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Response of a maize or dry bean intercrop to maize density and dry bean arrangement under rainfed conditions

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Key words: Dry bean arrangement, Grain yield, Intercropping, Maize density.

Abstract

An experiment was conducted under dryland conditions at the University of Limpopo experimental farm, Syferkuil, in Capricorn district in 2009/10 and 2010/11 growing seasons to determine the effect of maize density and dry bean arrangement on performance of a maize/bean intercrop. The trial was a 2 x 3 factorial arrangement consisting of ten treatments: three maize densities (18500, 24700 and 37000 plants/ha), and two dry bean arrangements (single and double row arrangement). Sole treatments were added to enable comparison of the performance of sole crops and intercrops. Maize density of 18500 plant/ha achieved significantly ($P<0.05$) lower maize yield than 24700 and 37000 plants/ha in both seasons. Intercropping with double rows of dry bean resulted in higher maize yield in both seasons. The Combination of 37000 plants/ha with double arrangement achieved highest maize yield in both seasons. Maize density of 24700 plants/ha produced higher dry bean yield than 18500 and 37000 plants/ha. The double row bean arrangement resulted in higher dry bean grain yield in both seasons. The combination of 24700 plants/ha and double row arrangement attained the highest dry bean yield in both seasons. Intercropping achieved LER values greater that one. Maize density of 37000 plants/ha with double row of dry bean gave the highest LER value of 1.76 in 2009/10 season while in 2010/11 maize density of 18500 plants/ha with double row of dry bean arrangement achieved the highest LER value of 1.92. Maize/bean combination of 37000 plants/ha maize with double row arrangement of dry bean is recommended.

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Introduction

Maize (*Zea mays* L.) is the principal summer cereal crop grown by many smallholder farmers in either mixed or sole cropping systems and is also a priority crop to farmers because it is the staple food in many rural communities of South Africa. Regardless of its importance in South Africa, its production by smallholder (SH) farmers is declining due to low and erratic rainfall and pest attack (Pandey, 2000), and declining soil fertility caused by continuous monocropping of maize and inadequate fertilization of crops. Intercropping 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). However, plant density is one of the most important agronomic management decisions to consider when deciding to practice intercropping. Craufurd (2000) noted that poor management of planting density could be detrimental to intercropping. Plant densities that are too low limit the potential yield, and plant densities that are too high lead to increased stress on the plant, and increased interplant competition for light, water and nutrients (Ayisi *et al.*, 2004) which also decreases the yield. The other important management aspect is spatial arrangement which can improve radiation interception through more complete ground cover and determine whether an intercrop system will be advantageous or not with regard to yield gains. According Mutungamiri *et al.* (2001), a bean spatial arrangement of two bean rows in between maize rows and beans planted in the same row as maize gave lower maize yield than where bean was planted in alternate rows with maize. The other reports has differed with the findings as it indicates that planting two rows of soybean after one row of maize was the best arrangement over single alternate rows (Ofori and Stern, 1987), and also according to Banik and Sharma (2009), a wide range of other legume-maize intercrops have been found to respond better to two rows of legume after one row of maize. However, the greater challenge for researchers is to find the correct combination of intercropping pattern and planting density that will maintain or enhance growth and yield of maize under increased population of legume in the intercrop (Moriri *et al.*, 2010). Most of the maize produced by SH farmers in the Province is grown as intercrops with grain legumes, mostly cowpea and dry bean. Since lack of arable land is a constraint, optimizing intercropping performance can assist in effective use of space and nutrients. The study was therefore undertaken to determine the optimum combination of maize density and dry bean arrangement that can maximize yield of the intercrop system under marginal rainfall conditions.

Materials and methods

Trial site

The trial was conducted under dryland conditions at the University of Limpopo experimental farm, Syferkuil (23° 53' 10"S, 29° 44' 15"E) in the Capricorn district during 2009/10 and 2010/2011 growing seasons. The experimental farm is characterized by hot dry summer, cool dry winter and the soil is sandy-loam. The rainfall and temperature data at Syferkuil in the two seasons are given in Figure1 and Table 1.

