Effect of Spatial Arrangement and Variety on Performance of Common Bean (*Phaseolus Vulgaris L*) in Western Kenya

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Abstract

Dry common bean is one of the most important food security pulse crops produced in Kenya. Its production is limited by a number of agronomic practices including spatial crop arrangement. A study was conducted from March to June 2016 at Mabanga ATC in Bungoma and University of Eldoret in Uasin Gishu Counties to determine the suitable field spatial arrangement for optimum bean yield. Three bean varieties (Canadian wonder, KAT B1 and Rose coco) were studied under the following spatial arrangement: 60 cm x 15 cm, 45 cm × 20 cm, 36 cm × 25 cm and 30 cm × 30 cm. Randomized complete block design replicated three times was used to conduct the experiment on both sites. Data was collected on plant height, number of flowers per plant, pods per plant, seeds per pod, 1000 seed weight and seed weight/hectare. Data was subjected to ANOVA in GENSTAT software and means separated by Tukey's HSD at $p \leq 0.05$. The results indicated significant differences due to spatial arrangement on plant height in Mabanga site only. There were significant differences on number of pods, number of seeds per pod, 1000 seed weight and seed weight/hectare (kg/ha) in both sites. It is concluded that the spatial arrangement of 30 cm × 30 cm and 36 cm × 25 cm gave better yield in Mabanga while a spatial arrangement of 36 cm × 25 cm and 45 cm × 20 cm gave better yield in terms of 1000 seed weight at University of Eldoret. In this study spatial arrangement of 30 cm × 30 cm and 36 cm × 25 cm is therefore recommended for farmers within Bungoma County (Mabanga) while 36 cm × 25 cm and 45 cm × 20 cm recommended for farmers within Uasin Gishu County (University of Eldoret).

Key words: Common bean, spatial arrangement and yield

INTRODUCTION

Common bean is a principal food crop (Broughton *et al.,* 2003; Vance, 2013) and supplements other staple foods in production areas (Vance, 2013). Besides, it has a short maturity period of only three months and, hence, it fills gaps for household food needs during the hunger period and serves as a substitute for income provision (Amare, 2011; Ayele, 2009).

According to GOK (2014), there exist 75% yield gap between the potential and the actual bean yield production. This has been attributed to a number of factors such as low yielding varieties, poor soil fertility, pests, diseases, high cost of fertilizer, poor market prices, poor cropping system and poor plant arrangement management. Poor spatial arrangement may also contribute to low production of beans especially in Western Kenya and its effect is not well understood. However, there is small-scale production of dry beans in every region of Kenya, where dry beans have been grown as an intercrop with maize on a small scale for over 100 years Ismail (2002). The study focus was on the need to determine suitable field spatial arrangement to improve bean yield production among small holder farmers in Western Kenya. And this can be achieved by determining the best spatial arrangement in the field that supposedly give high crop yield. Hence need to determine effect of spatial arrangement on the growth and development of bean.

There are different growth habits for common bean cultivars but a common spacing recommendation has been given without paying attention to the specific bean growth patterns. This may give room to either overcrowd or under population leading to low bean yield. There are two types of common bean: determinate, in which the main axis is terminated in an inflorescence and produces no vegetative nodes after flowering and the other is indeterminate which produce vegetative node after flowering. The determinate type is short, self supporting or bushy and of short growth duration while indeterminate genotypes show a wide range of node number on the main stem, climbing tendency and growth (Danial, 2013).

Spatial arrangement is defined as the pattern of plants over the ground, which determines the shape of the area available to the individual plant (Reddy, 2000) and is also the ratio of the inter row spacing to the intra row spacing (Willey and Osiru, 2012). Spatial arrangement of plants determines resource utilization such as light, nutrients and water; the extent of vegetative growth and development of crops particularly that of plant height and also yield components (Jettner *et al.,* 2012; Matthews *et al*., 2013). It also affects canopy development and distribution of pods (Matthews *et al*., 2012). Solomon (2010) worked on haricot bean and reported that thousand seed weight decreased with reduction in plant inter row space. Ayaz *et al.* (2001) and Abdel (2008) reported that number of seeds per pod increased with increased intra row space of faba bean. Moreover, Oad *et al*. (2002) while working on safflower reported that higher number of seeds per pod was associated with wider inter and intra-row spacing. Ball *et al*. (2000) reported that decreasing intra row space reduced yield of individual plants but increased yield per unit area of common bean. Taj *et al*. (2002) found that competition for light in narrow spacing in mung bean resulted in taller plants while at wider spacing light distribution was normal. Similarly, Shamsi and Kobraee (2009) worked on spatial arrangement experiment on soybean, observed that decreasing intra row spacing led to significant increases in plant height. This was primarily because of lower amount of light intercepted by plants planted in a close intra row space resulting into increased inter node length. In contrast to the result of this study, Turk *et al*., (2003) worked on lentil and reported negative correlation of plant height with spatial arrangement of plants in relation to inter row space. Similarly, Hodgson and Blackman (2005) and Abdel (2008) worked on faba bean and reported that the development of more and vigorous leaves under wide intra and inter row space in spatial arrangement helped to improve the photosynthetic efficiency of the crop and supported large number of pods.

