

Original Research Article

Influence of phosphorus forms on growth and yield of cowpea, Kales and Amaranth vegetable species

Abstract

Maximum production potential of leafy vegetable is limited by phosphorous (P) deficiency in the soils. This is due to the high cost of the phosphate fertilizer and the fixed form of the available phosphorous in the soil. There is therefore, need for farmers to use alternative and cheaper sources of P that are economic friendly to supply the required mineral nutrition to their crops. Rock phosphate is widely available but has a challenge in solubilization to make P available to the crops. In the current study, the aim was to evaluate the effect phosphate forms and acidulate rock phosphate on growth and yield of selected leafy vegetables. The experiment was laid out in Randomized Complete Block Design in split-plot arrangement, with three leafy vegetables (cowpeas, kales and amaranth) being the main plots, and various sources of P (Triple super phosphate (TSP) Mijingu Phosphate Rock(MPR), Mijingu phosphate Rock + sulphur (MPR)PR+S and control) constituting the subplots with three replicates. The collected data included the root dry weight, leaf area, shoot fresh weight and leaf area and was subjected to SAS for ANOVA and where there were significant differences between means were further separated using the Fischer's LSD at 5% level of significance. The results revealed that there were significant increase in the growth parameters of the vegetables as an effects of phosphorus application compared with the control. TSP elicited the best results in all the tested parameters in 5 WAP, 6 WAP and 7 WAP respectively in both seasons. The highest value of root dry weight (11.2g), leaf area (1905.0cm²), number of branches (40.67) shoot fresh weight (236.8g) as influenced by TSP application in the vegetable species. The MRP +sulphur also followed in superiority of increasing the growth parameters which is an indication that sulphur can be used in solubilizing rock phosphate and making it a suit alternative for farmers. Thus, farmers are advised to directly apply rock phosphate and sulphur to soil as a possible alternative to the more expensive soluble phosphate fertilizers in tropical cropping system.

Key words: Rock phosphate, Available Phosphorous, sulphur, soil fertility

32 1.0 Introduction

33 Phosphorus is one of the most needed elements for crop production in many tropical soils.
34 Phosphorus has been reported to have a tremendous effect on proper root formation,
35 establishment and formation for the absorption of mineral salts and water from the soil [
36 1]. Regardless of its imperative role in plant growth, its deficiency in the soils has limited
37 farmers from achieving maximum yield. The situation is aggravated in smallholder agriculture
38 where use of mineral fertilizers is limited or even non-existent, as peasant farmers, due to their
39 low purchasing capacities, cannot afford high costs of these fertilizers [2,3]. Specifically,
40 vegetable farmers have experienced great challenges in increasing yield due to the fact that
41 vegetable species consume significant amount of phosphorus that is way beyond their potential
42 to purchase the chemical fertilizers [4]. There has been a rising demand of African Leafy
43 vegetables (ALV) in the recent past in Kenya. The priority species marketed include leafy
44 amaranth (*Amaranthus* spp), cowpeas (*Vigna unguiculata*), Ethiopian kale (*Brassica*
45 *carinata*), African black nightshades (*Solanum* spp), pumpkin leaves (*Cucurbita maxima*) [5].
46 African leafy vegetables have gained commercial importance over the past 15 years as a
47 result of the enormous growth in market [5]. The production of ALVs has its advantages
48 because of the uniqueness [] such as short production cycles, are resistant to pests and
49 diseases and are quite acceptable to local tastes [5]. This could be contributed by their
50 perceived nutritional and medicinal values on diseases and alleviation of conditions such
51 as diabetes, high blood pressure, cancer and HIV/AIDS. Due to this high demand there is need
52 to look for alternate supply of phosphorus nutrients to the vegetable and consequently increase
53 yield. Rock phosphate (PR) provides an alternative to the expensive soluble P. Unfortunately,
54 use of Rock phosphate (PR) to alleviate P deficiency in the soils remains a great challenge due to
55 their low solubility [6]. The PR is water-insoluble but acid-soluble indigenous P source, that

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56 may be more relevant for these resource-limited farmers, in comparison to the
57 prohibitive expensive soluble P [7]. The PR is acid-soluble and any activities that increase
58 rhizosphere acidification increase its solubility. However, studies have shown that elemental
59 sulphur has high dissolution rate of phosphorus from rock phosphate that is locally available and
60 can be used in reducing the problem of phosphorus deficiency in soils and increase the yield of
61 leafy vegetables. Therefore, in this study, the focus was to compare the performance of the
62 synthetic phosphorus forms with rock phosphate on the selected African leafy vegetables on their
63 growth responses.