Experimental design and treatments

The treatments were laid out as a 2 x 3 factorial arrangement in randomized complete block design with three replications over two seasons. The experiment consisted of ten treatments from two factors, three maize densities: M_1- Maize at (90 x 30 cm – 37000 plants/ha), M_2- Maize at (90 x 45 cm – 24700 plants/ha), and M_3- Maize at (90 x 60 cm - 18500 plants/ha) and two dry bean arrangements: L_1- one row of dry bean between maize and L_2- two rows of dry bean between maize. Sole treatments of the two crops were added to enable comparison of the performance of sole crops and intercrops.

Trial management

Both maize and dry bean were planted by hand on the same day. There was no fertiliser application in the trials. Weeding was done by means of hoeing twice at two and five weeks after planting in both seasons. Pests, notably aphids, were controlled immediately they were discovered using Malathion 50EC. The trial received survival irrigation only and data were collected throughout the trial period.

Maize data collected included : days to 50% germination, days at 50% tasseling, days to physiological maturity, plant height (5 plants/plot), number of cobs per plant (5 plants/plot), cob height (5 plants/plot), total above ground biomass, grain yield and harvest index (grain yield / total above ground biomass). Dry bean data included; days to 50% flowering, days to physiological maturity, number of primary branches per plant (5 plants/plot), number of pods per plant (5 plants/plot), number of seeds per pod (5 pods/plot), 100 seed weight, grain yield and shelling percentage.

Intercropping efficiency was evaluated using the land equivalent ratio (LER) and aggressivity indices were determined to evaluate competition between the intercropped species.

LER $=Y_{ab}/Y_{aa} + Y_{ba}/Y_{bb}$. Where Y_{ab} and Y_{ba} are the individual crop yields in intercropping of crop 'a' and 'b', respectively, and Y_{aa} and Y_{bb} are their respective yields as sole crops.

Aggressivity, $A_{ab} = Y_{ba}/ Y_{bb}xZ_{ba} - Y_{ab}/Y_{aa}xZ_{ab}$. Where Y_{ab} and Y_{ba} are the respective individual yields of crops 'a' and 'b' in intercropping and Y_{aa} and Y_{bb} are their yields as sole crops. Z_{ab} and Z_{ba} are the proportions of the land occupied in intercropping when compared to sole crop for species crop 'a' and 'b', respectively.

Monetary value of grain yield was calculated using the price of R1907/ton for maize and R4224/ton for dry bean in 2010 (1US$ = R10-00). Same Safex prices were also used in 2011.

The data were subjected to ANOVA through the general linear model of Statistix 9.0 package. Mean comparisons were done using the least significant difference (LSD) method at the 5% probability level.

Results and discussion

Weather conditions at experimental location

The two seasons in which the experiment was conducted were considerably drier than the long-term average rainfall for Syferkuil, having recorded 65.7 and 73.1% of the long-term average rainfall in the 2009/10 and 2010/11 seasons, respectively. The rainfall recorded over the two growing seasons typifies marginal rainfall conditions experienced in most of South Africa. The rainfall peaks in 2009/10 and 2010/11 were in January and December, respectively. In 2010/11, the average rainfall during planting in December was higher (197.04 mm) as compared to 2009/10 (33.04 mm). The rainfall was poorly distributed during the flowering stage of both crops in February in both seasons (Figure1). There was little variation in temperature between the months in both seasons; however the maximum temperature of both seasons was reasonably similar as compared to long-term average temperature of 28°C (Figure 1).

