



Effect Of spacing and phosphorus levels on growth and yields of sorghum in teso north sub-county, western Kenya

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Abstract

Sorghum production in Teso Sub County has great potential but this remains a dream due to various challenges including a lack of clear recommendation of inorganic phosphorus and appropriate plant spacing. An on-farm experiment was conducted on two experimental sites in Busia County, Teso North Sub-County between August and December 2019 to evaluate the effect of Phosphorus levels and spacing on growth and yield of Gadam sorghum. The study design was randomized complete block design, RCBD with twelve treatment combinations of 0, 50, 60 and 75 P₂O₅ kg ha⁻¹ and spacings of 50×30, 60×20 and 60×10 cm replicated three times on each site. Agricultural lime was applied 3 weeks before planting at a rate of 1,875 kg ha⁻¹. TSP was used as source of P while topdressing was done using CAN at 40 kg ha⁻¹ N at 50 cm height. Data was collected on the number of days to first flowering, number of days to physiological maturity, plant height at maturity and yield. The data was summarized in MS Excel and analyzed using SPSS version 20 for ANOVA and LSD at $\alpha = 0.05$. There was a significant difference on number of days to first flowering with the combination 0 P₂O₅ kg ha⁻¹ at 50×30 cm giving a significantly longer period of 66.83 days, while the combination 75 kg ha⁻¹ P₂O₅ with 60×10 cm had the shortest period of 54.09 days ($p < 0.05$). A significant difference was also observed in time to physiological maturity with the combination 0 kg ha⁻¹ P₂O₅ at a spacing of 50×30 cm giving a significantly longer period of 116.33 days while the combination 75 kg ha⁻¹ P₂O₅ at 60×10 cm gave the shortest period of 91.19 days, ($p < 0.05$). Height at maturity was significantly affected with the combination 75 kg ha⁻¹ P₂O₅ at 60×10 cm giving the largest average height of 134 cm while the combination 0 kg ha⁻¹ P₂O₅ with 50×30 cm recorded the smallest average height of 101 cm, ($p < 0.05$). Similarly, there was a significant effect on yield with the combination 75 kg ha⁻¹ P₂O₅ with 60×10 cm giving the highest yield of 2400.10 kg ha⁻¹ while the combination 0 kg ha⁻¹ P₂O₅ at a spacing of 50×30 cm gave the lowest yield of 841.33 kg ha⁻¹, ($p < 0.05$). Our study recommends that farmers in Teso Sub- County adopt the combination of 75 kg ha⁻¹ P₂O₅ and spacing of 60×10 cm. Further research on sources of Phosphorus can be undertaken.

Keywords: Sorghum, phosphorus, spacing, Teso north sub-county

Introduction

Globally, agriculture employs 35% of the population (AGRA, 2015) [3] and in most African countries this goes as high as 70% in rural areas accounting for 25% of gross domestic product (Adenle *et al.*, 2017) [2]. In Kenya, agriculture is likely to remain the engine propelling many economic activities in the coming decades because it contributes 26% directly and 27% indirectly to the GDP (Miano *et al.*, 2010) [19]. In comparison, manufacturing, transportation and communication cumulatively contribute 10% to the GDP (USAID, 2010) [28].

Unfortunately, agriculture is negatively affected by droughts which in Kenya have reached alarming levels between 1971 and 2008, exposing about 12.5 million people to hunger (Rarieya & Fortun, 2010) [24]. That is the reason why drought-tolerant crops should be given proper attention and sorghum is one such crops tolerant to drought and early maturing (KARI, 2006; Miano *et al.*, 2010) [17, 19]. Sorghum is ranked second in sub-Saharan Africa in fighting food insecurity (FAO, 1995) [13] and third in Kenya after Maize and potatoes, where it is grown mostly in Eastern, Nyanza, and Coastal regions (Mwadalu & Mwangi, 2013) [20]. Sorghum grain contains 72.41% carbohydrate, 9.35% protein and 3.35% fat (Adebiyi *et al.*, 2005) [1] and a big portion of the grains produced is channeled into human food chains such as making beer, bread, cakes and biscuits. Compared to other cereals, sorghum has other health benefits as it is gluten-free (Ciacci *et al.*, 2007) [12].

