

## **Original Research Article**

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

5

#### **Abstract**

7 Maximum production potential of leafy vegetable is limited by phosphorous deficiency in the  
8 soils. This is due to the high cost of the phosphate fertilizer and the fixed form of the available  
9 phosphorous in the soil. There is therefore, need for farmers to use alternative and cheaper  
10 sources of P that are economic friendly to supply the required mineral nutrition to their crops.  
11 Rock phosphate is widely available but has a challenge in solubilization to make P available to  
12 the crops. In the current study, the aim was to evaluate the effect phosphate forms and acidulate  
13 rock phosphate on growth and yield of selected leafy vegetables. The experiment was laid out in  
14 Randomized Complete Block Design in split-plot arrangement, with three leafy vegetables  
15 (cowpeas, kales and amaranth) being the main plots, and various sources of P (Triple super  
16 phosphate(TSP) Mijingu Phosphate Rock(MPR), Mijingu phosphate Rock + sulphur  
17 (MPR)PR+S and control) constituting the subplots with three replicates. The collected data  
18 included the root dry weight, leaf area, shoot fresh weight and leaf area and was subjected to  
19 SAS for ANOVA and where there were significant differences between means were further  
20 separated using the Fischer's LSD at 5% level of significance. The results revealed that there  
21 were significant increase in the growth parameters of the vegetables as an effects of phosphorus  
22 application compared with the control. TSP elicited the best results in all the tested parameters in  
23 5 WAP, 6 WAP and 7 WAP respectively in both seasons. The highest value of root dry weight  
24 (11.2g), leaf area (1905.0cm<sup>2</sup>), number of branches (40.67) shoot fresh weight (236.8g) as  
25 influenced by TSP application in the vegetable species. The MRP +sulphur also followed in  
26 superiority of increasing the growth parameters which is an indication that sulphur can be used  
27 in solubilizing rock phosphate and making it a suit alternative for farmers. Thus, farmers are  
28 advised to directly apply rock phosphate and sulphur to soil as a possible alternative to the more  
29 expensive soluble phosphate fertilizers in tropical cropping system.

30 **Key words:** Rock phosphate, Available Phosphorous, ~~sulphur~~Sulphur, ~~soil~~Soil fertility

31

#### **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  
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 12.8<sup>0</sup> C during the cold months and 24.6<sup>0</sup> 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 P<sub>2</sub>O<sub>5</sub> /ha), MRP +S (120 kg P<sub>2</sub>O<sub>5</sub>  
82 /ha) using 240g of elemental sulphur, and TSP (60 Kg p /ha). The rate of 120 kg P<sub>2</sub>O<sub>5</sub>/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% K<sub>2</sub>O) 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**

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~~seasons. The RP+sulphur  
 108 was the second best in terms of root growth which is an indication of high availability of  
 109 phosphorus from this particular source of phosphorous. The control recorded the least root  
 110 biomass compared to other sources of phosphorous.

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 <sup>a</sup>	7.08 <sup>a</sup>	9.84 <sup>a</sup>	3.73 <sup>a</sup>	7.25 <sup>a</sup>	9.83 <sup>a</sup>
Amaranth	2.79 <sup>ab</sup>	4.60 <sup>ab</sup>	5.46 <sup>b</sup>	2.80 <sup>ab</sup>	4.59 <sup>ab</sup>	5.46 <sup>b</sup>
Cowpea	1.80 <sup>b</sup>	3.06 <sup>b</sup>	3.77 <sup>b</sup>	1.79 <sup>b</sup>	3.06 <sup>b</sup>	3.77 <sup>b</sup>
<b>LSD</b>	<b>1.40</b>	<b>2.61</b>	<b>3.56</b>	<b>1.40</b>	<b>2.72</b>	<b>3.56</b>
<b>Treatments</b>						
Control	1.12 <sup>c</sup>	1.92 <sup>c</sup>	2.78 <sup>b</sup>	1.12 <sup>b</sup>	1.92 <sup>c</sup>	2.78 <sup>b</sup>
TSP	4.76 <sup>a</sup>	8.47 <sup>a</sup>	11.22 <sup>a</sup>	4.65 <sup>a</sup>	8.69 <sup>a</sup>	11.22 <sup>a</sup>
RP+S	3.22 <sup>b</sup>	5.59 <sup>ab</sup>	6.88 <sup>ab</sup>	3.44 <sup>a</sup>	5.59 <sup>ab</sup>	6.87 <sup>ab</sup>
RP	1.88 <sup>bc</sup>	3.66 <sup>bc</sup>	4.54 <sup>b</sup>	1.88 <sup>b</sup>	3.66 <sup>bc</sup>	4.54 <sup>b</sup>
<b>LSD</b>	<b>1.10</b>	<b>2.42</b>	<b>3.70</b>	<b>1.15</b>	<b>2.56</b>	<b>3.70</b>
<b>SXPF</b>	*	*	*	*	*	*

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

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.

