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Full Length Research

Assessment of maize and dry bean productivity under different intercrop systems and fertilization regimes

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The productivity of different maize-dry bean intercrop systems (single and double rows of dry bean planted between two maize rows at low and high bean population) was assessed in 2006/07-08 seasons at different fertilizer application regimes (unfertilized control, low, adjusted low and optimum). Sole maize and dry bean plots were included as checks and together with the intercrop systems, they constituted the main treatment while the fertilizer regimes constituted the sub treatment. Treatments were arranged as a split plot design with three replications. There was a significant season x fertilizer interaction effect on maize grain and total biomass yields, and a significant season x cropping system interaction on dry bean grain yield. Grain yield for both crops were significantly ($P<0.001$) higher in 2007/08 with the highest maize grain yield of 2644 kg ha^{-1} obtained at optimum fertilizer rate. Dry bean grain yield of 875 and 829 kg ha^{-1} obtained in 2007/08 at optimum and adjusted low fertilizer rates, respectively were comparable. The highest mean grain yield of 2101 kg ha^{-1} for maize and 728 kg ha^{-1} for dry bean across the two seasons were obtained in single-bean row intercrop planted at low and high population, respectively. The single dry bean row intercrop system gave the highest productivity based on the total LER values and thus appears the most appropriate for small-scale farmers.

Key words: Fertilizer application, food security, intercrop, land equivalent ratio (LER), planting density and seed inoculation.

INTRODUCTION

Maize (*Zea mays* L.) and dry bean (*Phaseolus vulgaris* L.) are important staple food crops in South Africa. Maize is consumed both as roasted or boiled fresh green mealies on cobs to fill hunger gap while milled dried grains is cooked and served as porridge meal in many households. Similarly, dry bean can be consumed as harvested fresh vegetable (green pods) while dry grains can either be cooked and eaten with soft maize as relish or processed into soups and canned products such as baked beans. The crops like many other field crops, are commonly grown by smallholder farmers (SHF) mostly at subsistence level but are both characterized with low yield and hence the widespread food insecurity, hunger and mal-nutrition in many rural households. Regrettably, abiotic stress such as drought, which besotted many Southern African countries in recent past (Buckland et al., 2000) have always impacted a worsening effect on the low productivity of crops that already exist on smallholder farmlands. The situation is further exacerbated by the widespread soil fertility problems and poor farmers' management practices (Kutu, 2008a). The resource-poor condition of these farmers and high cost of inputs especially inorganic fertilizers constitute additional constraints to increased productivity. While most SHF ~~have~~ relied on the native soil fertility or low organic input supply mostly as manures to achieve marginal crop yield increases, few of them often supplemented manure application with low to sub-optimal inorganic fertilizers so as to marginally boost their yields. Intercropping cereals with legumes, an age long practice, has also been used by SHF to increase crop productivity, reduce risks and conserve soil (Kutu, 2008b).

Among practices of SHF that promote low productivity are low planting densities and the use of poor quality seeds. Evidence from a study by Joubert (2000) in

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Ciskei, Eastern Cape Province of South Africa, showed that maize plant density is normally below 15000 plants per hectare on smallholder farmlands while Tittonell et al. (2007) also reported mean range of one to four plants per square meter area on smallholder farms from three districts in Kenya. Several authors have different views regarding farmers' practice of planting at low densities. While Carsky et al. (1998) and Tittonell et al. (2007) considered it as part of farmers' management strategies to minimize the adverse effect of low soil fertility, Chikoye et al. (2004) attributed it to possible production constraints such as poor weed management. Agricultural production at the level of SHF is mainly dependent on rainfall, which affects farmers' numerous farm operations due to their limited resources, which include time and farm labour. The highly unpredictable rainfall characteristics increase production risks and costs while the low planting density and yields that accompanied this result in reduced production benefits for farmers. Thus, attempts to mitigate this challenge will require assessment of strategies that not only fit into farmers' practices but also alleviate production constraints. Hence, the objective of this study was to assess the productivity of different maize-dry bean intercrops and fertilizer application regimes as management strategy to increased food availability, particularly at the rural household level. Successful achievement of higher productivity on smallholder farmland will help reduce food insecurity problem through increased access to diverse food. It would also lead to increased income, alleviate poverty and improved rural farmers' living condition.

