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Effects of Phosphorus Fertilizer on Plant Growth, Fruit Yield and Proximate Composition of Hot Pepper (*Capsicum annuum,* Rodo Variety)

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Authors' contributions

This work was carried out in collaboration between both authors. Author OJA designed the study and wrote the protocol. Author EOA managed the analyses of the study and the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

Phosphorus deficiency is widespread in the soils in Nigeria which makes phosphorus fertilizer application at appropriate rates a component of the improved technologies needed for hot pepper (*Capsicum annuum L*) production. Atarodo (rodo) variety of hot pepper is cultivated in all agro-ecological zones and gives low fruit yields of variable quality which should be maximized with phosphorus fertilizer use but the information on the requirements is limited. The growth and fruit yield responses of rodo to phosphorus fertilizer were evaluated in 2013 and 2014 at Ado-Ekiti, southwest Nigeria in order to determine the optimum rates. The phosphorus fertilizer was applied at 0, 20, 40 and 60 kg P_2O_5 ha^{-1} in four replicates arranged in randomized complete block design. Data were collected on growth parameters from 2 weeks after fertilizer treatment and at 2-week intervals, number and weight of ripe fruits, fruit parameters and proximate composition, vitamin C and mineral contents. The growth parameters increased with age; plant height, number of leaves,

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leaf area and dry matter yield of plant portions showed linear increase up to the 60 kg P_2O_5 ha^{-1} rate. The 60 kg P_2O_5 ha^{-1} rate gave the highest fruit and seed yields in both years but the agronomic efficiency was maximized at 60 and 20 kg P_2O_5 ha^{-1} in 2013 and 2014 respectively. The fruit proximate composition, minerals and vitamin C contents increased to the highest values at 60 kg P_20_5 ha^{-1}. The linear responses to 60 kg P_2O_5 ha^{-1} in soils containing low available P suggest that higher rates and soils with variable P contents should be the focus to attain the optimum rates.

Keywords: Hot pepper; phosphorus fertilizer; growth; fruit yield; agronomic efficiency; mineral and proximate composition.

1. INTRODUCTION

The output of pepper (*Capsicum* spp) in Nigeria was 204,200 tons (t) in 2007, which accounted for 29% of the total production in Africa [1]. Pepper is widely cultivated during the rainy season and under irrigation in the dry season, especially in states of the savannah agro-ecological zones from where the fruits of sombo, tatasai, atarodo (rodo) varieties are transported to markets in the southern states [1]. However, the regular supplies and availability of pepper are now being hampered by abnormal weather conditions due to climate change, seasonal price fluctuations and the risks posed to production and marketing activities by unpredictable social, political and religious crises.

The Agricultural Promotion Policy (2016-2020), as a refreshed strategy to increase the supply of agricultural commodities and attain food and nutrition security, has prioritized the accelerated production and activities in horticultural crops (fruits and vegetables) development [2]. The dry savannah zone has specialized in the production of sombo, tatasai and sweet pepper whereas rodo which exhibits the widest adaptation [3] will be cultivated in all the agro-ecological zones. Rodo cultivation is widespread in Ekiti State, south-western Nigeria but the average yield at 2.64t hectare $(ha)^{-1}$ obtained from local landraces [4] is very low compared to national productivity at 3.85 t ha^{-1} [5] and estimated 13.4 t ha^{-1} global average [6].

The constraints to high pepper fruit yield include weather uncertainty, poor soil fertility and use of local varieties with low yield potentials, pests and diseases, small-scale level of production and multiple cropping systems, lack of and low rate of adoption of improved technologies [7]. Thus, one of the components of improved technology to be developed is fertilizer management, which alone can be responsible for 60-70% incremental yield in crops [8]. Pepper requires continuous, adequate and balanced supply of nutrients as a condition for the improved nutrition that will ensure good growth, yield and fruit quality. The nutrients mostly used are nitrogen (N) and phosphorus (P) but, adequate P is required for initial root development, energy transfer and photosynthesis, water use efficiency, fruit and seed formation, seed size and number and yield [9]. The natural forms of P are stable or insoluble in soils such that only a small proportion exists in the soil solution at any one time. In the competition between the plants and soils for this solution P, the winner is usually the soil especially the highly-weathered soils in the tropics with various levels of acidity and which contain large amounts of iron and aluminium oxides responsible for P fixation into unavailable forms. This, together with plant removal under continuous cropping, mean reduced amounts of available P but which can be built up by the application of adequate rates of appropriate P fertilizers [10].

