusted and the competing weeds were controlled so that the trees were not competing for nutrients.

Design Specifics:

The experimental design at site E was a randomized block design with four replications. Eight treatments were applied within each replication. Two treatments were P and K sources applied separately, and five treatments of P and K fertilizer combined to meet the analysis ration of 16-16-16 were applied at five different rates. The rates applied to each tree within each plot were 0.23 kg 16-16-16, 0.45 kg, 0.91 kg, 0.45 kg applied twice, and 0.91 kg applied twice during the growing season. One control treatment that only received 0.32 kg nitrogen (N) was also part of the treatments.

The eight treatments were designed to test yield and fruit quality response to P and K application rate, as well as determine the influence of P and K applied alone, on the performance of the trees. The eight treatments were applied to 10-tree plots. The first treatments were applied on 21 May 2011 prior to a rainstorm. The second application of the two treatments was applied on 21-24 June 2011 prior to a scheduled irrigation (Table 3.2).

Various sources of P and K nutrients were used throughout the study. With these nutrient sources, a rate response comparison was possible as well as a formulation comparison. The rate-response comparison was designed to determine optimal rates of specific nutrients and the effects of those rates on yield and fruit quality. The nutrient ratio that was used for the rate response comparison was the balanced ratio of 16-16-16.

The formulation-response comparison was designed to compare effects of different sources of P and K on yield and fruit quality. Eight different formulations were prepared consisting of N, P, and K nutrient sources. The nitrogen source used was Urea (46-0-0) and held constant throughout the experiment.

Various P sources were used in the experiment. The P sources used were: Steric P III™, Mono Ammonium Phosphate (MAP, 11-52-0), and Triple Super Phosphate (TSP, 0-46-0). Steric P III™ (2-14-0) is a source of P that contains some MAP mixed with a proprietary organic carrier.

Various K sources were used in the experiment. The K sources used were: Steric K™, Potassium Magnesium Sulfate (KMag, 0-0-21), Potassium Sulfate (SOP, 0-0-50), and Potassium Chloride (KCl, 0-0-60). Steric K™ (1-0-7) is a K source containing some Potassium Nitrate, Potassium Sulfate, and Muriate of Potash mixed with a proprietary organic carrier. By varying P and K nutrient sources, the effects of each source on fruit quality and yield could be determined. Each of the different nutrient sources included in the study are currently used in the tart cherry industry for nutrient management. The first application of nutrients was applied in the early growing season prior to a rainstorm. The second application was applied during the growing season and was applied prior to scheduled irrigation (Table 3.23).

Liquid and water soluble nutrients were applied using a six-tank motor driven sprayer (Rears Manufacturing, Eugene, OR), and the granular materials were applied using a three point, PTO driven, side discharge spreader (Herd Seeder Co., Logansport, IN).

From each of the individual sites, fruit and leaf tissue samples were collected throughout the growing season. At sites A and B, samples were taken every 14 days throughout the 2010 and 2011 growing seasons, and were taken from the top half of the tree. At sites C, D, and E samples were taken prior to harvest during the 2011 season.

The fruit tissue samples were tested for soluble solids content and titratable acidity (both measures of fruit quality). The flesh from the fruit samples and the juice from the frozen fruit were thawed in a 30 °C water bath and filtered. Soluble solids content was analyzed using a bench top refractometer (Abbe-3L, Bausch and Lomb). Fruit acid content was determined by measuring titratable acidity (Ozkan et al., 2002; Poll et al., 2003). Titratable acidity was determined on a 5 mL aliquot of the unfiltered flesh and juice samples, by titrating with 0.1 N NaOH in 95 mL of double distilled water to a final pH of 8.1 (Papenfuss, 2010) using a Brinkman 719 S Titrino titrator. Fruit sugar and acid content are important factors in fruit quality.

Data analysis for yield, sugar, and acid concentrations were compared and tested for correlations. At harvest time yield was measured at each site in the different plots. Yield was determined by measuring fruit volume in the harvest tank at the beginning and ends of each plot and employed the established industry conversion constant of 7.94 kg/cm. Plot sizes at each site were large enough to determine fruit yield. Treatment means were compared using PROC MIXED, ANOVA (V.9.2; SAS Institute, Inc., Cary, NC, USA).

RESULTS AND DISCUSSION

General Seasonal Results:

Tart cherry tonnage was significantly lower in 2010 across the entire Utah fruit industry. Utah produced a total of only 10,433 metric tons (23.0 million pounds) compared to an average of 11,793 metric tons (26 million pounds) over the last 10 years. The decrease in yield can be attributed to environmental factors, tree health, and recovery from the previous crop load, among other contributing factors. Fruit quality measures increased substantially in 2010 due to the decrease in fruit tonnage. Tart cherry tonnage increased again in 2011, to 15,694 metric tons (34.6 million pounds). The increase in yield was primarily due to no spring frosts and improved tree health from the small crop in 2010.

Growing conditions for the state of Utah in 2010 and 2011 were similar. In 2010 cool temperatures and very moist conditions shifted the growing season one to two weeks later than average. Spring of 2010 also brought spring frosts which resulted in a decrease in fruit set. Throughout the growing season, conditions were cool with significant amounts of moisture. The smaller crop brought larger fruit with increased fruit quality from the previous two years. In 2011 on the other hand, with similar growing conditions to 2010, there were no significant spring frosts to reduce crop load. Cool temperatures and significant moisture also delayed the 2011 growing season 10 to 14 days. Spring and early summer conditions were cool and moist. Conditions throughout the summer of 2011 were significantly drier and warmer than in 2010. With a larger crop and warmer conditions later in the growing season, the industry average yield was significantly increased in 2011. Increased yields also decreased fruit quality measures in 2011.

