

MAIZE GROWTH AND YIELD RESPONSE TO INCREMENTAL RATES OF PHOSPHORUS IN P-DEPLETED LIXISOLS OF NOTHERN GHANA

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ABSTRACT

It has long been postulated that the efficient use of phosphatic fertilizers must be based on information on inherent soil P-levels for the development of site-specific fertilization that must, in turn, be based on crop response to known nutrient levels. However knowledge remains relatively sparse on crop response to incremental rates of P₂O₅ fertilization on soils of known P levels to serve as proxy for development of site-specific P₂O₅ predicting tool that is required for optimum maize production. In the P-deficient Lixisols of northern Ghana, the effect of eleven rates of P₂O₅ fertilization were evaluated for growth and yield of maize. The P₂O₅ rates used were 00, 05, 10, 15, 20, 25, 30, 35, 40, 45, and 50 kg/ha; laid out in a Randomized Complete Block Design with four replicates. Data were collected on maize growth and yield and subjected to analyses of variance, where means were separated at a probability of 5% using the least significant difference. Results of the evaluation indicated significant effect of P₂O₅ rate on maize plant height, leaf area index, days to 50% flowering, cob weight, cob length, 100 seed weight, straw weight and grain yield. Increasing P₂O₅ rates had pronounced effect on growth, on grain yield and on yield components of maize. Application of 50 kg/ha resulted in maximum leaf area index (3.84), 100 seed weight (23.49 g), straw weight (9.3 t/ha) and grain yield (3.09 t/ha) as compared to the minimum values in the control treatments (1.57, 14.8 g, 3.3 t/ha and 0.71 t/ha respectively). The findings show that phosphorus fertilization is essential for maize growth and yield and serves as an entry point for relating soil test data with corresponding yield and the subsequent development of a fertilization tool that can help to predict site-specific P₂O₅ fertilization, based on soil test results.

Keywords: Maize growth, yield and yield components, phosphorus fertilization, site-specificity, crop nutrition.

1. INTRODUCTION

Maize is a versatile cereal crop that is cultivated under wide agro-ecological environments [1, 2]. The use of maize crop has replaced that of most indigenous cereal crops such as sorghum and millet in Ghana [3]. Maize remains a significant crop for the agricultural sector and for ensuring food security [4], being the prime source of feed for the livestock sub-sector [5]. The versatile environment under which the crop grows has made it possible to cultivate it under the diverse agro climatic conditions of Ghana: ranging from the coastal, savannah, transition, and the forest zones. For these reasons, most household livelihoods in the rural areas are dependent on the yield

of the crop. The average yield of maize, however, remains relatively low (about 1.7 t/ha) compared to an expected yield of around 6 t/ha [6, 7, 8].

Phosphorus (P) is the second most limiting nutrient in most cropping systems of Africa [9, 10]. The nutrient is required for most physiological and morphological functions of crops [11]. During maize growth, phosphorus is required for root and grain development [12]. It is also required for numerous biochemical processes and for the metabolism of carbohydrates, fats and proteins. Phosphorus is also required for the breakdown of carbohydrates to release energy for use by the plant [13]. According to [14] phosphorus is involved in leaf development and senescence in maize which in turn has profound effect on leaf area, light interception, photosynthesis and assimilate accumulation. Due to the numerous physiological and morphological functions of P in maize growth and development, knowledge on P nutrition has been used to improve yield in most nutrient-poor soils [15].

In most resource-poor rural communities of Ghana, maize farmers continue to depend on inherent soil fertility for maize production. The naturally low nutrient status on the other hand render such soils unsuitable for maize production [16], which necessitate application of external nutrients to meet the crop's nutrient demand [17]. In cases where external P fertilizers are applied, crop performances have been noted to improve with successive fertilization. In some cases, residual P has been noted to increase yield of successive maize crops [18]. In a study by [19], they noted that the application of a mixture of urea, triple superphosphate (TSP) fertilizer and farmyard manure improved the crop use of N and P₂O₅ fertilizer.

As P₂O₅ remains an important and irreplaceable fertilizer for maize production, the source of the nutrient is reported to be limited and depleting at an alarming rate [20]. [21] Reported that the global stock pile of phosphatic minerals used for the synthesis of P₂O₅ fertilizers will be depleted in the next decade. This notwithstanding, excessive use of P fertilizers have been noted to cause eutrophication and other environmentally alarming phenomena [22]. To reduce pollution and also help to extend the shelf life of natural P deposits for sustainable and continuous production of food, mankind is required to make judicious use of P fertilizers.

P uptake varies by crop type and level of soil-P [23]. Therefore, crop and site-specific fertilization that are based on individual crop's need has been propounded as the most resilient and environmentally sustaining approach to P fertilization. The development of such site-specific nutrient prediction tools, however, requires three tier levels of studies and data collection: knowledge on crop response to known soil fertility status as base for tool development, development and evaluation of the performance of the given predicting tool, and then validation of the performance of the developed tool [24, 25].

Across the Lixisols of the northern savannah Agro-ecological zone where the bulk of corn is grown, limited data exist on crop responses to known soil phosphorus levels to serve as the first step in the development of any phosphorus-predicting tools for maize production. This lack in knowledge hinders efforts that are aimed at developing site-specific fertilization regimes; and has largely informed a one-suite recommended rate of 45 kg/ha of P₂O₅ for all maize growing sites

irrespective of the inherent differences and variations in soil phosphorus levels at different locations [24]. Therefore, this study was carried out to assess the response of maize growth, yield and yield components to known levels of P₂O₅ to serve as an entry point for subsequent development of a phosphorus predicting-tool for site-specific P₂O₅ fertilization.

