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Flowering and maturation periods of Finger Millet as influenced by phosphorus and variety in different agro-ecologies in Kenya

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ABSTRACT

Phosphorus is important for finger millet production in many tropical African soils with low phosphorus fertility. Knowledge of redirection of this limited resource for reproduction is fundamental in realization of potential yields. The effect of four phosphorus levels (0, 12.5, 25.0 and 37.5 kg ha^{-1} P_2O_5) and three varieties (U-15, P-224 and a local check) on the days to flowering and maturity of finger millet were evaluated in three agro-ecologies in Kenya during the raining seasons of 2014-2015. Phosphorus application significantly ($P<0.05$) increased early flowering and physiological maturity in Kakamega and Busia. The varieties elicited significantly different days to 50% flowering and maturation periods in all the study sites. The days to flowering and maturity were found to be lowly but negatively correlated with the grain yield of finger millet in all the sites.

Introduction

Finger millet (*Eleusine coracana*) is one of the important food crops in Kenya because it plays a significant role in areas where production of other cereals are reduced by marginal environments and erratic rainfall distribution. In Kenya, where agriculture is the foundation of the country's economy, the importance of finger millet in relation to climate variability, especially unpredictable rainfall and recurrent drought cannot be overstated. The crop has wide adaptability, probably due to its C4 photosynthetic nature. In Africa, smallholder farmers grow finger millet with area allocated to the crop varying from country to country. In eastern Africa, finger millet is produced in Uganda, Kenya, Tanzania, Rwanda, Burundi and Ethiopia (Obilana *et al*., 2002; Oduori 2005). Kenya and Uganda are among the leading producers of finger millet in Africa and the rest of the world (Oduori, 2008).

Tropical soils are inherently low in nutrients particularly nitrogen and phosphorus (Haruna *et al*., 2013). Phosphorus is among the most needed elements for crop production in many tropical soils. It is critical to finger millet because it stimulates growth, initiates flower formation, fertilization and grain formation as well as influence positively the efficiency of the uptake of other nutrients (Haruna and Aliyu, 2011). It is required in large quantities in young cells such as shoot and root tips where metabolism is high and cell division is rapid. In maize it is reported that it aids in flower initiation, seed and fruit development (Ndakidemi and Dakora, 2007). However, many tropical soils are P-deficient (Osodeke, 2005). The deficiency can be so acute in some soils of the Sub-Saharan Africa that plant growth ceases as soon as the P stored in the seed is exhausted (Mokwunye and Bationo, 2002).

Soil P-deficiencies primarily result from either inherent low levels of soil P or depletion of P through cultivation.

Many researchers have undertaken to evaluate effects of phosphorus levels on several cereal crops yields, but until now information on finger millet maturation and flowering periods and how these traits impact on the eventual grain yield has been scarce. During reproductive phase, most plants redirects resources from vegetative growth to formation of reproductive parts and by the time pollination begins, vegetative growth of the plant is complete and the metabolic activities of the plant tissues are at peak. Knowledge of the stages of reproductive development in finger millet can help farmers to manage the plant during these phases to minimize the effects of various stresses and maximize yield. Lack of this relevant literature is one of the main constraint to the productivity of the crop in the different agro-ecological zones in Kenya where it is grown and necessitated the laying out of the current study in Makueni, Kakamega and Busia Counties.

Materials and methods

The experiments were carried out in three agro-ecological zones: Makueni, found in the Lower Midland zone 5; Kakamega, found in the Upper Midland zone 3; and Busia, found in the Lower Midland zone 2 (Jaetzold *et al*., 2007). The On-station studies were at ICRISAT-Kiboko field station (37°38'60 E, latitudes 2°16'0 S and 975m a.s.l), ICRISAT-Alupe crops field station (latitude 0°30" N, longitude 34°07'50" E and 1157m a.s.l) and KALRO-Kakamega crops field station (latitude 0°16'60 N, longitude 34°45'0 E and 1523m a.s.l) and conducted for two seasons of 2014-2015.

