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Full Length Research Paper

Grain yield and biomass response of a maize/dry bean intercrop to maize density and dry bean variety

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An experiment was conducted under dryland conditions at the University of Limpopo experimental farm at Syferkuil in Capricorn district in 2007/2008 and 2008/2009 growing seasons to determine the effect of maize density and dry bean variety on maize/bean intercrop performance. The trial was at 2 × 2 × 2 factorial consisting of eight treatments: two maize densities (24 700 and 37 000 plants/ha), two dry bean varieties (small white haricot and red speckled sugar bean) and two cropping systems (sole cropping and intercropping). Open pollinated maize variety ZM 523 (ex CIMMYT) was used in the trial. The results showed that maize density of 24 700 plants/ha yielded lower maize grain than the recommended 37 000 plants/ha and maize grain yields in sole cropping were significantly higher than in intercropping in both growing seasons. Intercropping of maize with red speckled sugar bean resulted in lower grain yield than intercropping of maize with small white haricot in both seasons. Increasing maize density to 37 000 plants/ha reduced number of branches per plant and grain yield of dry bean in both seasons. Sole cropping produced the highest dry bean grain yield component values. Intercropping maize and beans was advantageous at the different bean variety x maize density combinations with all, except one, achieving Land Equivalent Ratio (LER) values greater than 1. Intercropping of maize plant density of 37 000 plants/ha with red speckled sugar bean gave the highest total LER value in 2007/2008 season but less than 1 in 2008/2009 season. Intercropping was more advantageous than sole cropping in this study. The highest monetary values were achieved by the bean sole crops and their intercrops with 24 700 plants/ha maize. In this study maize densities of 37 000 and 24 700 plants/ha were found to be suitable for sole maize and maize/bean intercropping, respectively.

Key words: Maize/bean, intercropping, smallholder, maize density, bean variety.

INTRODUCTION

Intercropping is a dominant cropping system practiced by smallholder (SH) farmers in developing countries of Africa, Asia and South America to better utilize limited resources, especially land (Muoneke and Asiegbu, 1997). Intercropping maize or grain sorghum (*Sorghum bicolor*) with leguminous species, mainly cowpea (*Vigna unguiculata)*, common bean (*Phaseolus vulgaris*), groundnuts (*Arachis hypogea*), lablab (*Lablab purpureus*) or bambara groundnut (*Vigna subterranean*) is a common practice among SH farmers in Limpopo Province (Mpangane, 2001). In most cases legume components are very low and cereal components are high (Maluleke, 2004). Most farmers in developing countries have adapted low-input systems mainly for climatic and socio-economic reasons (Okigbo and Greenland, 1976). Mixed cropping of cereals and legumes is widespread in the tropics (Ofori and Stern, 1987) because legumes used in crop production have traditionally enabled farmers to cope with erosion and with declining levels of soil organic matter and available N (Scott et al., 1987). Land productivity measured by land equivalent ratio and monetary gain showed advantages of mixed cropping of cereals and legumes (Mandal et al., 1990).

Plant density is considered one of the most important crop management practices and it affects maize yield by influencing yield components such as a number of ears

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per plant, number of kernels per ear, and seed weight (Ahmadi et al., 1993). The ideal plant number per area depends on several factors such as water availability, soil fertility, control of weeds and diseases, cultivar and row spacing. Under optimum water and nutrient supply, high plant density can result in an increased number of ears per unit area, with eventual increase in grain yield (Bavec and Bavec, 2002). Plant densities that are too low limit the potential yield, and plant densities that are too high lead to increased stress on the plants, which also decrease the yield. Plants planted close together usually have an increased risk of diseases, high percentage of lodging and increased interplant competition for light, water and nutrients. The number of plants that can be supported per unit area is largely dependent upon soil water availability. Most parts of South Africa are characterised by sandy soil, low erratic rainfall and high temperatures (Ayisi et al., 2004) and all of these lead to limited yield production. Ofori and Stern (1987) proposed that the growth and yield of the legume component is remarkably reduced when intercropped with high densities of the cereal component. In a maize/bean intercrop system, the density of maize increased three-fold, from 18, 000 to *55,* 000 plants/ha while the area bean leaf and seed yield reduced by 24 and 70% (Gardiner and Craker, 1981). Mukhala et al. (1999) reported that yield advantages in maize/bean intercropping over the sole cropping were 17, 26 and 15% for the low (4.3 plants/m^2), medium (8.6 plants/m^2) and high plant densities (13.0 plants/m^2), respectively. Mutungamiri et al. (2001) reported that dry bean yields were generally higher with lower maize density and bean cultivar × maize density interaction effects were significant under dryland conditions. They indicated that at two maize spacing's of 90 × 30 and 90 × 45 cm, maize intercropped with Carioca resulted in higher maize yields than with Natal Sugar. Maize yields were lower at 90 × 45 cm spacing than at 90 × 30 cm for both bean cultivars (Mutungamiri et al., 2001).

