

Original Research Article

Phosphorus Fertilizer Sources and Application Time Affect Grain Yield and Nutrient Composition of Cowpea (*Vigna unguiculata* L., Walp)

Abstract

The appropriate time to apply water-soluble phosphate fertilizer sources for the production of cowpea (IT84E-2246-4) was evaluated in an Oxic Paleustalf at the Teaching and Research Farm, Ekiti State University, Ado-Ekiti. Cowpea growth and yield were significantly improved by single superphosphate (SSP) and triple superphosphate (TSP) applied at 45 kg $P_2O_5 \cdot ha^{-1}$. The increase in vegetative growth and nodulation enhanced earliness to flowering and whose combined effects produced significantly higher grain yield from TSP and SSP compared to NPK 15-15-15 and the control (0 kg $P \cdot ha^{-1}$) treatments. P fertilizer applied at sowing enhanced early vegetative growth and produced the highest number of nodules, flowers and pods.plant⁻¹ which ensured significantly higher grain yield than withholding the application till 3 and 5 weeks after sowing. The low grain yields obtained from application of P fertilizer at 3 and 5 weeks after sowing were not significantly different which favour applying P fertilizer at sowing time as the recommended practice.

Key words: Oxic Paleustalf, cowpea, superphosphates, grain yield, nutrient content

Introduction

The deficiency of phosphorus (P) is widespread in most of the soils in Nigeria and so this constitutes one of the soil fertility constraints to high yields in cowpea. Thus, P fertilizer is vital to output maximization as its application stimulates root and shoot growth, nodulation and general efficiency of the Rhizobium-legume symbiosis (Robson *et al.*, 1981) as well as flowering, pod and seed formation (Adu, 1994). The cumulative effects of these benefits is grain yield response to P fertilizer application from which the optimum requirements between 13 and 40

30 kg P.ha⁻¹ have been obtained and so indicated in several extension bulletins and cowpea
31 production guides (IAR, 1979; IAR&T, 1991; FFD, 2002).

32 Once the rate of nutrient to apply has been determined, there remains the need to
33 resolve the issue of the right type(s) of fertilizer that would be used to supply the nutrient for
34 the best results. There are several commercial P fertilizers out of which single superphosphate
35 (SSP; 18% P₂O₅), triple superphosphate (TSP; 45% P₂O₅) and a number of nitrogen (N)-
36 containing P sources: nitrophosphates, ammonium phosphates (di-ammonium phosphate, DAP,
37 18-46-0; mono-ammonium phosphate, MAP, 11-48-0) and compound NPK fertilizers have been
38 used as P sources in Nigeria (FFD, 2002). These sources contain P mainly in the water-soluble
39 form, being 90 and 95-98% in SSP and TSP respectively (Tisdale *et al.*, 1997) and so have been
40 recommended for cowpea production. Unfortunately, these sources are scarce in Nigeria,
41 especially at the beginning of the cropping season and so farmers are unable to sow seeds
42 timely in already prepared land, are compelled to establish cowpea farms without applying
43 fertilizer or do so late.

44 The search for alternative P fertilizer sources has necessitated the evaluation of rock
45 phosphate and basic slag- a by-product of the iron and steel industry. These sources contain
46 water-insoluble phosphate which has been found suitable for acid soils and give best results
47 when the sources are finely-ground, broadcast and incorporated with the top layer of soil
48 during land preparation (FAO, 2004). Rock phosphate leaves high residual P in the soil which
49 may not benefit a cowpea crop that matures in 60-90 days, more so as it is grown during the
50 late season when unreliable rainfall can affect solubilisation of the phosphate mineral
51 (Mokwunye, 1979). In these circumstances, water-soluble sources which give superior
52 performances during the year of application but leave less residual P in the soil than rock
53 phosphate (Kang and Juo, 1974) would be the choice. This paper presents results of studies

carried out to evaluate the performances of some water-soluble phosphate fertilizer sources and also determine how long after planting the fertilizer P can be applied without suffering significant cowpea grain yield losses.

Materials and Methods

This study was conducted in the late seasons of 2010 and 2011 on the Teaching and Research Farm, Ekiti State University, Ado-Ekiti (long. 7°47'N and lat. 5°13'E). Ado-Ekiti is located in the dry forest zone and experiences a warm sub-humid tropical climate with long-term mean annual rainfall of 1,367 mm received in 112 days between March and November. Table 1 shows the characteristics of the surface layer (0-15 cm) soil samples as slightly acid sandy loams containing low organic matter, total N, available P and exchangeable cations.

