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Growth, Production Potentials and Compatibility of Maize-Bean Intercrops: Results From On-Station Trials in Embu, Kenya

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Abstract

An on-station study was carried out at Embu County during the long rains (LR) and short rains (SR) of 2014-2015 to evaluate the agronomic performance of selected maize varieties and their compatibility with Embean-14 bean variety under an intercropping system. Four morphologically contrasting maize varieties were grown as sole crops or intercropped with beans. The experiment was laid out in a randomized complete block design with split plot arrangement with three replications. The cropping system (sole/intercrop) and maize variety were assigned to main plots and sub plots respectively. Maize plant height, ear length and maize grain yields were significantly affected by the maize variety ($p \leq 0.05$) with PHB 3253, DK 8031 and KH 500Q varieties having higher values. Sole maize gave higher yields than the intercrops except in long rains of 2015. Bean pods per plant, 100 seed weight and grain yields did not differ markedly under intercropping with the maize varieties.

Keywords: maize variety, cropping systems, growth parameters, yields.

Introduction

Agricultural intensification through introduction of legumes into the production systems is crucial in subsistence or low input agricultural systems (Brooker *et al* 2015; McCord *et al* 2015]. Intercropping is an agricultural practice of growing two or more crops simultaneously on the same piece of land in the same season. It is a common practice in most smallholder farming systems of East Africa and Kenya in particular, with high amounts of subsistence agriculture and low amounts of agricultural mechanization (Matusso *et al* 2014; Ngwira *et al* 2012) The practice seeks to maximize productivity through crop diversification and effective utilization of growth resources such as soil moisture, nutrients and solar radiation (Ngwira *et al* 2012). In addition, the practice brings about environmental benefits such as soil and water conservation, weeds, pests/disease control and improvement of soil fertility through nitrogen fixation by legume(s) in the intercrop components (Odendo *et al* 2011, Belel *et al* 2014, Karanja *et al* 2014, Brooker *et al* 2015). Other benefits of intercropping include reduction in farm input use, diversification of diet and increased income per unit area and time and labour use efficiency (Tsubo *el a*l 2005, Dolijanović *et al* 2009). The practice is further used by farmers as an insurance against total crop failure under adverse weather conditions (Lithourgidis *et al* 2011; Rusinamhodzi *et al* 2012). This is because the damage to one crop is buffered by the companion crop because they are not affected to the same extent in the face of adverse abiotic and/or biotic conditions.

Maize (*Zea mays L.*) and common beans (*Phaseolus vulgaris L.*) rank first and second in importance as staples food in Kenya (GoK 2010), are commonly intercropped. While these crops are important for addressing food and nutrition security in the country, the yields are often low. The average farm level maize yield is 1.8 (Mg ha^{-1}) and that of beans 0.6 Mg ha^{-1} (GoK, 2010) against a 6 Mg ha^{-1} and 2.3 Mg ha^{-1} , respectively (GoK 2010; Kwena *et al* 2017). . Such low yields are mainly due to the use of unimproved seed, sub-optimal fertilizer rates and traditional crop husbandry practices (GoK 2010; Matusso *et al* 2014). The cost of acquiring modern inputs remains beyond the reach of the majority of smallholder farmers who form the bulk of agricultural

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producers (Gachene *et al* 2003; Kwena *et al* 2017).

Intercropping of the maize and beans has also led to their reduced individual yields (Karuma *et al* 2016). The reduction of bean yield under intercropping with maize could be attributed to the interspecific competition between the intercrop components for water, light, air and nutrients and also the aggressive effects of maize (C_4 species) on bean, a C_3 species (Matusso *et al.* 2014). According to Matusso *et al.* 2014. and Brooker *et al.* 2015 crops with C_4 photosynthetic pathways have been known to be dominant when intercropped with C_3 species. The shading of the bean by the taller maize plants may also have contributed to the reduction of the yields of the intercropped bean (Muraya *et al.* 2006, Brooker *et al.* 2015, Karanja *et al.* 2014) Muraya *et al.*2006. further corroborates that leaf display is key to maize dominance in intercrop systems while the bean, especially the bush varieties, with its restricted extension potential is unsuited to compete with the vertically oriented maize growth.

