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Quality and Nutrition of Pummelo as Influenced by Potassium

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Abstract: This study aimed to determine the influence of different rates of K (potassium) and K foliar application on the quality and plant nutrition condition of 13-year old 'Magallanes' pummelo trees [*Citrus maxima* (Burm. ex Rumph.) Merr.]. The experiment was conducted at SODACO (South Davao Corporation) farm, Davao City, Philippines from March to October 2010. Five treatments with increasing K levels were applied per tree: control, no K, 150 g K basal, 225 g K basal and 225 g K basal + foliar application. Application of 225 g K rates positively influenced fruit quality of pummelo. Fruit pulp diameter and juice weight increased while peel thickness decreased. The 225 g K rates also increased juice pH, TA (titrable acidity) and TSS (total soluble solids) per tree. The yield of total phenol, flavonoid, vitamin C and oil per tree increased with 225 g K application. Results of the soil analysis before and after the conduct of the study showed an evidence of fertilizer absorption by the trees. It was also observed that foliar fertilization reduced soil acidity. This indicates the important role of K in improving the nutrient utilization and quality of 'Magallanes' pummelo.

Key words: Potassium, pummelo, quality, nutrition, foliar fertilization.

1. Introduction

'Magallanes' pummelo is one of the best pink varieties originated in Davao City growing as large as 16 cm in diameter and weighing as much as 1.4 kg. For trees over 10 years old, the yield is very economical with as much as 38 t/ha. At present, there is much interesting in citrus fruits because they are one of the major sources of antioxidants called flavonoids [1]. It also contains vitamins A, B_1, B_2, B_6 and B_{12}, C, protein, Ca, fiber, folate, K, Fe and essential oils with industrial applications.

As a health food with industrial use, there is a big demand for pummelo in both domestic and export market [2]. However, production of pummelo is limited by problems like nutritional disorders and unstable quality. Based on the Bureau of Agricultural Statistics data, the area devoted to pummelo production in the Philippines as of 2008 has increased to 5,306 ha from 4,592 ha in 1997.

Yet, the production volume decreased from 49,763 metric tons in 1997 to 36,686 metric tons in 2008 [3].

Thus, there is a need to improve the quality and plant nutrition of pummelo to cater to the increasing demands of health conscious consumers for both local and export markets. To obtain optimum plant nutrition and quality of pummelo, it is important to provide an efficient fertilizer program.

Potassium (K) is a macronutrient in plants that has multiple enzymatic and catalytic functions used in many photosynthetic and metabolic processes in plants.

Among the important elements in plant nutrition, K is the most abundant element found in fruits and the highest nutrient removed in the soil. Thus, K is considered a key element in fruit production and

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quality worldwide [4].

Studies on different rates of K fertilizers have been shown to increase the quality and plant nutrition of several plants such as 'Shatian' pomelo, orange, grapefruit, lemon, papaya, avocado, watermelon, plum, and peach [5-12]. Hence, study on the potential effect of K on the quality and plant nutrition of 'Magallanes' pummelo here in Davao was conducted.

2. Materials and Methods

2.1 Site and Duration

A field experiment was conducted at SODACO (South Davao Corporation), Calinan, Davao City, Philippines to evaluate the effect of K application on the yield of 'Magallanes' pummelo cultivar (Fig. 1). The area is located 7° latitude and 125° longitude with an elevation of 700 m above sea level (asl).

The study was carried out from March to October 2010. Based on modified coronas classification, Davao City belongs to the Type IV climate where rainfall is more or less evenly distributed throughout the year. Meteorological data of the area were taken within the duration of the study at the PAGASA (Philippine Atmospheric, Geophysical and Astronomical Services Administration) weather station at Sasa, Davao City (Table 1). Temperature, amount of sunshine, relative humidity, rainfall and wind speed were favorable for the growth and development of pummelo.

Fig. 1 The 13-year old 'Magallanes' pummelo trees at the experimental area of SODACO farm, Calinan, Davao City, Philippines.

2.2 Variety Used

The cultivar used in the study was 13-year old 'Magallanes' pummelo, the major variety grown in Davao region and reportedly one of the best pink varieties which originated in Davao City.