The land was ploughed, harrowed and a fairly level portion measuring 17x30 m marked out into four blocks, each subdivided into four 3x6 m plots separated by 1 m paths. In the first experiment, SSP, TSP and NPK 15-15-15 fertilizers were used to supply the 45 kg $P_2O_5 \cdot ha^{-1}$ optimum rate (Ayodele, 2013) and compared to a control treatment without P (0 kg $P \cdot ha^{-1}$) in the presence of 20 kg N and 50 kg $K_2O \cdot ha^{-1}$ as urea (46%N) and muriate of potash (MOP, 60% K_2O) respectively. In the second experiment, 45 kg $P_2O_5 \cdot ha^{-1}$ as SSP was applied at different times: at planting, 3 weeks after sowing (WAS) and 5 WAS. The control and all the treatments received basal 20 kg N and 50 kg $K_2O \cdot ha^{-1}$.

Seeds of IT84E-2246-4 variety of cowpea were sowed at 60x30 cm spacing and seedlings thinned to two $stand^{-1}$ to attain the recommended population of 111,110 plants ha^{-1} (IAR&T, 1991). Data of vegetative characters (plant height, number of leaves and branches, leaf area) and reproductive parameters (number of flowers and pods) were collected weekly from randomly selected plants in each plot beginning at 3 WAS. At 46 days after sowing (DAS), sample plants were carefully uprooted for the determination of nodulation count and weight.

Index leaf samples were taken and oven-dried at 70°C for 48 hours. Mature pods that had dried were harvested twice weekly, bulked for each plot into polypropylene bags and shelled by beating with heavy wooden sticks. The seeds were recovered by winnowing, further sun-dried and weighed.

The oven-dried index leaf samples were ground in a micro-hammer mill and digested in a ternary mixture of concentrated nitric-sulphuric-perchloric acids (25-5-5 v/v). Total P in the digest was determined using the vanado-molybdate yellow method, total K, Ca and Na by flame photometry and Mg by atomic absorption spectrophotometry while total N was determined with the micro-Kjeldahl digestion method using standard laboratory procedures described in IITA (1979) Laboratory Manual.

Growth and yield data were subjected to statistical analysis using the variance ratio method described in Steel et al (1997). The treatment means were separated with the Least Significant Difference (LSD) at 5% level of probability.

Results

The effects of P application at the optimum 45 kg P_2O_5 .ha⁻¹ on cowpea growth parameters are shown in Table 2. Cowpea plants increased in height with age but most growth was recorded in NPK 15-15-15 treatment (11.5 cm) while the least was from SSP application (0.9 cm). P application produced significantly ($P=0.05$) taller plants than those in the control and NPK15-15-15 treatments at 4 WAS with plants in SSP taller than TSP treatment. At 5 WAS, SSP still produced the tallest plants but the height did not differ from TSP and NPK 15-15-15 treatments. NPK 15-15-15 gave tallest plants at 6 WAS but the height did not differ from SSP treatment. TSP and SSP produced the highest number of branches.plant⁻¹ which differed significantly from the control treatment only. The control treatment gave 35 leaves.plant⁻¹ which was significantly different from NPK 15-15-15 and SSP which produced 30 and 28

leaves/plant⁻¹ respectively. TSP and control treatments gave largest leaf area.plant⁻¹ which differed significantly from SSP and NPK 15-15-15. Nodulation as indicated by number of nodules.plant⁻¹ was highest in TSP treatment followed by SSP while the difference between control and NPK 15-15-15 was significant. The number of flowers was highest in TSP and SSP followed by NPK 15-15-15 and least in the control treatment.

Table 3 shows the influence of P fertilizer sources and stage of development on biomass yield of cowpea. The pattern of biomass yield differed among the treatments at the various stages of development with highest yield produced as follows: control followed by NPK 15-15-15 before flowering; TSP and SSP at flowering; SSP and control at pod setting; and TSP and SSP at harvesting.