Dry bean yield and yield components

Dry bean arrangement did not significantly affect number of pods per plant, number of seeds per pod, and 100 seeds weight in both seasons (Table 2). Dry bean arrangement only influenced grain yield in 2010/11 season where the double row arrangement significantly ($P<0.05$) outyielded (+40.8%) the single row arrangement. This was expected given that the double row arrangement achieved significantly ($P<0.05$) higher plant density in both seasons (Table 3).Although not significantly different, the double row arrangement also achieved a higher grain yield than the single row arrangement in the 2009/10 season. The results agree with Addo-Quaye *et al.* (2011) who reported 50% increase in grain yield when double row of soybean alternated with single row of maize than when planted in alternate row arrangement. Undie *et al.* (2012) also reported 74% yield increase in 1:2 (maize: soybean) arrangement relative to 1:1 arrangement. Banik and Sharma (2009) indicated that a wide range of other legume-maize intercrops have been found to respond better to two rows of legume after one row of maize. This perhaps could be due to light interception which resulted in higher photosynthesis and consequently a higher grain yield in the double row arrangement. This is supported by Prasad and Brook, (2005) on maize/soybean; and Jiao *et al.*, (2008) on maize/groundnut, who reported that light interception by the legume grown in paired rows with maize was greater than when arranged in single alternative rows. Double rows of the legume also have potential for better weed suppression and moisture conservation.

Table 1. Mean monthly maximum and minimum temperatures during 2009/10 and 2010/11 growing seasons.

	2009/10 season		2010/11 season	
Month	Max(^{o}C)	Min(^{o}C)	Max (^{o}C)	Min (^{o}C)
December	28.8	16.15	27.56	15.98
January	27.98	17.22	26.56	16.89
February	27.84	16.58	26.46	14.48
March	28.73	14.95	28.82	14.89
April	23.79	13.9	23.95	12.12
May	24.23	8.69	23.72	6.99
June	21.23	1.75	21.58	1.26

Table 2. The influence of dry bean arrangement, maize density and their interaction on the number of pods/plant, number of seeds/pod, 100 seeds weight and grain yield of dry bean in 2009/10 and 2010/11 growing seasons.

		2009/10 growing season				2010/11 growing season			
Dry bean arrangement		No. of pods/plant	No. of seed/pods	100 seeds weight (g)	Grain yield (kg/ha)	No. of pods/plant	No. of seed/pods	100 seeds weight (g)	Grain yield (kg/ha)
1 row of dry bean between maize rows (L_1)		6.99	4.18	25.10	586.85	6.26	4.11	26.13	476.0^{b}
2 rows of dry bean between maize rows (L_2)		5.89	4.11	24.27	636.39	6.21	3.91	25.73	670.2^{a}
$LSD_{(0.05)}$		ns	ns	ns	ns	ns	ns	ns	103.2
Maize density Plant ha^{-1}									
37000 (M_1)		6.53	4.03	24.58	619.40	7.15^{a}	4.07	24.37^{c}	519.1^{b}
24700 (M_2)		6.67	4.37	24.68	635.37	6.38^{a}	4.13	27.57^{a}	701.4^{a}
18500 (M_3)		6.12	4.03	24.78	580.09	5.17^{b}	3.83	25.87^{b}	498.8^{b}
LSD $_{(0.05)}$		ns	ns	ns	ns	0.77	ns	1.02	126.4
Dry bean arrangement	Maize density Plant ha^{-1}								
	M_1	7.40	4.07	25.27	617.31	8.00^{a}	4.33	24.20^{b}	448.4^{bc}
L_1	M_2	6.93	4.73	23.47	602.59	5.13^{c}	4.33	27.23^{a}	691.3^{a}
	M_3	6.63	3.73	26.57	540.65	5.63^{bc}	3.67	26.98^{a}	288.3^{c}
	M_1	5.67	4.00	20.90	621.48	6.30^{b}	3.80	24.53^{b}	589.7^{ab}
L_2	M_2	6.40	4.00	25.90	668.15	7.63^{a}	3.93	27.90^{a}	711.5^{a}
	M_3	5.60	4.33	23.00	619.54	4.70^{c}	4.00	24.77^{b}	709.5^{a}
LSD $_{(0.05)}$		ns	ns	ns	ns	1.09	ns	1.44	178.80
CV $_{\%}$		21.56	15.85	8.01	17.28	9.62	15.86	3.06	17.15

ns = non significant.