2.3 Experimental Design

The experiment was carried out in RCBD (randomized complete block design). Field experiment was composed of five treatments replicated three times. There were three sample trees per replication per treatment for a total of 45 pummelo trees with a planting distance of 7 × 8 m in a rectangular planting system. Fruits were sampled from middle trees to minimize the border effects.

2.4 Soil and Leaf Analysis

Soil and tissue analyses were done before and after

Table 1 Meteorological data of the experimental area during the conduct of the study. Data taken at the PAGASA Davao Station, Sasa, Davao City.

2010	Mean temperature (°C)	Maximum temperature (°C)	Rainfall (mm)	Relative humidity (%)	Sunshine (%)	Average wind speed (km/h)
January	27.2	30.6	157.5	83	41.5	72
February	27.7	32.5	16.0	78	70.9	72
March	29.0	33.5	52.9	77	71.5	86
April	29.2	32.5	124.0	81	59.0	67
May	29.2	32.8	57.2	82	57.3	59
June	28.8	32.6	87.8	83	57.9	47
July	28.5	31.8	251.6	84	51.5	66
August	28.2	31.9	281.8	84	53.8	72
September	28.5	32.3	117.6	82	57.5	63

the conduct of the study to determine the nutrient requirement of the trees. Soil and leaf sampling methods were based on the standard procedure given by the Regional Soil Laboratory of the Department of Agriculture, Davao City, Philippines. Soil sample at 30 cm deep was air-dried, pulverized and placed in bags for analysis.

Four to six months old leaves from non-fruiting terminals in the mid-region of the tree were collected and placed in bags for analysis.

2.5 Treatments

Based on soil and leaf tissue analysis, the five treatments were: no fertilizer application (control); no potassium, recommended rate of nitrogen and phosphorus (400 g-100 g); recommended rate of nitrogen, phosphorus, and potassium (400 g-100 g-150 g); recommended rate of NPK + 50% of RR K (400 g-100 g-225 g) basal; and recommended rate of NPK basal + 50% of RR K (400 g-100 g-225 g) foliar. The different rates of fertilizers were applied in three installments: at flushing or flower bud initiation, 30 and 60 DAF (days after flowering). All treatments were applied with recommended rate of NP except for the control (no fertilization). Urea (46-0-0), Complete (14-14-14) fertilizer, Solophos (0-18-0) and Muriate of Potash (0-0-60) were the sources of NPK fertilizers. Fertilizers were applied basally at 1.5 m radius around the canopy. K foliar fertilizers were prepared by mixing the required amount of K fertilizer in water at the rate of 10 $g{\cdot}L^{-1}$ and applied at 30 and 60 DAFS (days after fruit set) on target fruits and leaves. Adjuvant concentrate was also added to improve performance of the K foliar fertilizer. The pummelo trees were maintained by irrigating, weeding, pruning and applying pesticide and fungicide whenever necessary. The pummelo fruits were harvested after 156 days from fruit set.

2.6 Data Gathered

To evaluate the effect of different K treatments on fruit quality of 'Magallanes' pummelo, the peel thickness, juice content (fruit weight, juice weight and percent juice), and physico-chemical properties such as pH, TSS (total soluble solids), TA (titratable acidity), TSS:TA were taken after harvest. There were three fruit samples per replication per treatment.

Peel thickness. Fruits were sectioned equatorially and peel thickness was measured at four points equatorially using a hand caliper.

Juice content. Fruit weight was taken by weighing fruit after harvest and fruit juice was extracted by hand and weighed using electronic weighing scale. This was done on a fresh weight basis and percent juice was computed.

Physico-chemical properties. The extracted juice was analyzed for its physico-chemical properties. Fruit juice was extracted by removing the fruit peel (flavedo and albedo) and blending the fruit juice sac and pulp for 3 min. The blended fruit juice was collected in 1,000 mL Erlenmeyer flask and filtered using cheese cloth.

Juice pH. pH was measured using pH meter. The juice samples were thawed in room temperature and mixed by turning the tightly closed bottle up and down three times. The pH meter was standardized using two buffer solutions nearest to expected pH of the test solution and pH calibration results were recorded. The glass electrode was dipped into the test solution and two readings were taken. The test results were reported to the nearest 0.01 [13].