Productivity of the intercrop can be enhanced through selection of bean cultivars suitable for intercropping as they have different growth habits and growth durations, which may result in different interactions with maize in the intercrop. The work of Santalla et al. (2001) demonstrated that different bean varieties responded differently in terms of yield reduction under intercropping. The bean variety PHA-0009 presented almost identical plant development in intercropping compared to sole cropping, implying tolerance to shedding or competition with the cereal (Santalla et al., 2001). Muoneke et al. (2007) noted that soyabean grain yield was depressed by intercropping with maize. The least depression in soya bean grain yield was in the strip-intercropping with 5 maize rows.

Dry bean is a high value crop on the market and is value as a vegetable protein by low income households in Africa, South Africa included. Development of a viable system for its intercropping with the maize could increase adoption of the system by SH farmers in Limpopo, which is a low rainfall environment, and thus improve their income. Performance of maize/bean intercropping in this environment has not been evaluated. This study was undertaken to determine the response of two bean varieties commonly grown by SH farmers in Limpopo to two maize plant densities. The objective was to test the suitability of either an additive model or a substitution model, focusing on the more aggressive component crop, for maize/dry beans intercropping in a marginal rainfall area.

MATERIALS AND METHODS

The trial was conducted under dryland conditions at the University of Limpopo experimental farm at Syferkuil (23°53°10S, 29°44°15 E) in Capricorn district in 2007/2008 and 2008/2009 growing seasons with total rainfalls of 433 and 452 mm in the respective seasons. The experiment was laid out as a 2 × 2 × 2 factorial arrangement in a Randomized Complete Block Design (RCBD) with four replications. A drought tolerant open pollinated maize variety ZM 523 (ex CIMMYT) was used in the trial. The experiment consisted of eight treatments from three factors: two maize densities: M_1 - sole maize at 90 × 30 cm (37 000 plants/ha) and M_{2}- Sole maize at 90 × 45 cm (24 700 plants/ha), two dry bean varieties: B_{1}-Small white haricot and B_2- Red speckled sugar bean and two cropping systems: Sole cropping and intercropping. Maize plant density of 37 000 plants/ha (90 × 30 cm) is the current general recommendation for sole maize under dryland conditions. Each maize plot had four rows at 90 cm inter-row spacing and 6 m in length. Each sole bean plot had six rows at 60 cm inter-row spacing x 6 m and for all the maize/bean plots bean plants were spaced at 90 cm that is, bean row between maize rows. All beans were planted at in-row spacing of 7.5 cm. Maize/bean plots had three rows of dry bean and four rows of maize. Sole maize plots were (21.6 m^2) while the net plot was two central rows by 4 m (7.2 m^2). The net area of intercropped beans was the central row by 4 m (3.6 m^2). Net area for sole beans comprised of the central two rows by 4 m (4.8 m^2).

The following parameters were measured from the trial: dry matter production and Stover yield, grain yield, harvest index, shelling percentage, land equivalent ratio (LER)(LER= maize intercrop yield/Sole maize yield + Dry bean intercrop yield/Sole bean yield), and monetary value. Monetary value was calculated using the price of R1050/ton for maize and R4020/ton for dry bean (1US$ = R7.60) in both seasons. For harvest index (HI), a sample of ears from rows was oven dried at 65℃ for 72 h, sh elled and grain weighed. HI = Grain yield/Total above-ground biomass.

