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Full Length Research Paper

Effect of organic and synthetic fertilization in grapefruit (*Citrus paradasi* Macf.) yield and juice quality

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The study was conducted during 2010 to 2011 production year on a 14 year grapefruit (*Citrus paradasi* Macf.) grove in the locality of "Las Anacuas" in the municipality of General Teran, N.L. Mexico. The objective of the study was to observe the effect of organic and synthetic fertilizer in the grapefruit yield and juice quality. Treatments were in 00-00-00, 100-00-00, 160-80-95, 200-80-95, 250-120-140, 5 tons per hectare of chicken manure+70-00-00 and 10 tons per hectare of chicken manure+ 35-00-00. Results indicated that treatment 160-80-95 and 5 tons per hectare of chicken manure+70-00-00, obtained the highest large fruit weight and total yield. Treatments 160-80-95 and 200-80-95 obtained the highest weight regarding medium fruits and 00-00-00 obtained the most weight of small fruits. Based on the results and costs, the recommendation is to apply 160-80-95 or 5 tons per hectare of chicken manure+70-00-00. Phosphorus and potassium dosage of 80 and 95 kg/ha respectively, are sufficient in order to obtain high yields when 160 kg/ha of nitrogen is added. No difference was found between the treatments regarding juice quality.

Key words: Grapefruit, fertilization, yield, organic, synthetic.

INTRODUCTION

Citrus groves require 15 essential nutrients; carbon, oxygen, hydrogen and part of nitrogen which are provided by rainwater or air, the remaining nitrogen and the rest of the essential nutrients must be provided by soil, irrigation water, organic or synthetic fertilizer. The most common worldwide deficiencies in citrus are nitrogen, potassium, iron, zinc and magnesium. If deficiencies are present, they are corrected by soil or foliar fertilization, except for iron that is normally present in clay soils with drainage problems or cold days. This deficiency will be automatically corrected when the excess water is drained off and/or warmer days are present (Martínez et al., 2010).

Grapefruit fertilization is a dilemma, some studies had reported no difference with the application of nitrogen, phosphorus, and potassium in clay soils in Texas, revealing that the necessities are supplied (Wiedenfeld et al., 2009). Regarding nitrogen, studies recommend for clay and sandy soils, dosage of 150 or 168 kg ha^{-1} (Wiedenfeld and Sauls, 2008), 170 kg ha^{-1} (Abdalla et al., 2008), from 150 to 250 kg ha^{-1} (Obeza, 2003) and 280 kg ha^{-1} of nitrogen (Alva et al., 2001) per year divided in at least two applications. But with dosage of 170 kg ha^{-1}, negative effects have been reported on fruit quality regarding epidermis thickness and vitamin C content (Abdalla et al., 2008). In Nuevo Leon Mexico, dosage from 150 to 200 kg ha^{-1} are recommended (Rocha and Padron, 2009; Martinez et al., 2010) but the majority of the producers do not apply fertilizers or manure. Reports of foliar analysis in the alternate year (low yield) with nitrogen dosage of 100 kg ha^{-1} obtained 2.14% and 1.93% in the control, both considered in the optimum level (Martinez et al., 2010). Synthetic nitrogen (170 kg ha^{-1}) application improves with the amendment of 3.1 ton ha^{-1} of sheep manure as organic matter (Abdalla et al., 2008) or woodchip (Nelson et al., 2008) increasing yield and fruit quality of grapefruit. But very few citrus growers in USA and Mexico amend manure because normally, it is not available to the groves and leads to high cost of

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transportation and application, but the benefit is important due to increase in yield and improvement of physical-chemical-biological aspects of the soil, therefore, it should be considered in a sustainable citrus production practices (Martinez et al., 2010).

Studies regarding phosphorus application in Texas indicate no difference in comparison to control (Wiedenfeld et al., 2009). But in Florida, the phosphorus applications with dosage of 100 kg ha^{-1} in poor phosphorus sandy soils improved the grapefruit yield (Obeza, 2003). In Nuevo Leon, Mexico, most of the citrus producers do not apply phosphorus, but the recommendation is from 70 to 90 kg ha^{-1} (Rocha and Padron, 2009; Martinez et al., 2010). Foliar analysis in a grove that did not receive phosphorus applications reported 0.11% of phosphorus, the level is considered slightly below optimum (Martinez et al., 2010).

