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Quality of Fruits of Three Varieties of Tomato (*Lycopersicon esculentum* (L.) Mill) as Affected by Phophorus Rates

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Abstract: Studies were conducted in the early and late seasons of 1999 and 2000 at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria to determine how tomato fruit qualities were affected by phosphorus (P) nutrition. The five levels of P evaluated were 0, 13.2, 26.4, 39.6 and 52.8 kg P ha^{-1} using single superphosphate fertiliser (18% P) while the three varieties of tomato used were Ibadan Local, Roma VF and NHLe 158-13. The experiment was a split plot in a randomised complete block design replicated four times. At 26.4 kg P ha^{-1}, significantly higher fruit diameter and fruit yields were obtained. Except for the moisture content and ether extract, the P level had significant ($p<0.05$) effects on the pH, Total Soluble Solids (TSS), lycopene, ascorbic acid, crude fibre and crude protein content of tomato fruits with the optimum values recorded at 26.4 kg P ha^{-1}. The season did not produce any significant ($p\leq 0.05$) effect on fruit yield and fruit diameter. The pH, moisture content and lycopene contents were significantly higher during the early season than late season while TSS, crude fibre, crude protein and ascorbic acid were significantly ($p<0.05$) higher in the late season than early season. The season had no significant effect on ether extract content. The study established that 26.4 kg P ha^{-1} was the optimum P level for the tomato varieties used in this study

Key words: Tomato, phosphorus, fruit qualities, cracking height

INTRODUCTION

Tomato (*Lycopersicon esculentum* (L.) Mill) has become widely disseminated all over the world. It is consumed fresh and as paste in all parts of the World (Alofe and Somide, 1982). Tomato fruit is adapted to various culinary uses either in the fresh form in salad or as puree in gravies, stew and soups, for the diet of the diverse cultures of the world. Alofe and Somide (1982) reported that while the average fruit yield in Northern Nigeria is 30-40 t ha^{-1}, the yield in Southern Nigeria is 10 tons ha^{-1}. Nutrient deficiency is a major problem militating against tomato production in Southwest Nigeria. Sobulo *et al.* (1975) reported that soils of southwest Nigeria are deficient in phosphorus. Adepetu (2000 persional Comunication) and Mokwunye (1999) stated that African soils and indeed Nigerian soils are deficient in phosphorus. The Institute for Natural Resources in Africa of the United Nations University, Ghana is presently studying the Lome (Togo) rock phosphate to solve the problem of phosphorus deficiency in Africa soils. Experience has shown that over the years, tomato and indeed other crops planted at the Obafemi Awolowo University, Ile-Ife farms manifest purplish colouration of leaves occasioned by suspected deficiency of phosphorus thereby corroborating the above claims. Agbede and Aduayi (1978) in a greenhouse experiment reported that 160 ppm of phosphorus depressed tomato plant growth. Maximum plant growth was recorded at 40 ppm of applied phosphorus beyond which growth was retarded. A generally poor plant growth, resulting in stunting and weaker stems was recorded when phosphorus was not applied. It was reported that lack of phosphorus could prevent other nutrients from being used by plants and this is described as induced deficiency.

Okelana and Okeleye (1994) reported the result of a study on growth and yield of snake tomato (*Trichosanthes cucumerina* L.) as influenced by phosphorus and staking. They also reported that phosphorus fertilization, especially 30 kg P ha^{-1} enhanced foliage development without increasing shoot dry weight. It also favoured flowering and ultimate fruiting of plants. The study concluded that a combination of horizontal trellis staking and 30 kg P ha^{-1} produced the best quality and quantity of fruits.

Much of the energy required for plant metabolism is stored chemically in the form of complex organic phosphates (ATP-adenosine triphosphate) and it is released as required, to drive the important chemical

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processes involved in growth. Phosphorus also plays an important role as a constituent of nucleic acids (Adams, 1986). Plant deficient in phosphorus become dwarfed and spindly, the leaves remain small and stiff, and purple tints develop on the undersides. Brown areas may develop at random in the oldest leaves, which become yellow and die prematurely as they lose the phosphate that is translocated elsewhere to maintain new growth. The effects of phosphorus on qualities of the tomato fruits have not been fully investigated, especially on the three varieties of tomato that were used in this study.