The few studies on the application of P fertilizers to pepper in Nigeria have involved tatasai *Capsicum annuum* [11] and hot pepper (*Capsicum frutescens*) [12] and showed significant growth and yield responses and the optimum rates obtained were 60 and 90 kg P_2O_5 ha^{-1} respectively. Rodo is different from these pepper types in terms of botany, physiology and biochemistry such that these rates would not be the requirement for high yields. Thus, it is desirable to assess the responses of rodo variety hot pepper to P application and determine the optimum rate as a component of the fertilizer management practices needed in the development of improved cultural practices for its production and the influence on proximate and mineral composition.

2. MATERIALS AND METHODS

2.1 Land Preparation and Experimental Design

The experiments were conducted at the Teaching and Research Farm, Ekiti State

University, Ado-Ekiti during the rainy season of 2013 and 2014. The experimental sites were 2-3 year fallow plots infested with Mexican sunflower (*Tithonia diversifolia*) and guinea grass (*Panicum maximum*). The land was ploughed, harrowed and fairly level portion measuring 17 x 15 metres (m) was marked out. The portion was divided into 2.8 x 2.4 m^2 plots separated by 1 m wide paths.

Surface (0-15 cm) soil samples were randomly taken and mixed to form a composite for each year. The samples were air-dried, sieved (<2 mm) and analyzed for particle size distribution, pH in water, organic carbon, total N, available P, exchangeable cations and acidity using the standard laboratory methods described in Udo et al. [13].

2.2 Fertilizer Rates and Evaluation of Plant Performance

The seed of pepper *(Capsicum annuum)* (Atarodo variety, NHCa(R)429) obtained from National Horticultural Research Institute, Idi-Ishin, Ibadan were sown in nursery beds and 5-6 weeks old seedlings were transplanted at 60 x 40 cm spacing. The treatments were P rates at 0, 20, 40 and 60 kg P_2O_5 ha^{-1} in four replicates and arranged in randomized complete block design. Each P level was mixed with 50 kg N ha^{-1} as urea (46% N) and 60 kg K_2O ha^{-1} as muriate of potash (60% K_2O) and applied in bands 6-8 cm away from each seedlings at 2 weeks after transplanting. The second half of N (25 kg N ha^{-1}) was applied at first fruit set. Data collection on plant height, stem girth, number of branches, number of leaves and leaf area, fresh and dry weights of stems, roots and leaves commenced 2 weeks after treatment (WAT) on randomly selected plants and continued at two week-intervals until 10 WAT. Ripe fruits were hand – picked at five-day intervals, counted and weighed over 10 harvests. Fruits were randomly selected from each treatment to measure fruit length and breath, and sliced open to determine pericarp thickness and seed weight. The agronomic efficiency of P use was calculated with the formula:

Phosphorus Agronomic Efficiency = $Y_F – Y_C / QP$

Where, Y_F = Fruit yield with fertilizer
Y_C = Fruit yield without fertilizer
QP = Quantity of P applied

Ripe fruits were selected from each treatment at peak harvest for proximate analysis to determine the moisture, ash, protein, crude fibre, fat and carbohydrate content using method described in AOAC [14]. The samples obtained during dry-ashing were dissolved in 10% HCI solution and filtered. The P in the filtrate was determined by the vanado-molybdate yellow while K, Na and Ca were measured by flame photometer and Mg by atomic absorption spectrophotometer.

2.3 Statistical Analysis

The data were subjected to statistical analysis using the Linear Model of the SAS Institute [15] package. Statistical inferences were drawn based on F (variance ratio) value and treatment means were separated using the test of least significant differences.