Potassium is available in high quantities in the soils of Nuevo Leon, Mexico, therefore, no application is recommended (Rocha and Padron, 2009). Positive results with application of 200 kg ha^{-1} have been found in Florida regarding fruit size and yield in a four year grapefruit trees with yield increase from 9 to 54 kg per tree (Obeza, 2003). Foliar analysis in a grove with no potassium application obtained 1.68% of potassium considered in the optimum level (Martínez et al., 2010).

The present study had the objective to observe the effect of organic and synthetic fertilizer in grapefruit yield and juice quality during the 2010 to 2011 production season, which was considered a good year regarding production which are normally pair years compared with the odd year that are alternate with low yields.

MATERIALS AND METHODS

The present study was conducted in a 14 year grapefruit grove "Rio Red" variety and sour rootstock with a density of 250 trees per hectare with a distribution of 8 m between rows and 5 m between trees. The grove is located in the Hacienda "Las Anacuas" in the municipality of Gral. Teran Nuevo Leon Mexico with geographical coordinates of 25^{0}-18'-38" north latitude and 99^{0}-35'-25" west longitude. The soil contains 14% of sand, 39% of silt and 47% of clay; it is considered a clay soil with slight alkalinity (pH 8.1), 2.93% of organic matter, 0.147% of nitrogen (considered as very low), critical level of phosphorus equal to 10.95 ppm and optimum in potassium (0.49 meq 100 g^{-1}), and soil conductivity of 1.12 mS cm^{-1} (classified as not salty). The water used for gravity irrigation came from 24 m deep well with 1.7 mS cm^{-1} conductivity, 7.0 pH, 891 ppm of sulfur, 2.03 ppm of nitrate, 0.0 ppm of phosphorus and 1.10 ppm of potassium.

The experimental design was a complete randomized block with 7 treatments and 4 replicates. Treatments consisted of T1: control (00-00-00), T2: 100-00-00, T3: 160-80-95, T4: 200-80-95, T5: 250-120-140, T6: 5 ton ha^{-1} of chicken manure + 70-00-00 and T7: 10 ton ha^{-1} chicken manure + 35-00-00. The chicken manure was amended in January and the synthetic fertilizer was distributed in 3 applications; the first in April (T2, T3, T4, T5 and T6), the second in June (T2, T3, T4 and T5) and the last in August (T2, T3 and T4). Sources of fertilizer used were urea (46-00-00), phosphate mono-ammonium (11-52-00) and potassium chloride (00-00-60). Fertilizer was applied with a commercial grain fertilizer at a depth of 10 cm to reduce evaporation one week after irrigation to reduce lixiviation. Chicken manure applied was exposed to high temperature (70 to 90°C for 20 min) and had a content of 2.92% of N, 1.55% of P and 2.1% K of the nutrients that are of interest for this study, and 52% of organic matter that was applied manually and incorporated with a harrow. Harvest was in April 2011 and consisted of one tree per experimental unit. Fruit were separated according to weight: large (>0.50 and <0.55), medium (>0.41 and <0.49) and small (>0.30 and <0.40 kg per fruit), all the fruit evaluated complied with the requirements for fresh market. °brix and acidity was also measured on ten fruits per experimental unit in order to obtain the °brix/acidity relation.

RESULTS AND DISCUSION

Total yield

Results indicated statistic difference among the treatments. Treatments T3, T6, T4 and T5 obtained the best yield in descendent order and were statistically similar; therefore, the best yield was obtained by T3 and T6. Similar results have been found when 150 or 168 (Wiedenfeld and Sauls, 2008), 170 (Abdalla et al., 2008) and from 150 to 250 kg ha^{-1} (Obeza, 2003) of nitrogen was applied. Better results were obtained when 3.1 ton ha^{-1} sheep manure was amended to the nitrogen fertilization (Abdalla et al., 2008). The lowest yield was obtained by T1 which is statistically similar to T2, T7, T5 and T4 (Table 1). Based on the results, synthetic fertilizer alone or even better amended with chicken manure improved yield. It is important to mention that manure also improves chemical, physical and biological soil characteristics compared with synthetic fertilizer that only add nutrients and may deteriorate soil properties within time (Martinez et al., 2010).