Compared to maize, sorghum offers advantages that include low cost of production (Staggenborg *et al.*, 2008) [27] and being able to survive in harsh environmental conditions where maize and other cereals fail (House, 1995) [16]. Hence, sorghum is a crucial crop to reduce effects of food uncertainty brought about by harsh conditions (Salasya *et al.*, 1996; Staggenborg *et al.*, 2008) [26, 27]. Gadam variety was particularly selected for this study because of its superiority to other sorghum varieties in terms of yields, tolerance to drought and shorter time to physiological maturity (KARI, 2006) [17].

Despite all these advantages, sorghum production is faced by various challenges including poor soil fertility, which can be reversed or improved by supplying the soil with lost plant nutrients by using inorganic fertilizers (Barasa *et al.*, 2013) [5]. Usually, the main limiting plant nutrients for crop production in low fertility soils are phosphorus, nitrogen and potassium. Phosphorus is an essential constituent of compounds whose functions determine physiological maturity (Haruna & Aliyu, 2011) [15]. Phosphorus causes extensive root development system, leading to absorption of more water and plant nutrients and hence increased yields (Wekha *et al.* (2016) [30]. Kenyan soils like most tropical soils are characterized by low phosphorus availability (Belay & Gebreslasie, 2016) [7]. They are expected to have a positive yield response to phosphorus application (Rurinda *et al.*, 2014) [25].

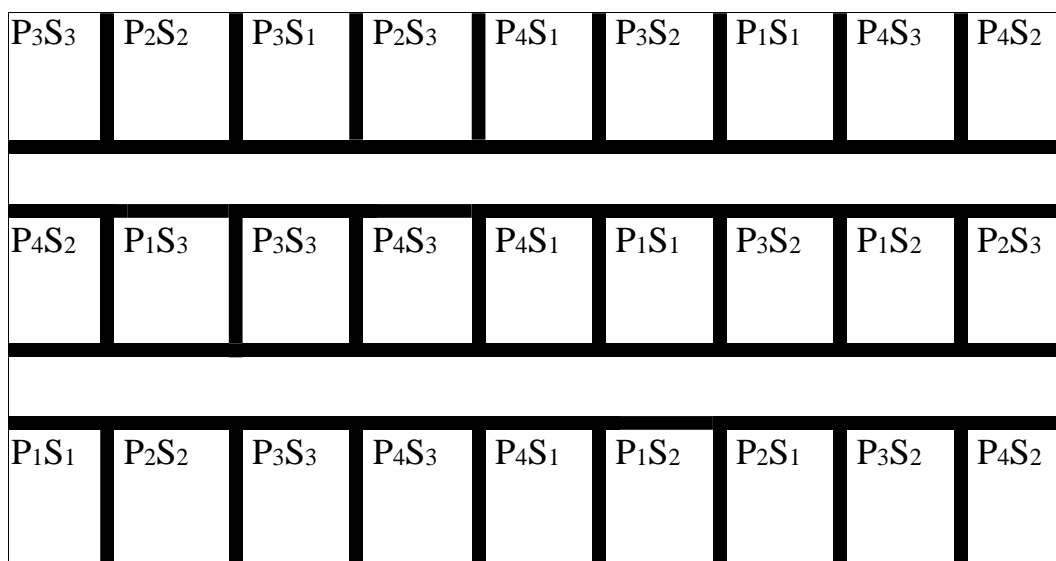
Despite efforts of introducing higher-yielding and more tolerant sorghum varieties such as Gadam, there is still a decline in grain yield per unit area in Busia County. This has been associated mainly to poor soil management especially unconfirmed phosphorus levels and plant population per unit area. Bosire and Karanja (2018) ^[9] noted that Gadam has less documented information on its response to different levels of phosphorus application under rain fed conditions. On the other hand, a study conducted by NAAIAP & KARI (2014) ^[21] in Teso North on soil sustainability evaluation for maize production in Kenya, recommended the use of triple super phosphate as a non-acidifying fertilizer and a source of P but failed to give its appropriate rate. This study, therefore included TSP as a source of phosphorus in order to ascertain this observation. The main objective of the study was to determine the effect of spacing and levels of inorganic phosphorus on the growth and yields of Gadam sorghum in Teso North sub-county in Busia, Kenya. The study had the following three specific objectives: (i) to determine the effect of P level on sorghum (Gadam variety) growth and grain yield in Teso North sub-County of Busia County, (ii) to evaluate the influence of plant spacing on sorghum (Gadam variety) in Teso North Sub-County, and (iii) to assess the interaction effect between phosphorus level and spacing on sorghum (Gadam variety) in Teso North sub-county.