MATERIALS AND METHODS

A field trial was conducted during two consecutive summer cropping seasons (2006/07 and 2007/08) at the North West Province Department of Agriculture Experimental Farm, Taung. The farm lies on latitude 27.55S and longitude 24.77E while soil at the farm is predominantly sandy. The area receives an annual mean rainfall of less than 400 mm. The trial consisted of different intercrop systems and fertilizer application regimes. The different intercrop systems included single and double dry bean row(s) planted between two maize rows at 7 and 15 cm intra-row spacing to obtain high and low bean plant population, respectively. Sole maize and dry bean plots were included as standard checks for the intercrop systems. The different intercrop systems constituted the main treatment effect while fertilization regimes constituted the sub treatment effect. These were combined and laid out in a split plot experiment fitted into a randomized complete block design (RCBD) with three replications. Open pollinated maize seed variety ZM521 and certified disease-free improved white dry bean seed variety PAN185 were planted. Maize was planted at 30 cm intra-row and 150 cm inter-row spacing while sole dry bean was planted at 7 cm intra-row and 90 cm inter-row spacing.

The different fertilizer regimes consisted of unfertilized control, low and optimum fertilization rates and an adjusted low fertilizer rates. Optimum rate (F1) of 150 kg N, 60 kg P and 40 kg K ha^{-1} for maize and 30 kg N, 22 kg P and 27 kg K ha^{-1} for dry bean were considered while half of these rates (F2) was considered to be relatively close to what small-scale farmers will apply with minimal risk. The adjusted low rate thus implies that F2 supplemented through seed inoculation (Si) using commercial B-Rus bacterial inoculants called stimuplant to promote better crop growth. The maize and dry bean inoculants respectively consisted of *Bacillus subtilis* (5×10^7 live cells/g) and *Rhizobium leguminosarum biovar phaseoli* strain (5×10^8 live cells/g) that were locally produced and marketed in the country as plant growth boosters. A paste of the inoculant mixed with powdered sticker (Stimulym) was prepared and thoroughly mixed with the seeds to achieve good inoculation. Inoculated seeds were air-dried and immediately planted.

Fertilizer was applied at planting using row-banding at 5cm away from each crop-row in sole plots. However in the intercrop plots, fertilizer was also banded in each plot prior to planting using dry bean fertilization rate. Maize plots were top-dressed at four weeks after plant emergence. Due to the low mean annual rainfall amount and poor distribution in that area during cropping season, supplementary irrigation (50 mm) was regularly applied using maize as indicator crop. Supplementary irrigation was terminated when crop attained 100% physiological maturity. Regular weeding was carried out as at when needed while Judo® was sprayed twice at two weeks interval after tasseling for the control of stem borer on maize. Yield and yield component data were taken on both crops at harvest. Final grain yield of crops was adjusted to a 12.5 and 11% moisture basis for maize and dry bean, respectively. Land equivalent ratio (LER) for assessment of crop productivity under the different intercropping systems was calculated using the equation:

$$LER_T = PLER_M + PLER_{DB} = [Y_{IM}/Y_{SM}] + [Y_{IDB}/Y_{SDB}]$$

Where: LER_T = total LER; $PLER_M$ and $PLER_{DB}$ = partial LER for maize and dry bean, respectively; Y_{IM} and Y_{IDB} = grain yields per unit area of intercropped maize and dry bean, respectively; Y_{SM} and Y_{SDB} = grain yields per unit area of sole maize and dry bean crop, respectively.

Data obtained from the trials were subjected to Analysis Of Variance using Stat Graphics plus Version 5.0 while differences amongst treatment means were separated using standard error of means (SEM) at 5% level of significance.

RESULTS

The effect of the different intercrop systems on maize and dry bean grain yield was inconsistent (Table 1). In 2006/07 season, the highest maize grain yield was obtained from double row intercrop plots planted at low bean population, which was approximately 22% higher than yield from sole maize plot, but in 2007/08 season, the highest maize grain yield was obtained from single bean row intercrop plots planted at low population. While sole dry bean plot gave the highest grain yield in 2006/07, single bean row intercrop plot planted at high population gave the highest bean yield in 2007/08. Generally, mean of grain yield across the two seasons was approximately 22 (maize) and 28% (dry bean) higher, in single bean row intercrop plot planted at low population and single bean row intercrop plot planted at high population, respectively, than in sole plot.