2. MATERIALS AND METHODS

2.1 Experimental site

The study was carried out under greenhouse conditions as a pot experiment. The experimental site is located on latitude 09°24’44.4” N and longitude 00°58’49.7” W. The area falls under savannah agro ecology with guinea savanna characteristics [26]. The area experiences a unimodal rainfall pattern, with an annual mean rainfall of 1000 to 1022 mm [24].

Mean monthly temperature ranges from minimum of 21.9°C and maximum of 34.1°C. Relative humidity ranges from a minimum of 46% to maximum of 76.8%. The soils were developed from ferruginized ironstone and gravels [27]. The soils were sandy loam in texture and moderately drained. They developed from Voltaian sandstone and classified as flaplic lixisol that are locally called the Nyankpala series [28].

2.2 Experimental design and treatment

A single factor experiment, consisting of inorganic P₂O₅ rates as treatment was used in the study. Eleven levels of P₂O₅ rates were used. These were 00, 05, 10, 15, 20, 25, 30, 35, 40, 45, and 50 kg/ha (Table 1). The experiment was laid out in a Randomized Complete Block Design to reduce errors that may be associated with heterogeneity of conditions within the glasshouse. The experiment was replicated four (4) times for each treatment. There were forty-four (44) experimental pots in totality. Nitrogen (N) and K₂O fertilizers were each applied at optimum rates of 120 and 60 kg/ha respectively. These optimum rates of the other primary nutrients were used so that observed differences in growth and yield parameters could be attributed solely to differences in P₂O₅ treatments.

Table 1: Rates of P₂O₅ used to study the response of maize growth and yield to incremental levels of P₂O₅ fertilization. **P₂O₅ rates applied to the pot experiment to calibrate soil test results for P₂O₅ fertilization.

Treatment	P ₂ O ₅ calibration rate (kg/ha)	**P ₂ O ₅ rate applied in pot experiment (kg/ha)	Mass of P ₂ O ₅ (g/kg soil)	**Mass of P ₂ O ₅ used (g P ₂ O ₅ / kg soil)
1	0	0	0.000	0.000
2	5	15	0.057	0.171
3	10	30	0.115	0.345

4	15	45	0.173	0.519
5	20	60	0.231	0.693
6	25	75	0.288	0.864
7	30	90	0.346	1.038
8	35	105	0.404	1.212
9	40	120	0.461	1.383
10	45	135	0.519	1.557
11	50	150	0.577	1.731

**Estimated root zone certainty between rhizosphere-applied rate and rate due to continuous mass of soil = three times the actual rate applied on a farmer's field.

The estimated root zone certainty between rhizosphere applied rate and rate due to continuous mass of soil (Table 1) was done by multiplying the actual rate by a factor of three. The factor of three represents an estimate of ratio of root zone surface area to total surface area between any two stands. This estimated root zone certainty was essential in the pot experiment because, in the normal farmers' fields, any rate to be added per unit area are point applied within the root's rhizosphere and not randomly spread over the entire surface area. So that at any time, soils picked within the inter and intra rows on a farmer's field would normally have lower nutrient concentrations than soils that would have been picked at the point where the fertilizers were applied. To ensure uniform concentration of nutrients at any sampled points of soils for the pot experiment, this proxy of nutrient content was essential. The estimated final rate of nutrient applied (Table 1) was then mixed thoroughly with the 10 kg soil to have a uniform nutrient concentration within the potted soil. In this case when soil samples are taken from the pot for analysis, the nutrient concentration will not differ from one point to another.

2.3 Soil sampling

Prior to planting, soil samples were collected from the experimental soil at depth of 0-20 cm. The collected soil samples were air-dried and passed through 2 mm sieve to remove large particles, debris and stones that were larger than 2 mm. Soil physico chemical parameters were then analyzed prior to fertilizer treatment. Soil pH was determined by using the electrometric method in a soil: water ratio of 1:2.5. Organic carbon was determined by the Wakley and Black procedure [29]. Total nitrogen was determined by the micro Kjeldahl method [30], while Bray 1 extraction solution procedure [31] was used for determination of available P. Textural analysis was done by using the hydrometer method.

Sieved soil samples were then mixed thoroughly with the given treatment rate of P₂O₅ (Table 1) and potted at rate of 10 kg soil/pot.

2.4 Agronomic practices

Hand-watering of the potted soils was done twice daily, in the morning and late afternoon, to enhance soil moisture availability to the plant and also to facilitate germination, and growth of the maize plants. Three (3) maize seeds were planted at stake. The maize plants were thinned-out, two weeks after planting to one plant per pot and all weeds that appeared in the pots were removed immediately by hand to prevent competition with the maize plants.

Nitrogen and potassium as N and K₂O were respectively applied as side placements. Nitrogen was applied in two splits. The first application was done 10 days after emergence, together with the K₂O at rates of 60 kg/ha each. The second application of N was done 20 days after the first application at an N rate of 60 kg/ha. Urea was used as the source of N. Muriate of potash (KCl) was used as the source of K₂O (60%), while triple super phosphate (TSP) Ca(H₂PO₄) was used as source of the P₂O₅ (45%).

2.5 Data collection

Data were collected on the following: initial nutrient levels before fertilization, plant height, leaf area index, days to flowering, straw weight, cob weight, cob length, cob weight, 100 seed weight, and grain yield.

2.5.1 Plant height

The height of the maize plants in each pot was measured at 3, 6 and 9 weeks after planting (WAP). Tape measure was used to measure the heights from the base of the plant to the longest tip and their averages recorded.