Fertilizer prices continue to change as prices of energy changes. This is due to the energy heavy process of fertilizer manufacturing as well as freight to transport the fertilizer. Table 3.3 shows the individual nutrient inputs that were used in this experiment as well as the price of each of the individual nutrients based on 427 trees per hectare. Each source of N, P, and K was used to compare the effects of applied nutrients on yield and fruit quality. Table 3.4 shows the cost of each of the rates and formulations that were used in both comparisons that were applied at all sites. Fertilizer costs are based on 427 trees per hectare. The nutrient inputs used at sites C and D were TSP (0-45-0) and KCL (0-0-60). The P and K inputs used at site E were the same as used at sites C and D and also included Urea (46-0-0) as the N source. The nitrogen source was added here because no N had been previously applied, whereas the other four sites, N was previously applied at a rate of 0.32 kg per tree.

Yield and Fruit Quality Results:

Aggressive Nutrient Management Site (A):

At site A where, historically, nutrients were managed and applied very aggressively yield and fruit quality for both 2010 and 2011 followed a similar trend. Due to environmental conditions in 2010, crop load was smaller than 2011 which resulted in higher soluble solids and acidity in the fruit but lower base yields. Independent of the annual difference in conditions, however, fertilizer application rate was not correlated with yield in either year. However, there were some significant differences on soluble solids and acidity among the different rates applied. Yield and fruit quality measures showed differences among formulation treatments in 2010.

The average yield in 2011 was much higher than in 2010. The increased yield resulted in a decrease in soluble solids as well as titratable acidity in the fruit. Among treatments in the rate comparison there were no significant differences in yield and fruit quality in either 2010 or 2011. However, there was a slight decrease in yield in the rate comparison in 2011. Also there were significant differences among treatments in the P and K comparisons in 2010 only. There were no significant differences on fruit yield in 2011 or on soluble solids or acidity in either year (Table 3.5).

Despite large differences in yield and fruit quality measures between years, it can be concluded that nutrient need in the plant is satisfied in a small crop as well as a large crop. The slight yield reduction in 2011 in the rate comparison might indicate that sufficiency has been reached and by adding more P and K yield will not increase. The addition of P and K nutrients at a site that has been aggressively managed will maintain adequate levels of yield and fruit quality.

Moderately Aggressive Nutrient Management Sites (B and D): Yield and fruit quality measures show large differences between treatments. Sites B and D consisted of moderately aggressive nutrient management programs. The management history at site B was annual N applications and no previous P and K applications. At site B during 2010 and 2011 there were significant differences that occurred between treatments, but there are no clear trends. Rather, the responses to rate and formulation are quite unsettled with large fluctuations between treatments. In the 2010 rate comparison the rate 0.45 kg per tree of 16-16-16 fertilizer resulted in yield that was significantly different from all other rates used and showed a significant quadratic relationship. The P and K formulation comparisons resulted in similar noisy data and statistical differences but did not result in one formulation being truly better than the rest. Soluble solids and acidity showed similar results. The P and K formulations showed significant differences on yield over the control treatment but among treatments there were no significant differences. There are no significant differences on soluble solids or acidity from the P comparison, and the K comparison showed significant differences on soluble solids but not acidity.

Average yield increased in 2011 at site B which resulted in a decrease in fruit quality. This was similar to the yield results between the two years that occurred at site A. The 2011 rate comparison showed similar results to that of 2010 with a significant quadratic trend. The rate of 0.45 kg per tree of 16-16-16 produced the largest yield and is significantly different from the other rates. There were significant differences of treatments over control on yield in 2011 in both formulation comparisons, but there are not differences among treatments. Soluble solids and acidity decreased in 2011 in both rate and formulation comparisons and there were some significant differences among treatments. Even though there were differences no formulation is clearly better than another (Table 3.6).

Site D is another site under historically moderately aggressive nutrient management. Nutrient management history at this site consisted of annual N and P applications but no previous K applications. Treatments were only applied in 2011, and yield and fruit quality measures were analyzed to determine nutrient differences. There were significant yield differences among treatments in the rate comparison as well as the formulation comparison. The rate response comparison up to 0.91 kg/tree of 0-16-16 shows a significant quadratic trend. Soluble solids and acidity show similar trends for the rate response comparison. Formulation had an effect on yield as well as titratable acidity. There were significant yield and acidity differences among treatments. The addition of P at site D appears to have had greater influence of yield and fruit quality than K additions (Table 3.7).

Sites with historically moderately aggressive nutrient management appear to be in a period of transition. Because additional nutrients have been applied when deficiency symptoms arise, variable residual nutrient levels in soils produce no clear trends among fertilizer rate or formulation treatments on yield and fruit quality. The variation indicates that regular application of nutrients is needed to stabilize yield and fruit quality in Utah orchards.

Less Aggressive Nutrient Management site (C):

Site C is the only site where, historically, nutrients were applied when deficiency symptoms became severe (N only). Yield increased as the rate of 0-16-16 fertilizer increased up to 0.45 kg per tree applied one time. This particular rate was significantly higher than any of the other rates including the split applications. Based on trend analysis there is a significant quadratic relationship at this site. The application of P and K alone also positively increased yield and resulted in significantly higher yields over control.

The rate comparison reveals an effect on soluble solids, but no clear trend can be determined to indicate whether or not a treatment was more effective than another. Acidity was not affected by the addition of different rates of fertilizer. Soluble solids content was not affected by the addition of P and K, nor was acidity affected (Table 3.8). Average fruit quality was higher at this site because of lower yields.

No Prior Nutrient Management site (E):

During the period in which the trees at site E have been in production, no nutrient additions were made. Yield and fruit quality measures were affected by increasing rates of N, P, and K nutrients. Yield increased as rate increased up to 0.91 kg per tree. Trend analysis indicates a significant linear trend at this site. The split applications of N, P, and K had no more significant effects on yield. Soluble solids and acidity were not affected by increasing rates of 16-16-16 fertilizer.

Yield was affected by the different nutrient formulations. The addition of K alone increased yield significantly more than the application of P alone and the control. Soluble solids and acidity were not affected by the different nutrient formulations. Base yield was low at this site which resulted in an increase in base fruit quality measures Table (3.9). Soluble solids and acidity values were the highest at this site due to the small crop as well as the added benefits from receiving additional nutrients during the growing season.