Materials and methods

Description of study

The study was carried out in Busia county Kenya Teso North sub-county in a smallholder farmer’s fields on a longitude of 34°07’E, on latitude of 0°29’ and altitude of 1,523 m above sea level. The area receives an average annual rainfall between 1500 mm and 1850 mm with an annual mean temperature of 30°C. The rainfall is bimodal, with long rains occurring from March to June and short rains from September to December. The soils are generally

Plot layout



Key
 P1-0P₂O₅ kg/Ha S1-(50×30) cm
 P2-50P₂O₅ kg/Ha S2- (60×20) cm
 P3-60 P₂O₅ kg/Ha S3- (60×10) cm
 P4-75 P₂O₅ kg/Ha

Fig 1: Above illustrate the field layout of blocks and plots of the experiment

acidic, table 1, and hence application of non-acidifying fertilizers is recommended to maintain soil pH and to prevent further pH decrease. Application of agricultural lime at 1,875 kg/ha in the study site was recommended. Furthermore, it was also noted that nitrogen, phosphorus, and potassium were below required amount.

Soil status of study site A and B

Table 1: Above shows soil status as in the experimental field

Soil parameter	Site A	Site B
pH	5.88	5.61
Organic carbon (%)	0.75	0.61
Total nitrogen (PPM)	0.19	0.16
Available P (PPM)	30.945	20.773
Potassium (PPM)	13.91	12.71
Calcium (PPM)	186.71	160.85
Textural class	Sandy loam	Sandy loam

Source: Soil test done by KARLO (2019)

Experimental design

The study design was a randomized complete block design (RCBD), which consists of treatment combinations assigned randomly to experimental units within a block. This design serves two purposes; it allows treatment combinations to be randomly allocated to experimental units but it also enables them to be replicated for precision purpose. The design also allows manipulation of treatment combinations of interest, while holding other factors as constant as possible. The experiment consisted of nine treatment combinations randomized in nine experimental units, as a block, each replicated thrice making a total of three blocks as shown in the layout given in figure 1. Each block measured 29.5 m by 2.4 m. The completed experimental site had an area of approximately 270 m². Each experimental unit had four rows. Outer two rows acted as the border rows, and were intended to eliminate the border effect.

Research center Karlo-Katamani from Machakos acted as a source of Gadam while Triple superphosphate, TSP (0-46-0), topdressing fertilizer (CAN), pesticides and fungicides were sourced from an agrochemical store called Bungoma Chemist located in Bungoma town. The four TSP fertilizer levels (0, 50, 60 and 75 P₂O₅ kg/ha) were used as main plot factors and the three spacings (50×30, 60×20 and 60×10cm) as sub-plots factors. The treatment combinations obtained are as given in Table 2.

Treatment combinations

Table 2: Above illustrate randomized combination of different levels of treatments

Fertilizer levels				
Spacing	P1	P2	P3	P4
S1	P1S1	P2S1	P3S1	P4S1
S2	P1S2	P2S2	P3S2	P4S2
S3	P1S3	P2S3	P3S3	P4S3

Key

P₁-0P₂O₅ kg/Ha P₂-50P₂O₅ kg/Ha P₃-60 P₂O₅ kg/Ha P₄-75 P₂O₅ kg/Ha
 S₁-(50×30) cm S₂- (60×20) cm S₃- (60×10) cm

Data collection procedures

In this study data collected included a record of days to physiological maturity, plant height and grain yield. To measure the physiological maturity, six (6) randomly selected plants were identified and tagged in each plot. Days to physiological maturity in each plot was recorded as the difference of the calendar date when sorghum was planted to calendar date when 75% of the ears of the selected plants in each plot were brown in colour. To measure the plant height, the pointing tip of the flap leaf was taken as the highest point while ground level as the lowest level and their difference was termed as plant height. This was done by averaging the height of six randomly selected plants. To measure the grain yield, the two inner rows plants were harvested when 95% of the heads were physiologically mature after turning colour from green to yellowish-brown. The heads were sun-dried to a constant weight before threshing of grains for weight measurement. The moisture content (MC) of the grains was determined using a moisture meter up to 13% moisture content before weighing the