Compatibility studies of maize and beans in an intercrop system have not been adequately done (Kitonyo 2013). Consequently, farmers may not be getting the best returns in terms of yield or cash because they do not necessarily select the most compatible maize varieties for intercropping (Kitonyo 2013). In view of the potential of intercropping systems in intensifying farm productivity, it is imperative to select both maize and bean varieties that are compatible with intercrop systems commonly practiced by farmers (Muraya *et al*. 2006). With this background, this on-station study was conducted to evaluate the agronomic performance of selected maize varieties that are currently grown in Embu County and to determine the compatibility of these maize varieties with Embean-14 bean variety under an intercropping system.

Materials and Methods

Study site description

The study was conducted at the Kenya Agricultural and Livestock Research Organization (KARLO - Embu) farm on the Eastern slopes of Mt. Kenya (00° 33.18'S; 037° 53.27'E); 1420 MSL and in the upper midlands (UM_3) zone in Embu County. The region receives an average annual bimodal rainfall of 1250 mm and the temperatures range from 21 to 28°C and 16 to 21°C mean maximum and minimum, respectively (Jaet zold *et al.* 2006). The two rainy seasons are the long rains (LR) lasting from March to August, and short rains (SR) from October to January. About 65 % of the rains fall during the LR and in some years end in July - August with scanty showers (Micheni *et al.* 2013). The soils are dominated by humic *Nitisols* and are of moderate to high inherent fertility due to their high minerals, water and cation exchange capacity levels (Gitari and Friesen 2001). The farming system in the area is mainly livestock keeping and growing medium maturity maize and field bean (Micheni *et al.* 2013).

Experimental design and layout

The trials were established in 2014 and ran for three cropping seasons during the long (LR) (March - August) and short rains (SR) (October - January) (i.e. SR 2014, LR 2015, SR 2015). Four morphologically contrasting maize varieties were grown as pure/sole crops or intercropped with beans. The experiment was laid out in a randomized complete block design with split plot arrangement with three replications. The cropping system (sole/intercrop) was assigned to the main plots while the maize variety to the sub plots. The maize varieties used in this study included; DK 8031, KH 500Q, PHB 3253 and KDV1 and a locally promoted bean variety, Embean-14.

All experimental plots were maintained under no – till conservation agriculture practices, with no ploughing of land. Only seeds and fertilizer holes were prepared. Weeds were controlled before crop seeding using Glyphosate herbicide at the rate of 3.5 L ha^{-1}. In each season, the seeding was done at the onset of the rains. Plot sizes measured 5 m by 6.75 m with 1 m wide paths provided between plots and replicates. Three seeds were planted per hill at the recommended spacing of 75 cm x 50 cm for maize, and thinned to 2 seeds per hill at 4 weeks after the crop emergence. In the intercrop systems, a row of beans was planted in between two rows of maize at an intra-row spacing of 15 cm. Maize was planted with NPK fertilizer (23:23:0) at the rate of 60 kg P_2O_5 ha^{-1} while beans were sown with Di-ammonium phosphate (DAP) at the rate of 20 kg N ha^{-1}. The fields were kept weed-free by hand pulling any weeds that might have emerged after the crop establishment. In beans, bean fly and other insect pests were controlled using Sumithion Super with active ingredients 25g L^{-1} fenitrothion and 12.5 g L^{-1} esfenvalerate at the rate of 15 m 20 L^{-1} litres of hand spray pump.

Crop measurements

Maize: The following maize data was collected; maize plant height, leaf length, leaf diameter, leaf area index (LAI) and maize grain yield. Maize plant height was measured at 3 Weeks After the crop Emergence (WAE), 6 WAE and at maturity, from the ground level to the surface to the insertion of the first tassel branch, using measuring tape. Maize leaf area was estimated by the length multiplied by maximum width and multiplied by 0.75, which is the maize calibration factor (Elings 2000). Ten measurements of each of the parameters were taken and then averaged and the corresponding leaf area index (LAI) computed. The LAI was computed by dividing the total leaf area of a maize plant stand by the total land area occupied by the single stand (Mauro *et al.* 2001). Final crop grain yields were determined from plants harvested in a sample area of 3 × 3 m at the center of each plot. Harvesting of maize was done after the crops were dry in the field. The grain yield was determined at 12.5 % moisture content.