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 <sup>f</sup>	1.86 <sup>g</sup>	2.69 <sup>f</sup>	1.24 <sup>h</sup>	1.85 <sup>i</sup>	2.69 <sup>h</sup>
Amaranth control	0.24 <sup>i</sup>	0.58 <sup>h</sup>	1.13 <sup>i</sup>	5.86 <sup>ab</sup>	5.83 <sup>b</sup>	5.83 <sup>ab</sup>
Cowpea control	0.81 <sup>h</sup>	1.79 <sup>g</sup>	2.17 <sup>h</sup>	5.12 <sup>d</sup>	4.99 <sup>d</sup>	5.25 <sup>cd</sup>
Kales TSP	2.61 <sup>a</sup>	3.81 <sup>b</sup>	4.87 <sup>b</sup>	2.60 <sup>f</sup>	3.81 <sup>f</sup>	4.87 <sup>e</sup>
Amaranth TSP	2.64 <sup>a</sup>	4.62 <sup>a</sup>	5.50 <sup>a</sup>	5.38 <sup>cd</sup>	5.31 <sup>c</sup>	5.27 <sup>cd</sup>
Cowpea TSP	1.39 <sup>e</sup>	2.46 <sup>e</sup>	2.84 <sup>e</sup>	5.51 <sup>c</sup>	5.48 <sup>c</sup>	5.49 <sup>bc</sup>
Kale RP	1.97 <sup>c</sup>	2.29 <sup>e</sup>	3.89 <sup>d</sup>	1.97 <sup>g</sup>	2.76 <sup>h</sup>	3.89 <sup>g</sup>
Amaranth RP	1.49 <sup>d</sup>	2.83 <sup>d</sup>	3.82 <sup>d</sup>	6.12 <sup>a</sup>	6.14 <sup>a</sup>	6.03 <sup>a</sup>
Cowpea RP	1.01 <sup>g</sup>	2.10 <sup>f</sup>	2.46 <sup>g</sup>	5.63 <sup>bc</sup>	5.69 <sup>b</sup>	5.76 <sup>ab</sup>
Kale RP+S	2.34 <sup>b</sup>	3.43 <sup>c</sup>	4.51 <sup>c</sup>	2.33 <sup>f</sup>	3.43 <sup>g</sup>	4.51 <sup>f</sup>
Amaranth RP+S	1.91 <sup>c</sup>	3.65 <sup>b</sup>	4.40 <sup>c</sup>	5.10 <sup>de</sup>	4.60 <sup>e</sup>	5.02 <sup>de</sup>
Cowpea RP+S	1.24 <sup>f</sup>	2.29 <sup>e</sup>	2.70 <sup>f</sup>	4.77 <sup>e</sup>	4.74 <sup>e</sup>	4.81 <sup>ef</sup>
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<0.05). TSP- Triple –super phosphate, RP+S-Rock Phosphate and sulphur, RP- Rock**  
 131 **phosphate,**

132  
 133 The current study agrees with the findings of Ojo *et al.* [9] who reported an increase in root  
 134 biomass on grain amaranth when supplied with phosphorus forms. Application of phosphorus  
 135 sources in cowpea has also reported to increase nodulation which is a sign of vibrant root growth  
 136 as reported by Kyei-Boahen *et al.* [10] particularly for cow pea. On the other hand the effective  
 137 utilization of rock phosphate in combination with sulphur was obvious where by the S seem to  
 138 play a role in decreasing soil pH, and consequently helped in transformation of insoluble P to  
 139 available form for plant uptake [11]. Moreover, mixing the RP with elemental S caused a  
 140 significant increase in the available P over those applied without S. As stated by Huang [Rankine](#)

141 *et al.* [12], phosphorus is an essential element for plant growth and is particularly important for  
 142 root growth during the establishment and early growth stages. The current study thus, indicates  
 143 that growers can embark on rock phosphate utilization in farming as an alternative in provision  
 144 of phosphorous nutrition in vegetable species.

### 145 3.2 Leaf area

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

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

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

LSD	329.2	518.8	810.00	246.1	485.3	815.5
SXPF	NS	NS	NS	NS	NS	NS

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

161

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

### 171 3.3 Shoot Fresh weight

172 Shoot fresh weight had significant differences ( $P \leq 0.05$ ) between the vegetable species and also  
173 phosphorus forms in season 1 and season 2. Kales had the highest accumulation of shoot fresh  
174 weight in all the sampling stages in—both seasons; with 7 WAP having the highest value of  
175 175.03 g and 174.96 g in season 1 and season two respectively as shown in table 4. Cowpea  
176 accumulated the—least shoot fresh weight in all the growth stages. Phosphorous forms also  
177 showed significant ( $P \leq 0.05$ ) increase in shoot fresh weight of vegetable species TSP recorded  
178 the highest shoot fresh weigh I in both season 1 and 2 at all the growth stages with the highest  
179 in 7 WAP (236.88 g) in season 1 and (228.0 g) in season 2. The high shoot fresh weight could

180 be as a result of more available phosphorus that promoted vibrant growth of the vegetative parts.