The nutrient concentrations of cowpea index leaves over the four-week period are shown in Table 4. Leaf P was least in the control treatment (1.4% P) before flowering (3 WAS), increased to 2.0% at flowering and decreased progressively until harvesting. The trend was similar for the P sources but with SSP containing the highest index leaf P at pod setting. NPK 15-15-15 contained 1.9% leaf P before flowering, increased to 2.1% at flowering and decreased to 1.0 and 1.6% at pod setting and harvesting respectively. Cumulative leaf P was 7.8, 6.7, 6.5 and 6.4% for TSP, SSP, control and NPK 15-15-15 respectively. Leaf Ca and Mg were not affected whereas application of the P sources increased mean index leaf N.

Table 5 shows the grain yield and yield components of cowpea as influenced by application of P sources. The effects of the P sources were significant on grain yield (P=0.05) with the performance being in the order: TSP>SSP>NPK 15-15-15>control. The trend was similar for number of pods.plant⁻¹, 100-seed weight, and pod length and seeds.pod⁻¹.

The effects of different times of P fertilizer application on cowpea growth parameters are shown in Table 6. P application at planting enhanced early vegetative growth in terms of

plant height, number of leaves and leaf area.plant⁻¹. The control treatment gave the least values of these growth parameters which did not differ significantly (P=0.05) from withholding P fertilizer application until 3 and 5 WAS. The same trend was observed for number of nodules, flowers and pods.plant⁻¹ and biomass dry matter yield.

Table 7 shows the dry grain yield and yield components of cowpea as influenced by the different times of P fertilizer application. Grain yield and components of yield- number of pods.plant⁻¹, average pod length, number of seeds.pod⁻¹ and 100-seed weight were best with P applied at planting, 3 and 5 WAS did not differ significantly while the control treatment gave least values.

The effects of different times of P fertilizer application on index leaf nutrient composition of cowpea are shown in Table 8. The control treatment gave lower index leaf %N, K, Ca and Mg contents whereas P application increased %P by 68-78% with the highest value obtained when P fertilizer was applied at planting.

Discussion

The vegetative response to P application is not surprising given the available P content of the soil which was below the 7.0 mg.kg⁻¹ critical level established for cowpea (Kang and Nangju, 1983). Similar responses of cowpea to P fertilizer application in soils deficient in available P have been reported (Agboola and Obigbesan, 1977; Adu, 1994; Sanginga *et al.*, 2000; Osunde *et al.*, 2007; Ayodele, 2013). Although cowpea can be more tolerant of the P stress associated with the soils in the sub-humid zone of Nigeria than other legumes like soyabean, the recommended 45 kg P₂O₅.ha⁻¹ rate applied significantly improved plant growth performance and gave optimum grain yield.

The increase in nodulation is one of the advantages of P application to cowpea and this was shown by the TSP and SSP treatments (Kang and Nangju, 1983; Sanginga *et al.*, 2000). On

the other hand, reduced nodulation from NPK treatment confirms earlier reports of the suppression of nodulation when NPK fertilizer was used as a P source for groundnut production (Ofori, 1973). The explanation is that NPK lowers the N-fixation potential of cowpea by reducing the population of rhizobium bacteria in the rhizosphere and hence the lower number of root nodules.

Cowpea performed better with the application of TSP and SSP, in terms of vegetative growth and reproductive characters, probably on account of the differential solubility of the phosphate forms and possible interactions with other soil nutrients. Since application of TSP and SSP increased index leaf N, then the choice of P sources to enhance N-fixation would be a strategy for N nutrition and balance of cowpea. The use of compound NPK fertilizers is widespread in Nigeria where NPK 15-15-15 has become the most popular product slate. However, the claim of its suitability for all crops and soil conditions has been criticized, especially for cowpea where the use to provide the required P would surreptitiously increase N supply. NPK 10-20-10 as the appropriate recommended slate for grain legumes (FFD, 2002) has not been produced by the local fertilizer industry. The choice will be to use the straight P sources (TSP, SSP which contain water-soluble phosphates) in addition to basal N+K for optimum grain yield of cowpea.

