Influence of chemical fertilizer on yield and fruit quality of Late Valencia sweet orange in Ghana

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SUMMARY

Studies were conducted to investigate the influence of inorganic fertilizers on the yield and fruit quality of *Citrus sinensis* [L] Osbeck cv. Late Valencia at the Agricultural Research Station, Okumaning near Kade (ARS-Kade). The trees which were 30 years old, had been budded onto either Rough lemon, *C. jambheri* Lush (RL), Cleopatra mandarin, *C. reticulata* Blanco (CM), or Rangpur lime, *C. limonia* (RGL), rootstocks. The fertilizer treatments common to all the rootstocks were as follows: T1 (control, no fertilizer); T2 (96.4, 40.2, 201 and 70 kg N, P_2O_5, K_2O and S/ha, respectively); T3 (204, 80.4, 402 and 135.6 kg N, P_2O_5, K_2O and S/ha, respectively). In treatments T2 and T3, the fertilizers applied were 15-15-15, sulphate of ammonia, and muriate of potash. For RL, an additional treatment (T4) was applied as in T3 but without S. The effects of fertilizer application rates on the *p*H, percent juice content, juice volume, total soluble solids (TSS), titratable acidity (TA), and TSS/TA ratio were investigated. Fertilizer application increased yield significantly, irrespective of rootstock. The increases ranged between 89 and 122 per cent for RL; 23 and 72 per cent for CM, and 26 and 67 per cent for RGL compared to the no fertilizer application. For RL, ammonium sulphate as N source tended to increase yield more than urea. Increasing fertilizer rate resulted in significant yield increases, irrespective of rootstock. While the *p*H and TSS/TA ratio of the juice was increased, titratable acidity was decreased by fertilizer application. Except for CM, the highest juice volume was observed from T2. In addition, the TSS was highest at T2 while ammonium sulphate application increased the TSS content of the fruit more than urea, suggesting the importance of sulphur in improving fruit quality. Fertilizer application reduced the maturity period of the fruit as measured by the TSS/TA ratio. A minimum TSS/TA ratio of 10 is recommended for acceptance as maturity index for sweet oranges in Ghana.

RÉSUMÉ

OFOSU-BUDU, K. G.: *L'influence d' engrais chimique sur le rendement et la qualité du fruit de Valence Tardif d' orange douce au Ghana.* Des études se sont déroulées pour faire une enquête sur l'influence d' engrais inorganique sur le rendement et la qualité de itrus sinensis [L] Osbeck cv. de Valence Tardif à ;a Station de Recherche d' Agriculture, à Okumaning auprés de Kade (ARS-Kade). Les arbres qui ont 30 ans, avaient été bourgeonnés soit sur les rhizomes de Citron rugueux, C. jambheri Lush (RL), de Cleopatra mandarin, C. reticulata Blanco (CM), ou de Limmette de Rangpur, C. limonia (RGL). Les traitements étaient: T1 (contrôle, engrais nul); T2 (96.4, 40.2, 201 et 70 kg N, P2 O5, K2O et S/ha respectivement); T3 (204, 80.4, 402 et 135.6 kg N, P2O5, K2O et S/ha respectivement) Dans les traitements T2 et T3, les engrais appliqués étaient 15-15-15, le sulfate d'ammonium et le muriate de potasse. Dans le cas de RL, un traitement supplémenttaire (T4) était appliqué comme et T3 mais sans S. Les effets des fréquences d' application d'engrais sur le pH, le pourcentage du contenu du jus, le volume du jus, le total des solides solubles (TSS), l acidité titrable (AT) et le rapport TSS/AT étaient enquêtés. L' application d' engrais augment ait le rendement considérablement, sana tenir compte de rhizome. Les augmentations variaient entre 89 et 122 pour cent pour RL; 23 et 72 pour cent pour CM et 26 et 67 pour cent pour RGL comparé à l'application d'engrais nul. Pour RL, le sulfate d'ammonium comme la source de N avait la tendance à augmenter le rendement plus que l'urée. L' augmentation de la fréquence d'engrais aboutissait à des augmentation de rendement considerable, sana tenir compte de rhizome. Pendant que le pH et le rapport TSS/AT du jus étaient augmentés, l'acidité titrable était diminuée par l' application d'engrais. A l' exception de CM, le volume de jus le plus elevé était observé de T2. En plus le TSS était le plus elevé à T2 pendant que l' application de sulfate d'ammonium augmentait le contenu du TSS du fruit plus que l'urée, suggérant l' importance du surfre dans l'amélioration d'engrais reduisait la période de maturité du fruit comme évalué par le rapport de TSS/AT. Le minimum 01 du rapport TSS/AT est recommandé pour acceptance comme l'index de maturité pour les oranges dource au Ghana.