Large grapefruits

Results indicated significant statistic difference between treatments. T3, T6, T7 and T5 were statistically similar and obtained the highest yield. The lowest yields were obtained by T1, T2 and T4 with statistical similarity among them. Based on the results, T3 is the best option regarding large fruit weight and has the least cost compared with the rest of the treatments that have statistical similarities. Similar reports have been obtained in other studies when 150 or 168 kg ha^{-1} were applied in clay soils (Wiedenfeld and Sauls, 2008), 170 kg ha^{-1} in loamy to clay soils (Abdalla et al., 2008) and from 150 to 250 kg ha^{-1} of nitrogen in sandy soil (Obeza, 2003). T6 is also a good option because, besides the nutrients that are added to the soil, organic matter is also amended, which improves physical, chemical and biological properties of the soil. Similar results have been found when 3.1 ton ha^{-1} of sheep manure were amended to the soil plus synthetic fertilizer (170 kg ha^{-1} of nitrogen) was added (Abdalla et al., 2008) or wood chips (Nelson et al.,

Table 1. Mean comparison (DMS 0.05* and 0.01**) of treatments regarding total, large, medium and small grapefruits (kg per tree).

Treatment	Total*	Large*	Medium*	Small**
T1 (00-00-00)	168.61^{C}	48.93^{C}	56.75^{B}	62.94^{A}
T2 (100-00-00)	191.07^{BC}	67.38^{BC}	87.41^{A}	36.27^{AB}
T3 (160-80-95)	244.99^{A}	114.34^{A}	104.38^{A}	26.26^{B}
T4 (200-80-95)	204.88^{ABC}	73.90^{BC}	105.79^{A}	25.19^{B}
T5 (250-120-140)	202.05^{ABC}	88.98^{AB}	87.92^{A}	25.5^{B}
T6 (CM-5+70-00-00)	227.48^{AB}	96.45^{AB}	91.94^{A}	39.09^{AB}
T7 (CM-10+35-00-00)	193.19^{BC}	93.19^{AB}	84.90^{A}	17.42^{B}

Common letter in columns represent statistically non significant differences; CM=chicken manure ton ha^{-1}.

2008) improving yield and fruit quality. The lowest fruit weight in this variable was obtained by the control (T1) which indicates that synthetic or organic fertilizer improves grapefruit yield (Table 1). Nitrogen had the most effect on large fruit compared to phosphorus and potassium, dosage of 80 and 95 kg ha^{-1}, respectively are sufficient in order to obtain large fruits when 160 kg ha^{-1} of nitrogen is added.

Medium grapefruits

Statistical difference was found between treatments. T4, T3, T6, T5, T2 and T7 were statistically similar, but T4 and T3 obtained the highest weight with small difference between them, therefore, T3 is the best option considering cost of fertilizers. Other studies have found similar results with high yields when 150 or 160 kg ha^{-1} of nitrogen were applied in clay soils (Wiedenfeld and Sauls, 2008), 170 kg ha^{-1} of nitrogen in loam-clay soils (Abdalla et al., 2008) and 150 to 250 kg ha^{-1} of nitrogen in sandy soil (Obeza, 2003). The results also indicate that it is not necessary to apply high dosage of chicken manure (10 ton ha^{-1}) in order to obtain high yield. Lower dosage of chicken manure should be explored according to results indicating that 3.1 ton ha^{-1} of sheep manure amendment had good results (Abdalla et al., 2008). The same pattern was observed regarding fertilizer dosage where high yield was obtained in intermediate dosage (160-80-95). The lowest medium fruit weight was obtained by the control (T1), therefore, organic or synthetic fertilizer should be applied to increase fruit weight. Nitrogen had the most effect on medium fruit compared to phosphorus and potassium, dosage of 80 and 95 kg ha^{-1}, respectively is sufficient in order to obtain medium fruits when 160 or 200 kg ha^{-1} of nitrogen is added (Table 1).