TA (titratable acidity). The total TA was determined by titrating the sample with a standard base. 5 mL of clear juice was titrated after adding 50 mL of distilled water. Two to three drops of phenolphthalein indicator was added with a standard base (0.1 N NaOH) to a faint pink color. Sampling was done per treatment. The percent TA was then computed from the amount of NaOH consumed to reach the end point [13].

Total soluble solids. The % TSS was determined in 1-2 drops of the titrate using the hand held brix refractometer and expressed as percent by weight of sucrose or degree Brix [13].

TSS/TA ratio. This was computed by dividing the TSS by TA.

2.7 Statistical Analysis

Data were analyzed using ANOVA (analysis of variance) and means were compared using HSD (Honest Significant Difference Test).

3. Results and Discussion

3.1 Soil and Plant Nutrition Condition

Soil and leaf tissue analyses were taken before and after the conduct of the study to evaluate the physical and chemical characteristics of the soil as well as the nutrient status of the plants. The experimental area had a clay type of soil with pH ranging from 4.7 to 6.0 (Tables 2 and 3). Soil applied with 225 g K basal + foliar had a moderately acidic pH; the rest had strongly acidic pH. Foliar fertilization of K was observed to reduce soil acidity.

Percent N of the soil was initially low. N level after harvest ranged from low in no K and 225 g K basal to medium in the control, 150 g K basal and 225 g K basal + foliar. There was initially medium P level before the experiment and varied greatly among treatments from very low to very high amounts after the experiment was done. The P level became very low in 150 g K basal, low in no K and 225 g K basal + foliar, medium in 225 g K basal, and very high in the control. K level was initially very deficient before the experiment and became deficient in all treatments including the control (no fertilizer application).

Results of the soil analysis before and after the conduct of the experiment showed an evidence of fertilizer absorption by the trees. There was an increase of NPK levels in various treatments after the study. However, the low level of NPK in some treatments with higher yield after harvest may indicate that there was nutrient absorption of the fertilizers applied.

On the other hand, increase in NPK level was also observed in the control. Organic matter in the soil of the control also increased after the conduct of the study.

The increase in K without fertilizer application was possibly due to two reasons: first, through increase in organic matter from the degraded weeds left on the ground. Second, K may be trapped between layers of clay minerals when the soil was dry and can serve as a reservoir of soil K which is released when the soil becomes wet. This is frequently referred to as being “fixed” which was not measured by the routine soil testing procedure [14].

Leaf tissue analysis shows the amount of nutrients absorbed by the plants from the soil and indicates whether there is adequate nutrient supply for the plant or not.

The leaf N concentration was initially optimum at the start of the study, but became deficient in no K and 225 g K basal + foliar and low in the control, 150 g K basal and 225 g K basal after the experiment (Tables 4 and 5).

Table 2 Soil analysis before and after the conduct of the study.

Treatments	Class	pH	OM (%)	OC (%)	N (%)	P (ppm)	K (ppm)
Initial	Clay	5.1	2.82	1.64	1.4	27	228
Control	Clay	4.7	4.75	2.76	2.5	52	300
No K	Clay	5.2	2.86	1.66	1.7	13	295
150 g K basal	Clay	5.4	3.54	2.06	2.3	8	388
225 g K basal	Clay	5.5	3.32	1.93	1.7	27	355
225 g K basal + foliar	Clay	6.0	3.47	2.02	2.1	16	325

All treatments were applied with recommended rate of NP except for the control (no fertilization).

Table 3 Soil analysis legend based on the Bureau of Soils, Department of Agriculture Regional Field Unit XI, Davao City.