Beans: Bean data collected included the number of pods per plant, 100 seeds weight and bean grain yield. Ten plants per plot were sampled for determining the parameters. Bean grain yield at 15 % moisture content was recorded.

Statistical analysis

Yield and yield components data were subjected to analysis of variance (ANOVA) using Genstat 14th Edition statistical software (Genstat 2016). Differences among treatment means were compared using Fishers Least Significant Difference (LSD) test at 5 % probability level.

Results and Discussion

Effect of cropping systems and maize variety on crop performance

Maize height

The average plant height increased significantly ($p \leq 0.05$) with time within the different treatments (Table 1). When the maize height at different weeks after planting was averaged for three seasons, there were significant differences ($p \leq 0.05$) observed of time of measurement and cropping season. Varietal differences were also noted at the grain filling stage in all the three seasons and at 3 WAE and 6 WAE of SR 2015 ($p \leq 0.05$). The varietal average of plant height observed across the seasons was DK 8031 > KH 500Q > PHB 3253 > KDV1 (Table 1). DK 8031 maize variety prove to have good stability as

Table 1. Maize plant height (cm) of four maize varieties intercropped with Embean-14 in Embu, Kenya (WAE = Weeks after emergence)

Cropping system (C)	Short rains 2014			Long rains 2015			Short rains 2015		
	3 WAE	6 WAE	Grain filling	3 WAE	6 WAE	Grain filling	3 WAE	6 WAE	Grain filling
Intercrop	38.20	52.41	104.5	21.27	51.50	183.6	29.54	67.32	231.7
Pure maize	39.47	52.77	106.3	21.16	49.13	188.4	32.34	68.42	218.8
LSD (5%)	7.60	8.55	5.56	2.00	10.58	17.5	4.99	8.38	15.9
Variety (V)									
DK 8031	42.19	56.62	111.2	21.03	51.90	197.8	35.50	72.0	257.5
KDVI	35.53	50.67	93.3	21.23	50.70	157.8	20.27	47.0	145.3
KH 500Q	39.34	52.38	108.4	22.93	50.87	198.3	33.67	74.4	252.8
PHB 3253	38.27	50.70	108.7	19.67	47.80	190.1	34.33	78.0	245.4
Mean	32.84	52.59	105.4	21.22	50.32	186.0	30.94	67.9	225.3
LSD (5%)	5.00	8.06	6.98	2.99	5.26	16.59	4.273	7.14	19.10
Significance levels									
C	0.544	0.874	0.318	0.825	0.437	0.362	0.137	0.629	0.073
V	0.080	0.369	<.001	0.182	0.401	<.001	<.001	<.001	<.001
C × V	0.788	0.678	0.949	0.637	0.424	0.970	0.124	0.393	0.481
CV %	2.3	7.7	2.5	7.0	7.2	1.8	6.2	3.9	1.6

compared to the other varieties. Maize height did not differ markedly in the pure stands and in the intercrops (Table 1). The sole maize maintained taller plants at the various WAE within the seasons, except at 3 WAE and 6 WAE (LR 2015) and grain filling stage in SR 2015. Non-significant interactions between cropping system and maize variety were observed at the different time of measurement and cropping seasons (Table 1).

Plant height is an important morphological attribute because it is a function of combine effect of genetic makeup of plant, soil nutrition status, seed vigor and environmental conditions under which it was grown (Anjum *et al*. 2014). The plant height increased progressively and was influenced by the time of measurement, cropping system and maize variety in each season. High plant establishment in intercrops creates competition for water, light and nutrients with the beans (Vandermeer 1989). Increased plant height is advantageous because height is related to the final grain yield in that the stem of maize can serve as a reservoir of labile non-structural carbohydrates which are mobilized as sugars and translocated to the filling grains during post flowering period (Edmeades & Lafitte 1993) Taller plants provide an advantage of trapping more solar radiation than the intercropped legumes, which is very critical for the growth and development of the crop. Maize plant height is determined by the number and lengths of nodes, whose meristemic elongation is influenced by both growing conditions and genetics (Dlamini 2015).