64 **2.0 Materials and methods**

65 **2.1 Description of the study site**

66 The experiment was carried out at Kenyatta University farm, Kiambu County, Kenya. The site
67 lies at an altitude of 1745 meters above sea level and is within latitude 110 0.012 S and longitude
68 3649 59.880 E. The average amount of rainfall received is 989 mm per year (where 1200 mm
69 rains were recorded during the long rains whereas 780 mm recorded during the short rains).
70 Temperature ranges between 12.8⁰ C during the cold months and 24.6⁰ C during the hot seasons.
71 The soils are loamy, acidic, well drained and moderately deep [8].

72 **2.2 Experimental Layout and Design**

73 The experiment was arranged in a split-plot arrangement, with three leafy vegetables (cowpeas,
74 kales and amaranth) being the main plots, and various sources of P (TSP, MPR, MRP+S and
75 control) constituting the subplots with three replicates. Each experimental plot measured 2m x
76 2m. Individual blocks were spaced 1 m apart while the plots within the blocks were separated by
77 a 0.5 m path. The kale and amaranth seedlings were first raised in a nursery and transplanted at

78 six leaf stage (4 weeks) into a seedbed prepared to a medium tilth at a spacing of 30 cm x 15 cm
79 for amaranth, 45 cm x 15 cm for cowpeas, and 45 cm x 15 cm for kales. The seedlings were
80 subjected to treatment during transplanting to the field. Four treatments used consisted of;
81 control (zero fertilizer input), Mijungu rock phosphate (120 kg P₂O₅ /ha), MRP +S (120 kg P₂O₅
82 /ha) using 240g of elemental sulphur, and TSP (60 Kg p /ha). The rate of 120 kg P₂O₅/ha used in
83 this experiment was adapted from the recommendations of FURP & KARI (1994). Appropriate
84 rates of Calcium Ammonium Nitrate (26%N) at 60 kg N/ha and Muriate of potash (60% K₂O) at
85 30 kg/ha were uniformly administered and incorporated into the soil to supply sufficient amounts
86 of N and K to ensure the two nutrients were not limiting factors on plant growth when studying
87 the effects of P. The fields were kept weed free by manual weeding. Pests and diseases were also
88 controlled.

89 **2.3 Data collection and Analysis**

90 Data on plant height, fresh weight, dry weight, leaf area and root area were recorded. A well-
91 calibrated ruler in centimetres, electronic weighing balance in grams and physical counting were
92 used. Plant height was measured from the ground level up to the apex of the youngest leaf. Fresh
93 weight measurement entailed picking all the leaves and tender shoots and weighing them
94 immediately using an electronic weighing balance. The collected data was subjected to analyses
95 of variance (ANOVA), using the General Linear Model (GLM) procedure of SAS-computer
96 software (SAS 2002, version 19.0). Mean separation was done using least significant difference
97 (LSD) test at 5% significant level.

98 **3.0 Results and Discussions**

99 **3.1 Root Dry weight**

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100 Significant differences ($P \leq 0.05$) were observed between the phosphorus treatments in the three
 101 root dry weight of the vegetable species in season 1 and season 2. Kales recorded the highest root
 102 biomass in 5 WAP, 6WAP and 7 WAP in both season 1 and season 2 with the 7WAP being
 103 superior with 9.84 g and 9.83 g in season 1 and 2 respectively. This could be due to high growth
 104 rate of the kales as a result of phosphorous nutrition. Cowpea had the least biomass
 105 accumulation in root in both seasons as shown in Table 1. Phosphorous forms also exhibited
 106 significant differences in root biomass with TSP being superior during the whole growth period
 107 with the highest being recorded at 7WAP with 11.2 g in the two season. The RP+sulphur was the
 108 second best in terms of root growth which is an indication of high availability of phosphorus
 109 from this particular source of phosphorous. The control recorded the least root biomass
 110 compared to other sources of phosphorous.