Small grapefruit

Results indicated statistic difference among treatments. T1, T6 and T2 were similar; statistically obtaining the highest yield of small fruits, among them the highest yield was obtained by T1. Statistical similarity was found between T7, T4, T5, T3, T2 and T6 in ascendant order. Therefore, if small fruit is not the fresh market objective, best treatment would be T7 which obtained the lowest small fruit yield, indicating that fruit weight was improved by the amendment of manure and synthetic fertilizer (Table 1). Grapefruit size is important for fresh market and requires a minimum diameter of 70 mm and minimum fruit weight of 300 g (Martinez et al., 2009). In this study, fruit harvested was heavier than 300 g and larger than 90 mm. Nitrogen had the most effect on fruit weight compared to phosphorus and potassium; dosage of 80 and 95, respectively, are sufficient in order to obtain less small fruits when 160 kg ha^{-1} or higher dosage of nitrogen is added.

Juice quality

Regarding °brix/acidity relation in grapefruit, results indicated no statistic difference. Figure 1 indicates the °brix/acidity relation behavior of the treatments; T4 followed by T1 obtained the highest relation. Values above 13 are insipid (Martinez et al., 2009), therefore treatments T2, T3, T6 and T7 obtained the best fruit quality in the study.

Conclusion

i. Highest total and large fruit yield was obtained by synthetic fertilizer (160-80-95) and chicken manure 5 ton ha^{-1} plus synthetic fertilizer (70-00-00).
ii. Regarding medium grapefruit yield, treatments of 160-80-95 and 200-80-95 obtained the maximum yield.
iii. Control (00-00-00) obtained the highest yield of small fruits.
iv. Nitrogen had more effect on large fruits as compared to phosphorus and potassium.
v. Phosphorus and potassium dosage of 80 and 95 kg ha^{-1} respectively, are sufficient in order to obtain high yields

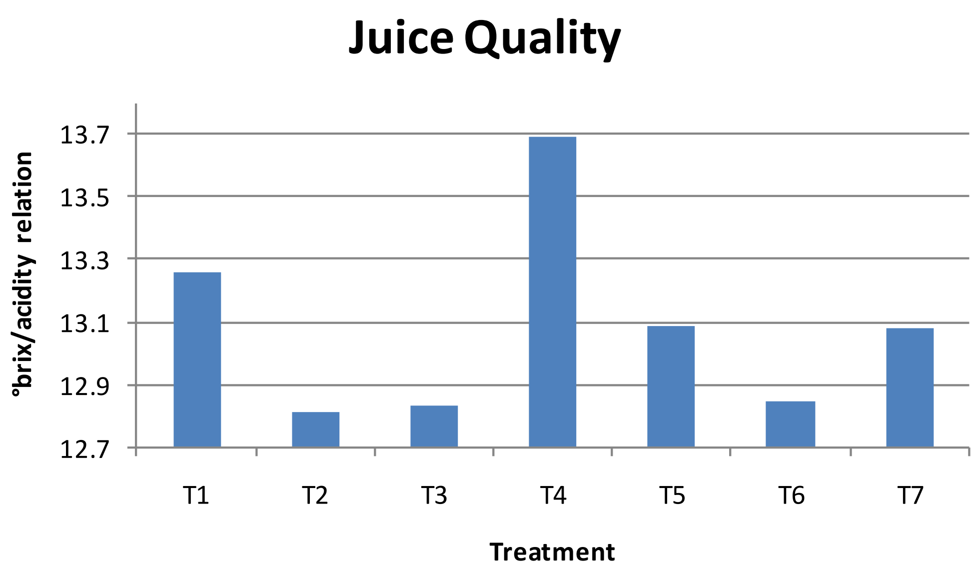

Figure 1. Comparison of °brix/acidity relation in grapefruits.

when 160 kg ha^{-1} of nitrogen is added.
iv. No difference was found regarding juice quality.

RECOMMENDATION

i. Based on the results, synthetic fertilizer (160-80-95) or 5 ton ha^{-1} of chicken manure plus synthetic fertilizer (70-00-00) is recommended for grapefruit in Nuevo Leon.
ii. The study must continue at least 3 years in order to include alternate years.
iii. Dosage of 2 ton ha^{-1} of chicken manure is recommended in order to recover nutrient absorption and to maintain organic matter in soil.
iv. Synthetic and/or organic fertilization is recommended in grapefruit groves in Nuevo Leon, Mexico.

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