The effectiveness of fertilizer rates and formulations vary depending on the nutrient management history of any given site. Sites with aggressive nutrient management history (annual N, P, and K additions) do not respond to increased rates or sources of nutrient applications (Figure 3.1). Yield results in 2011 however, show a significant downward slope (Table 3.10). This decrease indicates that plant need has been satisfied previously and by adding additional nutrients there is no added benefit. The question that arises is how long these levels of yield and fruit quality will be maintained if additional P and K applications are not made. Harvest removes significant amounts of P and K and those nutrients must be replenished to continue to produce high quality fruit.

Sites with historically moderately aggressive nutrient management show the most variation among the different nutrient rates and sources of nutrients applied. Yield and fruit quality measures are affected by P and K additions, but because of transitional and variable soil nutrient levels, there are no trends that clearly indicate which rate or formulation will give the best results (Figure 3.2). At site B the 0.45 kg per tree rate of 16-16-16 fertilizer indicates the rate for the largest yield increase. This is a significant quadratic trend (Table 3.10) and indicates that rates above 0.45 kg/tree will have no effect on increasing yield. The addition of P clearly had an effect at site D and will need to be maintained to reach optimum levels of yield. But no other trends can be determined. Nutrients should be applied in order to move such sites to aggressive nutrient management programs and receive the most benefit from P and K additions.

For sites with little to no nutrient management history it is necessary to annually apply P and K nutrients to increase yield and fruit quality. In these situations K additions appear to provide the most benefit with regard to yield. Additions of 0.45 to 0.91 kg per tree of 16-16-16 fertilizer increases yield the most, and there is no added benefit splitting the application. For such low residual soil nutrient sites, increasing rates of 16-16-16 fertilizer will increase yield (Figure 3.3). A question arises of what affects are going to be seen in years to come from the 2011 nutrient applications. It remains to be determined if yield and fruit quality levels will be maintained or if there will be a rise towards optimum levels as well as how long before yield levels reach the same levels at which a moderate or aggressive site produces.

Even though there are not many significant differences among rate or formulation treatments, a significant conclusion can be made: the conventional Triple-16 fertilizer formulation, which is the least expensive (Table 3.4), will result in yields that are just as good as those produced by more expensive formulations. Fruit quality measures reveal the same results: more expensive formulations are no more effective than Triple-16. Analysis of leaf tissue samples (based on recommendations discussed previously) are the most effective way to determine nutrient thresholds as well as optimum timing of application for nutrient sufficiency.

The addition of P and K are not the main limiting factors to the yield and fruit quality at the different sites. There are many different contributing factors that change these levels between sites. Some of them include: irrigation management, tree architecture, as well as previous nutrient management practices. Irrigation management practices varied among sites and contribute to differing yield levels. Timing and quantity of irrigation application must by sufficient for optimal vegetative and reproductive growth as well as good tree health which can contribute to increased yield levels. Tree architecture also influences yield levels. Tree pruning determines the structure of trees and will contribute to adequate vegetative and reproductive growth. Tree that are large and have an adequate leaf to fruit ratio will have higher yield levels than those that are not structured for such. These factors also contribute to the contrast in yield levels between sites and must be considered as part of the management practices.

These results and conclusions from this thesis however, provide tart cherry producers adequate information to continue to apply additional P and K nutrients, and if the grower has not implemented the addition of these nutrients into the nutrient management program historically, there is evidence of justifiable benefit of additional P and K applications.

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Table 3.1. Standard sufficiency ranges for foliar nutrient contents of important Utah fruits. Contents are based on percent of each nutrient contained within leaves from each respective fruit.

Sufficient Foliar Nutrient Content				
Element	Apple	Pear	Peach	Cherry
% Nitrogen	1.5-3.0	1.8-2.6	2.5-3.5	2.2-3.4
% Phosphorus	0.11.0.30	0.12-0.25	0.15-0.4	0.16-0.4
% Potassium	1.2-2.0	1.0-2.0	1.5-2.5	1.0-3.0

Table 3.2. Fertilizer application dates for all sites in both 2010 and 2011. Applications in May were made prior to a large rainstorm and applications in June were made prior to a scheduled irrigation turn.

Application Date	Site
2010	
24-25 May	A
25-27 May	B
22 June	A & B
2011	
20 May	C
21 May	A, B, D, & E
23 May	A & B
9-10 June	A & D
21-22 June	B, C, & E

Table 3.3. Material composition, amount, and price of each nutrient source applied during 2010 and 2011. Prices are based on the industry prices from March 2012. The amounts of each nutrient input are based on the need of each nutrient to make the formulation equivalent to 0.45 kg of 16-16-16 per tree. The dollars per hectare based on amount applied is for 427 trees per hectare.

Material		Units	$/Metric Ton	Rate/Tree	$/Hectare based on Amount Applied
Triple-16	16-16-16	kg	$542	0.45 kg	$115.67
Urea	46-0-0	kg	$551	0.113 kg	$39.34
				0.122 kg	$31.67
				0.136 kg	$35.31
				0.159 kg	$41.28
MAP	11-52-0	kg	$667	0.141 kg	$44.25
TSP	0-45-0	kg	$634	0.163 kg	$48.65
SOP	0-0-50	kg	$1088	0.145 kg	$74.30
KMag	0-0-21	kg	$671	0.331 kg	$104.59
KCL	0-0-60	kg	$557	0.122 kg	$31.99
Steric P	2-14-0	liters	$1827	0.454 liters	$390.43
Steric K	1-0-7	liters	$1650	0.908 liters	$705.26

Table 3.4. Cost per hectare based on each rate and formulation used at all sites. Fertilizer rates were applied on a per tree basis. Nutrients for the formulation comparison were mixed as to produce an equivalent formulation to 0.45 kg of the 16-16-16 mix.