2.5.2 Leaf area index (LAI)

Leaf area index was taken at 6 and 9 weeks after planting by measuring the length and the width of the leaves. LAI was computed by formula, $L \times W \times A$, where: L = leaf length, W = leaf width and A = a factor of 0.75 for maize crop as described by [32].

2.5.3 Days to flowering

The number of days to tasselling was determined as the number of days between when the crop was planted and when it tasseled.

2.5.4 Cob length

The cobs from each treatment were selected and their length measured and their averages were recorded. A pair of callipers and a rule was used to measure the cob length.

2.5.5 Cob weight

The cobs were selected from each treatment and weighed and their averages recorded. An electronic scale was used to determine the cob weight at harvest.

2.5.6 Weight of hundred seeds

100 maize seeds from each pot were counted and weighed using an electronic scale.

2.5.7 Straw weight

The straws of harvested pots were weighed after harvesting and recorded. The harvested straw weights were converted into tons/ha (t/ha) using the equation used by [24, 33] below.

$$\text{Straw weight (t/ha)} = \frac{\text{Straw weight (kg/pot)} \times \text{Plant density}}{1000} \quad (1)$$

Where plant population density = number of plant stands in 10,000 m² when planted at spacing of 80 cm x 25 cm (interspacing arrangement for the pot experiment), at one seed per stand. Hence, 1 ha (10,000 m²) area has plant density of 50,000 with same spacing.

2.5.8 Grain yield

The grains obtained from pots were threshed, cleaned, dried and weighed in gram for each pot. Total weight of all the grains of a particular pot gives the grain yield in gram per pot and were finally converted into tons/hectare (t/ha), using the equation 2 below, used by [24, 33].

$$\text{Grain yield (t/ha)} = \frac{\text{Grain yield per pot } \left(\frac{\text{kg}}{\text{pot}}\right) \times \text{Plant density}}{1000} \quad (2)$$

Where plant population density = number of plant stands in 10,000 m² when planted at spacing of 80 cm x 25 cm (interspacing arrangement for the pot experiment), at one seed per stand. Hence, 1 ha (10,000 m²) area has plant density of 50,000 with same spacing.

2.6 Data analyses

Data collected from the pot experiments were subjected to analysis of variance (Anova) to compare crop growth and yield responses between the treatment levels using Genstat 18th edition. Treatment means were separated at a 5% probability level using the least significant difference.

3. RESULTS

The physico-chemical properties of the soil prior to planting are shown in Table 2. The soil was loamy sand in texture. The soil had a pH of 5.85 which was moderately acidic. The soil's available P was low and the exchangeable cations (K, Ca and Mg) were not also high. The total nitrogen and percentage organic carbon were also low.

Table 2: Initial soil physico chemical properties

BD g/cm ³	pH H ₂ O (1:2.5)	O.C %	N mg/kg	P mg/kg	K mg/kg	Ca Cmol+/kg	Mg Cmol+/kg	SAND %	SILT %	CLAY %
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1.40	5.85	1.055	0.101	7.457	65.0	1.8	0.72	77.44	21.4	1.16
±0.254	±0.295	±0.041	±0.308	±0.403	±2.677	±0.285	±0.097	±9.395	±0.985	±0.047

* Moisture content on air dry weight basis, BD = Bulk density, OC = Organic carbon, N = Nitrogen, P = phosphorus, K = Potassium, Ca = Calcium, and Mg = Magnesium

Plant height

The application of different rates of phosphorus significantly ($P = 0.049$) influenced plant height during the third week after planting. Plant height increased as the P_2O_5 rates increased (Figure 1). Application of P_2O_5 at rate of 50 kg/ha recorded the highest height followed by application at rate of 45 kg/ha. P_2O_5 application at rate of 00 kg/ha recorded the least height (Figure 1). Different rates of phosphorus applied had significant ($P = 0.001$) effect on plant height at sixth week after planting. P_2O_5 Application at rate of 50, 45 and 40 kg/ha recorded the highest and comparably similar height. Application of P_2O_5 at rate of 00 kg/ha recorded the least height at 6 WAP. At the ninth week after planting, there was significant difference ($P = 0.001$) in plant height between the different rates of phosphorus application. Application of P_2O_5 at rate of 50 kg/ha recorded the highest height followed by P_2O_5 application at rate of 45 and 40 kg/ha. The application of P_2O_5 at rate of 00 kg/ha recorded the least height at the ninth week after planting.