3. RESULTS

3.1 Physical and Chemical Properties of Soil

Table 1 shows the properties of the soils used for the studies. In 2013, the soil was a moderately acid sandy loam with very low organic matter, total N (0.60 g kg-^{1}) and available P contents (3.56 mg kg^{-1}), very low exchangeable cations (0.23 cmol kg and effective Cation Exchange Capacity CEC (5.25 cmol kg^{-1}). In 2014, the soil was a moderately acid sandy clay loam with slightly higher organic matter, total N (0.64 g kg^{-1}) available P (2.48 g kg^1) an exchangeable Ca(4 .26 g kg-^{1}).

The effects of P rates on plant height, number of leaves and leaf area in 2013 and 2014 are shown in Table 2. All the plant growth parameters considered, increased with age, with most growth occurring between 4 and 8 WAT. And at each sampling time, P application significantly (P=0.05) increased plant height, number of leaves and leaf area to the highest values at 60 kg P_2O_5 ha^{-1}. In 2013 and 2014, the highest values of these growth parameters at 10 WAT were 44.75 cm, 125.78 and 43.23 cm^2; and 47.78 cm, 148.23 and 46.96 cm^2 respectively. Dry matter yield of pepper increased with age of the plants and at each sampling time. P application significantly (P= 0.05) increased the root, stem and leaf dry weights as indicated in Table 3. The pattern was the same for the two years with the least values obtained in the control treatment and the highest at 60 kg P_2O_5 ha^{-1}.

Table 4, shows the effects of P application rates on number of fruits, fruit yield and seed yield ha^{-1}

and fruit size, fruit length and breadth and fruit pericarp thickness in 2013 and 2014. Pepper responded significantly (P=0.05) to P application with all the yield parameters increasing from the least values in the control to the highest at 60 kg P_2O_5 ha^{-1}. The highest number of fruits (1.155 x 10^6) and fruit yield (13.13 t ha^{-1}) were produced at 60 kg P_2O_5 ha^{-1} in 2013 while the response pattern was the same in 2014 with corresponding values 3.73 x 10^6 fruits and 14.89 t ha^{-1}. The application of 60 kg P_2O_5 ha^{-1} produced the highest fruit size (3.89 g and 4.71 g), fruit length (4.22 cm and 4.34 cm) and breadth (2.04 cm and 2.25 cm) and pericarp thickness (0.3 cm and 0.36 cm) which are significantly different in 2013 and 2014. The differences between 40 and 60 kg P_2O_5 ha^{-1} rates (4.26 cm and 4.34 cm) were not significant for fruit length and pericarp thickness in 2014. The seed yield increased significantly (P=0.05) with P application such that 60 kg P_2O_5 ha^{-1} produced the highest seed yields in 2013 and 2014 at 249.52 and 834.99 kg ha^{-1} respectively.

Table 5 shows the agronomic efficiency of P application based on number of fruits, fruit yield and seed yield ha^{-1}. In 2013, the agronomic efficiency increased to maximum at 40 kg P_2O_5 ha^{-1} based on the number of fruits and to 60 kg P_2O_5 ha^{-1} for fruit and seed yield. In 2014, the yield parameters gave highest agronomic efficiency at 20 kg P_2O_5 ha^{-1} and decreased to the highest rates.

The effects of P application rates on the proximate composition and mineral contents of hot fruits pepper are shown in Table 6. The moisture content decreased significantly from 84.46% in the control to 79.38% at 60 kg P_2O_5 ha^{-1} in 2013. A similar trend of decreased in moisture content was observed in 2014. The highest value of 84.27% in the control differed significantly (P=0.05) from 83.68, 80.84 and 79.84% at 20, 40 and 60 kg P_2O_5 ha^{-1} respectively. The ash, crude fibre, protein, carbohydrate and fat contents increased from the least values in the control to the highest at 60 kg P_2O_5 ha^{-1} in 2013 and 2014. The vitamin C content increased with P application and the values differed significantly (P=0.05) among the rates in 2013 and 2014. The 60 kg P_2O_5 ha^{-1} rate produced the highest values (109.67 and 111.34 mg kg^{-1}) of vitamin C while the least values (85.38 and 103 mg kg^{-1}) in both year were obtained in control treatment. Fruit N, P and K contents increased from the control treatment to the highest values at 60 kg P_2O_5 ha^{-1} which differed significantly from the lower rates. Also, the fruit Ca, Mg and Na increased with P application in each year such that the control treatment had the least values while the highest values were obtained at 60 kg P_2O_5 ha^{-1} rate.