Location	Nutrient Source	$/Hectare of Formulation
Sites A and B	Rate (16-16-16; kg/tree)	
	0.23	$57.84
	0.45	$115.67
	0.91	$231.34
	Formulation (rate equivalent to 0.45 kg/tree 16-16-16)	
	16-16-16	$115.67
	Urea, Steric P, Steric K	$1130.99
	Urea, Steric P, SOP	$500.04
	Urea, MAP, Steric K	$781.18
	Urea, MAP, KMag	$180.51
	Urea, MAP, SOP	$150.22
Sites C and D	Rate (0-16-16; kg/tree; Urea, TSP, KCL)	
	0.23	$40.32
	0.45	$80.64
	0.91	$161.28
	1.82	$322.56
	Formulation (rate equivalent to 0.45 kg/tree)	
	0-16-0 (TSP)	$48.65
	0-0-16 (KCL)	$31.99
Site E	Rate (16-16-16; kg/tree; Urea, TSP, KCL)	
	0.23	$40.32
	0.45	$80.64
	0.91	$161.28
	1.82	$322.56
	Formulation	
	16-16-0 (Urea and TSP)	$48.65
	16-0-16 (Urea and KCL)	$31.99

Table 3.5. Yield and fruit quality results (soluble solids and acidity) from site A in both 2010 and 2011. Yield values were measured in kilograms per tree. Soluble solids are a percent of total solids contained in the fruit juice and acidity is measured in meq acid per 100 mL of solution.

		2010			2011		
Treatment	Rate (kg/tree)	Yield (kg/tree)	Soluble Solids (%)	Acidity (meq)	Yield (kg/tree)	Soluble Solids (%)	Acidity (meq)
Rate Comparison							
Control	0	49.1	15.2	10.4	103.6	10.9	7.10
16-16-16	0.23	47.9	14.5	9.70	100.6	11.8	7.32
	0.45	49.0	14.0	10.6	99.9	11.4	7.09
	0.91	50.5	15.5	11.4	96.6	11.0	6.77
	0.45 @2X	49.7	14.1	10.4	94.0	12.4	7.77
P Formulation Comparison							
Control	0	49.1 a[z]	15.2	10.4	103.6	10.9	7.10
16-16-16	0.45	49.0 a	14.0	10.6	99.9	11.4	7.09
Steric P	0.45	46.2 a	15.1	11.2	102.0	11.5	7.46
Steric P and K	0.45	44.1 b	14.4	11.3	91.2	11.7	7.34
K Formulation Comparison							
Control	0	49.1 a	15.2	10.4	103.6	10.9	7.10
16-16-16	0.45	49.0 a	14.0	10.6	99.9	11.4	7.09
Steric K	0.45	45.5 ab	14.2	11.0	92.1	11.3	6.73
KMag	0.45	45.0 ab	14.4	11.1	93.1	10.9	7.17
SOP	0.45	47.0 ab	13.8	10.9	98.9	11.4	7.05
Steric P and K	0.45	44.1 b	14.4	11.3	91.2	11.7	7.33
Analysis of Variance		P-value			P-value		
Overall		0.007	0.720	0.348	0.738	0.571	0.405
Rate: Linear		0.375	0.707	0.087	0.299	0.842	0.290
Rate: Quadratic		0.677	0.123	0.255	0.889	0.262	0.481

[z]Means within a column followed by the same letter are not significantly different (P>0.05) according to LSD.

Table 3.6. Yield and fruit quality results (soluble solids and acidity) from site B in both 2010 and 2011. Yield values were measured in kilograms per tree. Soluble solids are a percent of total solids contained in the fruit juice and acidity is measured in meq acid per 100 mL of solution.

Treatment	Rate (kg/tree)	2010 Yield (kg/tree)		2010 Soluble Solids (%)		2010 Acidity (meq)		2011 Yield (kg/tree)		2011 Soluble Solids (%)		2011 Acidity (meq)	
Rate Comparison													
Control	0	25.3		15.2		10.4		63.7		12.5		7.01	
16-16-16	0.23	27.9		14.5		9.70		68.9		12.9		6.88	
	0.45	35.1		14.0		10.6		76.1		11.0		6.51	
	0.91	29.7		15.5		11.4		67.9		12.5		6.93	
	0.45 @2X	28.5		14.1		10.4		69.4		12.4		6.89	
P Formulation Comparison													
Control	0	25.3	b[z]	15.1		10.4		63.7	b	12.5	ab	7.01	
16-16-16	0.45	35.1	a	15.3		10.6		76.1	a	11.0	b	6.51	
Steric P	0.45	32.8	ab	14.2		11.2		66.5	ab	13.3	a	6.49	
Steric P and K	0.45	32.7	ab	13.5		11.3		65.7	ab	11.5	b	6.60	
K Formulation Comparison													
Control	0	25.3	b	15.1	ab	10.9		63.7	b	12.5	ab	7.01	a
16-16-16	0.45	35.1	a	15.3	ab	10.9		76.1	a	11.0	b	6.51	ab
Steric K	0.45	33.5	ab	13.6	b	11.6		70.0	ab	12.2	ab	6.30	b
KMag	0.45	31.0	ab	13.5	b	11.5		70.5	ab	12.3	ab	6.71	ab
SOP	0.45	27.8	b	16.5	a	11.4		69.7	ab	12.8	a	6.52	ab
Steric P and K	0.45	32.7	ab	13.5	b	11.3		65.7	ab	11.5	ab	6.60	ab
Analysis of Variance		P-value						P-value					
Overall		0.352		0.082		0.353		0.786		0.350		0.068	
Rate: Linear		0.152		0.973		0.580		0.492		0.774		0.750	
Rate: Quadratic		0.031		0.771		0.823		0.067		0.174		0.140	

[z]Means within a column followed by the same letter are not significantly different (P>0.05) according to LSD.

Table 3.7. Yield and fruit quality results (soluble solids and acidity) from site D in 2011. Yield values were measured in kilograms per tree. Soluble solids are a percent of total solids contained in the fruit juice and acidity is measured in meq acid per 100 mL of solution.