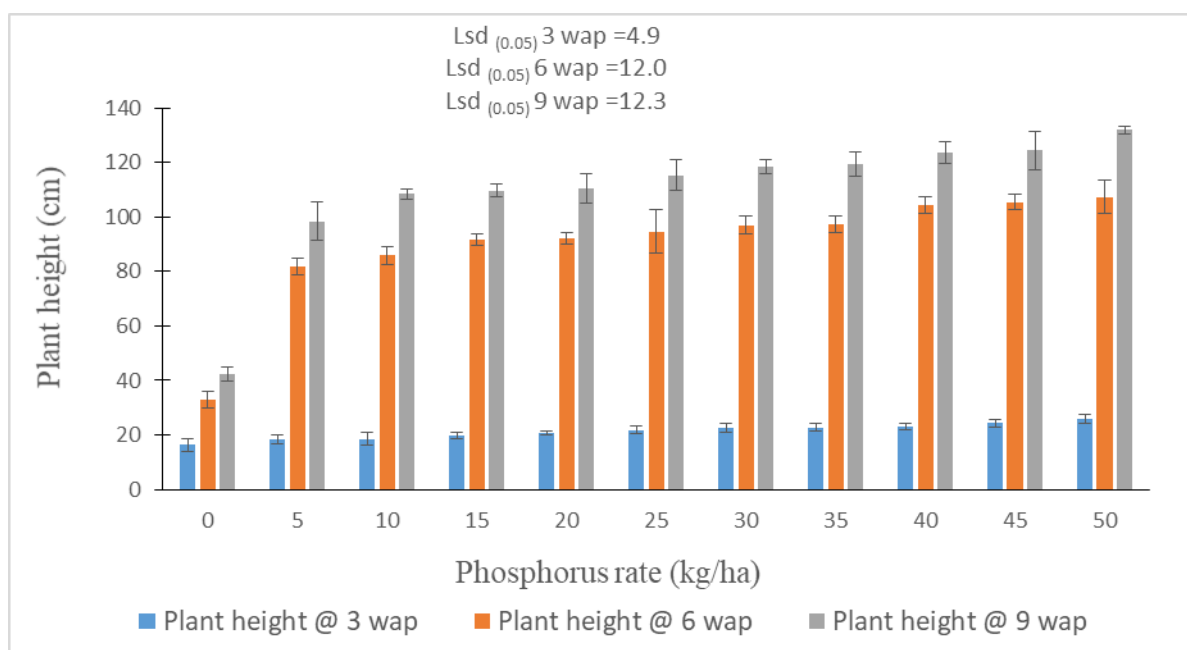


Figure 1: Impact of P_2O_5 calibration rate on plant height of maize at three (3) weeks after planting (wap), 6 weeks after planting and 9 weeks after planting in the guinea savannah zone of Ghana. Error bars represent standard error of means (SEM).

Leaf area index

The application of different rates of phosphorus significantly ($P = 0.001$) influenced leaf area index at sixth week after planting with 50 kg/ha of P_2O_5 recording the highest followed by 25 kg/ha of P while 00 kg/ha P recorded the least (Figure 2). Moreover, leaf area index at ninth week after planting was also significantly ($P = 0.05$) affected by the application of different rates of P_2O_5 . However, at the 9 WAP, treatments that received P_2O_5 fertilization did not differ statistically in leaf area index (Figure 3). In contrast, P_2O_5 fertilized treatments had higher leaf area indices than treatments that did not receive P_2O_5 fertilization (Figure 3).

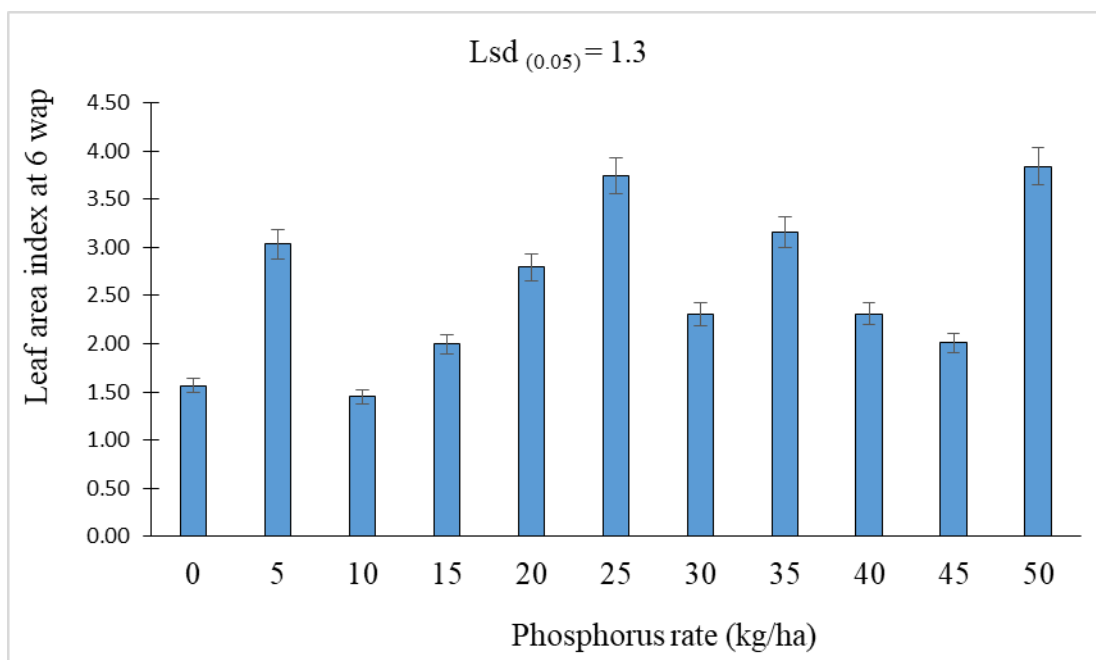


Figure 2: Impact of P_2O_5 calibration rate on leaf area index of maize at six (6) weeks after planting (wap) in the guinea savannah zone of Ghana. Error bars represent standard error of means (SEM).