MATERIALS AND METHODS

Study sites

University of Eldoret

University of Eldoret (UOE) farm is within the Uasin Gishu plateau which is in the lower highlands (LH3) agro-ecological zone (Jaetzold and Schmidt, 2008). The site is located at latitude $0^{\circ}30'$ N and longitude $35^{\circ}15'$ E; at an elevation of 2180 m above sea level which is a medium altitude for bean growing (Jaetzold and Schmidt, 1982). The site is characterized by a mean maximum temperature of 23°C and a relative humidity range of 45 to 55 % (Jaetzold and Schmidt, 2008). An annual rainfall of 900-1100mm p.a. has been recorded for this site. These rains are bimodal with the long rains starting in month of March and second rains normally starting in months of September/October (Jaetzold and Schmidt, 1982). The soils are shallow, well drained non –humic cambisols

Mabanga ATC

The area is within Bungoma County and lies between latitude $0^{o}26'$ to $0^{0}18'$north, longitude $33^{\circ}58'$east and $34^{\circ}33'$ west and an altitude of 1100 to 1400 meters above sea level. Mean annual temperature of 22.5°C and mean annual precipitation of 1800-2000mm (Jaetzold and Schmidt, 2008). The rains are bimodal (Jaetzold and Schmidt, 2008).

Treatments: Spatial arrangement:

The same bean population of 120 plants per plot was achieved by spacing the three bean varieties (Canadian Wonder, Rose Coco and KAT B1) at 60 cm X 15 cm, 45 cm X 20 cm, 36 cm X 25 cm and 30 cm X 30 cm hence four different spatial arrangements giving 12 different combinations. The design used was RCBD replicated three times in both sites.

Data collected

Plant height

The plant height was measured from the ground level to the highest tip of the stem for the three randomly sampled plants using meter rule at harvest maturity and average of each treatment calculated.

Number of flowers/ plant at early stage of flowering

Flowers of the three random plants were counted and average taken for each treatment

Number of pods/plant

Three randomly sampled plants were taken from each plot when the crop had reached the harvest maturity stage, counted manually and the average pod number was calculated.

Number of seeds/pod

Three randomly sampled pods from each plot were picked at harvest (maturity stage). Seeds were counted in each pod, and the average calculated.

1000 seeds weight

1000 seeds from the threshed and oven dried seeds from each plot were picked when the crop had reached maturity stage. These were weighed to represent the mean seed weight.

Seed weight/ hectare

Seed yield per hectare was determined by threshing the harvested plants from the central one square meter of each plot. These were put in labelled envelopes and oven dried to a constant moisture level of 12.5 % at 60 °C for 48 hours, and then weighed using electric balance. The resulting weights, in grams (g) per meter square were then scaled up to kg per hectare basis to get the average seed yield per hectare.

Statistical Analysis

All collected data was subjected to analysis of variance (ANOVA) using Genstat statistical programme version 13. Tukey's at 5% level of significance was used to separate means.

RESULTS AND DISCUSSION

The results of the study and their discussions are as presented in Tables below.

Table 1: Effect of spatial arrangement on growth and yield of beans at University of Eldoret site

Spatial Arrangement	Plant Height (cm)	Flowers/Plant	Pods/ Plant	Seeds/ Pod	1000 seed weight	Seed Yield (Kg/Ha)
30cm x 30cm	24.9a	26.7a	18.3a	5.2a	278.0b	332.6b
36cm x 25cm	27.4a	23.8a	13.7b	5.1b	279.3b	484.8a
45cm x 20cm	27.0a	25.1a	14.6b	6.4a	276.5b	479.4a
60cm x 15cm	25.3a	24.1a	12.2b	5.0b	279.4a	363.7b
CV%	8.4	20.1	15.8	13.2	3	7.5
Turkey's HSD(0.05)	2.8	9.9	3	0.9	10.91	39.8

Table 2: Effect of spatial arrangement on growth and yield of beans at Mabanga site