Commenté [T4]: The methodology of this work does not invoke the season

Commenté [T5]: Year??

Commenté [T6]: season 1 and 2 means what?? dry or rainy season??

111 **Table 1: Influence of phosphorous forms and vegetable species on root dry weight**

Species	Season 1			Season 2		
	5WAP	6WAP	7WAP	5WAP	6WAP	7WAP
Kales	3.65 ^a	7.08 ^a	9.84 ^a	3.73 ^a	7.25 ^a	9.83 ^a
Amaranth	2.79 ^{ab}	4.60 ^{ab}	5.46 ^b	2.80 ^{ab}	4.59 ^{ab}	5.46 ^b
Cowpea	1.80 ^b	3.06 ^b	3.77 ^b	1.79 ^b	3.06 ^b	3.77 ^b
LSD	1.40	2.61	3.56	1.40	2.72	3.56
Treatments						
Control	1.12 ^c	1.92 ^c	2.78 ^b	1.12 ^b	1.92 ^c	2.78 ^b
TSP	4.76 ^a	8.47 ^a	11.22 ^a	4.65 ^a	8.69 ^a	11.22 ^a
RP+S	3.22 ^b	5.59 ^{ab}	6.88 ^{ab}	3.44 ^a	5.59 ^{ab}	6.87 ^{ab}
RP	1.88 ^{bc}	3.66 ^{bc}	4.54 ^b	1.88 ^b	3.66 ^{bc}	4.54 ^b
LSD	1.10	2.42	3.70	1.15	2.56	3.70
SXPF	*	*	*	*	*	*

112 **Means followed by the same letter within the same column are not significantly different**
 113 **($P \leq 0.05$). TSP- Triple –super phosphate, RP+S-Rock Phosphate and sulphur, RP- Rock**
 114 **phosphate, S-vegetable species, PF-phosphorous sources **LSD? WAP?****

115 Interaction effects between the vegetable species and phosphorus source at various growth stages
 116 in the two experimental sites. During the first season, amaranth supplied with TSP was superior
 117 in root biomass in three sampling stages recording 2.64 g, 4.62 g and 5.50 g in 5WAP, 6 WAP

118 AND 7 WAP respectively as shown in table 2. In the second season, significant differences
 119 were observed in the interaction of the vegetable species and phosphorus with amaranth supplied
 120 with rock phosphate having the highest root dry weight of 6.12 g, 6.14 g and 6.03 in 5 WAP, 6
 121 WAP and 7 WAP respectively. (Table 2) RP+S followed in root biomass accumulation which
 122 was an indicator of vibrant root growth as influenced by phosphorus from dissolved rock
 123 phosphate. There was a significant influence on the all-vegetable species compared to the
 124 control which could be as a result of promoted growth of young cells and rapid cell division as a
 125 result of phosphorus nutrition. Phosphorous has also been associated with increased root
 126 formation which is confirmed from the current study.

Commenté [T7]: No discussion, no justification of the results??

127 **Table 2: Interaction effects on vegetable species and phosphorous sources on root dry**
 128 **weight in season 1 and season 2**

Treatments	Season 1			Season 2		
	5WAP	6WAP	7WAP	5WAP	6WAP	7WAP
Kale control	1.24 ^f	1.86 ^g	2.69 ^f	1.24 ^h	1.85 ⁱ	2.69 ^h
Amaranth control	0.24 ⁱ	0.58 ^h	1.13 ⁱ	5.86 ^{ab}	5.83 ^b	5.83 ^{ab}
Cowpea control	0.81 ^h	1.79 ^g	2.17 ^h	5.12 ^d	4.99 ^d	5.25 ^{cd}
Kales TSP	2.61 ^a	3.81 ^b	4.87 ^b	2.60 ^f	3.81 ^f	4.87 ^e
Amaranth TSP	2.64 ^a	4.62 ^a	5.50 ^a	5.38 ^{cd}	5.31 ^c	5.27 ^{cd}
Cowpea TSP	1.39 ^e	2.46 ^e	2.84 ^e	5.51 ^c	5.48 ^c	5.49 ^{bc}
Kale RP	1.97 ^e	2.29 ^e	3.89 ^d	1.97 ^g	2.76 ^h	3.89 ^g
Amaranth RP	1.49 ^d	2.83 ^d	3.82 ^d	6.12 ^a	6.14 ^a	6.03 ^a
Cowpea RP	1.01 ^g	2.10 ^f	2.46 ^g	5.63 ^{bc}	5.69 ^b	5.76 ^{ab}
Kale RP+S	2.34 ^b	3.43 ^c	4.51 ^c	2.33 ^f	3.43 ^g	4.51 ^f
Amaranth RP+S	1.91 ^e	3.65 ^b	4.40 ^c	5.10 ^{de}	4.60 ^e	5.02 ^{de}
Cowpea RP+S	1.24 ^f	2.29 ^e	2.70 ^f	4.77 ^e	4.74 ^e	4.81 ^{ef}
LSD	0.12	0.17	0.11	0.35	0.18	0.34