	2011			
Treatment	Rate (kg/tree)	Yield (kg/tree)	Soluble Solids (%)	Acidity (meq)
Rate Comparison				
Control	0	59.5	10.5	8.54
16-16-16	0.23	80.6	11.5	7.95
	0.45	60.9	12.3	7.70
	0.91	64.0	11.1	8.00
	0.45 @2X	72.2	12.7	8.23
	0.91 @2X	61.8	11.5	7.84
Formulation Comparison				
No P and K	0	59.5 b[z]	10.5	8.54 a
Phosphorus	0.45	71.7 a	11.2	7.75 b
Potassium	0.45	64.5 ab	11.5	7.98 ab
Analysis of Variance		P-value		
Overall		0.001	0.068	0.051
Rate: Linear		0.492	0.592	0.183
Rate: Quadratic		0.033	0.107	0.043

[z]Means within a column followed by the same letter are not significantly different (P>0.05) according to LSD.

Table 3.8. Yield and fruit quality results (soluble solids and acidity) from site C in 2011. Yield values were measured in kilograms per tree. Soluble solids are a percent of total solids contained in the fruit juice and acidity is measured in meq acid per 100 mL of solution.

	2011				
Treatment	Rate (kg/tree)	Yield (kg/tree)		Soluble Solids (%)	Acidity (meq)
Rate Comparison					
Control	0	45.7		13.6	7.53
16-16-16	0.23	48.8		12.3	6.64
	0.45	57.0		13.1	7.34
	0.91	52.3		14.2	6.67
	0.45 @2X	48.3		13.2	7.76
	0.91 @2X	46.5		12.0	6.66
Formulation Comparison					
No P and K	0	45.7	b[z]	13.6	7.53
Phosphorus	0.45	53.8	ab	12.6	6.82
Potassium	0.45	58.8	a	12.7	6.73
Analysis of Variance		P-value			
Overall		0.118		0.156	0.651
Rate: Linear		0.116		0.195	0.521
Rate: Quadratic		0.090		0.116	0.981

[z]Means within a column followed by the same letter are not significantly different (P>0.05) according to LSD.

Table 3.9. Yield and fruit quality results (soluble solids and acidity) from site E in 2011. Yield values were measured in kilograms per tree. Soluble solids are a percent of total solids contained in the fruit juice and acidity is measured in meq acid per 100 mL of solution.

	2011			
Treatment	Rate (kg/tree)	Yield (kg/tree)	Soluble Solids (%)	Acidity (meq)
Rate Comparison				
Control	0	30.9	14.1	9.76
16-16-16	0.23	33.6	14.4	9.58
	0.45	36.4	13.7	9.89
	0.91	38.5	13.9	9.50
	0.45 @2X	37.4	15.0	10.4
	0.91 @2X	38.8	13.8	9.91
Formulation Comparison				
No P and K	0	30.9 b[z]	14.1	9.76
Phosphorus	0.45	34.9 b	14.2	9.74
Potassium	0.45	42.1 a	14.4	9.95
Analysis of Variance		P-value		
Overall		0.008	0.562	0.523
Rate: Linear		0.004	0.528	0.681
Rate: Quadratic		0.447	0.750	0.708

[z]Means within a column followed by the same letter are not significantly different (P>0.05) according to LSD.

Table 3.10. Yield trends at sites A, B, and E. Site A has a historically aggressive nutrient management program and indicates that there is a slight decrease in yield as rate increases. Site B has a historically moderate aggressive nutrient management program and the trend indicates increased yields as rate increases up to 0.45 kg/tree of 16-16-16. Site E had no previous nutrient additions and as rate increases to 0.91 kg/tree yield also increases significantly.

Site	Regression Equation	R^2	P-value	Trend (P-value)
A	$Y = -6.91x + 103.04$	0.95	0.0242	Decreasing (0.0242)
B	$Y = -43.13x^2 + 45.01x + 62.93$	0.90	0.3161	Increasing (0.2170)
E	$Y = 8.25x + 31.55$	0.74	0.0307	Increasing (0.0307)