Maize leaf area index (LAI), ear lengths and grain yields

The leaf area index, ear lengths and grain yields of the maize varieties grown in association with the Embean-14 bean variety were significantly different ($p \leq 0.05$) in the LR 2015 and SR 2015 cropping seasons (Table 2). No significant differences in LAI, ear lengths and grain yields due to cropping systems were observed for the three seasons (Table 2). Non-significant interactions between cropping system and maize variety were noted in all the cropping seasons except for grain yield in SR

Table 2 Growth parameters and grain yield of four maize varieties intercropped with a bean variety in Embu, Kenya (LAI = Leaf area index)

Cropping system (C)	Short rains 2014			Long rains 2015			Short rains 2015		
	LAI	Cob length (cm)	Grain yield (Mg ha^{-1})	LAI	Cob length (cm)	Grain yield (Mg ha^{-1})	LAI	Cob length (cm)	Grain yield (Mg ha^{-1})
Intercrop	0.15	22.92	2.98	0.20	13.53	3.10	0.195	15.19	3.41
Pure maize	0.20	22.36	3.16	0.22	13.35	2.90	0.189	15.74	3.47
LSD (5%)	0.19	1.64	1.15	0.02	4.24	1.82	0.053	1.09	0.82
Variety (V)									
DK 8031	0.18	23.88	2.69	0.21	13.21	2.91	0.210	15.69	3.91
KDVI	0.15	21.72	2.84	0.15	10.63	2.13	0.151	14.14	3.14
KH 500Q	0.22	20.76	3.44	0.26	14.57	3.35	0.212	16.14	3.09
PHB 3253	0.16	24.19	3.30	0.21	15.35	3.61	0.196	15.89	3.63
Mean	0.18	22.64	3.07	0.21	13.44	3.00	0.192	15.47	3.44
LSD (5%)	0.12	3.47	0.95	0.02	1.52	0.64	0.026	1.39	0.28
Significance levels									
C	0.35	0.281	0.588		0.878	0.686	0.701	0.166	0.762
V	0.58	0.143	0.305		<.001	0.002	<.001	0.034	<.001
C × V	0.61	0.643	0.321		0.206	0.258	0.787	0.517	0.005
CV %	16.3	4.8	11.9	6.7	8.2	16.8	5.7	1.76	5.3

2015 (Table 2). The interaction shows that the grain yield harvested was influenced by the maize variety within the cropping system.

Leaf area index is a measure of leafiness and photosynthetic area of a crop (Rahman *et al.* 2009). It can also be described as the leaf area of a crop per unit area on which it stands (Mauro *et al.* 2001). The LAI did not differ markedly in the pure stands and in the intercrops. The reduction of LAI under intercropping is a common phenomenon in crop plants as the LAI of a crop increases on account of more area occupied by green canopy of plants per unit area (Rahman *et al.* 2009).

There was a seasonal difference observed in the ear lengths (Table 2). The seasonal means of ear length were SR 2014 (22.64 cm), LR 2015 (13.44 cm) while in the SR 2015 (15.47 cm). Varietal differences were noted for ear length with PHB 3253, DK 8031, KH 500Q and KDV1 having averages of 18.5 cm, 17.6 cm, 17.2 cm and 15.5 cm, respectively for the three seasons. Sole maize had an average of 17.15 cm and the intercrop 17.21 cm.

Work done by Kariuki *et al.* (2017) indicate that difference in ear length among maize genotypes is a genetic characteristic more than the growing conditions of plants. For grain yields, PHB 3253 and KH 500Q varieties gave higher means of 3.5 Mg ha^{-1} and 3.29 Mg ha^{-1}, respectively, compared to DK 8031 (3.17 Mg ha^{-1}) and KDV1 (2.70 Mg ha^{-1}). This results corroborates with findings by Gwenzi *et al.* (2008) working in a semi-arid region in Zimbabwe who observed that maize yields depended more on the maize genotype. Sole maize gave higher yields than the intercrops except in the LR 2015. Higher yields in sole crops indicate the relative competitive effect of intercrops compared to sole cropping (Ijoyah 2012).