Element	Very low	Low	Medium	High	Very high
pH	< 4.4	4.4-5.5	6.1-6.6 5.6-6.0	7.3-7.8 6.7-7.2	> 9.0 8.5-9.0 7.9-8.4
Organic matter (OM) Walkey black (%)	< 3.44	3.44-6.88	6.88-17.20	17.20-34.40	> 34.40
Organic carbon (%)	< 2	2-4	4-10	10-20	> 20
Nitrogen (%) OM (Wilde's method)	Low < 1.5		Medium 1.6-3.0		Adequate > 3.0
Olsen phosphorus (ppm)	Very low < 10	Low 10-20	Medium 20-30	High 30-50	Very high > 0
Extractable potassium (ppm)	Very deficient < 250	Deficient 260-500	Possibly deficient 510-750		Adequate > 750

Table 4 Leaf tissue analysis before and after the conduct of the study.

Treatments	Total N (%)	Total P (%)	Total K (%)	OM (%)	OC (%)
Initial	2.66	0.26	1.04	70.40	
Control	2.21	0.32	1.11	83.59	48.6
No K	2.17	0.11	1.06	70.69	41.1
150 g K basal	2.21	0.32	1.06	58.31	33.9
225 g K basal	2.34	0.18	0.92	75.85	44.1
225 g K basal + foliar	2.14	0.16	0.63	65.53	38.1

All treatments were applied with recommended rate of NP except for the control (no fertilization).

There was initially high P level before the experiment and became low in no K, optimum in 225 g K basal + foliar and high level in the control, 150 g K basal and 225 g K basal after the conduct of study. There was optimum K content at initial determination. The final level of K was also optimum for all treatments except for 225g K basal + foliar treatment which had the lowest K content at 0.63%.

The high amounts of P and optimum supply of K in the tissue may indicate that these abundant nutrients would not limit growth and yield; however, this may also indicate that these nutrients were not fully utilized by the plant for growth and yield.

On the other hand, low or deficient amount of NPK in the tissue may imply that these nutrients were utilized by the plant that may result to better growth, yield and quality.

Initial leaf tissue analysis revealed that there was an optimum to high amount of nutrients absorbed by the plants from the soil. After the conduct of the experiment, there were low or deficient amount of N and K in the tissues applied with 225 g K rates with foliar application which imply that these nutrients were utilized by the plant resulting to greater growth, yield and quality.

N and P generally have the same nutrient recommendation before and after the conduct of the study with 0.40 kg·N/tree/yr, 0.10 kg·P/tree/yr while K increased from 0.15 kg to 0.45 kg per tree/yr based on the results of soil and leaf tissue analysis. Lime requirement decreased from 7 tons at initial to 3 tons per ha/yr in 225 g·K basal + foliar (Table 6).

Table 5 Leaf analysis legend based on the Bureau of Soils, Department of Agriculture Regional Field Unit XI, Davao City.

Element	Deficient	Low	Optimum	High
Nitrogen (%)	< 2.2	2.3	2.4-2.6	2.7-3.0
Phosphorus (%)	< 0.10	0.11	0.12-0.16	0.17-0.25
Potassium (%)	< 0.4	0.5-0.6	0.7-1.2	1.3-2.3

Table 6 Recommended amounts of nutrients to apply before and after the conduct of the study.

Treatments	Nutrient recommendation			Lime t/ha/yr
	N	P_2O_5 (kg/tree/yr)	K_2O	
Initial	0.40	0.10	0.15	7
225 g K basal + foliar	0.40	0.10	0.45	3

Table 7 Peel thickness, fruit pulp diameter and fruit diameter (cm) of 'Magallanes' pummelo as influenced by K fertilization.

Treatments	Fruit diameter (cm) ^{ns}	Fruit pulp diameter (cm)	Peel thickness (cm)	% Peel thickness
Control	11.2	8.8 b	2.4 a	21 a
No K	12.9	10.6 ab	2.3 a	18 b
150 g K basal	13.4	11.6 ab	1.9 b	14 c
225 g K basal	12.6	12.0 a	1.6 b	13 c
225 g K basal + foliar	13.7	12.0 a	1.6 b	12 c

Values with a common letter in a column are not significantly different at 0.05 level using HSD. All treatments were applied with recommended rate of NP except for the control (no fertilization). ns: no significant difference.