Number of days to physiological maturity

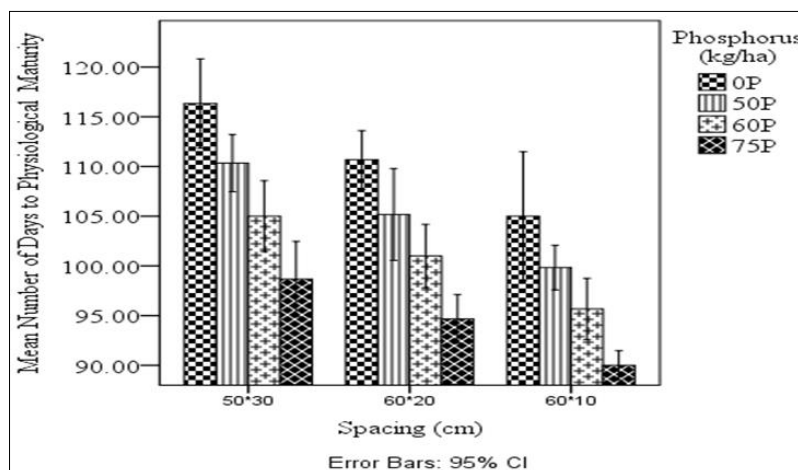


Fig 2: Shows difference in days to maturity as determined by phosphorus and spacing is sorghum

grains to determine the yield in kilograms per hectare for each plot.

Data was computed using Microsoft Excel and then analysis of variance (ANOVA) was done by Statistical Social Sciences Package (SPSS) version 20. The variance analysis was performed at a meaning level of 5 per cent. Where there were major variations between treatments, post-hoc trials were performed using an LSD (p<0.05) to determine the recorded variations.

Results and discussion

In this study we sought to show that phosphorus and spacing could affect sorghum production in Teso North sub- County. We looked for factors such as maturity, plant height and grain yield of Gadam sorghum. Analysis of variance (Table 3) revealed the three variables were significant and were subjected to LSD and summarized in tables 4 and 5 respectively.

Time to physiological maturity for the sorghum crop

Figure 2 showed that both phosphorus and spacing had an effect on days to physiological maturity. Phosphorus higher rates give fewer days than lower rates while shorter spacing give more days than longer spacing. Analysis of variance (Table 3), revealed both spacing and P level were significant (p<0.05) and they were further analyzed by LSD, and summarized in table 4 and 5 respectively.

Table 4 shows that the spacings differed from each other with the narrower spacing recording fewer mean days to physiological maturity than wider spacing. This result is in agreement with what Larson *et al.* (2011) [18] reported that increasing plant population resulted in decreased number of days that it took for the grain sorghum to reach physiological maturity. Baumhardt *et al.* (2005) [6] concluded that more tillers might have further extended filling period resulting to delayed maturity.

Table 5 showed a decrease in duration to attain physiological maturity with an increase in P level. Bosire and Karanja (2018) [9] reported similar results that the application of P led significant reduction in days to physiological maturity of Gadam and Seredo in Machakos. This is due to shortened vegetative phase of growth and increase in efficient utilization of plant nutrients.

Sorghum plant height at physiological maturity

It was observed in figure 3 that while phosphorus rates seem to have an effect with higher rates giving superior height, spacing seemed to have the opposing effect with the

narrower spacing giving taller plants. ANOVA (Table 3) revealed that both variables were significant ($p < 0.05$) and were further subjected to LSD.