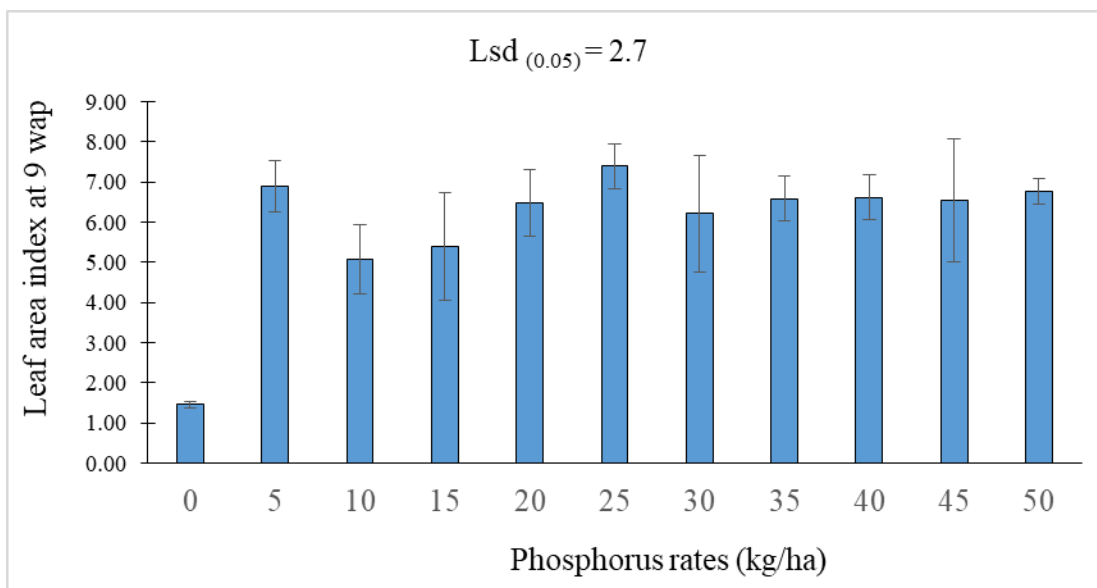


Figure 3: Impact of P₂O₅ calibration rate on leaf area index of maize at nine (9) weeks after planting (wap) in the guinea savannah zone of Ghana. Error bars represent standard error of means (SEM).

Days to flowering

Days to flowering was significantly affected ($P = 0.05$) by the rates of P₂O₅. The 50 kg/ha rate of P₂O₅ recorded the least days to flower, which did not differ significantly from application at 25 and 20 kg/ha (Figure 4). Application at 0 kg/ha, 5 kg/ha, 10 kg/ha and 15 kg/ha recorded the highest days to flower which were statistically comparable (Figure 4).

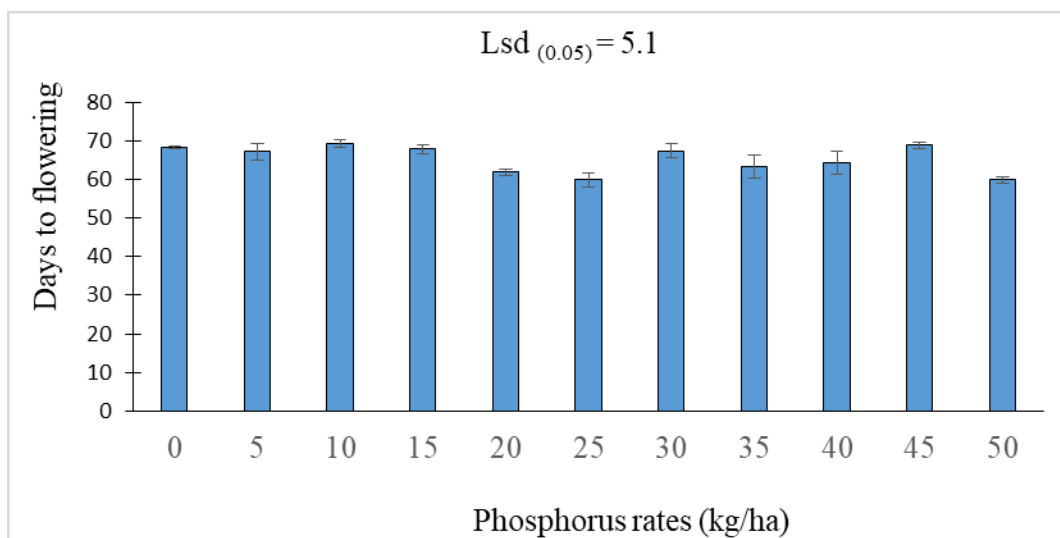


Figure 4: Impact of P₂O₅ calibration rate on days to 50% flowering of maize cultivated in the guinea savannah zone of Ghana. Error bars represent standard error of means (SEM).

Cob weight

Cob weight was highly significantly affected ($P = 0.001$) by the application of different rates of phosphorus. Treatments that received P_2O_5 fertilization had higher cob weight than those that did not receive P_2O_5 fertilization (Figure 5). Within treatments that received phosphorus fertilization, cob weights were statistically comparable.

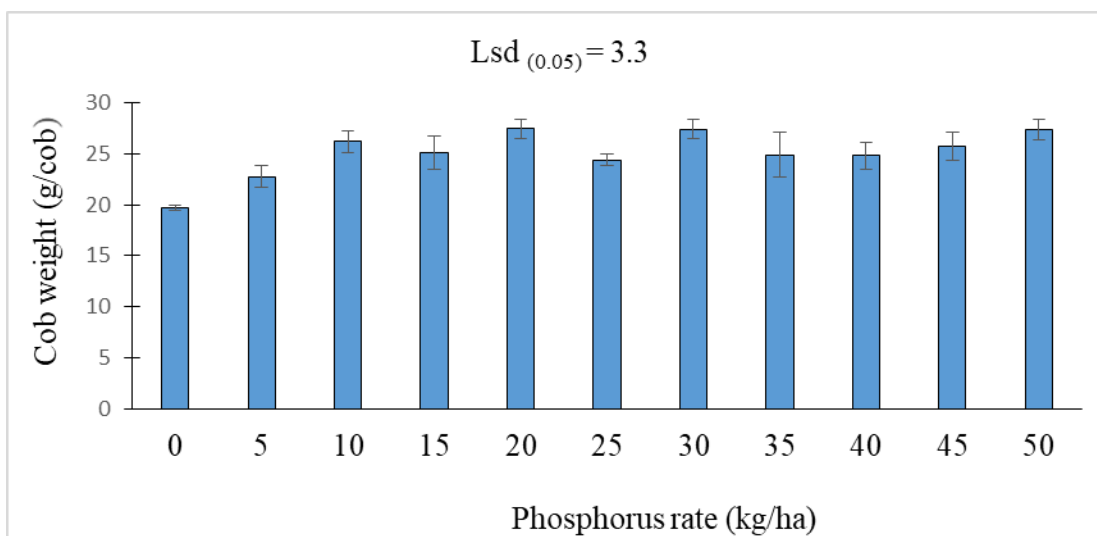


Figure 5: Impact of P_2O_5 calibration rate on cob weight of maize cultivated in the guinea savannah zone of Ghana. Error bars represent standard error of means (SEM).