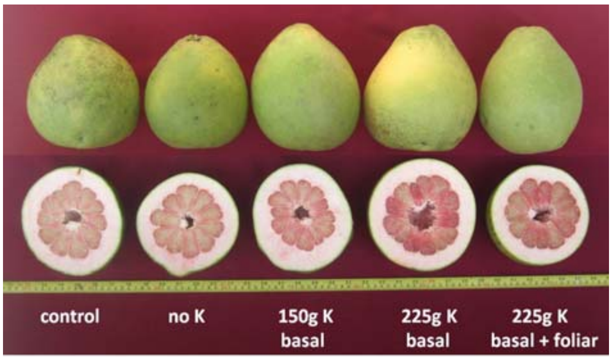

Fig. 2 Peel thickness, fruit pulp diameter and fruit diameter (cm) of 'Magallanes' pummelo as influenced by K fertilization. All treatments were applied with recommended rate of NP except for the control (no fertilization).

3.2 Effect of K Fertilization on the Fruit Quality of Pummelo

3.2.1 Peel Thickness

Peel thickness is an important parameter that determines quality of 'Magallanes' pummelo. Large fruits with thin rinds are desirable based on consumer preference.

Higher K rates increased fruit pulp of pummelo (Table 7 and Fig. 2). The application of 225 g K basal increased fruit pulp diameter of pummelo by 36% increase compared with the control. The control treatment was just similar to 150 g K basal and no K treatments in terms of fruit pulp diameter. In a similar study [8], it was found out that K nutrition also increased pulp thickness of papaya fruits.

No K treatment and control produced significantly thicker peels which were 0.5-0.8 cm thicker than the treatments with 150 g K and 225 g K rates.

The highest % peel thickness was obtained in the control followed by no K treatment, which were 50%-75% and 29%-50% thicker, respectively, compared with the other rates of K. K fertilization decreased peel thickness of 'Magallanes' pummelo by 29%-75% compared with the control and no K treatments. This conforms to previous reports that K reduced peel thickness of 'Valencia' and 'Hamlin' oranges [15, 16] and lemon [7].

This study found out that application of 150-225 g K effectively decreased peel thickness and increased fruit pulp diameter of 'Magallanes' pummelo. These observations indicate the importance of K in the fruit quality of pummelo.

3.2.2 Juice Content

The juice weight of pummelo applied with 225 g K basal + foliar increased by 39% compared to the control (Table 8). The juice weight from trees given 225 g K basal, 150 g K basal and no K were, however, not significantly different from that obtained from the control. Highest % juice was obtained in 150 g K basal with 15% increase compared with the control

Table 8 Juice content of 'Magallanes' pummelo as influenced by K fertilization.

Treatments	Fruit weight ns (g)	Juice weight (g)	% Juice	Amount of juice (kg/tree)
Control	880.44	287.33 b	32.98 b	0.7 d
No K	951.44	311.89 ab	33.01 b	1.9 cd
150 g K basal	1,023.00	387.22 ab	38.00 a	3.8 bc
225 g K basal	848.78	300.89 ab	35.52 ab	5.9 b
225 g K basal + foliar	1,118.56	399.33 a	35.71 ab	8.2 a

Values with a common letter in a column are not significantly different at 0.05 level using HSD. All treatments were applied with recommended rate of NP except for the control (no fertilization). ns: no significant difference.

Table 9 Physico-chemical properties of 'Magallanes' pummelo as influenced by K fertilization.

Treatments	pH	TA (%)		TSS (%)		TSS:TA
		per fruit ns	per tree	per fruit ns	per tree	
Control	4.54 a	0.39	1.04 b	10.47	27.83 c	26.85 a
No K	4.07 b	0.54	3.33 b	10.04	64.23 bc	19.04 ab
150 g K basal	4.39 a	0.54	5.36 ab	9.42	92.05 b	17.49 b
225 g K basal	4.50 a	0.52	10.11 a	9.27	181.79 a	18.44 b
225 g K basal + foliar	4.55 a	0.48	10.51 a	9.70	201.61 a	20.73 ab

Values with a common letter in a column are not significantly different at 0.05 level using HSD. All treatments were applied with recommended rate of NP except for the control (no fertilization). ns: no significant difference.

and no K treatments. Higher K rates decreased percent juice by 6% and were not significantly different with the control.