Data were subjected to analysis of variance (ANOVA) using the General Linear Model procedure of Statistical Package of Social Sciences (SPSS 17.0). Differences between treatment means were separated using the Least Significant Difference ($LSD_{0.05}$) procedure (Gomez and Gomez, 1984). Biological performance of the intercrop treatments was evaluated using the land equivalent ratio (LER) method (Mead and Willey, 1980).

RESULTS AND DISCUSSION

In the 2007/2008 season interaction of bean variety with maize density and that of bean variety with cropping system did not influence number of pods per plant, number of seed per pod, 100 seed weight, shelling

Table 1. Number of pods per plant, number of seeds per pod, 100 seed weight, shelling percentage and grain yield of drybean as influenced by interaction of bean variety with maize density and bean variety with cropping system in 2007/2008 season.

Bean variety	Maize density	No. of pods/plant	No. of seeds/pod	100 seed weight (kg)	Shelling (%)	Yield (kg/ha)
Small white haricot	37000 plants/ha	6.64	4.51	0.033	69.54	661
	27400 plants/ha	10.20	4.33	0.031	76.29	914
Red speckled	37000 plants/ha	8.20	4.73	0.046	69.81	795
	27400 plants/ha	9.93	4.13	0.046	72.27	1092
LSD (5%)		NS	NS	NS	NS	NS
CV %		35.3	19.2	28.8	28.8	68.2
Bean variety	**Cropping system**					
Small white haricot	Sole cropping	8.60	4.47	0.032	66.38	1035
	Intercropping	8.42	4.42	0.032	72.92	788
Red speckled	Sole cropping	12.13	6.00	0.048	91.67	1683
	Intercropping	9.07	4.93	0.046	71.04	943
LSD (5%)		NS	NS	NS	NS	NS
CV%		32.2	18.2	8.7	27.5	52.6

ns = non significant. Means followed by the same letter in the same column are not significantly different from each other at 5% level.

percentage and grain yield (Table 1). Bean intercropped with 24 700 plants/ha maize achieved the highest grain yield whilst small white haricot at 37 000 plants/ha of maize had the lowest grain yield (Table 1).

Maize density and bean variety interaction showed a significant influence on dry bean 100 seed weight; shelling percentage and grain yield in 2008/9 season but had no influence on leaf chlorophyll content, number of branches per plant, number of pods per plant and number of seeds per pod (Table 2). Both bean varieties achieved higher yields at the lower maize density of 24 700 plants/ha in both seasons. These results are similar to those of Mutungamiri et al. (2001) where bean yields of two varieties were generally higher with lower maize density. Gardiner and Craker (1981) also reported reduction of bean leaf area by 24% and seed yield by 70% after they tripled maize density from 18 000 to 55 000 plants/ha. In Limpopo Province, SH farmers have been reported to intercrop with maize densities of 5 000 to 29 000 plants/ha (Lephale et al., 2008). Bean variety and maize density interaction effects at these lower maize densities may be more relevant for SH farmers in the province.

Red speckled sugar bean had a significantly superior 100-seed weight than small white haricot. This was expected as red speckled sugar bean is a large seeded cranberry type. Maize density did not influence 100-seed weight of both bean varieties (Table 2). Seed size is a genetic trait hence it is unlikely to respond to neither maize density nor cropping system. Shelling percentage of red speckled sugar bean was not influenced by both maize densities. It was also not influenced by interactions of small white haricot with both maize densities and interaction of red speckled sugar bean and 37 000 plants/ha. Red speckled sugar bean with 24 700 plants/ha achieved the highest shelling percentage which was significantly higher than for small white haricot at both maize densities (Table 2).

The two bean varieties achieved similar yield levels when intercropped with 24 700 plants/ha maize. The highest bean grain yield was obtained by red speckled sugar bean at 24 700 plants/ha and this was higher than when intercropped with 37 000 plants/ha maize. These results indicate that the bean component crop fares better under reduced maize density. This agrees with Mukhala

Table 2. Effect of bean variety with maize density and bean variety with cropping system interactions on leaf chlorophyll content, number of branches per plant, number of pods per plant, number of seeds per pod, 100 seed weight, shelling percentage and grain yield of dry bean in 2008/2009 season.