Soil samples were collected before planting from the plough layer of the experimental sites and analytical results showed the soils were critically low in phosphorus (5-6 ppm) and moderately acidic (5.2-5.6) in Kakamega and Busia while the soil phosphorus in Makueni was above the critical value

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(13 ppm) and alkaline (9.32). The treatments consisted of three varieties (U-15, P-224 and a Local check) and four phosphorus doses (0, 12.5, 25.0 and 37.5 kg ha^{-1} P_2O_5). The layout of the experiment was randomized complete block design with three replications. The crop was planted by hand drilling and the phosphorus applied as whole at planting supplied as TSP. Standard cultural practices were followed as recommended for the crop during the growing period.

Data on the days to 50% flowering was calculated from the difference between the calendar date recorded when the ears had emerged from 50% of main tillers and that of sowing. The same was calculated on the days to physiological maturity when 75% of the ears were brown in color. The data obtained were subjected to analysis of variance to test significance due to treatments using SAS Version 9.1 and where significant differences were observed mean separation was performed using Tukey's studentized range (HSD) test. Spearman's rank correlation analysis was used to estimate the relationship between days to 50% flowering and days to maturity with the grain yield.

Results and Discussion

Application of phosphorus significantly ($P<0.05$) reduced the days to 50% flowering of finger millet in Kakamega and Busia for both seasons (Table 2) while no significant differences were observed between the phosphorus treatments in Makueni for both seasons (Fig. 1). The control had the longest period to flowering of between 5 to 6 days more compared to the 25 and 37.5 kg ha^{-1} P_2O_5 treatments respectively in Busia and 5 days more compared to the highest rates of phosphorus in Kakamega.

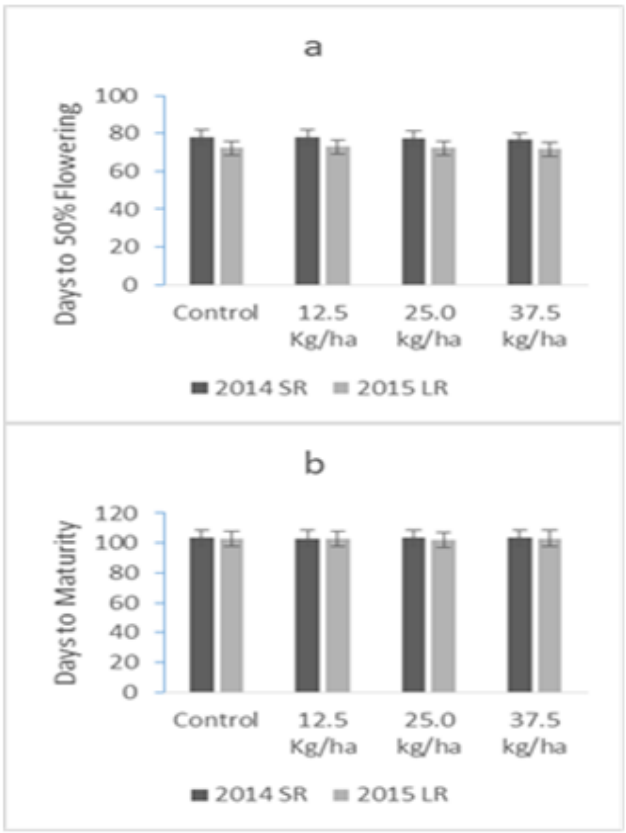

Fig 1. The influence of phosphorus doses on the days to 50% flowering (a) and days to maturity (b) in Makueni.

The main reason for the positive response was the low phosphorus level on the study soil. Rao and Reddy (1997) also found similar results in the response of hybrid pigeon pea to phosphorus in P-deficient soils. It has been reported that P nutrition is of utmost importance to crops before than after anthesis (Aulakh *et al*., 2003) where it influenced the production of cytokinins in the root apices and auxins in the shoot apices which increased lateral growth and development leading to early flowering. It also raised the efficiency of plants in photosynthesis and ultimately increased the flowering potential. Panhawar *et al*. (2011) also reported that the days to flowering of aerobic rice was significantly reduced due to application of phosphorus up to 50 kg ha^{-1} P_2O_5.