In terms of amount of juice produced per tree, 225 g K basal + foliar generated the highest value, which was 11 times higher than the control and 38% higher than those applied with 225 g K basal. The juice yield for the no K treatment was not significantly different from the ones extracted for both the control and 150 g K basal treatments. Results of this study agree to the findings [15] that the juice content of 'Valencia' orange increased with K fertilization as compared to those which did not.

Increasing K rates to 225 g K basal + foliar application increased juice yield of 'Magallanes' pummelo by 2-8 kg/tree which indicates the importance of K fertilization in improving the volume of juice in pummelo.

This is most likely related to the function of K in the translocation of assimilates and absorption of water and nutrients. K increases fruit juice by acting as an osmoticum in plant cells to regulate water and solute uptake [17]. K can substitute for H^- and the most important metabolites required for growth, storage, and transport of sucrose and amino compounds along the phloem [18].

3.2.3 Physico-chemical Properties

The pH, TA, TSS and TSS: TA of the fruit juice extracts are essential in determining quality traits in pummelo. The sweetness and sourness which gives a characteristic taste of the fruits are influenced by the fruits TSS which is attributed to the hydrolysis of insoluble starch into soluble sugar and the TA which can be accounted for by the increase in the activity of organic acid enzymes.

There was an 8%-12% increase of pH in different rates of K and control compared with the no K treatment (Table 9). The TA/tree of 225 g K rates was 9 times higher than the control. The control was not significantly different from no K and 150 g K rate.

Highest TSS/tree was also obtained in 225 g K application which increased by 100% up to 6 times compared with the 150 g K, no K and control. The TSS/tree of no K treatment was also similar to that of the control and 150 g K level. Increasing K rates did not increase TSS:TA per fruit and highest TSS:TA was obtained from the control.

Previous studies also showed that K fertilization

Table 10 Cost and return of pummelo per hectare per harvest.

Production and maintenance cost of 13-year old pummelo bearing trees -178 trees/ha (7 × 8 m^2)	Control (no fertilizer)	No K	150 g K basal	225 g K basal	225 g K basal + foliar
Gross sales [Yield (kg/ha) × P30.00/kg farm gate price]	312 × 30	682 × 30	1,340 × 30	2,806 × 30	3,141 × 30
Gross sales	P 9,360	P 20,460	P 40,200	P 84,180	P 94,230
Total cost of production	27,250	34,802	35,199	35,760	35,438
Net income	-17,890	-14,342	5,001	48,420	58,792
Return on investment			14%	135%	166%

increased juice acidity of 'Marsh' grapefruit [5], lemon [6, 7], 'Hamlin' 'Pineapple' and 'Valencia' orange trees [10, 11] and strawberry [19]. As reviewed [15], among the juice quality parameters, only acid content (TA and pH) was positively influenced by K application. In some studies, there was also an increase in TSS content with an increase in K supply in papaya [8], plum and peach [9].

Results of this study indicate that higher K level increased the pH of 'Magallanes' pummelo. It is not known how the K level affects the accumulation or degradation of acids in citrus fruit [4]. In pummelo, K possibly activates enzymes that are involved in organic acid activity such as citric acid.

3.3 Cost and Return of Pummelo per Hectare per Harvest

Table 10 showed that trees applied with 225 g K basal + foliar had the highest gross sales of Php 94,230, net income of Php 58,792 and "ROI (return of investment)" of about 166% followed by trees with 225 g K basal application. Moreover, application of 225 g K basal had the highest cost of production.

This indicates that foliar application is more economical compared with basal application of K fertilizer.

4. Conclusion

Based on the results of the study, higher K rates had higher nutrient utilization and quality of 'Magallanes' pummelo. This elucidates the important role of K in the growth and quality of 'Magallanes' pummelo. The role of K may involve the activation of at least 60 different enzymes needed for metabolic processes and catalytic functions which include the synthesis of carbohydrates and proteins and its act on as an osmoticum for the uptake and transport of assimilates [20].

Though significant difference between basal alone and basal + foliar application of K was observed in terms of juice yield per tree, fruit weight and ROI, however, were obtained from the basal + foliar application. This may indicate that there was higher mobilization of K in the leaves than K uptake by the roots.