MATERIALS AND METHODS

The studies were conducted at the Teaching and Research Farm, Obafemi Awolowo University, Ile-Ife, Nigeria during the early and late seasons of 2000 and 2001. The Obafemi Awolowo University is located on latitude 07°28′N and longitude 04°33′E and the altitude is about 224 m above sea level. Ile-Ife lies in the transitional zone between the humid and sub-humid tropical climates and has a bimodal rainfall pattern with peaks in June and September, with a short rainfall break in August. Early rains usually last from late March/early April to end of July while late rain usually starts in early September and terminate at Ile-Ife in November. The dry season lasts from November to March. Soil samples taken for the analyses were air-dried, crushed, passed through a 2 mm sieve and analysed. Soil total N and organic carbon were determined by the Kjedahl method and Walkey and Black method, respectively. Soil pH was measured using 1:2 (W/V) soil-water suspension ratio. Available phosphorus was determined by Bray 1-P method (Bray and Kurtz, 1945) while K, Ca and Mg were first extracted using neutral normal NH_4OA_c, thereafter, K was determined by flame photometry and, Mg and Ca by spectrophotometry using the atomic absorption spectrophotometer.

Four field experiments were conducted using a split plot in randomized complete block design replicated four times. The first two experiments were conducted during the early and late seasons of 1999. The same set of experiments were repeated in the early and late seasons of the year 2000. The factors were three tomato cultivars and five levels of phosphorus fertilizer. The phosphorus level formed the main plot while the varieties formed the subplot. The five levels of phosphorus supplied by single super phosphate (18% P) were 0, 13.2, 26.4, 39.6 and 52.8 kg P ha^{-1}). The three tomato varieties of tomato are Roma VF, Ibadan Local and NHLe 158-13. The Roma VF was planted at 50×50 cm, Ibadan Local at 50×70 cm and NHLe 158-13 at 50 cm×50 cm. The five levels of phosphorus were chosen based on the result of the soil analyses as presented in Table 1.

Table 1: Pre-planting and post-planting soil chemical properties at 0-10 cm depth in the experimental area

Chemical property	Values
pH (H_2O)	6.6
Organic carbon g kg^{-1}	8.5
Total N(g kg^{-1})	1.10
Available P (mg kg^{-1})	5.80
Exchangeable K^+ (cmol kg^{-1})	0.37
Exchangeable Mg^{2+} (cmol kg^{-1})	0.38
Exchangeable Ca^{2+} (cmol kg^{-1})	2.64
ECEC (cmol kg^{-1})	4.60
Physical property	
Sand (g kg^{-1}	80.2
Silt (g kg^{-1}	9.7
Clay (g kg^{-1}	10.1

The seedlings were first raised in the greenhouse and transplanted onto the field at 24 days after sowing. Each subplot measured 2.0×2.0 m and a path of 0.5 m separated adjacent plots. There were four rows per plot for each of the varieties. There were ten plants per row for Roma VF and NHLe 158-13 while Ibadan Local plots had seven plants per row. Each main plot measured 7.0×2.0 m and adjacent main plots were separated by a path of 1.0 m. Each replicate measured 2.0×39.0 m and adjacent replicates were separated by a path of 1.0 m. The total experiment area was 39.0×11.0 m i.e., 429 m^2. The P fertilizer was applied at two weeks after transplanting.

At full ripening, data were collected on fruit yield and fruit diameter. The fruits of the three varieties of tomato were chemically analyzed. The tomato fruits were first homogenized in Wiley Micro-Hammer Stainless mill. The pH of the homogenized pulp was determined using KENT EIL pH meter. The crude fiber was determined by digesting the 50 g homogenized pulp in 1.25% tetra-oxo-sulphate (IV) acid and 1.25% sodium hydroxide. The digest was put in crucible and transferred into a muffle furnace at 660°C for 3 h. The weight difference expressed as a percentage of the fresh weight constitute the percent crude fibre. The crude protein content was determined by micro-Kjedhal method while the ether extract content was determined by Soxhlet extraction technique. The Total Soluble Solids (TSS) was determined by using the hand refractometer and the ascorbic acid content was determined by using the indophenol dye method. The lycopene content was determined by grinding 20 mL of the homogenized pulp in 25 mL acetone and 20 mL hexane and the absorbance was read at 501 nm using a colourimeter. All these methods followed the Association of Official Agricultural Chemist (AOAC) (1980) methods.

Statistical analysis was carried out using the ANOVA according to Steel and Torrie (1980). Depending on the number of samples, means were separated using the least significant difference or Duncan's Multiple range test at 5% level of probability.