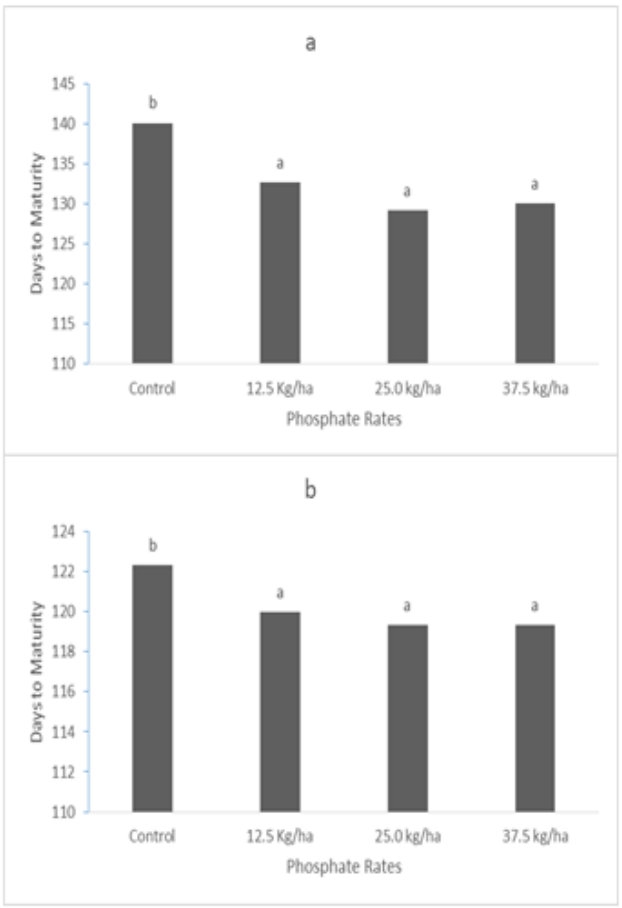

Fig 2. The influence of phosphorus doses on the days to maturity in short rain (a) and long rain (b) seasons in Kakamega.

The seasons showed differences where flowering was delayed during the short rain season in comparison to the long rain season (Fig. 2). Makueni showed the least days to flowering followed by Busia then Kakamega albeit the treatments. This is mainly due to the difference in climatic conditions where the semi-arid conditions hastened flowering and maturity of the crop in Makueni while the sub-humid conditions in Busia had an intermediate impact while the humid conditions in Kakamega delayed flowering and maturation of the crop. Similar results were reported in corn by Strachan (2001) where he noted that temperature and moisture are significant drivers of the crops flowering and maturation where moisture stress and higher temperatures accelerated flowering and maturation.

The varieties showed significant differences at $P<0.05$ in all the sites for both seasons on the days to 50% flowering (Table 1). The local variety, Ekalakala flowered the earliest in Makueni for both seasons while P-224 flowered 8 and 9 days later during the short and long rain seasons respectively. In Kakamega and Busia, variety U-15 flowered the earliest for both seasons while the local variety, Ikhulule showed the longest period to 50% flowering in both sites for both seasons.

Table 1. Varietal differences on the days to 50% flowering in the study sites

Variety	Makueni		Kakamega		Busia	
	2014 SR	2015 LR	2015 SR	2015 LR	2015 SR	2015 LR
U-15	76b	61b	92c	75c	67c	66c
P-224	82a	68a	96b	82b	75b	73b
Local Check	74c	59c	98a	87a	78a	78a
P-Value	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
LSD (0.05)	1.126	1.462	2.161	2.594	1.979	1.2
CV%	1.7	2.8	2.7	3.8	3.2	1.9

Means having a common letter within a column are not significantly different at P<0.05, SR-Short rain season, LR-Long rain season

During the long rain seasons in Kakamega and Busia the local variety flowered 12 days later compared to improved variety U-15 and 6 days in Kakamega and 11 days in Busia during the short rain seasons.