129 Means followed by the same letter within the same column are not significantly different
 130 ($P \leq 0.05$). TSP- Triple –super phosphate, RP+S-Rock Phosphate and sulphur, RP- Rock
 131 phosphate, **LSD? WAP?**

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 133
 134 The current study agrees with the findings of Ojo et al. [9] who reported an increase in root
 135 biomass on grain amaranth when supplied with phosphorus forms. Application of phosphorus

136 sources in cowpea has also reported to increase nodulation which is a sign of vibrant root growth
137 as reported by Kyei-Boahen *et al.* [10] particularly for cow pea. On the other hand the effective
138 utilization of rock phosphate in combination with sulphur was obvious where by the S seem to
139 play a role in decreasing soil pH, and consequently helped in transformation of insoluble P to
140 available form for plant uptake [11] Moreover, mixing the RP with elemental S caused a
141 significant increase in the available P over those applied without S. As stated by Huang Rankine
142 *et al.* [12], phosphorus is an essential element for plant growth and is particularly important for
143 root growth during the establishment and early growth stages. The current study thus, indicates
144 that growers can embark on rock phosphate utilization in farming as an alternative in provision
145 of phosphorous nutrition in vegetable species.

146 **3.2 Leaf area**

147 Vegetable species exhibited significant differences ($P \leq 0.05$) in leaf area in the two study
148 seasons. Kales recorded the largest leaf area in season 1 and season 2 with the greatest values
149 being recorded during the 7 WAP with 2088.0 cm² in season one and 1905.0 cm² at 7 WAP in
150 season 2 as illustrated in table 3. The significant high leaf area in kales could be as a result of
151 proper utilization of the applied phosphorous to match the shoots and root demand. Cowpea had
152 the lowest leaf area in the entire growing season for both season 1 and season 2. The TSP
153 treatment elicited the greatest leaf area followed by the rock phosphate plus sulphur treatment.
154 The control had the least effect on leaf area in vegetable species during the season 1 and season
155 2. There were significant interactions observed between the vegetable species and phosphorous
156 species.

157 **Table 3: Leaf Area as affected by vegetable species and phosphorous sources during season**
158 **1 and season 2**

Species	Season 1			Season 2		
	LA5WAP	LA6WAP	LA7WAP	LA5WAP	LA6WAP	LA7WAP
Kales	775.4 ^a	1221.0 ^a	2088.0 ^a	573.7 ^a	1129.3 ^a	1905.0 ^a
Amaranth	263.0 ^b	691.2 ^{ab}	1141.0 ^{ab}	263.0 ^b	607.9 ^{ab}	1149.0 ^{ab}
Cowpea	189.9 ^b	285.4 ^b	596.0 ^b	189.9 ^b	267.9 ^a	525.0 ^a
LSD	279.2	560.9	866.3	241.9	510.0	860.00
Treatments						
Control	131.3 ^b	187.1 ^c	333.0 ^c	109.1 ^b	176.0 ^b	329.0 ^c
TSP	760.8 ^a	1543.2 ^a	2472.0 ^a	649.7 ^a	1442.1 ^a	2393.0 ^a
RP+S	553.8 ^{ab}	910.1 ^{ab}	1665.0 ^{ab}	431.6 ^{ab}	710.1 ^b	1420.0 ^{ab}
RP	191.9 ^b	289.7 ^{bc}	630.00 ^{bc}	178.5 ^b	345.3 ^b	630.0 ^{bc}
LSD	329.2	518.8	810.00	246.1	485.3	815.5
SXPF	NS	NS	NS	NS	NS	NS