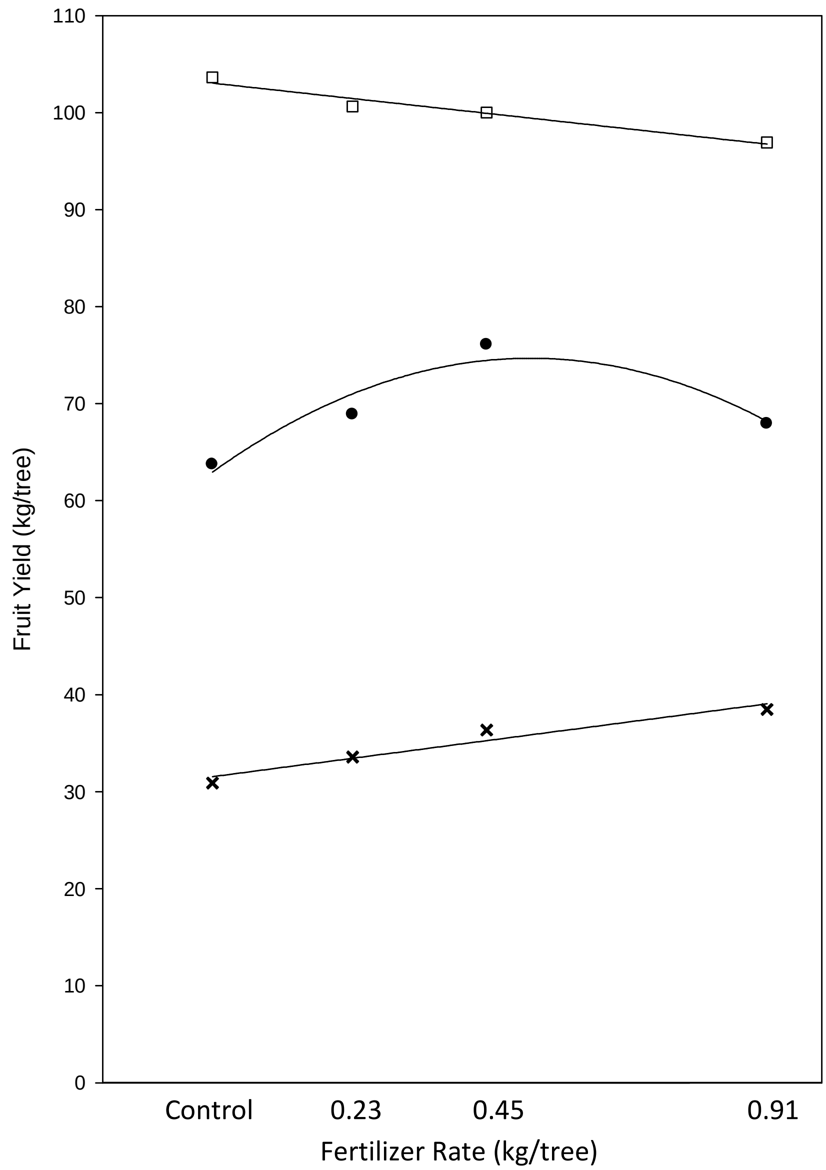

Figure 3.1. Fruit Yield results (kg/tree) in 2011 from site A (), site B (), and site E (x). Yields at site A (aggressive nutrient management) decreased slightly but were maintained. Yields at site B (moderately aggressive nutrient management) increased up to 0.45 kg/tree. Yields at site E (no prior nutrient management) increased as rates increased up to 0.91 kg/tree.

CHAPTER 4

MACRONUTRIENT MANAGEMENT FOR UTAH ORCHARDS[2]

Introduction

Proper fertility management is necessary to maintain fruit tree productivity, maximize the quality and health benefits of the fruit, and optimize the profits for the producer and processor. Much of the research that has been conducted on fruit tree responses to fertilizer application was conducted in the prominent production regions of the country, which are very different from Utah in both climatic and soil conditions.

Typical Nutrient needs for Tree Fruits

Fruit trees need to maintain an appropriate balance between vegetative growth and reproductive (fruit) growth. This growth balance is partially influenced by the availability of macronutrients, including: nitrogen (N), phosphorus (P), and potassium (K). N, P, and K are used by plants for structure, nutrient transport, and movement of water, which are among many other important functions. The lack of macro nutrients or nutrient imbalances may result in decreases in both vegetative growth as well as fruit yield. Also, fruit ripening and quality can be negatively affected when nutrient deficiencies are present. Generally, leaf tissue nutrient content is a good basis for determining plant needs.

Nitrogen

Nitrogen deficiency can be detected visually. Trees with N deficiency have little to no new shoot growth. Deficient leaves are pale green to yellow. Symptoms first

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[2]Coauthored by S.D. Rowley, G.E. Cardon, and B.L. Black

appear in older leaves because N moves form older tissue into actively growing younger leaves. Leaves from deficient trees tend to drop earlier in the fall. Fruit set might be light and mature fruits can be smaller and mature somewhat earlier than usual. In-season additions of N can be made, but should be made at least six weeks prior to fruit ripening to ensure optimum fruit quality at harvest. Fruit from trees with excess N can color poorly and lose firmness in storage. Excess N can result in dark green leaves that remain on the tree late in the fall. Growth tends to continue late into the fall and trees will have delayed dormancy and become more susceptible to winter injury. In orchard crops there is a tradeoff between vegetative growth and fruit yield. Too much vegetative growth may reduce fruit set and yield the following year. Insufficient new vegetative growth will also limit long term productivity.

In general, the following guidelines are suggested for Utah fruit crops. Typical nitrogen needs are between 0.01 to 0.04 lbs N per tree, per year of age with a limit of 0.3 lbs N per tree. Vegetative growth is the primary indicator for N requirements. New growth in younger trees should be between 10 and 30 inches per year, depending on tree type (see Table 4.1), but in older trees it should be between 4 to 18 inches depending on tree type. If the growth is greater than this, adjust the N rate down in subsequent additions, and conversely if the rate of growth is too low. The amount that needs to be applied to reach this range will depend on soil texture, soil organic matter content, degree of dormant pruning, etc.

Phosphorus and Potassium

The level of P and K in the soil doesn't change as rapidly as that of nitrogen, so their management is monitored more effectively by soil testing (at a depth of 1 foot and 2 feet, within the tree row) and periodic tissue sampling (at each important stage of growth) for sufficiency.

Phosphorus (P) is critical to root growth and function and the proper cycling of energy in the plant. Phosphorus deficiency symptoms affect older leaves first which may be small and bluish green on the margins. Other symptoms might include: reduced flowering, decrease in fruit quality, and delayed fruit maturity. Phosphorus is not very mobile in the soil, so sufficiency at the time of planting a new orchard, or renovation of orchard sections, is important for new plant establishment. Sufficient P should be applied and incorporated within the root zone of new trees before planting. In older plantings, excess P can cause imbalances in the uptake of zinc (Zn) and iron (Fe) and adjustment is best made on soil test levels. Mid-season adjustment of P levels in soils is generally not practical, so providing adequate levels at the beginning of the season is the best strategy for management. Annual adjustment of P nutrition is recommended with the use of Mono-ammonium Phosphate.

Potassium (K) is critical in the water relations of plants and in the assimilation and cell-to-cell transfer of other nutrients, particularly calcium (Ca) which is so important for fruit quality, particularly in pome fruits. Potassium deficiency symptoms are usually yellowing of leaf tissue (later turning to a bronze color and eventually death) along the margins and appear in older leaves first. Levels of K in Utah soils are regulated by the weathering of clay minerals and are generally sufficient without fertilizer application. However, on sandy or gravelly soils low in clay content, K deficiencies do occur and will often be expressed by Ca or other micronutrient imbalances in the plant. In-season adjustment of K nutrition is possible with foliar sprays of Potassium Chloride or Potassium Sulfate solutions, or injection of these materials into the irrigation water. Adequate tissue levels of N, P, and K for fruit trees in Utah are given in Table 4.2.