181 The control had the least shoot fresh weight in all the growth stages.

182 **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 <sup>a</sup>	107.49 <sup>a</sup>	175.03 <sup>a</sup>	50.80 <sup>a</sup>	107.49 <sup>a</sup>	174.96 <sup>a</sup>
Amaranth	25.25 <sup>ab</sup>	46.42 <sup>ab</sup>	91.54 <sup>ab</sup>	25.25 <sup>ab</sup>	53.09 <sup>ab</sup>	81.54 <sup>ab</sup>
Cowpea	13.32 <sup>b</sup>	22.34 <sup>b</sup>	31.26 <sup>a</sup>	13.66 <sup>b</sup>	23.01 <sup>b</sup>	32.53 <sup>b</sup>
<b>LSD</b>	<b>23.79</b>	<b>49.38</b>	<b>93.0</b>	<b>24.17</b>	<b>48.40</b>	<b>92.2</b>
<b>Treatments</b>						
Control	6.31 <sup>b</sup>	11.87 <sup>b</sup>	17.44 <sup>b</sup>	5.58 <sup>c</sup>	12.76 <sup>b</sup>	18.91 <sup>b</sup>
TSP	60.71 <sup>a</sup>	135.43 <sup>a</sup>	236.88 <sup>a</sup>	61.38 <sup>a</sup>	130.98 <sup>a</sup>	228.0 <sup>a</sup>
RPS+S	37.28 <sup>ab</sup>	64.93 <sup>b</sup>	96.06 <sup>b</sup>	37.39 <sup>ab</sup>	64.93 <sup>b</sup>	96.06 <sup>b</sup>
RP	15.76 <sup>b</sup>	36.12 <sup>b</sup>	46.86 <sup>b</sup>	15.26 <sup>bc</sup>	36.12 <sup>b</sup>	42.41 <sup>b</sup>
<b>LSD</b>	<b>23.99</b>	<b>48.42</b>	<b>89.0</b>	<b>23.66</b>	<b>49.10</b>	<b>91.2</b>
<b>SXPF</b>	*	*	NS	*	*	NS

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

186

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

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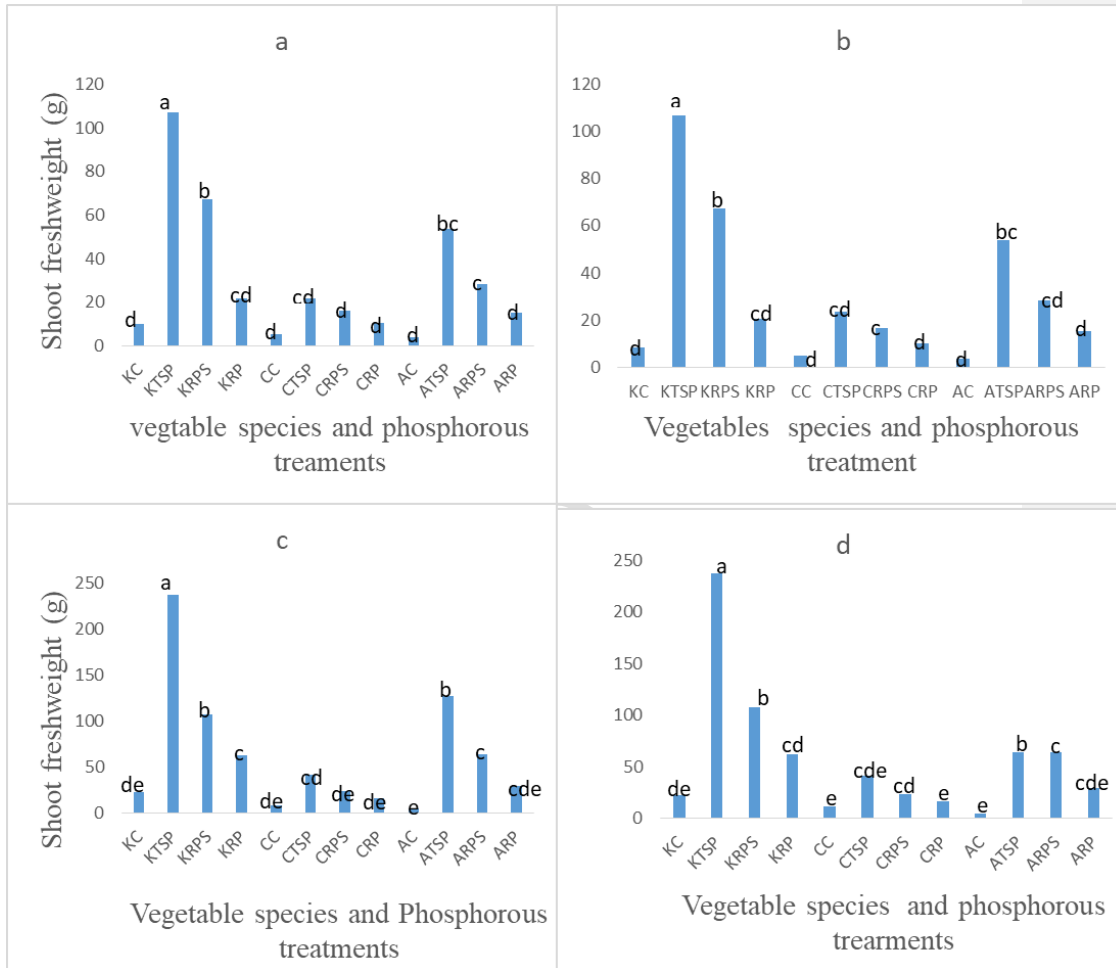
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**Figure 1: Interaction effects of phosphorus forms and vegetable species on shoot fresh weight in season 1 5WAP (a), 6WAP (b) season 2 5WAP (c), 6WAP (d). KC- kales control, KTSP- Kales TSP, KRPS- kales RPS, KRP- Kales RP, CC- Cowpea control, CTSP-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