Bean variety	maize density	Leaf chlorophyll content (nm)	No. of branches/plant	No. of pods/plant	No. seeds/pod	100 seed weight	Shelling (%)	Yield (kg/ha)
Small white haricot	37000 plants/ha	30.18	5.25	8.25	5.15	0.025[c]	70.18[b]	1569[b]
	24700 plants/ha	28.68	3.95	6.40	4.10	0.027[b]	68.50[b]	1978[ab]
Red speckled	37000 plants/ha	25.76	4.00	5.45	5.25	0.042[a]	71.43[ab]	1540[b]
	24700 plants/ha	26.91	4.25	9.10	4.80	0.050[a]	78.65[a]	2974[a]
LSD (5%)		ns	ns	ns	ns	0.01	8.43	1242
CV %		14.9	30.9	39.24	18.9	3.55	7.8	41.9
Bean variety	**Cropping system**							
Small white haricot	Sole cropping	28.97	5.30	8.30	6.00[a]	0.030[bc]	69.48	2626
	Intercropping	29.43	4.60	7.33	4.63[b]	0.026[c]	69.34	1759
Red speckled	Sole cropping	26.89	4.90	8.90	5.55[ab]	0.042[ab]	69.58	2219
	Intercropping	26.33	4.13	7.28	5..03[ab]	0.046[a]	75.04	2271
LSD (5%)		ns	ns	ns	1.34	0.008	ns	ns
CV %		15.1	28.5	36.0	17.2	5.2	7.9	37.2

ns = non significant. Means followed by the same letter in the same column are not significantly different from each other at 5% level.

et al. (1999) who reported that maize/bean intercropping reduced the yield of beans significantly by 59, 66 and 72%, respectively, at low, medium and high maize density. This yield reduction can be explained by increased com-petition for growth factors, particularly light and moisture, which is likely to reduce the legume component of the intercrop Bean variety and cropping system interaction significantly influenced number of seeds per pod, but did not influence leaf chlorophyll content, number of branches per plant, number of pods per plant, 100 seed weight, shelling percentage and grain yield of beans in 2008/2009 season (Table 2). There was only a significant difference in number of seeds per pod between sole and intercropped small white haricot. Both bean varieties achieved higher number of seeds per pod in sole cropping than in intercropping. Low number of seeds per pod in intercropping might be due to competition of resources such as solar radiation, water and nutrients. The differences were small as expected since this trait is mostly genetic.

Interaction of bean variety with maize density did not significantly influence plant height, cob height, number of cobs per plant, total above ground dry matter, stover, shelling percentage, harvest index and grain yield of maize but significantly influenced number of cobs per plant in 2007/2008 season (Table 3). Intercropping small white haricot at 24 700 plants/ha maize had higher number of cobs per plant than plants intercropped with red speckled sugar bean at both maize densities. There was no significant difference in number of cobs per plant for the two maize densities intercropped with small white haricot (Table 3).

In 2007/2008 season interaction of cropping system with maize density significantly influenced cob height, total above ground dry matter and shelling percentage but had no significant influence on maize plant height, number of cobs per plant, stover, harvest index and grain yield (Table 3). Total above ground dry matter and shelling percentage of maize had similar levels across all bean variety and maize density interactions (Table 3). There was a significant difference of total above ground dry matter and

Table 3. Plant height, number of cobs per plant, cob height, total above ground dry matter, stover, shelling percentage, harvest index and grain yield of maize as influenced by interaction of bean variety with maize density and cropping system with maize density in 2007/2008 season.