Data reported from the second experiment indicate the importance of applying the P at the early stages of cowpea growth, particularly to stimulate root elongation and proliferation, nodule formation and development of vegetative structures. Since P plays vital roles in the reactions involving energy transfer, cowpea which depends on fixed N for growth would require large amounts (Israel, 1987). N-fixation is usually optimum between flowering and early pod-fill stages which coincides with demand for high P levels needed in the energy transfer for the development of reproductive structures and seed formation. For a P-deficient soil, delaying P

application till 3 and 5 WAS (closer to flowering stage) would have starved the plants and the applied P not effectively utilized. A major consideration in P fertilizer management is the fear of high P fixation in soils of the tropics for which initial heavy dosages needed to satisfy the fixation capacity and divert the excess for plant use is a control measure (Tisdale *et al.*, 1993). Thus, the recommendation to broadcast P fertilizer before splitting the ridges or at seed bed preparation conforms to this measure. However, in view of the low P fixation capacity of coarse-textured soils developed on basement complex granitic rocks in Western Nigeria (Ayodele and Agboola, 1981), P applied at planting would remain available to enhance efficient P use, as indicated by the higher %P of the index leaf. P applied at 5 WAS gave better grain yield than the control treatment but would not be recommended given that this cowpea variety matures in 65-75 days.

References

- Adu, J.K. (1994). Effect of delayed application of phosphorus fertilizer on nodulation, growth and yield of cowpea. In: Menyonga, J.M. *et al.*, (eds). Progress in Food Grain Research and Production in Semi-Arid Africa. Proceedings of SAFRAD Inter-Network Conference held at Palais des Congres, Niamey, Niger Republic; 7-14th March 1991: 95-104.
- Agboola, A.A. and Obigbesan, G.O. (1977). Effect of different sources and levels of P on the performance and P uptake of Ife-Brown variety of cowpea. *Ghana J. Agric. Sci.* 10: 71-75.
- Ayodele, O. and Agboola, A. (1981). Evaluation of phosphorus fixation capacity of tropical savannah soils of Western Nigeria. *Soil Sci. Soc. Amer. J.* 45: 462-464.
- Ayodele, O.J. (2013). Cowpea responses to phosphorus fertilizer application at Ado-Ekiti, South-western Nigeria. (In Press)
- FAO, (2004). Use of phosphate rocks for sustainable agriculture. In: Zepata, F. and Roy, R.N. (eds) Fertilizer and Plant Nutrition Bulletin 13. FAO Land and Water Development Division and International Atomic Energy Agency, Vienna Austria.
- FFD, (2002). Fertilizer Use and Management Practices for Crops in Nigeria. Fertilizer Use Series No 3 (Aduayi, E.A. *et al.*, eds). Federal Fertilizer Department, Federal Ministry of Agriculture and Rural Development, Abuja, Nigeria.

- 202 IAR, 1979. Notes on the Cowpea and Grain Legume Research Programme. Cropping Scheme
203 Meeting; Institute of Agricultural Research, Ahmadu Bello University, Zaria. 26pp.
- 204 IAR&T, (1991). Report of the 14th Conference of the Package of recommendations for Food
205 Crops and Livestock Production in South-Western Nigeria. Institute of Agricultural
206 Research and Training, Moor Plantation, Ibadan. 101pp.
- 207 IITA, 1979. Selected Methods for Soil and Plant Analysis. Manual Series No 1. International
208 Institute of tropical Agriculture, Ibadan. 70pp
- 209 Israel, D.N. (1987). Investigation of the role of rock phosphate in symbiotic dinitrogen fixation.
210 *Plant Physiol.* 84: 835-840
- 211 Kang, B.T. and Juo, A.S.R. (1974). Preliminary report on evaluation of phosphorus sources in
212 Western Nigeria. Paper presented at TVA-AID Fertilizer Research Project Workshop, IITA,
213 Ibadan.
- 214 Kang, B.T. and Nangju, D. (1983). Phosphorus response of cowpea (*Vigna unguiculata*, L., Walp).
215 *Tropical Grain Legume Bulletin* 27: 11-16
- 216 Mokwunye, A.U. (1979). Phosphorus fertilizers in Nigerian savannah soils: evaluation of three
217 phosphorus sources applied to maize in Samaru. *Trop. Agric. (Trinidad)* 56: 65-68
- 218 Ofori, C.S. (1973). The importance of fertilizer nitrogen in grain legume production on soils of
219 granitic origin in the Upper Volta region of Ghana. Proceedings of First IITA Grain legume
220 Improvement Workshop, IITA. Ibadan.
- 221 Osunde, A.O., Bala, A. and Uzoma, A. (2007). Differential responses of cowpea (*Vigna*
222 *unguiculata*) lines to phosphorus fertilizer in a low phosphorus soil in the southern guinea
223 savannah of Nigeria. *Nigerian J. Soil Sci.* 17: 52-64.
- 224 Robson, A.D., O'Hara, O'G.W. and Abbott, L.K. (1981). Involvement of phosphorus in nitrogen
225 fixation of subterranean clover (*Trifolium subterneana*, L.). *Aust. J. Plant Physiol.* 8: 427-
226 436.
- 227 Sanginga, N., Lyasse, O. and Singh, B.B. (2000). Phosphorus use efficiency and nitrogen balance
228 of cowpea breeding lines in a low P soil of the derived savannah zone in West Africa. *Plant*
229 *and Soil* 220; 119-128.
- 230 Steel, R.D.G., Torrie, J.H. and Dickey, D.A. (1997). Principles and Procedures of Statistics: A
231 Biometrical Approach. 3rd Edition. McGraw Hill, New York. 665pp.
- 232 Tisdale, S.L., Nelson, W.L., Beaton, J.D. and Havlin, J.L. (1993). Soil Fertility and Fertilizers. 5th
233 Edition. Macmillan, New York.