4. DISCUSSION

The coarse surface layer and slightly acid reaction in the experimental soils are the features of Alfisols whose parent materials had developed from coarse-grained granitic rocks of the basement complex in Nigeria [16]. The soil testing criteria for pepper have not been

Table 1. Physical and chemical characteristics of the soils in the experimental sites

Soil Properties	2013	2014
Soil pH (1:2 soil: water)	5.92	6.00
Organic matter, g kg^{-1}	12.40	12.20
Total N, g kg^{-1}	0.60	0.64
Available P mg kg^{-1}	3.56	2.48
Exchangeable cations, cmol kg^{-1}		
K	0.23	0.20
Ca	3.65	4.26
Mg	1.05	1.98
Na	0.12	0.08
Al + H	0.20	0.11
ECEC	5.25	6.63
Particle size distribution, g kg^{-1}		
Sand	676.2	684.
Silt	177.8	97.0
Clay	146.0	218.4
Textural class	Sandy loam	Sandy clay loam

Table 2. The effects of P application rates on the growth of hot pepper

Treatments	Weeks after treatment				
	2	**4**	**6**	**8**	**10**
Phosphorus (Kgha^{-1})	**Plant height (cm)**				
0	14.45d	18.95d	24.05d	33.80d	43.85d
20	16.58c	22.53c	26.23c	42.88c	42.90c
40	17.75b	23.73b	28.13b	43.20b	44.15b
60	18.03a	24.13a	32.73a	44.18a	44.75a
S.E.	0.10	0.07	0.08	0.12	0.12
	Number of leaves plant $^{-1}$				
0	31.60d	50.20d	60.00d	89.73d	91.63d
20	36.75c	64.23c	74.83c	101.10c	116.73c
40	42.95b	66.50b	78.70b	112.53b	120.23b
60	43.02a	72.33a	82.43a	117.35a	125.78a
S.E.	0.12	0.20	0.60	0.64	0.72
	Leaf area plant $^{-1}$ (cm^2)				
0	11.45d	17.55d	29.75d	35.98d	35.88d
20	16.20c	19.70c	32.95c	37.23c	38.48c
40	18.96b	20.60b	36.68b	41.72b	42.51b
60	19.22a	21.53a	38.75a	42.93a	43.23a
S.E.	0.08	0.12	0.10	0.12	0.20
2014	**Plant height (cm)**				
0	15.10d	17.90d	24.35d	34.13d	34.63d
20	16.70c	22.63c	26.88c	38.70c	40.80c
40	17.93b	23.68b	29.65b	44.88b	45.86b
60	18.13 a	25.15a	33.18a	46.20a	47.78a
S.E.	0.06	0.05	0.02	0.08	0.08
	Number of leaves plant -1				
0	9.67d	31.75d	62.43d	91.15d	103.45d
20	10.77c	36.88c	76.18c	103.65c	123.28c
40	13.23b	45.93b	79.20b	114.43b	143.30b
60	13.38a	49.25a	83.05a	117.95a	148.23a
S.E.	0.03	0.05	0.04	0.06	0.06
	Leaf area plant-1 (cm2)				
0	13.25d	18.13d	28.93d	33.18d	35.52d
20	16.55c	20.10c	31.38c	36.13c	39.75c
40	18.58b	22.68b	35.30b	42.15b	43.13b
60	21.25a	25.01a	37.93a	44.15a	46.96a
S.E.	0.032	0.04	0.063	0.08	0.08

Means followed by the same letters in each column are not significantly different (P=0.05)

developed but the organic matter and total N contents are very low based on critical levels of 25.0 and 2.5 g kg^{-1} respectively in Nigeria [17]. The available P values are below 8.0 mg kg^{-1} suggested as critical level for pepper and tomato in South Western Nigeria while the exchangeable Ca is low and the Mg and K are medium to high [18]. The low fertility observed as constraint in the soil means that pepper would benefit from additional nutrients and elicit significant responses to organic and inorganic fertilizers in terms of vegetative growth, fruit yield and quality.