Bean variety	Maize density	Plant height (cm)	No. of cobs/plant	Cob height (cm)	Total above ground DM (t/ha)	Stover (t/ha)	Shelling (%)	Harvest index	Yield (kg/ha)
Small white haricot	37000 plants/ha	2.01	1.33[ab]	83.07	10.69	3.84	80.35	0.24	3583
	24700 plants/ha	1.97	1.53[a]	79.33	9.26	3.84	80.63	0.23	2984
Red speckled	37000 plants/ha	2.01	1.13[b]	82.67	10.37	4.72	80.29	0.23	3249
	24700 plants/ha	2.04	1.27[b]	85.80	10.37	4.40	79.28	0.20	2879
LSD (5%)		ns	0.24	ns	ns	ns	ns	ns	ns
CV (%)		6.9	10.19	14.3	14.3	18.8	1.18	14.1	16.4
Cropping system	**Maize density**								
Sole cropping	37000 plants/ha	1.95	1.20	93.67[a]	13.10[a]	5.93	81.77[a]	0.201	3674
	24700 plants/ha	1.85	1.33	79.07[b]	10.53[ab]	4.44	80.32[ab]	0.201	3113
Intercropping	37000 plants/ha	2.01	1.23	82.87[b]	11.20[ab]	4.12	80.59[ab]	0.236	3416
	24700 plants/ha	2.01	1.40	82.57[b]	9.82[b]	4.28	79.95[b]	0.215	2931
LSD (5%)		ns	ns	9.30	2.65	ns	2.45	ns	ns
CV (%)		7.0	10.4	4.9	13	16.8	1.67	15	15.8

ns = non significant. Means followed by the same letter in the same column are not significantly different from each other at 5% level.

shelling percentage between sole cropping of 37 000 plants/ha maize and intercropping with 24 700 plants/ha of maize. Total above ground dry matter and shelling percentage of maize were highest in sole cropping of 37 000 plants/ha of maize than in 24 700 plants/ha. Interaction of bean variety and maize density also did not influence plant height, cob height and number of cobs per plant, shelling percentage and grain yield of maize in 2008/2009 season (Table 4). Maize at 37 000 plants/ha intercropped with small white haricot achieved a significantly higher total above ground dry matter and maize stover than maize at 24 700 plants/ha intercropped with small white haricot and that intercropped with red speckled sugar bean at 37000 plants/ha maize in 2008/2009. There was no significant difference of total above ground dry matter and maize stover between maize at 24 700 plants/ha intercropped with small white haricot and the two maize densities intercropped with red speckled (Table 4). Sole cropping resulted in higher total above ground dry matter and stover than intercropping in the two seasons (Tables 3 and 4). Total above ground dry matter and stover increased with increasing plant density. Moriri (2008) obtained similar results where there was an increase in maize stover from 3129, 8673, 12206 and 13484 kg/ha respectively at 10 000, 20 000, 30 000 and 40 000 plant density, respectively. Any treatment that results in an increase in stover are likely to be adopted by SH farmers since they depend on stover as fodder for livestock during winter.

The harvest indices obtained in both seasons were rather low as reflected in the maize grain yields, particularly in the 2007/2008 season. Moriri (2008) reported higher harvest indices in the range of 27.3 to 44.6% in her maize/cowpea intercropping trials at Syferkuil.

Maize density by bean variety interaction effects was significant for maize yields in 2008/2009 season. In both seasons at both maize densities, maize intercropped with small white haricot resulted in higher maize yields than red speckled sugar bean. Maize yields were higher at 37 000 plants/ha than 24 700 plants/ha in both seasons with both bean varieties. These results agree with those of Mutungamiri et al. (2001) where maize

Table 4. Plant height, cob height, number of cobs per plant, total above ground dry matter, Stover, shelling percentage, harvest index and grain yield of maize as influenced by interaction of bean variety with maize density and cropping system with maize density in 2008/2009 season.