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Introduction

The Late Valencia is the most important sweet orange cultivar widely grown in Ghana. Over 5000 ha of land has been cropped to Late Valencia mostly in the forest region, especially in the Kwaebibirem district of the Eastern Region. The interest in cultivating this cultivar is mainly due to its high income generation to farmers. Currently, the income per hectare of Late Valencia sweet orange outstrips that of oil palm or cocoa, its close competitors (ARS-Kade, 1988).

The growth, yield, and fruit quality of citrus were influenced by several factors including its varieties, climate, and soil conditions (Delfs-Fritz, 1970; Tang & Tian, 1992). Climate is a major factor affecting the quality of citrus fruits (Hilgeman, Tucker & Hales, 1959; Newman *et al.*, 1967; Nauer *et al.*, 1972). Sweet oranges grown in the tropics have been described generally as follows: coarse-skinned, juicy, low total soluble solids (TSS) and total acidity (TA), and do not develop desirable external colour when compared with fruits grown in the subtropics (Nauer *et al.*, 1972; Passos, 1979). However, Scotza *et al.* (1982) reported significant differences in sweet orange fruit size, juice volume, TSS, TA, TSS/TA ratio, and seed number. They observed that the fruit quality of orange juice in the hot tropical region in Bolivia met the standards in USA and concluded that the local climatic conditions within a tropical zone, rather than a generalized concept of tropical climate, are the most important factors when considering sweet orange fruit quality in the tropics. Sweet orange production is increasing in Ghana; therefore, there is the need to evaluate its fruit quality for the export market and other products.

Soil conditions have long been considered a critical factor in determining the yield and fruit quality of citrus (Tang & Tian, 1992). The acid content of sweet oranges in Ghana is strongly influenced by the environment, particularly, the soil type in which the rootstock grows (Sam-Aggrey, 1973). The adequate supply of nutrients to citrus trees is important for higher yield and nutrient concentration of citrus (Embleton, Reitz & Jones, 1973). Reese & Koo (1976) reported that the growth and yield of Temple orange responded to application of N, P, and K. Koo & Reese (1976) also reported that the acid content in the juice of Temple orange responded to rates of K application.

Fruit composition can be consistently influenced in the right direction by the selection of the proper rootstock. The lower content of soluble solids experienced on RL rootstock in contrast to sweet orange on Cleopatra mandarin has been reported (Harding, Winston & Fisher, 1940; Marloth, 1949). The influence of rootstock on the composition of citrus fruits has been noted by several workers. Rough lemon and CM are the recommended rootstocks for sweet oranges in Ghana. Opoku (1972) advised against the indiscriminate use of RL as a rootstock as it was found to be susceptible to the exocortis virus disease which has infected some citrus clones in Ghana. Rough lemon rootstock tends to give high yields of fruit with a low juice content, which is low in soluble solid content and acidity. At the other extreme, trifoliate orange and its hybrids tend to give low yields of fruits with a high juice content, which is high in soluble solids and acidity (Gardner & Horanic, 1961).

Previous works on citrus nutrition in Ghana had been mainly on RGL, with little or no work on the other rootstocks such as RL or CM. However, Opoku (1971) noted that application of complete fertilizers was beneficial to citrus varieties around 9 years.

The Kwaebibirem district of the Eastern Region is the major citrus-growing belt in Ghana. Information on the fruit quality of these sweet oranges, and also on the mineral requirements of citrus in Ghana are scanty or unavailable. The age of these orchards ranges between 1 and over 30 years. The yields of mature trees over 20 years have been declining for sometime now.

This study aimed to develop a fertilization programme to improve on the fruit quality and yield of citrus in Ghana. It reports on the results of the effect of fertilizer trial conducted at ARS-Kade on the yield and fruit quality of Late Valencia sweet orange, budded onto RL, CM or RGL rootstocks.