It has been observed that in high fruit load situations, fruit quality (as measured by soluble solids and titratable acidity) tends to decrease. Recent work in Utah has shown that supplemental phosphorus (P) and potassium (K) improve fruit quality under high crop load conditions when conventional soil tests would indicate sufficiency. Tart cherry is Utah's primary fruit crop, and P and K additions could also benefit fruit quality in heavy crop years.

Case Study: P and K Management in Tart Cherries

Nutrient management is an important part of successful tart cherry production. With the recent increase in input costs, including fertilizer costs, additions of fertilizer to improve fruit quality need to be carefully considered. In addition to fertilizer rate, time of application is also an important consideration. A range of N, P, and K rates and formulations were applied to replicate plots of mature tart cherries (*Prunus cerasus* 'Montmorency') on several Utah County farms in 2010 and 2011. Yield and fruit quality characteristics were compared.

At sites with historically aggressive nutrient management programs additions of P and K maintained adequate yield and fruit quality, but showed no significant increase among treatments (Figure 4.1). At the aggressively managed site N, P, and K additions have been (on average) about 1 pound per tree of 16-16-16 annually over the past four to five years. Fertilizer additions did result in a significant increase in yield (but not in fruit quality) at sites where nutrient management programs were historically much less aggressive (Figure 4.2). In order to increase yield and fruit quality where nutrient management is much less aggressive a minimum of 1 pound of Triple-16 (16-16-16) per tree (173 lbs/acre) should be applied in the early growing season.

Summary

Applying additional P and K to producing tart cherry trees will positively affect yield and fruit quality. Yield levels will be maintained at historically aggressive managed sites and will increase at both moderately and minimally managed sites with the additions of P and K. Fruit quality levels are maintained with the addition of P and K at both aggressively and moderately managed sites and increase slightly at minimally managed sites.

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Table 4.1. Sufficient annual vegetative growth ranges of important Utah fruits. Growth ranges for young trees as well as mature trees are measured in inches.

Sufficient Annual Vegetative Growth		
Tree Fruit	Young Tree	Mature Tree
Apple	10 to 20	4 to 10
Pear	20 to 30	12 to 18
Peach	10 to 24	8 to 15
Cherry	10 to 20	8 to 15

Table 4.2. Standard adequacy ranges for foliar nutrient contents of important Utah fruits.

	Sufficient Foliar Nutrient Content			
Element	Apple	Pear	Peach	Cherry
% Nitrogen	1.5-3.0	1.8-2.6	2.5-3.5	2.2-3.4
% Phosphorus	0.11.0.30	0.12-0.25	0.15-0.4	0.16-0.4
% Potassium	1.2-2.0	1.0-2.0	1.5-2.5	1.0-3.0

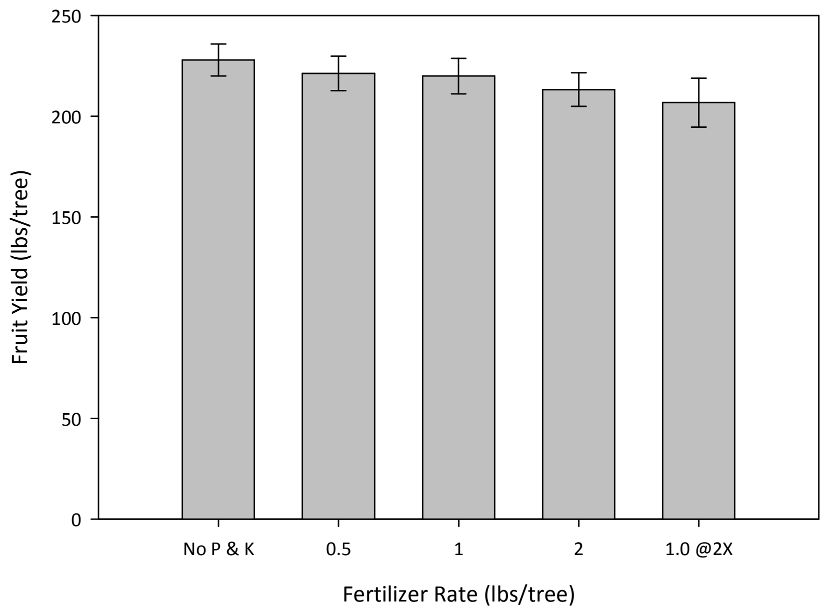

Figure 4.1. Yield results from an aggressive nutrient management site (annual N, P, and K additions). Fruit yield is measured in lbs/tree. Fertilizer rate is different rates of 16-16-16 fertilizer and is measured in lbs/tree.

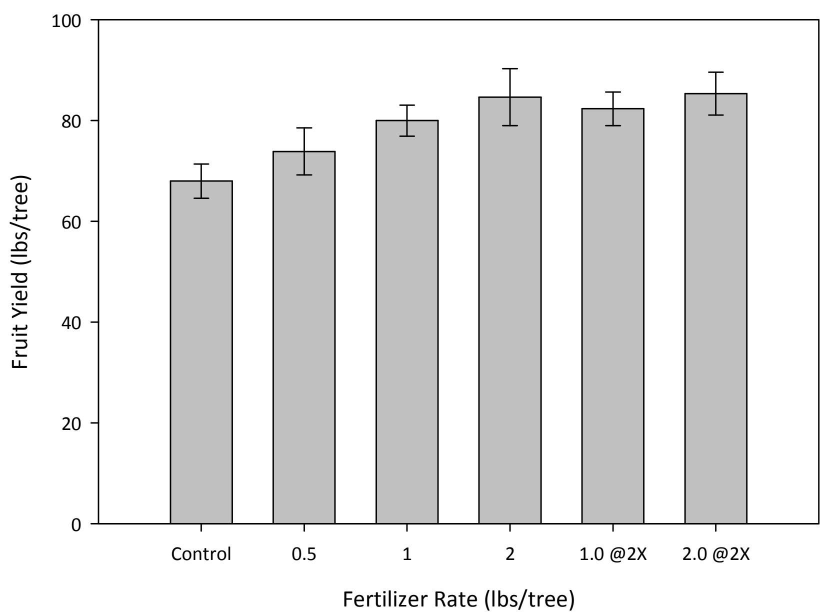

Figure 4.2. Yield results from a site with less aggressive nutrient management (no previous history). Fruit yield is measured in lbs/tree. Fertilizer rate is different rates of 16-16-16 fertilizer and is measured in lbs/tree.