159 Means followed by the same letter within the same column are not significantly different
160 ($P \leq 0.05$). TSP- Triple –super phosphate, RP+S-Rock Phosphate and sulphur, RP- Rock
161 phosphate, S-vegetable species, PF-phosphorous sources

162 **LSD? WAP? LA?**

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164 Application of phosphorous promotes growth and differentiation of major organs such as leaf s
165 hence results to increase in leaf area. According to Yan *et al.* [13], adequate phosphorus nutrition
166 has been reported to lead to an increase in leaf growth and consequently recording a high leaf
167 area in brassica family which also supports the findings of this study. Additionally, phosphorus
168 helps in the conversion of other nutrients into usable building blocks for growth and
169 photosynthesis. It is also indispensable for cell differentiation and for the development of the
170 tissues that form the growing points of the plants [14]. This study conforms to the findings of
171 Singh *et al.* [15] who reported phosphorus that leads to an increase in leaf expansion that's result
172 into high leaf area hence increasing the photosynthetic area of various crops.

173 3.3 Shoot Fresh weight

174 Shoot fresh weight had significant differences ($P \leq 0.05$) between the vegetable species and also
175 phosphorus forms in season 1 and season 2. Kales had the highest accumulation of shoot fresh
176 weight in all the sampling stages in both seasons; with 7 WAP having the highest value of

177 175.03 g and 174.96 g in season 1 and season two respectively as shown in table 4. Cowpea
 178 accumulated the least shoot fresh weight in all the growth stages. Phosphorous forms also
 179 showed significant ($P \leq 0.05$) increase in shoot fresh weight of vegetable species TSP recorded
 180 the highest shoot fresh weigh I in both season 1 and 2 at all the growth stages with the highest
 181 in 7 WAP (236.88 g) in season 1 and (228.0 g) in season 2. The high shoot fresh weight could
 182 be as a result of more available phosphorus that promoted vibrant growth of the vegetative parts.
 183 The control had the least shoot fresh weight in all the growth stages.

184 **Table 4. Shoot Fresh weight as influenced by vegetable species and phosphorous sources**

Species	Season 1		Season 2			
	5WAP	6WAP	SFW7WAP	SFW5WAP	SFW6WAP	SFW7WAP
Kales	51.48 ^a	107.49 ^a	175.03 ^a	50.80 ^a	107.49 ^a	174.96 ^a
Amaranth	25.25 ^{ab}	46.42 ^{ab}	91.54 ^{ab}	25.25 ^{ab}	53.09 ^{ab}	81.54 ^{ab}
Cowpea	13.32 ^b	22.34 ^b	31.26 ^a	13.66 ^b	23.01 ^b	32.53 ^b
LSD	23.79	49.38	93.0	24.17	48.40	92.2
Treatments						
Control	6.31 ^b	11.87 ^b	17.44 ^b	5.58 ^c	12.76 ^b	18.91 ^b
TSP	60.71 ^a	135.43 ^a	236.88 ^a	61.38 ^a	130.98 ^a	228.0 ^a
RPS+S	37.28 ^{ab}	64.93 ^b	96.06 ^b	37.39 ^{ab}	64.93 ^b	96.06 ^b
RP	15.76 ^b	36.12 ^b	46.86 ^b	15.26 ^{bc}	36.12 ^b	42.41 ^b
LSD	23.99	48.42	89.0	23.66	49.10	91.2
SXPF	*	*	NS	*	*	NS