Spatial Arrangement	Plant Height (cm)	Flowers/Plant	Pods/ Plant	Seeds/ Pod	1000 seed weight	Seed Yield (Kg/Ha)
30cm x 30cm	17.6a	12.6a	20.6a	6.2b	273.7b	549.1a
36cm x 25cm	35.9a	13.8a	19.4a	6.1b	277.7b	454.0ab
45cm x 20cm	24.0a	13.0a	16.3b	7.4a	275.0ab	317.5bc
60cm x 15cm	20.2bc	13.0a	16.3b	6.0b	279.2a	426.2b
CV%	7.1	10.7	8	15.6	1.4	17.1
Turkey's HSD(0.05)	5.5	1.9	2.09	1.1	5.1	100.8

Table 3: Interaction effect between spatial arrangement and varieties on number of pods/plant in Mabanga

Spatial arrangement	Varieties		
	Canadian wonder	KAT B1	Rose Coco
60 cm × 15 cm	15.67 de	20.00 abc	13.33 e
45 cm × 20 cm	15.00 de	16.67 cde	17.33 bcde
36 cm × 25 cm	15.67 de	18.67 bcd	24.00 a
30 cm × 30 cm	20.67 abc	20.00 abc	21.00 ab
CV (%)	8.0		
Tukey's HSD($p \leq 0.05$)	5.12		

Table 4: Interaction effect between spatial arrangement and varieties on 1000-Seed weight (g) at University of Eldoret

Spatial arrangement	Bean Varieties		
	Canadian wonder	KAT B1	Rose Coco
60 cm × 15 cm	317.1 a	293.2 ab	281.9 bc
45 cm × 20 cm	289.6 bc	267.1 c	273.0 bc
36 cm × 25 cm	277.6 bc	276.9 bc	283.2 bc
30 cm × 30 cm	280.9 bc	271.9 bc	281.2 bc
CV (%)	3.0		
Tukey's HSD($p \leq 0.05$)	24.2		

Table 5 : Interaction effect between spatial arrangements and varieties on 1000- Seed weight in Mabanga

Spatial arrangement	Varieties		
	Canadian wonder	KAT B1	Rose Coco
60 cm × 15 cm	289.3 a	282.9 ab	265.4 cd
45 cm ×20 cm	290.6 a	273.0 bcd	261.5 d
36 cm × 25 cm	283.5 ab	282.6 ab	267.1 cd
30 cm × 30 cm	277.0 bc	275.1 bc	269.0 cd
CV (%)	1.4		
Tukey's HSD ($p \leq 0.05$)	11.5		

Table 6 : Interaction effect between spatial arrangement and variety on Seed weig ht/ hectare in University of Eldoret

Spatial arrangement	Bean Varieties		
	Canadian wonder	KAT B1	Rose Coco
60 cm × 15 cm	2848 e	5051 ab	3013 de
45 cm × 20 cm	3889 cd	4918 ab	5576 a
36 cm × 25 cm	4566 bc	4465 bc	5514 a
30 cm × 30 cm	4882 ab	2543 e	2551 e
CV 9%)	7.5		
Tukey'sHSD($p \leq 0.05$)	895.2		

Plant height at maturity

The effect of spatial arrangement on plant height was significant ($p \leq 0.05$) on beans planted in Mabanga site only as shown in Table 2.

The significant effect on plant height at Mabanga site only in plant height could be justified on the basis of differences in agro-climatic factors and soil factors which favoured the growth of beans in this site in comparison to the University of Eldoret site.

Additionally, increase and decrease in plant height could be justified on the basis of how plants were arranged in space. The increase in plant height could be justified on the basis of plants planted closely to each other within the row leading to increase in plant competition for solar radiation within the row. Thus lower amount of light intercepted by plants through crop canopy results into increased inter node length due to the intra specific plant competition for light which causes such variation in plant height. This result was in line with Taj *et al*. (2002) who found that competition for light in narrow spacing in mung bean resulted in taller plants while at wider spacing light distribution was normal. Similarly, Shamsi and Kobraee (2009) worked on spatial arrangement experiment on soybean, observed that decreasing intra row spacing led to significant increases in plant height. This was primarily because of lower amount of light intercepted by plants planted in a close intra row space resulting into increased inter node length. In contrast to the result of this study, Turk *et al*. (2003) worked on lentil and reported negative relationship of plant height with spatial arrangement of plants in relation to inter row space.

Number of pods / plant

There was significant difference *($p \leq 0.05$)* on number of pods per plant of common bean in University of Eldoret and Mabanga ATC (Tables 1 and 2). Number of pods per plant is a key factor for determining the yield performance in leguminous plants Abdel (2008). There was significant effect on number of pods per plant in both sites because of plant architecture in time and space at both site which enhanced the significant effect and also the differences in environmental and soil factors which favoured pod formation in both sites.