Materials and methods

The climate and soils at ARS, Kade are representative of those in the forest region of Ghana. The mean annual rainfall ranges between 1200 and 1500 mm and is spread for most part of the year. However, a dry season starts from late December until mid-March, and another short dry period for about 3 weeks to a month around mid-July to mid-August. The mean minimum and maximum annual temperatures are 22 and 32 °C, respectively, with a relative humidity of around 65 to 70 per cent. The soil which has free drainage belongs to the Nzima series, which was developed over Lower Birrimian phyllite.

The experiment was conducted within the citrus orchards, Ci 24 and Ci 9 at ARS-Kade. The orchard at Ci 24 was planted to Late Valencia budded onto Rangpur lime or rough lemon. Similarly, at Ci 9, the orchard was planted to Late Valencia budded onto Cleopatra mandarin. The planting distance for the 30-year-old trees at both orchards was 6 m × 6 m. Plots consisted of five healthy trees, and were separated from adjacent plots by a guard row. The randomized complete block design with four replications was adopted. The orchards had experienced little fertilization over the years. Management of the orchards had been slashing the undergrowth with machetes, and occasional control of mistletoes.

The fertilizer treatment common to all the rootstocks were as follows: T1 (control, no fertilizer); T2 (96.4, 40.2, 201 and 70 kg N, P_2O_5, K_2O and S/ha, respectively); T3 (204, 80.4, 402 and 135.6 kg N, P_2O_5, K_2O and S/ha, respectively). In treatments T2 and T3, the fertilizers applied were 15-15-15, sulphate of ammonia, and muriate of potash. For RL, an additional treatment (T4) with N, P_2O_5 and K_2O was applied as in T3 but without S.

The fertilizers were applied after controlling the undergrowth with "Roundup™", a herbicide with glyphosate in the form of isopropylamine salt, as the active ingredient. The fertilizers were applied to the soil about 1 m away from the trunk in July, in a ring form. The circumference of the rootstock and scion 10 cm away from the bud union were measured to determine the rootstock and scion ratio. The mean canopy width (measured in north-south and east-west directions) and height were used to estimate the canopy volume. The formula for an oblate spheroid was used: 4/3 (π) (tree height) (canopy radius)^2 (Obreza, 1993). Samples of 10 fruits per replicate were chosen at random from the fruits harvested from each tree for fruit quality analyses. Three replicates per treatment were performed. Grossly undersized, oversized or injured fruits were excluded. Fruit weight was measured and yield in relation to tree volume was used as a measure of tree efficiency (grams of fruit /m^3 of canopy).

Fruit juice was extracted with a Sanyo Food Factory, and the volume was recorded. The juice was strained through muslin cloth and used for the determination of total soluble solids (TSS) with a hand refractometer (ATAGO model ATC-1). The *p*H of the juice was determined with a digital *p*H meter (*p*H Pro; Trans Instruments). Total titratable acidity was determined using 50 ml of aliquots of juice and titrated against 0. 1*N* NaOH to *p*H 8.1 (Ruck, 1963), and expressed as percentage citric acid. Percent juice was calculated as (total juice volume/total fruit weight) × 100. The TSS/tree was calculated as (yield/tree × percent juice content × Brix).

Results

Growth measurements and yield

There was not much difference in the circumferences of the rootstock and scion of the trees selected for the experiment. There were some variations in the height, diameter, and canopy volume for the trees on all the rootstocks (Table 1); however, this could not account for the differences in yield. Fertilizer application significantly increased yield for both fruit number and total fruit weight per tree. Increasing the amount of fertilizer applied to Late Valencia on RL rootstock resulted in increases in yield, compared to the control. Although the amount of fertilizer applied was doubled from T2 to T3, there was no corresponding increase in yield. Nitrogen applied in the form of ammonium sulphate gave higher yield than urea; however, this was not significant. On applying fertilizer to the trees, they produced fruits more efficiently (Table 2).

For Late Valencia on RL rootstock, application of fertilizer at T2, increased the fruit number by 79 per cent, while total fruit weight increased by 90 per cent. However, when the amount of fertilizer applied was doubled (T3), the increases in fruit number and total fruit weight responded differently. A similar trend was observed for Late Valencia on RGL rootstock. On the other hand, for Late Valencia on CM roostocks, when fertilizer was applied at T2, the increase in yield was 23 per cent, compared to the control. Similarly, when the fertilizer amount was doubled (T3), the increase in total yield was greater than the increase between T1 and T2.