The application of P increased the growth and yield parameters of hot pepper. The poor available P status in the soils used for the studies provides the basis for the significant responses. Marchner (2012) had noted the positive roles of adequate P supply in stimulating healthy root growth which helps plants in better utilization of water and nutrients thereby promoting strong stem and foliage development, production of a large number of flowers and early fruit set. Akinrinde and Adigun [12] noted that the application of 60 kg P_2O_5 ha^{-1} provided adequate available P throughout the rooting zone which ensured the rapid growth needed to produce the tallest hot pepper plants. The implication is that this rate complemented the little native soil available P to meet the increasing demand of pepper as it aged and stimulated efficient utilization of water and nutrients. The overall effect of improved plant growth performance was reflected in the dry matter yield which was highest at 60 kg P_2O_5 ha^{-1} throughout the sampling period. Emongor and Mabe [19] noted that the increase of P rates from 20 kg P_2O_5 ha^{-1} to 60 kg P_2O_5 ha^{-1} significantly affected dry matter accumulation and root: shoot ratio with the higher rate producing greater dry weights of the various pepper plant portions.

The highest number of fruits, fruit yield, fruit parameters and seed yield in 2013 and 2014 at 60 kg P_2O_5 ha^{-1} rate compared to the control treatment was due to the improved plant growth performance. These attributes are inter-related. The highest fruit yield was an outcome of the maximum number of fruits harvested in relation to the contribution of added P to the translocation of larger amounts of assimilates to respective plant parts up to maturity thereby promoting growth, flower formation, fruit and seed development [20]. Although pepper fruit yield response to P was linear up to 60 kg P_2O_5 ha^{-1} in both years, the agronomic efficiency increased to 40 kg P_2O_5 ha^{-1} for number of fruits and to 60 kg P_2O_5 ha^{-1} for fruit and seed yields in 2013 and was highest at 20 kg P_2O_5 ha^{-1} in 2014. The lower efficiency at 60 kg P_2O_5 ha^{-1} means that

Table 3. The effects of P application on the dry matter yield of hot pepper

Treatments	**Weeks after treatment**				
	2	**4**	**6**		**10**
Phosphorus (Kgha^{-1})	**Root dry weight plant^{-1} (g)**				
0	0.23d	0.27d	1.85d	1.04d	1.24d
20	0.28c	0.37c	0.98c	1.63c	1.78c
40	0.36b	0.52b	1.22b	1.97b	2.14b
60	0.48a	0.80a	1.63a	2.16a	2.38a
S.E.	0.023	0.014	0.032	0.043	0.024
	Stem dry weight plant^{-1} (g)				
0	0.82d	0.84d	1.49d	2.67d	2.83d
20	1.01c	1.62c	2.40c	3.54c	3.69c
40	1.09b	1.78b	2.68b	3.95b	4.18b
60	1.20a	1.89a	3.22a	5.13a	5.31a
S.E.	0.024	0.013	0.022	0.043	0.093
	Leaf dry weight plant^{-1} (g)				
0	0.29d	0.44d	1.42d	2.20d	2.34d
20	0.51c	0.53c	2.26c	3.89c	4.02c
40	0.61b	0.69b	2.53b	4.01b	4.18b
60	0.76a	0.83a	2.89a	4.19a	4.39a
S.E.	0.093	0.014	0.033	0.022	0.023
2014	**Root dry weight plant^{-1} (g)**				
0	0.26d	0.42d	0.72d	1.26d	1.38d
20	0.35c	0.54c	1.27c	1.61c	2.06c
40	0.48b	0.85b	1.49b	1.82b	2.24b
60	0.58a	0.92a	1.68a	2.21a	2.63a
S.E.	0.023	0.014	0.043	0.054	0.032
	Stem dry weight plant^{-1} (g)				
0	0.98d	1.13d	1.54d	2.69d	2.92d
20	1.06c	1.72c	2.43c	3.63c	3.76c
40	1.14b	1.86b	2.69b	3.86b	4.54b
60	1.26a	2.09a	3.58a	4.64a	5.16a
S.E.	0.022	0.024	0.032	0.063	0.034
	Leaf dry weight plant^{-1} (g)				
0	3.07d	3.48d	6.22d	6.57d	6.93d
20	3.51c	3.72c	8.14c	8.57c	8.83c
40	3.87b	3.98b	8.64b	9.11b	9.86b
60	4.48a	4.81a	10.12a	10.39a	10.62a
S.E	0.027	0.029	0.051	0.044	0.063