Cob length

Cob length of maize varied significantly with rate of P_2O_5 application ($P = 0.05$). Application of P_2O_5 at rate of 35 kg/ha resulted in the longest cob length of 14.9 cm (Figure 6). The cob length at rate of 35 kg/ha were statistically same as cob length of P_2O_5 at rates between 15 and 50 kg/ha. The cob length at the higher rate of 35 kg/ha, however, differed significantly from cob length obtained at 0, 5, and 10 kg/ha of P_2O_5 .

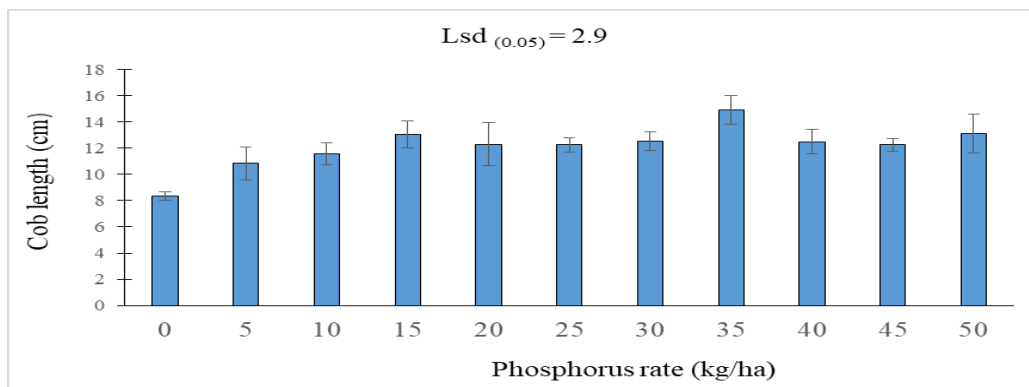


Figure 6: Impact of P_2O_5 calibration rate on cob length of maize cultivated in the guinea savannah zone of Ghana. Error bars represent standard error of means (SEM).

Weight of 100 seeds

The weight of hundred seeds was significantly affected by the application of different rates of phosphorus. There was a general increase in hundred seeds weight with increasing rates of P_2O_5 application (Figure 7). Application of P_2O_5 at rate of 45 kg/ha recorded the highest 100 seeds weight of 23.5 g followed by 50 kg/ha (23.4 g) respectively. The lowest 100 seeds weight of 14.8 g was recorded at P_2O_5 rate of 00 kg/ha (Figure 7).

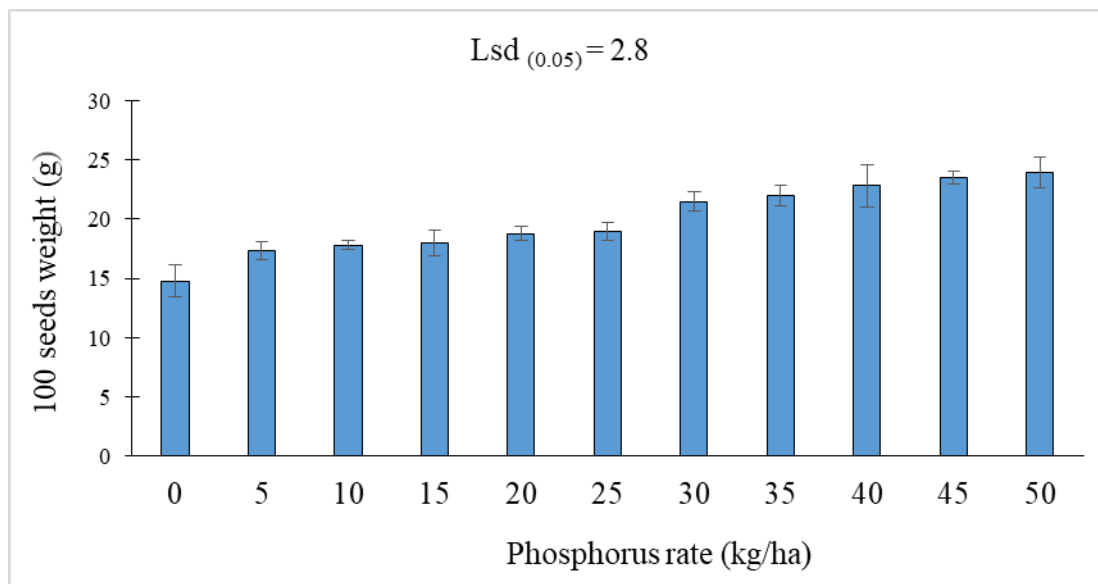


Figure 7: Impact of P_2O_5 calibration rate on 100 seeds weight of maize cultivated in the guinea savannah zone of Ghana. Error bars represent standard error of means (SEM).