Maize grain yield was significantly ($P<0.001$) increased by the different fertilizer regimes while inconsistent fertilizer effect was obtained on dry bean grain yield (Table 2). Maize grain yield obtained at the adjusted low fertilizer rate did not differ significantly from yield at the optimum fertilizer rate but was approximately 16% higher than the

Table 1. Maize and dry bean grain yield (kg ha^{-1}) as affected by cropping systems.

Cropping systems	Maize		Mean	Dry bean		Mean
	2006/2007	2007/2008		2006/2007	20072008	
Intercrop, 1R Hp	1325	2277	1801	420	1036	728
Intercrop, 2R Hp	1306	1933	1702	420	793	606
Intercrop, 1R Lp	1471	2395	2101	429	916	673
Intercrop, 2R Lp	1807	2236	1771	377	860	618
Sole crop	1486	1965	1726	478	662	570
Prob. **(0.05)**	ns	ns	ns	ns	ns	ns
Mean	1479	2161	1820	424	845	639
CV %	10.5	9.9	6.9	5.9	9.8	8.1

CV = coefficient of variation; ns = not significant; 1R = single row of bean and 2R = double rows of bean; Lp and Hp = low and high bean population, respectively.

Table 2. Effect of fertilizer regimes on maize and dry bean grain yield (kg ha^{-1}).

Fertilizer regimes	Maize		Mean	Dry bean		Mean
	2006/2007	2007/2008		2006/2007	2007/2008	
Optimum	1661	2644	2153	427	889	658
Adjusted low	1564	2586	2075	439	836	637
Low rate	1544	2234	1889	425	885	655
Control	1145	1181	1163	408	804	606
Prob. **(0.05)**	***	***	***	ns	ns	ns
Mean	1479	2161	1820	425	853	628
SEM	160.7	192.3	113.6	25.5	27.9	37.7

SEM = standard error of means; ns = nonsignificant; *** implies significant at 0.1% probability.

yield from the low rate in 2007/08. However, dry bean grain yield at the different fertilizer rates did not differ from each other. The values of the partial land equivalent ratio for dry bean ($PLER_{DB}$) as well as the total land equivalent ratios (LER_T) in the different intercrop systems differed significantly ($P<0.001$) across the two seasons (Table 3). Maize grain yield was generally improved by dry bean intercrop as supported by the partial LER values of maize, which were all greater than one during the second season. Mean LER_T values across the two seasons ranged between 1.386, where two rows of dry bean were planted at low population and 2.786, where one-row was planted at high population suggesting increased productivity of between 38 and 279% over the sole treatments.

The variance ratio of grain and total biomass yields for the two crops are shown in Table 4. The differences among seasons, fertilizer regimes and the interaction between seasons and fertilizer regimes were highly significant for maize grain and total biomass yields. Seasons and the interaction between seasons and cropping systems similarly exerted a highly significant effect on dry bean grain yield while dry bean total biomass yield was significantly affected by cropping systems and fertilizer regimes.

DISCUSSION

A non-significant effect of the different intercrop systems on maize yield component data was expected. Nevertheless, the different intercrop systems generally gave higher grain yield advantage than sole cropping. This might be related to the reduced competition and increased complementary effects of the crop varieties used for the trial. Similar observation was reported in maize-soybean intercrop trials by Martin et al. (1991) and Mudita et al. (2008). Higher dry bean grain yield was reported under intercrop than sole crop particularly in 2007/08 and this may be partly attributed to possible reduced negative impact of shading effect of maize due to the simultaneous planting of both crops on the same day. The significant maize grain increase following fertilizer application and seed inoculation over unfertilized control suggests that an extra investment by farmers on less expensive plant growth booster such as the inoculants utilized in this study, which costs fifteen South Africa rand per sachet (approximately two USA dollar), will be advantageous. This would be of great benefits to resource-poor farmers in view of the high cost of inorganic fertilizers and the associated risks of fertilizer application under the highly varied and unpredictable

Table 3. Partial and total LER for the different test crops and intercrop systems.