The decrease in the number of pods per plant with a decrease in intra row spacing could be due to increased intra specific competition which eventually might have caused reduction in the number of pods per plant.

Furthermore, the increase in the number of pods per plant with increased intra and inter row spacing might be as a result of higher net assimilation rate due to reduction in competition in wider intra row space in crop spatial arrangement. On the other hand, decreased intra and inter row space induced competition between the early and late emerged flowers that could lead to flower abortion. In wider inter and intra-row spacing, the growth factors (nutrient, moisture and light) for individual plants might be easily accessible hence retaining more flowers for pod formation and support the development of lateral branches for more pod development. In agreement to the result of this study Hodgson and Blackman (2005) and Abdel (2008) who worked on faba bean reported that the development of more and vigorous leaves under wide intra and inter row space in spatial arrangement helped to improve the photosynthetic efficiency of the crop and supported large number of pods.

The interaction effect was significant at Mabanga (Table 3) because of genetic factor, environmental factor and how plants were arranged in space that might have favoured the formation of pods. This is in line with (Mekonnen, 2010) who reported that a major factor influencing plant arrangement for any particular crop is the genotype. Therefore, Genotype by plant spatial arrangement interaction was found to be evident in faba bean (Amare and Adamu, 2000), field pea (Rezene, 2014).

Number of seeds / pod

Analysis of variance revealed that there was statistical differences *($p \leq 0.05$)* on number of seeds per pod of common bean both at University of Eldoret and Mabanga ATC (Table 1 and 2). Number of seeds per pod is considered an important factor that directly imparts in exploiting potential yield recovery in leguminous crops (Ayaz et al., 2001). The significant effect in both sites could be due to the environmental factors, soil factors of the site that enhanced the formation of seeds in the pods and how the plant arrangement is done in space and time. This variation might be due to the fact that wide intra row spaced plants encountered less intra plant competition than closely spaced plants and thus exhibited better growth that contributed to more number of seeds per pod. This result was in agreement with (Ayaz *et al.* 2001 and Abdel, 2008), who reported that number of seeds per pod increased with increased intra row space of faba bean. Moreover, Oad *et al*. (2002) while working on safflower reported that higher number of seeds per pod was associated with wider inter and intra-row spacing.

1000- Seed weight

There was significant ($p \leq 0.05$) effect of spatial arrangement on 1000-seed weight for common beans planted in Mabanga and University of Eldoret.

The significant effect in both sites could be justified on the basis of how plants were arranged in this different location and soils. This decrease could be attributed to assimilates division among seeds as a result of the increased inter plant competition in utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues, hence decrease in weight. However, in wider inter row spaced plants, there could be improved supply of assimilates stored in the seed, hence, increase in a thousand seed weight. The result of this study was in agreement with those obtained by Solomon (2010) on haricot bean, who reported that thousand seed weight decreased with reduction in plant inter row space. The interaction effect was significant in both sites (Table 4 and 5) due to the environmental differences and the way the bean cultivars were arranged that favoured the production of 1000-seeds in both sites.

Seed weight / hectare (Kg/ha)

Spatial arrangements resulted to significant seed yield ($p \leq 0.05$) for the beans planted in University of Eldoret and Mabanga. The significance was a result of the effect of spatial arrangement in both sites. The environmental and soil differences in both sites favoured the bean production and also how the beans were arranged in intra and inter space to each other. Therefore, the reduced yield was as result of decreased intra row space and leading to intense interplant competition for resources such as nutrients, water and solar radiation. This is manifested by high plant mortality and low number of pods per plant at the narrow intra space plant. The latter might be attributed to high level of flower abortion due to competition for the available resource. The result of this study was in line with Ball *et al*. (2000) who reported that decreasing intra row space reduced yield of individual plants but increased yield per unit area of common bean. Significant effect due to interaction at UoE (Table 6) only could be due to type of soil, environmental differences and how the varieties were arrangement in space and time which enhanced the production.

CONCLUSIONS

The conclusions from the results of this study are: The spatial arrangement of 30 cm × 30 cm and 36 cm × 25 cm was the best at Mabanga ATC while the spatial arrangement of 36 cm × 25 cm and 45 cm × 20 cm was the best at the University of Eldoret. It is therefore recommended that: Beans under the agro-climatic conditions of Uasin Gishu (36 cm × 25 cm and 45 cm × 20 cm) and Mabanga (30 cm × 30 cm and 36 cm × 25 cm) should be grown using this spatial arrangement in order to achieve maximum yield.

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