Means followed by the same letters in each column are not significantly different (P=0.05)

Table 4. The effects of P application rates on fruit yield and fruit parameters of hot pepper

Treatment (kg P_2O_5 ha^{-1})	Number of fruits ha^{-1} (χ10^6)	Fruit yield (t ha^{-1})	Fruit size (g)	Fruit length (cm)	Fruit breadth (cm)	Pericarp thickness (cm)	Seed yield (kg ha^{-1})
2013							
0	0.819d	9.31d	2.38d	3.62d	1.74d	0.24c	171.27d
20	0.886c	10.07c	2.85c	3.95c	1.82c	0.21d	186.10c
40	1.045b	11.89b	3.75b	4.10b	1.89b	0.32b	220.70b
60	1.155a	13.13a	3.89a	4.22a	2.04a	0.36a	249.52a
LSD	0.010	0.052	0.04	0.07	0.06	0.02	0.10
2014							
0	2.100d	11.88d	3.35d	3.65d	1.87c	0.26b	611.89d
20	3.300c	13.19c	3.60c	4.12c	2.15b	0.28b	699.01c
40	3.600b	14.50b	4.58b	4.26b	2.10b	0.32ab	776.07b
60	3.730a	14.89a	4.71a	4.34a	2.25a	0.34a	834.99a
LSD	0.084	0.113	0.048	0.084	0.102	0.061	0.21

Means followed by the same letters in each column are not significantly different (P=0.05)

Table 5. Agronomic efficiency of P application determined for yield parameters of hot pepper

P_2O_5 kg ha^{-1}	Number of fruits kg^{-1}	Fruit yield kg kg^{-1}	Seed yield kg kg^{-1}
2013			
0	-	-	-
20	3,350	38.0	0.742
40	5,650	64.5	1.236
60	5,600	83.7	1.304
2014			
0	-	-	-
20	60,000	65.5	4.356
40	37,500	65.5	4.105
60	27,167	50.2	3.768

Table 6. The effect of P application on proximate composition and nutrient contents of ripe hot pepper fruits

	Rate of P application (kg P2O5 ha-1)				
Property	**0**	**20**	**40**	**60**	**LSD**
2013					
Moisture content (%)	84.46a	82.69b	81.48c	79.58d	0.55
Ash (%)	1.91c	1.98bc	2.02b	2.16a	0.09
Fat (%)	3.09c	3.15b	3.17b	3.28a	0.05
Crude protein (%)	4.50d	5.06c	5.50b	5.94a	0.05
Crude fibre (%)	3.22d	3.41c	3.50b	3.65a	0.07
Carbohydrate (%)	2.82d	3.71c	4.33b	5.39a	0.05
Vitamin C (mg 100 g^{-1})	85.38d	98.93c	103.09b	109.67a	2.40
N (%)	0.72d	0.81c	0.88b	0.95a	0.05
P (mg kg^{-1})	74.50d	76.10c	85.00b	95.48a	0.98
K (mg kg^{-1})	2086.97d	2218 08c	2222.07b	2226.06a	0.36
Ca (mg kg^{-1})	113.21d	129.68c	136.43b	147.55a	3.90
Mg (mg kg^{-1})	637.95d	639.10c	670.47b	1022.54a	33.35
Na (mg kg^{-1})	81.65d	92.84c	97.44b	99.80a	0.01
2014					
Moisture content (%)	84.27a	83.68b	80.84c	79.84d	0.08
Ash (%)	1.39b	1.41ab	1.42ab	1.46a	0.06
Fat (%)	3.13b	3.15b	3.17b	3.28a	0.04
Crude protein (%)	4.89d	5.13c	5.63b	6.38a	0.04
Crude fibre (%)	3.23d	3.45c	4.08a	3.59b	0.05
Carbohydrate (%)	3.09d	3.18c	4.86b	5.45a	0.15
Vitamin C (mg 100 g^{-1})	87.87b	101.65c	105.74b	111.34a	2.37
N (%)	0.78	0.82	0.90b	1.02a	0.03
P (mg kg^{-1})	72.28d	82.44c	88.52b	96.72a	1.00
K (mg kg^{-1})	2088.42d	2223.61c	2225.38b	2229.41a	0.37
Ca (mg kg^{-1})	122.80a	122.85a	124.80a	124.89a	4.01
Mg (mg kg^{-1})	637.80c	638.21c	670.82b	1022.21a	3.38
Na (mg kg^{-1})	82.68d	93.09c	96.45b	104.18a	0.01