Bean variety	Maize density	Plant height (cm)	Cob height (cm)	No. of cobs/plant	Total above ground DM (t/ha)	Stover (t/ha)	Shelling (%)	Harvest index	Yield (kg/ha)
Small white haricot	37000 plants/ha	176.55	60.70	1.35	7.36[a]	4.86[a]	80.50	0.33	3380[a]
	24700 plants/ha	155.10	51.80	1.43	4.45[b]	2.92[b]	80.77	0.31	1938[ab]
Red speckled	37000 plants/ha	158.20	51.35	1.15	3.79[b]	3.33[b]	80.83	0.30	2023[ab]
	24700 plants/ha	178.20	65.35	1.18	4.86[ab]	4.10[ab]	79.93	0.28	1556[b]
LSD (5%)		ns	ns	ns	2.89	1.19	ns	ns	1816
CV (%)		10.7	17.5	21.3	37.5	20.8	2.1	20.7	54.2
Cropping system	**Maize density**								
Sole cropping	37000 plants/ha	183.70[ab]	61.60	1.28	6.39[ab]	2.19[b]	81.40	0.32	2969
	24700 plants/ha	197.10[a]	68.85	1.60	7.95[a]	2.29[b]	82.85	0.33	3658
Intercropping	37000 plants/ha	167.38[b]	56.03	1.25	5.57[ab]	4.10[ab]	80.66	0.32	2468
	24700 plants/ha	166.65[b]	58.58	1.30	4.65[b]	3.51[a]	80.35	0.30	1980
LSD (5%)		26.99	ns	ns	2.89	2.89	ns	ns	ns
CV (%)		10.0	20.1	20.1	31.2	26.2	2.1	20.1	43.5

ns = non significant. Means followed by the same letter in the same column are not significantly different from each other at 5% level.

yields were significantly lower at 90 × 45 cm spacing than at 90 × 30 cm for both Carioca and Natal sugar bean cultivars. In this study maize density of 37 000 plants/ha intercropped with small white haricot gave the highest maize yields in both seasons.

The maize yield levels attained in this trial are quite reasonable for low input production. The maize yields clearly show that interaction between dry bean variety and maize density is important. The results from this study suggest that red speckled sugar bean offers more competition to the maize. It is necessary to test interaction of maize density levels and red speckled bean population levels, since sugar bean is the most preferred type.Evaluation of maize and bean productivity in the different treatments is given in Table 5. The results show modest reduction in maize yield due to intercropping as seen in high PLER values for maize in 2007/2008. Maize PLER values in 2008/2009 were lower especially for maize intercropped with sugar bean (Table 5). PLER values for dry bean were lower for both bean varieties at the higher maize population in both seasons. This clearly shows the effect of maize density on dry bean productivity in a maize/bean intercrop. As then expected, dry bean yields were higher at the lower maize density in both seasons (Table 5).

In 2007/2008 season, all the intercrop combinations achieved LER values ranging from 1.49 to 1.76, implying that intercropping was far more productive than growing sole crops. In 2008/9 season LER values ranged from 0.94 to 1.40. The intercrops of red speckled sugar bean with maize at 37 000 plants/ha achieved LER value less than 1.0, implying that it would have been more productive to grow individual crops than to intercrop them. These results suggest that red speckled should be intercropped with lower maize densities than 37 000 plants/ha. Ofori and Stern (1987) reported reduction of bean yield with increased cereal density. The results from this study also agree with those of Mutungamiri et al. (2001) who reported similar dry bean variety by maize density interactions. Further studies should consider looking at testing more bean varieties at more maize plant densities since bean variety ×

Table 5. Productivity of maize/bean intercrops in response to maize density, bean variety and cropping system in 2007/2008 and 2008/2009 seasons at Syferkuil.

Treatment	2007/2008 growing season					2008/2009 growing season				
	Maize		Bean		LER	Maize		Bean		LER
	Yield (kg/ha)	Partial LER	Yield (kg/ha)	Partial LER		Yield (kg/ha)	Partial LER	Yield (kg/ha)	Partial LER	
Sole maize - 37000 plants/ha (M1)	3674	-	-	-	-	3658	-	-	-	-
Sole maize - 24 700 plants/ ha (M2)	3583	-	-	-	-	3379	-	-	-	-
Sole drybean - small white haricot (B1)	-	-	1092	-	-	-	-	2626	-	-
Sole drybean - red speckled (B2)	-	-	1083	-	-	-	-	2974	-	-
M1B1	3249	0.88	661	0.61	1.49	2969	0.81	1540	0.59	1.4
M1B2	3113	0.85	795	0.73	1.58	1556	0.43	1569	0.53	0.94
M2B1	2984	0.83	914	0.84	1.67	2023	0.6	1979	0.75	1.35
M2B2	2879	0.8	1035	0.96	1.76	1938	0.57	2219	0.75	1.32

Table 6. Monetary value of sole and intercropped bean and maize as influenced by drybean variety and maize density at Syferkuil.