Thus, increasing K level to 50% of the recommended rate as well as foliar application of K, and further study on different rates of K in controlled condition using containerized trees for one year duration or more are highly recommended to verify results.

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References

[1] H.L. Tsai, S.K.C. Chang, S.J. Chang, Antioxidant content and free radical scavenging ability of fresh red pummelo [*Citrus grandis* (L.) Osbeck] juice and freeze-dried products, J. Agric. Food Chem. 55 (8) (2007) 2867-2872.

[2] The National Research, Development and Extension

Agenda and Program for Fruit Crops, Bureau of Agricultural Research, Quezon City, 2002.

[3] Bureau of Agricultural Statistic Home Page, http://www.bas.gov.ph (accessed Jan. 12, 2010).

[4] Y. Erner, B. Artzi, E. Tagari, M. Hamou, Potassium affects citrus tree performance, Department of Fruit Trees, Institute of Horticulture, The Volcani Center , 2005.

[5] D.V. Calvert, Response of ‘marsh’ grapefruit trees in the Indian river area to potassium application and fruit quality, Proceedings of Florida State Horticulture Society 86 (1973) 13-19.

[6] T.W. Embleton, W.W. Jones, Potassium and lemon fruit quality, California Citrology 51 (1964) 269.

[7] R.C.J. Koo, Nitrogen and Potassium Rates Study on Lemon, Annual report, Florida University of Agriculture Experiment Station, 1963.

[8] N. Kumar, N. Meenakshi, J. Suresh, V. Nosov, Effect of potassium nutrition on growth, yield and quality of papaya (*Carica papaya* L.), Indian Journal of Fertilizers 2 (4) (2006) 43-47.

[9] M. Mimoun, M. Ben, M. Ghrab, M. Ghanem, O. Elloum, Effects of Potassium Foliar Spray on Olive, Peach and Plum, International Potash Institute, Switzerland, 2009.

[10] R.L. Reese, R.C.J. Koo, Responses of ‘hamlin’, ‘pineapple’ and ‘valencia’ orange trees to nitrogen and potash applications, Proceedings of Florida State Horticulture Society 87 (1974) 1-5.

[11] R.L. Reese, R.C.J. Koo, Effects of N and K fertilization on internal and external fruit quality of three major Florida orange cultivars, Journal of American Society of Horticulture Science 100 (1975) 425-428.

[12] J.W. Sites, E.J. Deszyck, The effect of varying amounts of K on the yield and quality of Valencia and Hamlin oranges, Proceedings of Florida State Horticulture Society 68 (1952) 65-72.

[13] Official Methods of Analysis, AOAC International, American Organization of Agricultural Chemistry International Maryland, USA, 2005.

[14] G. Rehm, M. Schmitt, Potassium for crop production, Ph.D. Thesis, Regents of the University of Minnesota, 2002.

[15] A.K. Alva, S. Paramasivam, B. Patil, D. De Mattos, Jr.H. Dou, K. Sajwan Revisited, International Potash Institute [Online], (2002), http://www.ipipotash.org/udocs/potassiumcitrusproduction.pdf (accessed January 25, 2010).

[16] D.W. Reische, D.A. Lillard, R.R. Eitenmiller, Chemistry, Nutrition and Biotechnology, Marcel Dekker, New York, 1998, pp. 423-448.

[17] P. Perkins-Veazie, W. Roberts, Can potassium application affect the mineral and antioxidant content of horticultural crops, in: Symposium on Fertilizing Crops for Functional Food, Switzerland, 2002.

[18] A.J.E. Van Bel, A.J. Van Erven, A model for proton and potassium co-transport during the uptake of glutamine and sucrose by tomato internode disks, Planta 145 (1979) 77-82.

[19] A. Choureitah, G. Bünemann, The effect of K-supply on chemical composition of *Fragaria Vesca* Var. Semperflorens Duch, Gartenbauwissenschaft 37 (1972) 243-249.

[20] N.K. Fageria, H.R. Gheyi, Efficient crop production, Campina, Grande, Brazil: Federal University of Paraiba, Brazil, 1999.