Plant height (cm)

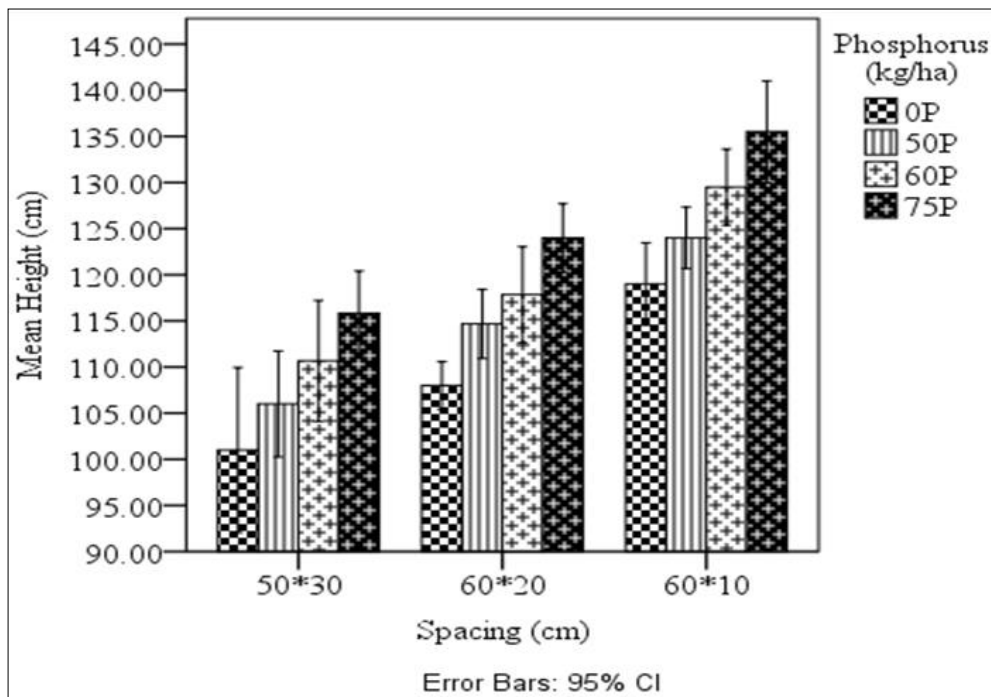


Fig 3: Above portrays maximum height attained by sorghum under different spacing and phosphorus levels

Table 4 shows that mean heights of plants increased with increase in plant population. These results are consistent with the observation by Goldsworthy and Tayler (1970) [14] who confirmed narrow-spaced plants were significantly taller than wide-spaced plants. Competition for light might be responsible for an increase in plant height due to closer inter-plant spacing Table 5 showed plants increased in height with increase in phosphorus application. Observations of the same trend were earlier observed by Ashiono *et al.* (2005a) [4] and Pratyusha (2014) [22] who reported increase in height with increase in phosphorus.

This could have been attributed by the fact that phosphorus as is essential for vigorous growth and development of reproductive parts.

Grain yield

Both increase in the rate of phosphorus applied and alternative spacing had a positive effect on the grain yield of sorghum in the experimental sites (Figure 4). It showed lower rates phosphorus give lower yield and narrower spacing give higher yields. ANOVA (Table 3) revealed that both variables were significant ($p < 0.05$) and were further subjected to LSD.

Combined ANOVA outputs for all the variables

Table 3: Shows statistical significance of each variable at 0.05 level of significance

Source	Dependent variable	Type III sum of squares	df	Mean square	F	Sig.
Block	Maturity	46.861	2	23.431	2.159	.124
	Height	25.583	2	12.792	.574	.566
	Yield	232236.778	2	116118.389	2.946	.060
Phosphorus	Maturity	2556.611	3	852.204	78.520	.000
	Height	2418.444	3	806.148	36.175	.000
	Yield	2201314.153	3	733771.384	18.618	.000
Spacing	Maturity	1191.194	2	595.597	54.877	.000
	Height	4201.750	2	2100.875	94.274	.000
	Yield	13351806.861	2	6675903.431	169.387	.000
Error	Maturity	694.611	64	10.853		
	Height	1426.222	64	22.285		
	Yield	2522373.194	64	39412.081		
Total	Maturity	4489.278	71			
	Height	8072.000	71			
	Yield	18307730.986	71			