Treatment	Monetary value (Rand/ha)					
	2007/2008			2008/2009		
	Bean	Maize	Total	Bean	Maize	Total
Sole maize - 37000 plants/ha (M1)	-	3858	3858	-	3841[a]	3841[b]
Sole maize - 24 700 plants/ha (M2)	-	3269	3269	-	3548[a]	3548[b]
Sole drybean - small white haricot (B1)	4264	-	4264	11340[ab]	-	11340[ab]
Sole drybean - red speckled (B2)	6934	-	6934	11857[a]	-	11857[a]
M1B1	2725	3763	6487	6346[b]	3118[ab]	9464[a]
M1B2	3274	3412	6686	6465[b]	1633[b]	8098[ab]
M2B1	3764	3133	6898	8151[ab]	2124[ab]	10275[a]
M2B2	4498	3023	7520	9814[ab]	2035[ab]	11849[a]
LSD (5%)	ns	ns	ns	5290	1907	4472
CV (%)	57	16	40	40	47	40

ns = non significant. Means followed by the same letter in the same column are not significantly different from each other at 5% level.

maize density interaction was significant. Further studies should also be conducted on-farm so that farmer evaluation can be captured. There is need for a more detailed survey on current maize/bean intercropping in the SH farming sector of Limpopo focusing on component crop densities and arrangement and on diseases and pests. This can better guide future research.

The relatively high PLER values for beans in this study suggest that inter-row intercropping may be the planting pattern to adopt in order to reduce component crop competition. This agrees with Mutungamiri et al. (2001) who reported lower maize yields when beans were planted in the same row as maize than when beans were planted in alternate rows with maize. The results of this study also suggest that red speckled sugar bean is more aggressive than small white haricot and that adoption of the substitution model is likely to be more successful than the additive model of maize/bean intercropping under dryland conditions, particularly those of marginal rainfall. That model requires a balance in the reduction of maize plant density with the dry bean plant population.

From a monetary value perspective, the most profitable treatments were sole red speckled sugar bean, sole small white haricot bean, and intercropping both bean varieties with 24 700 plants/ha maize (Table 6). Table 6 shows that in the 2007/2008 season intercropping had the potential to double returns to the farmers if they sold all their produce. The results for 2008/9 season again show the high monetary productivity of all intercropping treatments over maize sole crops. The higher value dry bean also generated the highest returns as sole crops. The lowest monetary values were for sole maize at both densities. These results strongly justify reduction of maize plant density from the recommended 37 000 plants/ha for sole maize in maize/bean intercropping. Maize yields may be higher but the crop has a considerably lower value than dry beans. Lowering maize yields also reduces moisture stress for the intercrop in marginal rainfall environments such as Limpopo. Although sole dry beans generated the highest levels of income, smallholder farmers in Zimbabwe do not plant sole dry bean as they are prone to vertebrate pest (rabbits, impala etc.) damage unlike the intercropped beans which are not attacked by the same animals (Mutungamiri et al., 2001). Land scarcity may also preclude adoption of sole dry bean in Limpopo since maize is the staple food.

Some parameters measured in this study had relatively high coefficients of variation of around 50%. This reflects the variability in crop growth under moisture stress conditions. Future studies in similar environments should increase the number of replicates to at least five to enhance precision in the evaluation of treatments.

Conclusion

Results show that 37 000 plants/ha produces higher maize yields than 24 700 plants/ ha in monoculture. For intercropping with dry bean, 24 700 plants/ha, and probably less maize densities, is more suitable. Dryland maize/bean intercropping is feasible in the marginal rainfall areas if Limpopo Province, with about 500 mm of rainfall, provided a substitution model is adopted to control intercrop demand for production factors. The two bean varieties tested are equally suitable for dryland maize/bean intercropping. Maize stover is slightly reduced by intercropping with dry bean. Maize/bean intercropping was clearly superior to sole maize in terms of monetary returns.

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