Intercrop systems	PLER-dry bean	PLER-maize	LER_T
2006/2007 season			
Single row of dry bean, Hp	0.649	0.858	1.506
Double row of dry bean, Hp	0.717	1.068	1.785
Single row of dry bean, Lp	0.803	1.325	2.127
Double row of dry bean, Lp	0.447	0.938	1.386
Mean	0.654	1.047	1.701
20076/2008 season			
Single row of dry bean, Hp	1.641	1.144	2.786
Double row of dry bean, Hp	1.370	1.025	2.395
Single row of dry bean, Lp	1.294	1.262	2.556
Double row of dry bean, Lp	1.247	1.144	2.392
Mean	1.388	1.144	2.532
SEM across seasons	0.147	0.166	0.358
$Prob._{(0.05)}$ across seasons	<0.001	ns	<0.01

Lp and Hp = Dry bean planted at low and high plant population, respectively; SEM = Standard error of means.

Table 4. Variance ratio of testing differences for selected yield parameters for maize and dry bean across the two growing seasons.

Parameters	Maize		Dry bean	
	Grain yield	TAgB yield	Grain yield	TAgB yield!*
Season (S)	36.1***	48.98***	128.57***	nd
Intercrop syst. (Cs)	1.62ns	1.8ns	2.15ns	4.92**
Fertilizer regime (F)	15.6***	23.3***	0.38ns	3.05*
S x F interaction	4.20**	4.72**	0.24ns	nd
S x Cs interaction	0.78ns	1.8ns	3.81**	nd

!* indicates data reported was for 2006/07 season; nd = not determined due to frost action in 2007/08; *, ** and *** indicate significant at 5, 1 and 0.1% probability, respectively; ns = nonsignificant.

rainfall condition in dry land areas. The use of only 2 - 3 sachets of the inoculants is recommended by the manufacturer for the planting of twenty five kilograms of seeds.

The non-significant effect of the different fertilizer regimes on dry bean grain yield may be attributed to the nematode and bacterial blight infestations recorded on the field which consequently impacted negatively on the performance of dry bean plants. This was worsened by the sandy nature of the soil and might have been responsible for the low grain yield obtained during the first year of the study. This problem was however better managed in 2007/08 season with timely application of nematicide (Counter®) on the field at planting, which possibly explained the significantly higher grain yield over the previous season. Regrettably, the synergistic effect of the adjusted low fertilizer rate on dry bean through seed inoculation could not be clearly established in this study. The adjusted low fertilizer regime achieved through seed inoculation could serve as better fertilization strategy to obtain increased maize yield than the traditional farmers' practice of low or none fertilizer use. Ndakidemi et al. (2006) had also reported considerably increased yield following the use of growth stimulants such as bacteria inoculants. However, more studies are currently on for further verification under a wide range of soil and climatic conditions.

The mean value of LER_T across the two seasons, however, were unexpectedly high for a semi-arid environment like Taung but may have arisen due to the supplementary irrigation enjoyed by the crops throughout the growing season. The partial LER values for maize that was generally greater than one particularly during the 2007/08 season could be attributed to both the residual N and the possible transfer of fixed N to maize. The latter had been similarly reported in maize-soybean intercrop by Martin et al. (1991) and Mudita et al. (2008). Hence, the LER values reported in this study for the different intercrop systems underpin the higher grain yield advantages over sole cropping. This explains why resource-poor farmers continue to rely on intercropping as a beneficial practice to guarantee increased productivity and avert risks. Higher productivity under intercrops will promote increased income and availability of diverse foods for farmers.

Conclusion

Our data revealed that integrated planting of single row of dry bean between two maize rows at low bean population with application of adjusted low fertilizer rate appears appropriate and most promising for resource-poor small-scale farmers. This will promote easy and convenient post planting operations; as well as a guaranteed high productivity that is evident in the obtained higher LER_T value than in any other intercrop systems. This will go a long way in promoting increased availability of diverse foods in many rural homes.

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