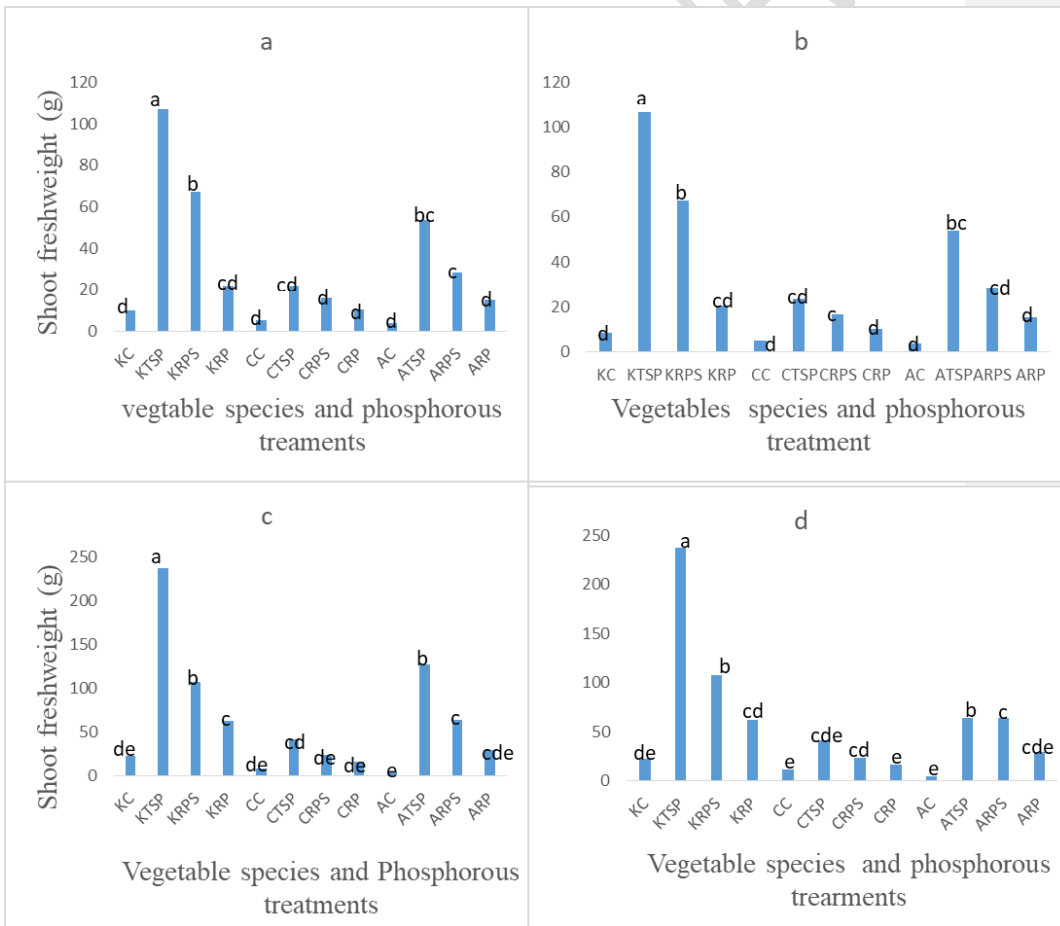
185 **Means followed by the same letter within the same column are not significantly different**
 186 **($P \leq 0.05$). TSP- Triple –super phosphate, RP+S-Rock Phosphate and sulphur, RP- Rock**
 187 **phosphate, S-vegetable species, PF-phosphorous sources **LSD? WAP?****

188 Interactions effects between the phosphorus forms and vegetable species on the influence of
 189 shoot fresh weight during 5 WAP and 6 WAP in season 1 and 2 are illustrated in figure 1. Kales
 190 applied with TSP had the highest shoot fresh weight (106.91 g) in season one for both 5 WAP
 191 and 6 WAP respectively and 233.91 g in 5 WAP and 6 WAP in season 2. Like other parameters,
 192 the control recorded the least shoot fresh weight.

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205 **Figure 1: Interaction effects of phosphorus forms and vegetable species on shoot fresh**
206 **weight in season 1 5WAP (a), 6WAP (b) season 2 5WAP (c), 6WAP (d). KC- kales control,**
207 **KTSP- Kales TSP, KRPS- kales RPS, KRP- Kales RP, CC- Cowpea control, CTSP-**
208 **cowpea TSP, CRPS- cowpea RPS, CRP- cowpea RP, AC- Amaranth control, ATSP-**
209 **Amaranth TSP, ARPS- Amaranth RPS, ARP- Amaranth RP.**

210 The findings of this study agree with those of Chen *et al.* [16] who reported an increase in the
211 shoot biomass in Chinese kale upon application of phosphate fertilizers. In another study by
212 Kim *et al.* [17] application of high phosphorous form led to high growth of the above ground
213 biomass as well as the roots. In soils where P-is deficient in plants, shoot growth was found to be
214 more affected than root growth due to assimilate partitioning towards the roots and this led to a
215 decrease in the shoot: root dry matter ratio [18]. The authors also observed a reduction in trunk
216 diameter, bunch size and a pronounced pyramid shape of the palm due to the progressive
217 depletion of soil P. The superior effect of TSP fertilizer shoot biomass produced could be
218 ascribed to high solubility of phosphate in TSP [19].