There was a significant and positive response of finger millet varieties on the days to maturity due to application of phosphorus in Kakamega and Busia for both seasons (Fig. 3). However, phosphorus application did not significantly impact on the days to maturity of finger millet in Makueni for both seasons (Fig. 1) probably due to optimal availability of P in the study soils. In Kakamega during the short rain season, the 25 kg ha^{-1} P_2O_5 rate led to the earliest maturation of finger millet compared to the control with a difference of 11 days and by 4 days in the long rain season (Fig. 2). In Busia the control had the longest period to mature while the applied treatments of 25 and 37.5 kg ha^{-1} P_2O_5 matured the earliest with 4 days compared to the control and 2 days earlier than the 12.5 kg ha^{-1} P_2O_5 treatment (Fig. 3).

Phosphorus deficit is the most important restrictive factor in plant growth and development (Alinajati and Mirshekari, 2011). Phosphorus is a major component of ATP, the molecule that provides energy to plants for photosynthesis, protein synthesis, nutrient translocation, nutrient uptake, respiration and transfer of genetic material DNA, RNA (Wilson *et al*., 2005) which are essential in the formation of seeds and ultimately led to early maturation under optimal supply of the nutrient. Earlier reports corroborate with this findings that phosphorus causes early ripening in plants, decreases grain moisture and improves crop quality (Malakooti, 2000; Gayle *et al*., 2001). Carbohydrates and protein are deposited in the kernel as it grows and ripens and these compounds formation and synthesis are majorly dependent on phosphorus which hastened their deposition. Strachan (2001) found that the final yield and quality is determined during this phase and is influenced not only by current conditions and management decisions but also by everything that has preceded it like appropriate application of limited nutrients.

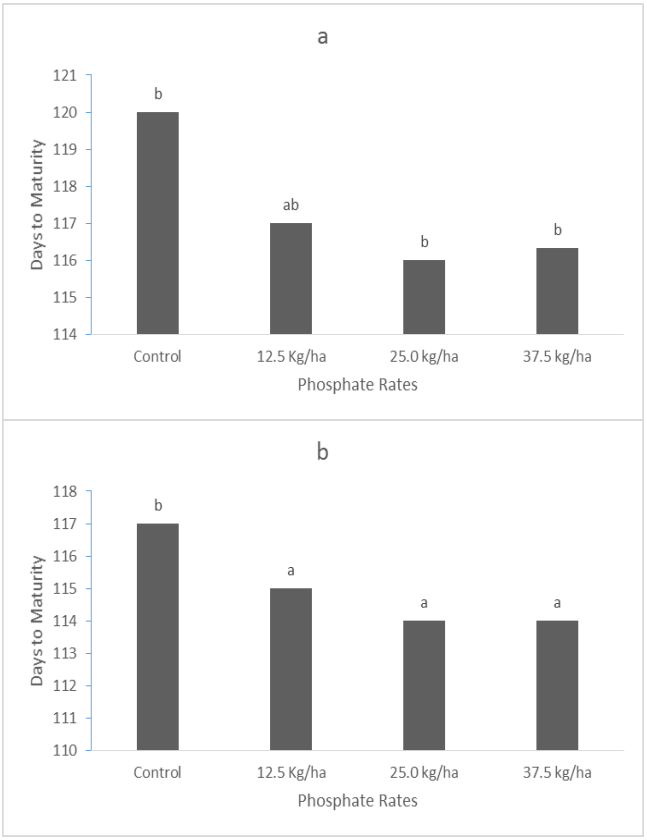

Fig 3. The influence of phosphorus doses on the days to maturity in short rain (a) and long rain (b) seasons in Busia.