Straw weight

Straw weight was highly significantly affected by the rates of P_2O_5 application. There was a general increase in straw weight with increasing rates of P_2O_5 application (Figure 8). Application of P_2O_5 at rate of 50 kg/ha recorded the highest straw weight of 9.3 t/ha followed by 45 kg/ha and 40 kg/ha with 7.9 and 7.3 t/ha respectively, while 00 kg/ha recorded the minimum straw weight (Figure 8).

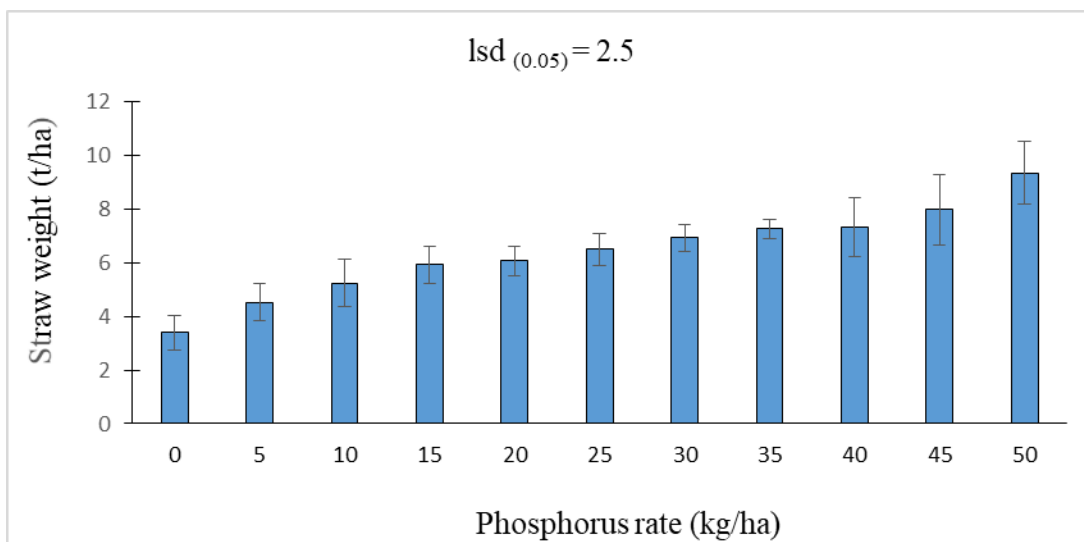


Figure 8: Impact of P₂O₅ calibration rate on straw weight of maize cultivated in the guinea savannah zone of Ghana. Error bars represent standard error of means (SEM)

Grain yield

Grain yield was highly significantly affected ($P = 0.05$) by phosphorus application at different rates. There was a general increase in grain yield with increasing rates of P₂O₅ application (Figure 9). From 35 kg/ha to 50 kg/ha of P₂O₅, grain yield was comparably similar. Generally, the yield obtained at 45 kg/ha was similar to that obtained at 50 kg/ha (3.09 t/ha). Phosphorus application at rate of 00 kg/ha resulted in the lowest yield of 0.75 t/ha (Figure 9).

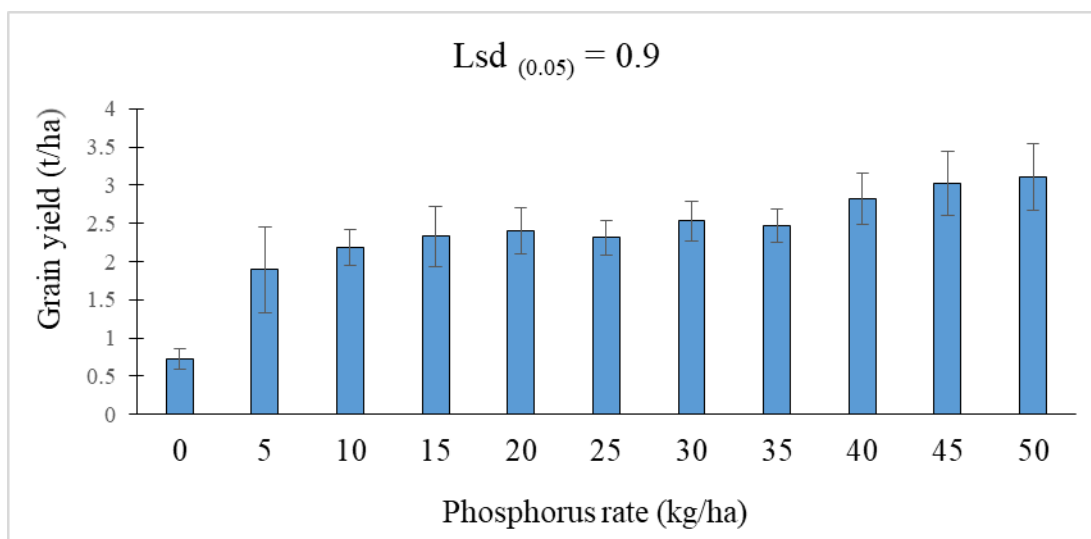


Figure 9: Impact of P₂O₅ calibration rate on grain yield of maize cultivated in the guinea savannah zone of Ghana. Error bars represent standard error of means (SEM).

4.DISCUSSION

The observed increases in plant height with increasing phosphorus fertilization rate (Figure 1) is in agreement with results of the study by [34, 35, 36] who indicated that plant height of maize increased with increase in P_2O_5 application rate. The increase in plant height at higher rate of fertilization could be attributed to higher capacity to supply the P nutrient as needed for growth, resulting in vigorous vegetative growth which reflected in the significant increases in plant height. The maximum height of 131.9 cm that was recorded by 50 kg/ha of P_2O_5 and minimum height of 42.1 cm that was recorded by 00 kg/ha P (Figure 1) is in agreement with the findings of [36] who reported that treatments with higher rate of phosphorus achieved higher plant height as compared with those with no phosphorus application. According to findings from studies by [37, 38], adequate amounts of phosphorus is necessary for early maturity, root and shoot development, rapid growth and also improves the quality of vegetative growth.