Dry bean arrangement significantly ($P<0.05$) affected plant density in both seasons and shelling % in 2010/11 season. Dry bean plant density of the double row arrangement was significantly higher than for the single row in both seasons. This was expected. Dry bean arrangement did not significantly influence number of primary branches in both seasons (Table 3) but the lighter plant density had higher number of primary branches per plant. This was expected as sparsely populated grain legume plants normally compensate for the low density through better growth. The results are in agreement with Sedaghathoor and Janatpoor (2012), who reported that the number of branches was decreased by double-row planting pattern in soybean. Ciftci *et al.* (2006) and Majnoun-Hosseini *et al.* (2001) also reported similar results about number of branches in maize/bean and maize/soybean intercrops, respectively.

Table 3. Number of plants/m², number of primary branches, and shelling percentage of dry bean as influenced by dry bean arrangement, maize density and their interaction.

Dry bean arrangement		2009/10 growing season Plants/ m²	No. of Primary branches	Shelling %	2010/11 growing season Plants/m²	No. of Primary branches	Shelling %
1 row of dry bean between maize rows (L_1)		27.34[b]	4.09	64.78	28.64[b]	4.56	59.33[b]
2 rows of dry bean between maize rows (L_2)		41.54[a]	3.88	68.78	41.67[a]	4.33	68.33[a]
$LSD_{(0.05)}$		3.07	ns	ns	3.05	ns	4.62
Maize density Plant ha^{-1}							
37000 (M_1)		31.94[b]	3.77	69.50	36.11	4.53	59.00[b]
24700 (M_2)		34.17[ab]	4.15	63.17	35.00	4.52	68.17[a]
18500 (M_3)		37.22[a]	4.03	67.67	34.35	4.28	62.00[b]
LSD $_{(0.05)}$		3.77	ns	ns	ns	ns	5.66
Dry bean arrangement	Maize density Plant ha^{-1}						
	M_1	25.18[c]	3.73	69.67	29.26[b]	4.40	54.33[b]
L_1	M_2	25.74[c]	4.33	61.00	28.52[b]	4.63	69.00[a]
	M_3	31.11[b]	4.20	63.67	28.15[b]	4.63	54.67[b]
	M_1	38.71[a]	3.80	69.33	42.96[a]	4.67	68.33[a]
L_2	M_2	42.59[a]	4.97	65.33	41.48[a]	4.40	67.33[a]
	M_3	43.33[a]	3.87	71.67	40.56[a]	3.93	69.33[a]
LSD $_{(0.05)}$		5.31	ns	ns	5.29	ns	7.99
$CV_{\%}$		8.51	15.01	10.02	8.27	15.91	6.89

ns = non significant.

Maize density did not influence dry bean yield and yield components in 2009/10 season (Tables 2). Number of pods per plant, 100 seed weight, shelling % and grain yield were significantly influenced by maize density in 2010/11 season (Tables 2 and 3). Number of pods per plant were similar under 24700 and 37 000 plants/ha maize and these were significantly ($P<0.05$) higher than under 18 500 plants/ha maize. This is surprising as one expected more pods on bean plants under lighter maize density. Dry bean seed size was highest under 24700 plants/ha maize and lightest under 37000 plants/ha maize, with intermediate value for 18 500 plants/ha maize. Dry bean yield was highest under 24700 plants/ha maize (Table 2). Grain yield of dry bean would be expected to be highest under the lighter maize density of 18 500 plants/ha which is expected to offer minimal competition for growth factors to the dry bean plants. Similarly, Mutungamiri *et al.* (2001) reported that maize density of 90 x 45 cm with two rows of beans in between gave the highest dry bean yields as compared to the higher maize density of 90 x 30 cm.

Table 4. The effect of maize density, dry bean arrangement and their interaction on the biomass, grain yield and harvest index of maize.