The varieties varied significantly for both seasons in all the sites for both seasons on the days to maturity (Table 3). The local variety in Makueni, Ekalakala matured the earliest for both seasons while P-224 matured the latest with a difference of 7 days. In Kakamega and Busia, the improved variety U-15 matured the earliest while the local variety Ikhulule was the latest for both seasons. The varieties showed a difference of between 11 to 14 days in Kakamega and 12 days in Busia.

Table 2. The effect of phosphorus fertilizer on the days to 50% flowering in Kakamega and Busia.

Phosphorus Rate	Kakamega		Busia	
	2015 SR	2015 LR	2015 SR	2015 LR
Control	98a	85a	77a	76a
12.5	96b	82b	72b	72b
25.0	93c	80b	72b	70c
37.5	93c	82b	72b	71bc
P-Value	**<.001**	**0.044**	**<.001**	**<.001**
LSD (0.05)	2.495	2.995	2.285	1.4
CV%	2.7	3.8	3.2	1.9

Means having a common letter within a column are not significantly different at P<0.05, SR-Short rain season, LR-Long rain season

Table 3. The effect of varieties on the days to maturity in the study sites.

Variety	Makueni		Kakamega		Busia	
	2014 SR	2015 LR	2015 SR	2015 LR	2015 SR	2015 LR
U-15	103b	103b	124b	115c	110b	108b
P-224	106a	106a	137a	120b	121a	119a
Local Check	101c	100c	138a	125a	122a	120a
P-Value	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**	**<.001**
LSD (0.05)	0.833	1.727	6.99	1.586	2.673	0.962
CV%	1	2	6.2	1.6	2.7	2

Means having a common letter within a column are not significantly different at P<0.05, SR-Short rain season, LR-Long rain season

The local variety might have had a poor remobilization rate of nutrients to reproduction activities of the crop at the expense of lateral growth. At these crucial stages of the crops reproduction, there was competition from other plant parts for the limited supply of assimilates from photosynthesis and if outcompeted, it led to a delayed flowering and maturation period (Strachan, 2001). This can later impact negatively on the grain yield due to formation of low grain number per spikelet. This difference on maturity between varieties appears to be due to differential sensitivity of the genetic traits to the different environments. This variation also might be related to the differential reaction of the varieties to the different environments that may have affected the rate of grain fill.

The days to 50% flowering and physiological maturity did not directly and significantly influence the grain yield of finger millet in all the study sites except in Makueni during the long rain season for the days to maturity (r=-0.345) as shown on Table 4. However, a negative but low correlation was observed where the reduction of the periods to flowering and maturity increased the potential for higher yields. This is in agreement with the findings of Khairwal *et al* (1999) who reported that there were generally negative and insignificant genotypic and phenotypic relationship between grain yield per plant with days to 50% flowering and days to maturity in pearl millet. Similarly, Bello *et al*. (2007) reported higher genotypic variance than phenotypic and environmental variance in sorghum for days to flowering, days to maturity and their impact on grain yield per hectare, which is supported by the present study.

Conclusion

The results showed that application of phosphorus can considerably reduce the periods to flowering and maturity in soils with low phosphorus. Reduced flowering and maturation periods are indicators of the crops survival in low or unpredictable rainfall availability and be able to produce considerable yields where other commonly grown cereal crops cannot survive to yielding stage. The early maturing variety (U-15 and Ekalakala) are highly recommended for adoption in the regions with sparsely distributed rainfall and low moisture areas.

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Table 4. Spearman's rank correlation coefficient for grain yield with the days to 50% flowering and days to maturity in the study sites.

	Correlation Coefficients	
	Days to 50% Flowering	Days to Maturity
Busia Long Rain Season	-0.064ns	-0.2801ns
Busia Short Rain Season	-0.1606ns	-0.0688ns
Kakamega Long Rain Season	-0.114ns	-0.1078ns
Kakamega Short Rain Season	-0.2915ns	-0.1385ns
Makueni Long Rain Season	-0.0621ns	-0.3450*
Makueni Short Rain Season	-0.1409ns	-0.0918ns

*=Significant at P<0.05, ns=Non significant

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