234 Table 1: Characteristics of the surface layer (0-15 cm) of soils in the study sites

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236	<u>Soil Characteristics</u>	<u>2010</u>	<u>2011</u>
237			
238	Sand, %	71.5	71.1
239			
240	Silt, %	18.2	10.6
241			
242	Clay, %	10.6	18.3
243			
244	Textural Class	SL	SL
245			
246	pH (Water)	6.0	5.8
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248	Organic Matter, %	1.99	2.24
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250	Total N, %	0.07	0.09
251			
252	Available P, mg.kg ⁻¹	5.90	3.10
253			
254	Exchangeable cations		
255	K, cmol.kg ⁻¹	0.19	0.23
256	Ca, cmol.kg ⁻¹	2.24	2.56
257	Mg, cmol.kg ⁻¹	0.45	0.52
258	Na, cmol.kg ⁻¹	0.09	0.06
259	Exchangeable acidity	0.76	0.68
260	Effective CEC	3.73	4.05
261	Base Saturation, %	79.6	83.2

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263 SL= Sandy Loam

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267 Table 2: Effect of different P sources on growth performance of cowpea

		<u>Treatments</u>				
	<u>Parameters</u>	<u>Control</u>	<u>SSP</u>	<u>TSP</u>	<u>NPK 15-15-15</u>	<u>SE</u>
270	Plant height 4 WAS	26.7	36.0	28.5	25.6	0.48
271	5 WAS	31.0	36.4	35.8	36.0	0.35
272	6 WAS	31.8	36.9	36.1	37.1	0.50
273	Number of branches	3.5	4.0	4.5	3.8	0.34
274	Number of leaves	35	28	34	30	1.27
275	Leaf area, cm ²	3213	2838	3414	1232	216.79
276	Number of flowers	7.8	24.0	28.0	17.0	0.90
277	<u>Number of nodules</u>	<u>10.0</u>	<u>16.5</u>	<u>22.8</u>	<u>5.0</u>	<u>1.34</u>

278 WAS= Weeks after sowing

279 Number of branches, number of leaves and leaf area determined at 4 WAS

280 Number of flowers and nodules determined at 6 WAS

281 SSP= Single superphosphate TSP= Triple superphosphate

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Table 3: Dry matter yield of cowpea biomass as affected by application of different P sources

<u>Sampling Periods</u>				
<u>Treatment</u>	<u>Before Flowering</u>	<u>At Flowering</u>	<u>Pod Setting</u>	<u>Harvesting</u>
<u>Biomass Yield (g.plant⁻¹)</u>				
Control	48.8	70.5	89.3	120.5
SSP	27.4	77.6	102.6	187.5
TSP	36.3	76.4	83.2	265.0
NPK 15-15-15	39.0	70.6	79.3	116.0
SE	0.44	0.95	1.26	1.55