Table 2: Effects of phosphoms levels and season on qualities of tomato fruits

P Level ($kg\ ha^{-1}$)	Season	pH	TSS (%)	Moisture Content (%)	Crude fibre (%)	lycopene (μg/100 g)	Crude protein (%)	Asorbic acid (μg/100 g)	Ether extract (%)
0	Early	5.36b	3.10d	11.60a	0.70d	13.20c	0.44b	0.11d	28.0a
	Late	5.39b	3.31c	10.21b	0.90c	11.50d	0.33c	0.20e	27.8a
13.2	Early	5.30b	3.27c	11.40a	0.76d	13.21c	0.48b	0.21c	28.2a
	Late	5.29b	3.50b	10.01b	1.18a	11.01d	0.32c	0.41d	28.3a
26.4	Early	5.77a	3.40c	11.41a	0.98c	16.60a	0.67a	0.44a	27.9a
	Late	5.78a	3.68a	10.03b	1.70a	13.90b	0.48b	0.61b	28.3a
39.6	Early	5.77a	3.36c	11.32a	0.87c	14.91b	0.63a	0.43a	28.5a
	Late	5.76a	3.66a	10.12b	1.76a	12.93c	0.42b	0.61b	28.3a
52.8	Early	5.78a	3.37c	11.38a	0.91c	14.20b	0.57a	0.41a	28.0a
	Late	5.79a	3.60a	10.22b	1.46b	13.00c	0.38b	0.60b	28.4a

Means in each column followed by different alphabets are significantly different at 5% level of probability according to DMRT

Table 3: Effect of variety and season on qualities of tomato fruits

Variety	Season	pH	TSS (%)	Moisture content (%)	Crude fibre (%)	lycopene (μg/100mg)	Crude protein (%)	Ascorbic acid (μg/100g)	Ether extract (%)
Ibadan Local	lEarly	5.21d	3.48b	10.41a	0.81b	26.3a	0.26b	10.11d	0.34b
	Late	5.07e	3.87a	10.00b	0.94a	21.0b	0.44a	13.40b	0.31b
Roma VF	Early	5.65a	3.52b	10.51a	0.80b	22.6b	0.24b	11.81c	0.43a
	Late	5.41b	3.94a	10.01b	0.93a	20.1c	0.47a	14.88a	0.42a
NHLe 158-13	Early	5.38b	3.45b	10.60a	0.84b	22.1b	0.26b	11.01c	0.35b
	Late	5.22d	3.89a	10.00b	0.94a	20.0c	0.44a	14.01a	0.36b

Means followed by different alphabets in each column are significantly different at 5% level of probability according to Duncan's Multiple Range Test

Table 4: Effect of phosphoms level and season on fruit yield and fruit diameter of tomato*

P level ($Kg\ P\ ha^{-1}$)	Fruit diameter (cm) Season Early	Late	Fruit yield ($Kg\ ha^{-1}$) Season Early	Late
0	3.2	3.3	13.5	13.5
13.2	4.0	3.4	15.5	15.7
26.4	6.8	6.9	21.7	21.6
39.6	5.2	5.3	19.7	19.5
52.8	5.4	5.3	19.5	19.7
LSD (5%)	1.6	1.7	2.5	3.1

*All values are means for 1999 and 2000 field studies

RESULTS

The results of general chemical and physical properties of the soil in Table 1 showed that surface soil is slightly acid with pH 6.6. The soil of the site was high in organic carbon (0.85%). The total nitrogen was adequate (0.17%) considering the critical value of 0.15% in Southwest Nigeria. Available P (Bray-P) was 5.80 mg kg^{-1} and was considered inadequate given a critical value of 10-12 mg kg^{-1} 1 in Southwest Nigeria. Exchangeable Mg was 0.38 cmol kg^{-1} and this was considered adequate given a critical value of 0.2-04 cmol kg^{-1}. The values of exchangeable Ca^{++} and K^{+} were 2.64 and 0.37 cmol kg^{-1}, respectively and were considered adequate considering the critical values of 2.5 and 0.16 cmol kg^{-1} for Ca^{++} and K^{+}, respectively. The soil of the site was classified ad sandy loam.

Table 2 shows that significantly higher pH, TSS crude fibre, crude protein, lycopene and ascorbic acid were recorded at 26 kg P^{-1} compared to 0 and 13.2 kg P^{-1} while there was no significant difference among 26.6, 29.6 and 52.8 kg P^{-1}. The pH, moisture content and lycopene contents were significantly higher during the early season than late season while TSS, crude fibre, crude protein and ascorbic acid were significantly higher in the late season than early season. The season had no significant effect on ether extract content.