The observed significant effect of phosphorus fertilizer rate on leaf area index (Figure 2) is in agreement with findings of [39] who noted that application of N and P fertilizer significantly influenced leaf area index and dry biomass of corn. The significant increase in leaf area index at higher rates of P application could be due to enhanced P availability to the plant. Enhanced availability has positive influence on the vegetative morphology of the maize plant which leads to increases in leaf area index [40, 41]. According to results of studies by [42, 43, 44] leaf area in maize increases with increasing rates of P application than under no fertilization.

The difference observed among the P_2O_5 application rates on cob weight and cob length (Figure 5 and Figure 6) is in agreement with results by [45, 46, 47, 48] who reported that growth parameters and yield of maize viz., plant height, cob length, cob weight, number of grain and grain yield were significantly influenced by phosphorus application and its levels. The increase in cob weight and cob length could be ascribed to enhanced P availability for the production of assimilates that were transformed to these yield components [49]. Similar results have been reported by [50]. Studies by [51, 52] reported that cob length, cob diameter, 100-grain weight and grain yield, significantly ($P = 0.05$) increased with increasing levels of P application.

Data regarding straw weight revealed that different levels of phosphorus had a significant ($P = 0.001$) influence on straw weight and is in agreement with studies by [53] who reported that application of P_2O_5 fertilizer at increasing rates of N and K significantly improved straw yield and grain yield. Highest straw weight of 9.3 t/ha was attained in plots with phosphorus applied at rate of 50 t/ha as compared with the plots without phosphorus application (control plot) where straw weight was lowest of 3.3 t/ha (Figure 8). The significant effect of P fertilization could be attributed to the test crop's root growth and development which was enhanced by the application of phosphorus and which resulted in increased straw weight due to photosynthesis and other biological functions. Similar reasoning are provided by [54, 55, 56]. According to report by [57, 58] dry matter production by crop plants is subject to nutrient availability, uptake and photosynthetic capacity of the vegetative parts of the plants. Generally, there was increase in straw weight with increase in phosphorus levels which was in agreement with findings of [59]. The authors reported that straw yield significantly increase with increasing levels of phosphorus application.

In estimating grain yield, the weight of hundred seeds is considered as one of the best yield components which help in crop grain estimation. As with the results of this study, weight of seeds differed statistically in results of studies by [60] who observed significant effect on 1000 seed weight as affected by different P levels. The highest weight of hundred seeds of 23.49 g was recorded in the plot with phosphorus applied at rate of 50 kg/ha while the minimum weight of hundred seeds of 14.8 g was recorded in treatments without phosphorus application (Figure 7). The observation in this study confirms a report by [61] who recorded highest thousand seed weight in treatments that received maximum rates of application of phosphorus and least thousand seed weight in treatments that received zero application of phosphorus. Phosphorus level, applied at 50 kg/ha was most yield-enhancing. Similar results of impact of phosphorus rate on hundred seed weight has been reported by [62, 63].

As with most parameters, grain yield was statistically affected by the rates of P fertilization as also observed by [60]. The resulting higher yields under higher P fertilization (Figure 9) is in line with observations by [64] who reported that higher grain yield was obtained in treatments with higher application rates of phosphorus fertilizer and least yield in those with zero application rates of phosphorus fertilizer. Application of phosphorus at higher rates resulted in longer cobs, and more weight of cob which reflected in greater grain yield as compared to the control plots [65]. The increase in yield at higher rates of fertilization is also attributed to desirable increases in production and dry mass accumulation per unit increase in P content. Such increases in grain yield with increasing P application has also been reported by [66, 67, 68]. Research by [54, 69] reported that optimum supply of P is associated with increased root growth due to which the plants are able to explore more soil environment and moisture and thereby facilitate nutrient uptake, crop growth and development.

The observation on response of maize to incremental rates of P fertilization is an essential knowledge which paves way for further development of site specific fertilizations for the nutrient-poor Lixisols. This knowledge is the first required step in a multi-level procedure for development of comprehensive crop and soil data for site-specific nutrient formulation. The next step is to develop the tool that can predict soil P fertility status and the required P₂O₅ top-up that is needed for optimum maize production. The developed tool will aid scientists and researchers to predict site-specific fertilization that are based solely on maize nutrient requirement and the results obtained from laboratory analyses of soil P. This will eliminate the current approach of using a one-suite recommended rate of 45 kg/ha of nitrogen for all sites irrespective of the inherent differences and variations in soil nutrients at different locations.

5. CONCLUSION AND RECOMMENDATION

Growth and yield parameters of maize increased with increasing rates of P₂O₅ fertilization in the P depleted Lixisols of northern Ghana. Higher leaf area index (3.84 m²/m²), 100 seed weight (23.49 g), straw weight (9.3 t/ha) and grain yield (3.09 t/ha) were obtained by higher rate of 50 kg/ha P₂O₅, but in most cases growth and yield at this rate was statistically similar with those obtained by P₂O₅ application rate of 45 kg/ha; indicating that a rate of 45 kg/ha is generally suitable for the P-depleted Lixisols of northern Ghana. The study confirms that growth and yield

of maize is affected by phosphorus fertilization and provides crop response data that are required as knowledge base for development of site-specific P₂O₅ fertilization regimes.

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