Yield in kg/ha

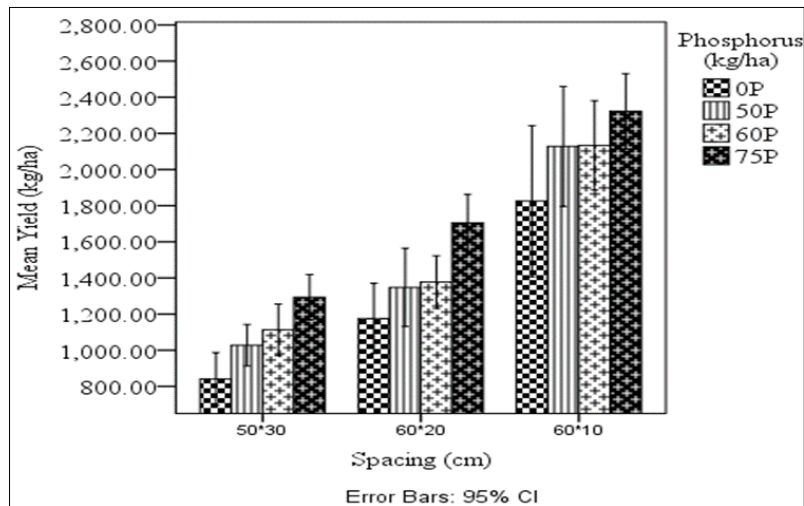


Fig 4: Above illustrate grain yield obtained by sorghum under different levels of phosphorus and spacing

Table 4 showed that yield increased with increase in plant density. Cavalaris *et al.* (2017) [11] reported similar observation in sorghum and attributed this to early closure of canopy in narrow spacing leading to suppression of weeds.

Combined table on effect of spacing on all variables

Table 4: Above reveals significance between different levels of spacing in each variable

		50x30	60x20	60x10
Time to maturity	50x30		4.7083*	9.9583*
	60x20			5.2500*
Height at maturity	50x30		-7.7500*	-18.6250*
	60x20			-10.8750*
Grain yield	50x30		-332.6250*	-1033.2083*
	60x20			-700.5833*

*. The mean difference is significant at the 0.05 level.

Table 5 showed that sorghum grain yield responded positively to P₂O₅ application. Similarly, Bhutada *et al.* (2019) [8] confirmed decline in Sorghum production with decrease in fertilizer application. Wekha *et al.* (2016) [30] gave similar report in finger millet and suggested this could have been attributed by the fact that P boosted root development which enhanced water and other plant

nutrients uptake compared to control regimes (P 0 kg/ha). High P availability has been attributed firstly to P from TSP itself, and secondly to the fact that TSP helps to raise soil pH, decreasing acidity (Barasa *et al.*, 2013) [5], thus releasing more P indirectly from enhanced organic matter decomposition which is pH-dependent (Vanlauwe *et al.*, 2015) [29].

Combined table on effect of p levels on all variables

Table 5: Above shows significant difference among the four p levels in each variable

	0 P	50 P	60 P	75 P
Time to maturity	0 P	5.5556*	10.1111*	16.2222*
	50 P		4.5556*	10.6667*
	60 P			6.1111*
Height at maturity	0 P	-5.5556*	-10.0000*	-15.7778*
	50 P		-4.4444*	-10.2222*
	60 P			-5.7778*
Grain yield	0 P	-220.2778*	-260.7222*	-492.8333*
	50 P		-40.4444	-272.5556*
	60 P			-232.1111*

*. The mean difference is significant at the 0.05 level

Conclusions

In this study we have shown that phosphorus was significant in the following variables: maturation period, plant height and yield. Post hoc results indicated each level of phosphorus differed from each other significantly in all the variables under observation.

Analysis of variance proved spacing to be a significant variable and post hoc, revealed that each plant population differed from each other significantly in all the variables under investigation. Anova analysis proved, there was no statistical significance in interaction between phosphorus and spacing in all the

variables. In terms of yield interaction 75 P₂O₅ kg/ha:60×10 cm gave best result than 75 P₂O₅ kg/ha:60×20 cm and 75 P₂O₅ kg/ha:50×30 cm. Interaction of level 75 P₂O₅ kg/ha gave better results than interactions in levels 0,50 and 60 P₂O₅ kg/ha.

Recommendations

Farmers in Busia County, particularly in Teso North Sub County involved in sorghum farming, particularly Gadam variety should apply to their farms' inorganic phosphorus at rate of at least 75 P₂O₅ kg/ha as it has proven to give superior yield and its components. Farmers should use the spacing of 60×10 cm as it has proven superior in terms of yield and its components compared to 50×30 cm and 60×20 cm spacings. The application of TSP as source of phosphorous proved positive in this area where the soil pH is low.

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