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

### 218 3.4 Number of branches

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

228 **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 <sup>b</sup>	11.75 <sup>a</sup>	14.00 <sup>b</sup>	9.08 <sup>b</sup>	12.12 <sup>b</sup>	14.00 <sup>b</sup>
Amaranth	17.75 <sup>a</sup>	27.50 <sup>a</sup>	30.83 <sup>a</sup>	17.75 <sup>a</sup>	30.00 <sup>a</sup>	45.58 <sup>a</sup>
Cowpea	9.00 <sup>b</sup>	11.50 <sup>b</sup>	13.75 <sup>b</sup>	9.00 <sup>b</sup>	11.35 <sup>b</sup>	13.75 <sup>b</sup>

<b>LSD</b>	<b>3.48</b>	<b>5.98</b>	<b>6.94</b>	<b>3.51</b>	<b>7.64</b>	<b>14.46</b>
<b>Treatments</b>						
Control	7.00 <sup>b</sup>	8.72 <sup>b</sup>	10.33 <sup>b</sup>	7.0 <sup>b</sup>	8.72 <sup>b</sup>	10.44 <sup>b</sup>
TSP	16.44 <sup>a</sup>	23.56 <sup>a</sup>	27.78 <sup>a</sup>	16.44 <sup>a</sup>	26.89 <sup>a</sup>	40.67 <sup>a</sup>
RPS+S	13.56 <sup>a</sup>	19.83 <sup>ab</sup>	22.22 <sup>ab</sup>	13.56 <sup>a</sup>	19.72 <sup>ab</sup>	27.78 <sup>ab</sup>
RP	11.00 <sup>ab</sup>	15.56 <sup>ab</sup>	17.78 <sup>ab</sup>	10.78 <sup>ab</sup>	15.83 <sup>ab</sup>	18.89 <sup>ab</sup>
<b>LSD</b>	<b>4.67</b>	<b>8.82</b>	<b>9.60</b>	<b>4.71</b>	<b>10.75</b>	<b>19.95</b>
<b>SXPF</b>	*	*	*	*	*	*

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

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

#### 238 **4.0 Conclusions and Recommendations**

239 Application of phosphorus forms influenced growth parameters of the vegetable species  
240 including cowpea, kales and Amaranthus compared to the control. The triple superphosphate  
241 treatment led to the highest fresh shoot weight, leaf area, root dry weight, and root dry weight  
242 especially under the amaranth and kale crop then followed by the rock phosphate plus sulphur  
243 treatment which at some instances under the cowpea they were not significantly different with  
244 the industrial fertilizer however being superior. Direct application of phosphate rock to soil is a  
245 possible alternative to the more expensive soluble phosphate fertilizers in tropical cropping  
246 system. Therefore, the acidulated rock phosphate (RP+sulphur) increased the growth parameters  
247 of amaranth, cowpea and kale as well as their yield parameters though less than the TSP

248 treatment which was superior. Thus the use of acidulated rock phosphate is a viable option in the  
249 smallholder farmers who may not be able to afford the industrial fertilizer.

## 250 **COMPETING INTERESTS**

251 Authors have declared that no competing interests exist.

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