Maize density plant $^{ha-1}$		2009/10 growing season Biomass (kg/ha)	Grain yield (kg/ha)	Harvest Index (HI)	2010/11 growing season Biomass (kg/ha)	Grain yield (kg/ha)	Harvest Index (HI)
37000 (M_1)		2314.9^{a}	1318.4^{a}	0.58^{a}	2569.4^{a}	1388.8^{a}	0.54^{a}
24700 (M_2)		2407.4^{a}	1221.7^{a}	0.52^{a}	2523.2^{a}	1077.1^{b}	0.44^{b}
18500 (M_3)		1666.7^{b}	640.4^{b}	0.38^{b}	1574.1^{b}	656.5^{c}	0.42^{b}
LSD $_{(0.05)}$		470.5	218.13	0.09	544.87	243.92	0.07
Dry bean arrangement							
1 row of dry bean between maize rows (L_1)		1990.7	1121.0	0.50	2114.2	921.9^{b}	0.44
2 rows of dry bean between maize rows (L_2)		2268.5	999.4	0.48	2330.3	1159.7^{a}	0.49
LSD $_{(0.05)}$		ns	ns	ns	ns	199.16	ns
Dry bean arrangement	Maize density plant $^{ha-1}$						
	M_1	2129.6^{ab}	1219.8^{a}	0.57^{a}	2222.2^{ab}	1172.5^{b}	0.53^{a}
L_1	M_2	2175.9^{ab}	1147.4^{a}	0.54^{a}	2546.3^{a}	938.1^{bc}	0.37^{c}
	M_3	1666.7^{b}	630.9^{b}	0.38^{b}	1574.1^{b}	655.0^{c}	0.42^{bc}
	M_1	2500.0^{a}	1417.1^{a}	0.57^{a}	2916.7^{a}	1605.0^{a}	0.54^{a}
L_2	M_2	2638.9^{a}	1295.9^{a}	0.49^{ab}	2500.0^{a}	1216.1^{b}	0.50^{ab}
	M_3	1666.7^{b}	649.9^{b}	0.39^{b}	1574.1^{b}	658.0^{c}	0.42^{bc}
LSD $_{(0.05)}$		665.33	308.48	0.12	770.56	344.95	0.095
CV$_{\%}$		17.17	15.99	14.87	19.06	18.22	11.25

ns = non significant.

Table 5. Cob height, plant height, and number of plants/m^2 of maize as influenced by dry bean arrangement, maize density and their interaction.

Maize density plant $^{ha-1}$		2009/10 growing season Cob height (m)	Plant height (m)	Plants/ m^2	2010/11 growing season Cob height (m)	Plant height (m)	Plants/m^2
37000 (M_1)		0.59	1.61	3.33^{a}	0.55^{b}	1.69^{a}	3.39^{a}
24700 (M_2)		0.64	1.62	2.1^{b}	0.62^{a}	1.65^{ab}	2.24^{b}
18500 (M_3)		0.59	1.54	1.5^{c}	0.57^{ab}	1.58^{b}	1.62^{c}
LSD $_{(0.05)}$		ns	ns	0.40	0.05	0.08	0.29
Dry bean arrangement							
1 row of dry bean between maize rows (L_1)		0.62	1.64^{a}	2.22	0.55^{b}	1.64	2.28^{b}
2 rows of dry bean between maize rows (L_2)		0.59	1.54^{b}	2.44	0.61^{a}	1.65	2.56^{a}
LSD $_{(0.05)}$		ns	0.07	ns	0.04	ns	0.24
Dry bean arrangement	Maize density plant $^{ha-1}$						
	M_1	0.59	1.63^{ab}	3.15^{a}	0.52^{bc}	1.68^{a}	3.18^{b}
L_1	M_2	0.67	1.69^{a}	2.13^{b}	0.61^{a}	1.69^{a}	2.08^{cd}
	M_3	0.60	1.59^{abc}	1.39^{c}	0.51^{c}	1.55^{b}	1.57^{e}
	M_1	0.59	1.59^{abc}	3.52^{a}	0.59^{ab}	1.72^{a}	3.60^{a}
L_2	M_2	0.62	1.53^{bc}	2.17^{b}	0.63^{a}	1.61^{ab}	2.40^{c}
	M_3	0.58	1.49^{c}	1.38^{bc}	0.63^{a}	1.61^{a}	1.67^{de}
LSD $_{(0.05)}$		ns	0.12	0.58	0.07	0.11	0.42
CV $_{\%}$		14.64	4.22	13.65	6.92	3.81	9.48

ns = non significant.