Table 5: Effect of variety and season on fruit yield and fruit diameter of tomato fmits

Variety	Fruit diameter (cm) Season Early	Late	Fmit yield ($kg\ ha^{-1}$) Season Early	Late
Ibadan Local	6.0	6.0	20.5	20.4
Roma VF	5.0	5.0	16.5	16.5
NHle 158-13	4.5	4.7	18.5	18.5
LSD (5%)	0.1	0.1	1.3	1.4

* All values are means for 1999 and 2000 field studies

Results showed Table 3 that the pH and ether extract contents were significantly higher in Roma VF compared to Ibadan Local and NHLe 158-13. The pH and ether extract content of Roma VF and NHLe 158-13 did not differ significantly. The lycopene content of Roma VF and NHLe 158-13 did not differ significantly but were significantly higher than that of Ibadan Local. The TSS, moisture content, crude fibre and crude protein did not differ significantly among the three tomato varieties. The pH, moisture content and lycopene contents of the three varieties of tomato were significantly higher during the early season compared to the late season while the TSS, crude fibre, crude protein and ascorbic acid were significantly higher during the late season compared to the early season. The ether extract contents of the three tomato varieties were not significantly affected by the season.

The fruits diameter and fruit yield were significantly affected by the phosphorus level, but not significantly by the season (Table 4). The fruit diameter and fruit yield of plants under 26.4 kg P ha^{-1} were significantly higher in both seasons than at 0 and 13.2 kg P ha^{-1}. There was no significant difference among fruit yields and fruit diameters under 26.4, 39.6 and 52.8 kg P ha^{-1} in both seasons.

Table 5 shows that significantly higher fruit diameter and fruit yield were produced by Ibadan Local compared to Roma VF and NHLe 158-13 in both seasons, while NHLe also significantly out yielded Roma VF in both seasons.

DISCUSSION

The results of this study showed that P is a major mineral element required for growth, fruit yield and production of good quality fruit the three varieties of tomato used for this study. On all the parameters measured, P at 26.4 kg P ha^{-1} produced the optimum values. In the ecology where this study was conducted, it had been reported that the P is a major crop yield limiting factor (IITA, 1999; Mokwunye, 1979, 1999; Aduayi *et al*., 2002). This study also showed that tomato could be grown in this ecology both in the early and late season with no appreciable change in fruit yield.

The significant effects of phosphorus on fruit diameter and overall fruit yield may be explained by the central role played by phosphorus in energy systems of plants. When phosphorus level is optimum. Adams (1986) reported that much of the energy required for plant metabolism which is stored chemically in the form of complex organic phosphates adenosine triphosphate (ATP) will be made available and released as required. Therefore, important chemical processes involved in growth will be driven steadily. The optimum phosphorus level established in this study was 26.4 kg P ha^{-1} where the fruit yield and qualities were at the optimum.

The higher lycopene content during the early seasons may be due to the quality and intensity of insolation. Jen *et al.* (1977) reported that light quality is important in carotenoid biosynthesis, the process that they suggested was partially photochrome mediated. The ripe tomato flavour results from the balance of sugars and acids in the fruit, and the numerous volatile compounds that produce the aroma (Griffiths *et al*., 1999).

The crude fibre and crude protein contents were higher during the late season compared to the early season. Konova Rainova (1981) had reported that soybean that received less water have higher crude protein and lower pH. They also stated that when moisture is high, the cell plasma is dilute, protein forming enzymes are retarded thus reducing protein synthesis. Since crude protein is derived from the total nitrogen content of the fruits, it can be suggested that during the early season when rainfall is heavy, there is the chance that nitrogen is leached and not readily available for root absorption compared to the late season. This explains in part why the crude protein content is higher in the late season than in the early season.

Except for the moisture content, the phosphorus level had significant effect on pH, TSS, ascorbic acid, crude fibre, lycopene, crude protein and ether extract of tomato fruits. The optimum amounts of these parameters were obtained at 26.4 kg P ha^{-1}. In a study of combined effects of sulphur and phosphorus on tomato, Kazim *et al.* (1978) reported marked changes in the pH of fruits juice and titratable acidity due to the treatments. It is interesting to note that phosphorus levels that were higher than 26.4 kg P ha^{-1} produced a reduction in the amounts of TSS, ascorbic acid, crude fibre and lycopene. High level of phosphorus has been reported to increase the proportion of unevenly ripened fruits (Winsor and Long, 1968) and increase the incidence of hollow fruit (Winsor, 1966). These two traits i.e. hollow fruits and uneven ripening were observed on the field at 39.6 and 52.8 kg P ha^{-1}, and could be responsible for the decline in the amounts of TSS, ascorbic acid, crude fibre and lycopene. It has been reported by Ismail *et al.* (2001) that application of 100-P resulted in highly significant increase in the dry matter yield and phosphorus uptake of tomato seedlings. This explains in part the reason that the crude fibre was significantly affected by phosphorus application. The findings in this study confirmed the findings of Winsor (1966), Winsor and Long (1968), Jens *et al.* (1977) and Ismail *et al.* (2001).

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