Fruit quality

The *p*H of Late Valencia juice increased when fertilizer was applied to RL, CM or RGL rootstocks. The *p*H of the juice increased with increasing fertilizer amount for RL and CM rootstocks. The TSS of the juice was highest at T3 for RL rootstock. For CM or RGL rootstocks, increasing the fertilizer amount increased the TSS. The juice percentage of the fruit did not respond to fertilizer application. The juice percentage of the fruits ranged between

TABLE 1

Growth Measurements and Production Efficiency of Late Valencia on either Rough Lemon, Cleopatra Mandarin or Rangpur Lime as Affected by Fertilizer Rates

Treatment code	*Scion stock ratio*	*Height (m)*	*Diameter (m)*	*Canopy volume (m^3)*	*Total fruit no.*	*Mean fruit weight (g)*	*Total fruit weight (kg/tree)*	*Efficiency (g/m^3)*
Rough Lemon								
T1	0.76	5.37	6.36	227.4b	368a	178	66b	289c
T2	0.83	4.53	7.00	231.8b	662b	190	126a	545b
T3	0.80	4.96	6.94	250.1b	800c	185	148a	631a
T4	0.78	5.57	6.94	280.48a	757c	190	144a	514b
Cleopatra Mandarin								
T1	0.89	5.28	6.56	237.8c	460c	239	110c	462c
T2	0.88	5.30	7.20	288.0b	741b	184	136b	472b
T3	0.84	5.03	7.34	283.2b	864a	219	190a	671a
Rangpur Lime								
T1	0.97	4.55	6.44	197.3b	700b	187	131c	665b
T2	0.95	3.65	7.41	195.2b	798b	225	180b	923a
T3	0.97	4.77	6.90	237.2a	1276a	172	220a	928a

Means followed by the same letter in the same column are not significantly different at 5 per cent level by Duncan's multiple range test.

TABLE 2

Fruit Quality of Late Valencia on either Rough Lemon, Cleopatra Mandarin or Rangpur Lime as Affected by Fertilizer Rates

Treatment code[1]	pH	TSS (%)	Vol. (ml)	Juice (%)	TA (%)	TSS/TA ratio	TSS/tree (%)
Rough Lemon[2]							
T 1	3.95c	13.1b	788c	39	0.93a	14.1c	337.2d
T 2	4.12b	12.8b	814c	37	0.75c	17.1a	596.7c
T 3	4.23a	13.9a	883b	41	0.81b	17.2a	900.4a
T 4	4.11b	12.5b	1132a	46	0.76c	16.4b	828.0b
Cleopatra Mandarin[2]							
T 1	4.04c	11.6c	964	42	0.86a	13.5c	535.9c
T 2	4.15b	11.9b	836	40	0.64b	18.6b	647.4b
T 3	4.31a	12.2a	880	35	0.59b	20.7a	811.3a
Rangpur Lime[3]							
T 1	3.90b	12.3c	715b	33	1.09a	11.3c	531.7c
T 2	4.07a	12.9	852a	40	0.82b	15.7b	928.8b
T 3	3.99a	13.8a	753b	40	0.70c	19.7a	1214.0a

[1]Means followed by the same letter in the same column are not significantly different at 5 per cent level by Duncan's multiple range test. [2] Sampling was conducted in March. [3] Sampling was conducted in February.

37 and 46 per cent for RL, 35 and 42 per cent for CM, and 33 and 40 per cent for RGL rootstocks. The total titratable acidity (TA) decreased with application of fertilizers. Increasing the fertilizer amount applied decreased the TA consistently for RGL rootstock. The TSS/TA increased with fertilizer application irrespective of the rootstock. Applying N as ammonium sulphate gave higher TSS/TA ratio than urea. This might be due to S in the ammonium sulphate. Similarly, the TSS/tree showed consistent increases with increase in fertilizer application.