CHAPTER 5

SUMMARY

The commercial tree fruit industry in Utah has a total of 2,688 hectares in operation with an estimated utilized product value of $24 million (National Agricultural Statistics Service data for 2010) which accounts for about 11% of crop-related cash receipts in Utah, and is surpassed only by hay and wheat. Utah is the second leading tart cherry producer in the United States, behind Michigan. Over the past three years, tart cherry production in Utah has fluctuated significantly, but tart cherry is Utah's most important fruit crop with 1,335 producing hectares and a reported crop value of $9.18 million from the 2009 crop (NASS, 2010).

Over the last four decades Utah's population has tripled and is projected to continue that increase over the next decade (US Census Bureau, 2009). With the loss of prime farm land, the number of fruit producing hectares has decreased dramatically. As the popularity of the local-food movement increases, questions arise as to the ability of individual states to generate sufficient produce for local demands.

Given the need for Utah-specific nutrient management guidelines for sustainable production, and the need to meet local produce demands from increasingly marginal orchard lands, this work has a two-fold purpose: 1) to review data on population growth, fruit consumption and fruit production to determine the extent to which Utah's fruit industry can meet increasing demands for local produce, and 2) to test fertilizer rate and formulation combinations that have the ability to maintain fruit production and quality levels on increasingly marginal lands in Utah.

To meet the first purpose of this work, state population and future population estimates were obtained from the U.S. Census Bureau (2009). Fruit acreage estimates and statewide annual production from 1989 to 2009 were obtained from the Utah Agriculture Statistics and Utah Department of Agriculture and Food Annual Reports (UASS, 2010). Prior to 1989, acreage and production data were obtained from quinquennial Census of Agriculture reports (USDA-NASS, 2007). Per capita fruit consumption was obtained from United States Department of Agriculture – Economic Research Service reports (USDA-ERS, 2011) based on nationwide food disappearance estimates. Regression analysis was carried out using the curve-fitting feature of SigmaPlot (version X, Systat Software, Inc., San Jose, California, USA) to project the ability of Utah fruit producers to meet future local produce demands.

Projections indicate that continued increases in Utah's population, and the growing local-food movement, will result in increased demand for local fruit. For Utah growers to recapture local markets there needs to be an increase in production area, an increase in yields per hectare, or a combination of both. However, pressure from urban development in prime fruit growing regions is making expansion of the fruit production area economically unviable. Irrigation water is also being diverted for urban and suburban use, further limiting the amount of water available for agricultural production. Without more aggressive preservation of land for orchard use and greater allocation of water for food production, maintaining the existing orchard area will be challenging. Improving yields through increased orchard management skill and improved fruit production technology will be the primary avenues for growers to meet the increasing demand for local fresh fruit.

With respect to the second purpose of this work, records show that the 2009 tart cherry crop in Utah was the largest ever in the state, with total production of 21,319 metric tons (47.0 million pounds); the last record was in 1992 with total production of 13,608 metric tons (30.0 million pounds). This number drastically exceeded previous production years. The large crop was associated with a dramatic decrease in fruit quality. The large crop coupled with the less-than-desirable fruit quality, was the impetus for research to determine optimal fertilizer rates and formulations. It is imperative to find fertilizer rates and formulations that will maintain both high yield and high fruit quality. In order to remain profitable, orchard managers need to determine the optimum and most cost effective method to reach proper fertility levels, while maintaining high quality fruit.

Tart cherry trees must have the correct ratio of leaves per fruit in order to produce the highest quality fruit. Determining the amounts of P and K in the leaves and fruit under a variety of conditions allows development of an economical and effective nutrient management plan specific to Utah conditions. The result is improved fruit for the consumer and increased profit for the tart cherry producers and processors. Current soil and plant tissue test interpretations and nutrient management guidelines used by Utah State University for tree fruit production are taken, primarily, from out-of-state research databases in the Pacific Northwest and the Eastern and Southeastern U.S. (James and Topper, 1993). Little published research has been done to evaluate and corroborate these guidelines for high elevation, alkaline soils and arid climate conditions.

To meet the second purpose of this work, the following experimental approaches were used: a rate-response evaluation using the industry-standard Triple-16 fertilizer (16-16-16), and comparison of P and K fertilizer formulations to determine the most cost effective sources of these nutrients with regard to yield and fruit quality. Moreover, tissue and soil testing of nutrient levels was also conducted to validate current interpretations used in Utah.

Soil additions of P and K maintained adequate yield and fruit quality, but showed no significant difference among treatments where historically aggressive nutrient management had been practiced. Fertilizer additions of 1-2 lbs/tree did result in significant increases in yield and fruit quality where nutrient management programs were historically much less aggressive. There appears to be no advantage to higher cost fertilizer formulations over standard low-cost sources (i.e.; Triple-16). Moreover, there is no significant advantage to splitting fertilizer application over time during the growing season.

As a direct result of this research, a USU Extension Fact Sheet (Rowley et al., 2012) was produced to provide growers with a summary of the results and refined fertility management recommendations. The fact sheet is regularly disseminated to local and regional fruit producers, which have commonly reported adoption of regular P and K additions to their orchards so as to raise the base of productivity and the stability of production and quality in Utah orchards.

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APPENDIX

Appendix 1 Permission-to-use letter from Dr. Teryl Roper for Chapter 2

[redacted]

Appendix 1 Permission-to-use letter from Taunya Ernst for Chapter 2