Beans pods per plant, 100 seed weight and grain yields

Pods per plant, 100 seed weight and grain yields did not differ markedly with intercropping with the maize varieties (Table 3). The number of pods per plant is among the most important yield components associated with seed yield of bean. Pods per plant have often been recommended as an indirect selection criterion for increasing yield, primarily because of its high and more consistent correlation with yield (Kitonya *et al.* 2013). The mean seasonal grain yields were 0.49 Mg ha^{-1} in SR 2014, 0.53 Mg ha^{-1} in LR 2015 and 0.69 Mg ha^{-1} in SR 2015 (Table 3). A three - season bean grain yield average by maize variety shows that PHB 3253 > DK 8031= KDV1 > KH 500Q, with values ranging from 0.54 Mg ha^{-1} to 0.61 Mg ha^{-1} (Table 3). This indicates that the choice of a compatible maize variety is important in maximizing bean productivity.

The bean grain yields obtained are low (< 1 Mg ha^{-1}) compared to the maize yields obtained (> 2.7 Mg ha^{-1}) (Table 2). The average bean grain yield was 0.57 Mg ha^{-1}, which was approximately 78 % lower compared to the expected 2.50 Mg ha^{-1} for the variety (Embean-14) which is a determinate bush bean with potential grain yield of 2.5 Mg ha^{-1} $season^{-1}$ in upper midland zones (Micheni *et al.* 2014). Matusso *et al.* 2014b attributes

Table 3. Pods per plant, seed per pod, 100 seeds weight and bean grain yield of Embean-14 intercropped with four maize varieties in Embu, Kenya (SR 2014 = Short rains 2014, SR 2015 = Short rains 2015, LR 2015 = Long rains 2015)

Maize variety	Pods per plant			100 seeds weight (g)			Bean grain yield (Mg ha^{-1})		
	SR 2014	LR 2015	SR 2015	SR 2014	LR 2015	SR 2015	SR 2014	LR 2015	SR 2015
DK 8031	4.00	4.00	3.00	4.90	5.37	5.47	0.44	0.55	0.72
KH 500Q	3.00	3.00	3.00	4.90	5.23	5.33	0.43	0.56	0.63
KDV1	5.00	4.00	4.00	4.90	5.47	5.53	0.54	0.49	0.67
PHB 3253	4.00	3.00	3.00	4.70	5.50	5.57	0.56	0.52	0.75
Mean	4.00	3.00	3.00	4.85	5.40	5.48	0.49	0.53	0.69
LSD (5%)	2.27	0.98	0.87	0.53	0.58	0.60	0.15	0.17	0.17
CV %	3.8	4.9	6.5	3.6	2.6	3.7	17.3	2.6	9.0

the reduced bean yields under intercropping with maize to the interspecific competition between the intercrop components for water, light, air and nutrients and also the aggressive effects of maize (C_4 species) on bean, a C_3 species. (Brooker *et al.* 2015) further reiterates that crops with C_4 photosynthetic pathways have been known to be dominant when intercropped with C_3 species. The shading of the bean by the taller maize plants may also have contributed to the reduction of the yields of the intercropped bean (Muraya *et al.* 2013, Brooker *et al.* 2015, karuma *et al.* 2016). The low competitive capacity of legumes compared to the cereals has been ascribed to its small root system, shallow root distribution, resulting to low competitive ability for mineral nitrogen [15].

Conclusion

This study found that in a maize/bean intercrop system, the bean component does not significantly affect maize grain yield and other yield components. However, the maize significantly affects beans performance by depressing the bean yields. The bean grain yields obtained were low (< 1 Mg ha^{-1}) compared to the maize yields obtained (> 2.7 Mg ha^{-1}). The choice of a compatible maize variety is thus essential to maximize bean productivity.

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