Discussion

The scion/stock ratios for RL, CM and RGL show the extent of compatibility between the scion and rootstock. This shows that Late Valencia could be budded onto any of the rootstocks used in this study for establishing citrus orchards. Opoku (1972) recommended that great care should be taken with the use of RGL as a rootstock in Ghana. Because the exocortis virus disease which is prevalent in the country has infected some sweet oranges; besides, RGL is susceptible to the disease. However, the growth measurements of the trees on RGL, observed in this study, confirms earlier observations (Opoku, 1972) that Late Valencia at ARS-Kade was not infected with the disease. The height of the trees on RGL, which was shorter than that on RL or CM, shows the relative dwarfing tendency of RGL rootstock. Rangpur lime rootstock can be used when exocortis-free bud wood is available.

The differences in the canopy volume of the selected trees could not account for the differences in yield. It is apparent from the results that the differences in yield were mainly due to the response to the fertilizer applied. This suggests that the nutritional status of the trees, rather than the canopy volume, is more important in promoting yield. The response of Late Valencia to fertilizer application was different for the same amount of fertilizer applied and rootstocks. The higher yield observed when N was applied as ammonium sulphate rather than urea could suggest that sulphur is limiting in the citrus orchards at ARS - Kade. Elsewhere, farmers use sulphur-containing materials as fungicides and insecticides or contaminate rainfall in polluted areas. None of these conditions exist nor been seen to be practised among management schedules. On the other hand, the trees could have benefited from more N from ammonium sulphate than from urea, as some of the N from urea could have been lost, under forest soils rich in organic matter (Antwi, personal communication). Thus, the increase in yield could be attributed to sulphur as limiting in the environment or increased benefit of N from ammonium sulphate or both.

The TSS /tree increased with increasing fertilizer application. Similarly, fertilizer application was more efficient in producing fruits. This clearly shows the benefits in applying fertilizer to the trees. At the present fertilizer and fruit prices, application of fertilizer would be beneficial to the farmer. The amount of fertilizer which should be applied may depend on the rootstock and the age of the tree.

Rough lemon is noted for its high yields (Opoku, 1971; Sam-Aggrey, 1973). A low yield of 66 kg/tree was recorded at T1. However, when fertilizer was applied at T2 and T3, the increases in yield were significant. At the time of harvesting, considerable amount of fruits had dropped from the trees of T1 while few fruits had dropped from trees of T2 or T3. The nutritional status of RL trees could therefore affect the extent to which the trees can hold the fruit after maturity. The fruits were harvested in March when they were juicy and sweet for the fresh market.

The TSS/TA ratio, which is the maturity index for the fruits, indicates that by applying fertilizers, the maturity period could be reduced. This is because, the rate of attaining an acceptable TSS/TA ratio increased faster when fertilizer was applied than when it was lacking (data not published). The TSS/TA values reported in the study were higher than those reported earlier for the same scion and rootstocks (Sam-Aggrey, 1973). These differences may be due to differences in age, soil type, and nutrition. Lower values of TSS/TA were observed for younger trees (Ofosu-Budu, unpublished).

In California, the basis for legal maturity of oranges is a ratio of 8 to 1 for TSS to TA. The balance between sugars, which accounts for about 80 per cent of the TSS, together with the sourness produced by the acidity, is the best criterion for correlating fruit quality with consumer preference. In Florida, the acidity of mature oranges usually ranges between 0.5 and 1 per cent (Harding, Winston & Fisher, 1940). The values attained in the study compare favourably with the accepted values for Florida.

The results obtained for TSS/TA ratio indicate that the juice of Late Valencia, on any of the rootstocks, satisfies this requirement. In fact, the legal maturity for California was reached around late January (data not published). However, the Ghanaian fresh market prefers a sweeter juice, so harvesting of the fruits are sometimes delayed. Most fruits are harvested around February-March, when the TSS/TA ratio is around 10 or more. It is, therefore, suggested that this ratio should be set for the fresh sweet orange market.

It was observed that the rootstock has effect on the earliness of attaining a high TSS/TA ratio. Fruits on RGL rootstocks were harvested in February, about a month earlier, compared to RL or CM, but the values for TSS/TA were comparable. It is, therefore, concluded that compared to RM or CM, RGL as rootstock with fertilizer application influences early fruit maturity.

The values of the TSS/TA for the sweet orange juice produced in the Kwaebibirem district are comparable to those published elsewhere (Harding, Winston & Fisher, 1940; Tang & Tian, 1992); therefore, the orange juice produced here can compete on international markets including that of the USA. Further research work to examine other mineral elements such as calcium, magnesium, and zinc on the yield and fruit quality should be encouraged.

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