SSP= Single superphosphate TSP=Triple superphosphate

315 Table 4: Effect of different P sources on index leaf nutrient composition of cowpea

316	<u>Treatments</u>					
317	<u>Nutrient Content</u>	<u>Control</u>	<u>SSP</u>	<u>TSP</u>	<u>NPK 15-15-15</u>	<u>SE</u>
318	N, %	1.79	1.97	2.34	1.76	0.048
319	P, % before flowering	0.28	0.32	0.36	0.56	0.002
320	At flowering	0.40	0.41	0.43	0.42	0.013
321	Pod setting	0.18	0.50	0.40	0.20	0.023
322	Harvesting	0.12	0.13	0.38	0.32	0.032
323	Total	1.22	1.34	1.56	1.30	0.049
324	K, %	3.60	4.13	4.17	4.43	0.102
325	Ca, %	0.41	0.50	0.48	0.51	0.015
326	Mg, %	0.58	0.35	0.31	0.50	0.011

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330 SSP= Single superphosphate TSP= Triple superphosphate

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Table 5: Effect of different P sources on yield components of IT84E-2246-4 variety of cowpea

	No of pods	Pod	No of seeds	100-seed	Grain
<u>Treatments</u>	<u>.plant⁻¹</u>	<u>length (cm)</u>	<u>.plant⁻¹</u>	<u>weight (gm)</u>	<u>(yield MT.ha⁻¹)</u>
Control	10.0	10.3	11.5	15.93	0.381
SSP	11.5	10.3	11.0	17.38	0.575
TSP	12.8	11.3	12.0	19.33	0.798
NPK 15-15-15	10.5	10.0	11.3	16.10	0.453
SE	0.82	0.34	0.52	0.57	0.064

SSP= Single superphosphate TSP= Triple superphosphate

Table 6: Effect of time of P fertilizer application on cowpea growth performance

		<u>Treatments</u>				
<u>Parameters</u>		<u>Control</u>	<u>T0</u>	<u>T1</u>	<u>T2</u>	<u>SE</u>
Plant height (cm), 4 WAS		26.1	33.4 `	29.4	29.8	0.40
5 WAS		28.4	34.0	32.9	30.1	0.41
6 WAS		27.8	34.2	33.3	31.7	0.37
Number of branches		4.0	4.2	3.3	4.1	0.85
Number of leaves		41.5	58.5	48.5	47.0	3.77
Leaf area (cm ²)		1820.0	2100.0	2201.0	2504.0	64.63
Number of flowers		18.0	25.0	16.4	16.9	0.69
Number of nodules		24.3	38.9	30.3	25.6	0.52
Biomass yield (g.plant ⁻¹)		30.0	35.2	32.5	31.6	0.64

T0= P application at planting time

T1= P application 3 weeks after sowing

T2= P application 5 weeks after sowing

WAS= weeks after sowing

Table 7: Effect of P fertilizer application times on cowpea yield components

		<u>Treatments</u>				
	<u>Parameters</u>	<u>Control</u>	<u>T0</u>	<u>T1</u>	<u>T2</u>	<u>SE</u>
	Number of pods.plant ⁻¹	10.5	12.5	10.1	10.0	0.99
	Pod length (cm)	9.8	10.8	10.2	10.1	0.28
	Number of seeds.pod ⁻¹	9.6	10.8	10.2	10.1	0.19
	Grain yield (MT.ha ⁻¹)	0.33	0.73	0.61	0.57	0.02
	100-seed weight (gm)	15.4	16.3	15.7	15.4	0.15

T0= P application at planting time

T1= P application 3 weeks after sowing

T2= P application 5 weeks after sowing

411 Table 8: Index leaf nutrient content as affected by time of P fertilizer application

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413 Nutrient Content (%)

414 <u>Treatments</u>	<u>N</u>	<u>P</u>	<u>K</u>	<u>Ca</u>	<u>Mg</u>	<u>Na</u>
415 Control	1.8	0.34	2.4	0.43	0.25	0.086
416 T0	2.2	0.61	2.8	0.52	0.27	0.096
417 T1	2.1	0.57	2.6	0.50	0.27	0.090
418 T2	2.0	0.58	2.5	0.49	0.26	0.092
419 SE	0.1	0.06	0.1	0.011	0.012	0.002

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421 T0= P application at planting time

422 T1= P application 3 weeks after sowing

423 T2= P application 5 weeks after sowing

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