219 **3.4 Number of branches**

220 There were significant differences ($P \leq 0.05$) on the number of branches between the vegetable
221 species and phosphorus forms treatments in both season 1 and season 2. Amaranthus recorded
222 the highest number of branches in both season with an increment from 5WAP, 6 WAP and 7
223 WAP. The highest number of branches was recorded in 7 WAP with 30.88 and 45.58 in season
224 1 and season 2 respectively (table 5). Cowpea had the least number of branches due to the P
225 treatments effect for both seasons. In phosphorous forms the highest number of branches per
226 plant were observed on the TSP treatment for both seasons while the lowest was on the control.
227 The rock phosphate plus sulphur treatment showed higher number of branches than that on the
228 sole rock phosphate treatment.

229 **Table 5: Number of branches as affected by vegetable species and phosphorous sources**

Species	Season 1			Season 2		
	5WAP	6WAP	7WAP	5WAP	6WAP	7WAP
Kales	9.25 ^b	11.75 ^a	14.00 ^b	9.08 ^b	12.12 ^b	14.00 ^b
Amaranth	17.75 ^a	27.50 ^a	30.83 ^a	17.75 ^a	30.00 ^a	45.58 ^a
Cowpea	9.00 ^b	11.50 ^b	13.75 ^b	9.00 ^b	11.35 ^b	13.75 ^b
LSD	3.48	5.98	6.94	3.51	7.64	14.46
Treatments						
Control	7.00 ^b	8.72 ^b	10.33 ^b	7.0 ^b	8.72 ^b	10.44 ^b
TSP	16.44 ^a	23.56 ^a	27.78 ^a	16.44 ^a	26.89 ^a	40.67 ^a
RPS+S	13.56 ^a	19.83 ^{ab}	22.22 ^{ab}	13.56 ^a	19.72 ^{ab}	27.78 ^{ab}
RP	11.00 ^{ab}	15.56 ^{ab}	17.78 ^{ab}	10.78 ^{ab}	15.83 ^{ab}	18.89 ^{ab}
LSD	4.67	8.82	9.60	4.71	10.75	19.95
SXPF	*	*	*	*	*	*

230 **Means followed by the same letter within the same column are not significantly different**
 231 **(P≤0.05). TSP- Triple –super phosphate, RP+S-Rock Phosphate and sulphur, RP- Rock**
 232 **phosphate, S-vegetable species, PF-phosphorous sources**

233 These results are in conformity with the findings of Shivakumar *et al.* [20] who reported that the
 234 increasing levels of phosphorus in the form of rock phosphate significantly increased the plant
 235 height, number of branches per plant, buds per plant, grain and stover yield during both the years
 236 indicating that application of higher levels of phosphorus. Similarly Shaktawat *et al.* [21]
 237 reported that, higher phosphorus dose through rock phosphate either alone or in combination
 238 with acidulates were better than the control in soybean-mustard cropping system.

239 **4.0 Conclusions and Recommendations**

240 Application of phosphorus forms influenced growth parameters of the vegetable species
 241 including cowpea, kales and Amaranthus compared to the control. The triple superphosphate
 242 treatment led to the highest fresh shoot weight, leaf area, root dry weight, and root dry weight
 243 especially under the amaranth and kale crop then followed by the rock phosphate plus sulphur
 244 treatment which at some instances under the cowpea they were not significantly different with
 245 the industrial fertilizer however being superior. Direct application of phosphate rock to soil is a

246 possible alternative to the more expensive soluble phosphate fertilizers in tropical cropping
247 system. Therefore, the acidulated rock phosphate (RP+sulphur) increased the growth parameters
248 of amaranth, cowpea and kale as well as their yield parameters though less than the TSP
249 treatment which was superior. Thus the use of acidulated rock phosphate is a viable option in the
250 smallholder farmers who may not be able to afford the industrial fertilizer.

251 **COMPETING INTERESTS**

252 Authors have declared that no competing interests exist.

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