Means followed by same letters in each row do not differ significantly (P=0.05)

large amounts of applied P were left in the soil after the season. The low efficiency can be attributed to the fertilizer P, which is 100 percent water-soluble, changing to less available forms through sorption and fixation reactions in the soil such that <10% of applied P is used by most arable crops [8]. The soils are coarse-textured and the pH values do not suggest that P fixation would explain the low agronomic efficiency but Qawasmi et al. [21] noted leaching and loss through erosion and runoff, excessive rainfall after application and inappropriate application methods as some of the possible conditions.

The trends of growth and yield responses to P rates were similar but the values were higher in 2014 than 2013. This relates to better weather in 2014 in terms of rainfall amount and distribution which ensured adequate soil moisture that would have made applied P more soluble to increase the availability and uptake by pepper. The higher indices of agronomic efficiency and the maximum values at 20 kg P_2O_5 ha^{-1} are a reflection of this availability of P such that higher rates become less efficient and would translate to economical loss to farmers.

The fruit moisture contents corroborates the results (60-90%) indicated some vegetables as FAO, 2006) and the values of this show the potential of pepper for high moisture content [9]. The reduction in the high moisture content from 0 kg P_2O_5 ha^{-1} (84.46 and 84.27 %) to 79.38 and 79.46 % at 60kg P_2O_5 ha^{-1} shows that with P application the shelf-life of pepper (*Capsicum annuum* rodo variety) can be improved and the tendency for rapid deterioration due to microbial contamination is moderated. Moreover, the reduction in moisture content did not indicate smaller fruits but ensured bigger sized fruits with thick fleshy mesocarp as outcomes of more efficient sink functions, higher number of cells and bigger sizes of individual cells [22]. The protein content increased in line with fruit N and

P contents as indicated by Hammad and El-Gamal, [23] and Khan, et al. [24]. The value of crude protein contents show that pepper would serve as an essential component of human diet and required for the replacement of dead tissues [25]. The crude fibre, fat, total ash and carbohydrate content increased to the highest values at 60 kg P_2O_5 ha^{-1} as obtained by Gill and Thakur [22] and Khan, et al. [24]. However, despite the high values of fat recorded, pepper would not be regarded as an oil seed even though an essential oil (olerosine) can be extracted from it. Also, it is important to note that human diet containing 1-3% calorific energy as fat are considered to be adequate for human beings as excess fat can cause cardiovascular disorders, cancer, obesity and aging [26]. The lower crude fibre content confirmed pepper as additive to other foods thereby boosting the total dietary fibre of the dishes in which it is used [27]. The range of values of ash (1.39 to 1.46 and 1.91 to 2.16) in both years were relatively low, which may account for the use of pepper as food adjuncts and not as nutrient sources. Similarly, the low level of carbohydrates revealed that pepper is a spice and may not serve as good source of energy.

The application of P slightly increased fruit P content because of corresponding higher availability of P for uptake and utilization by pepper. The vitamin C contents of the fruits increased slightly while K, Ca, Mg and Na increased significantly with P application as indicated by Zhang et al. [9] and Khan et al. [24]. The result differs with respect to K which did not accumulate in the pepper fruits from P application [23,28].

5. CONCLUSIONS AND RECOMMENDATION

Pepper (rodo) showed significant growth and yield responses to the highest rate of application in the two sites which contained low available P hence the 60 kg P_2O_5 ha^{-1} can be adopted. This rate improved the fruit quality in terms of physical properties and nutritive value. The reduced moisture content with higher dose of fertilizer may be an advantage. Since the response was linear up to 60 kg P_2O_5 ha^{-1}, further studies involving higher rates and soils containing various available P levels should be conducted to fine tune the P requirements as part of the fertilizer management practices being developed for hot pepper (rodo).

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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