Dry bean arrangement and maize density interaction significantly influenced number of pods per plant, 100 seeds weight and grain yield in 2010/11(Table 2). The highest dry bean yield was recorded from double row arrangement and 24700 plants/ha of maize in 2010/11 and this was statistically similar to the yield of the double row arrangement under 18 500 plants/ha maize. The lowest grain yield was obtained by the single row arrangement under 18 500 plants/ha maize. This was unexpected since this treatment combination posed the least competition for growth factors. In 2009/10 all dry bean X maize density combinations achieved statistically similar grain yields but the highest was obtained by the double row arrangement under 24700 plants/ha maize (Table 2).These results agree with those of Mohta and De (1980) who reported that in maize/soybean combination, there was 31% yield increase in intercropped soybean when arranged in double rows and only 1.25% in the single alternate row arrangement. Molatudi and Mariga (2012) also reported higher bean yield when intercropped with 24 700 plants/ha maize relative to 37000 plants/ha. Highest number of pods per plant were found in the single row arrangement under 37 000 plants/ha maize. This could be due to reduced intra-crop competition for growth factors and reduced competition between the maize and dry beans due to spatial separation of 45 cm. In terms of bean arrangement the results from this study agree with Majnoun-Hosseini *et al.* (2001) who reported that soybean yield components, such as number of pods, decreased linearly as bean population increased. However, the results differed with those of Ndung'u *et al.* (2006) and Ciftci *et al.* (2006), who reported highest number of pods per plant from two lines of dry bean + two lines maize while the lowest was obtained from two lines maize + one line of dry bean.

Table 6. Productivity of maize/dry bean intercrops in response to maize density, dry bean arrangement and cropping system in 2009/10 and 2010/11 seasons at Syferkuil.

Treatment	2009/10 growing season					2010/11 growing season				LER
	Maize		Dry bean			Maize		Dry bean		
	Yield (kg/ha)	Partial LER	Yield (kg/ha)	Partial LER	LER	Yield (kg/ha)	Partial LER	Yield (kg/ha)	Partial LER	
Sole maize-37000(M_1)	1596.8	-	-	-		1815.5	-	-	-	-
Sole maize - 24700(M_2)	1546.8	-	-	-		1308.7	-	-	-	-
Sole maize - 18500(M_3)	1079.6	-	-	-		668.5	-	-	-	-
Sole legume (L)	-	-	735.49	-		-	-	754.03	-	-
M_1L_1	1240.4	0.78	617.31	0.84	1.62	1332.6	0.73	448.43	0.59	1.32
M_1L_2	1474.4	0.92	621.48	0.84	1.76	1501.1	0.82	589.72	0.78	1.60
M_2L_1	1147.4	0.74	602.59	0.82	1.56	938.1	0.72	691.30	0.92	1.64
M_2L_2	1295.4	0.84	668.15	0.90	1.74	1216.1	0.93	711.48	0.94	1.87
M_3L_1	630.9	0.58	540.65	0.74	1.32	655	0.98	288.33	0.38	1.36
M_3L_2	649.9	0.60	619.54	0.84	1.44	658	0.98	709.35	0.94	1.92

LER = land equivalent ratio; L_1 = one row dry bean between maize rows; L_2 two rows dry bean between maize rows.

Maize yield and yield components

The maize biomass, grain yield and harvest index were significantly affected by maize density in both seasons (Table 4). Maize biomass was similar for 24 700 and 37 000 plants/ha but was significantly ($P<0.05$) lower at 18 500 plants/ha. Crop residues are an important source of livestock feed in winter for the smallholder farming sector. These results suggest that 18 500 plants/ha produces significantly less crop residues and will thus not provide adequate residues for livestock feed or compost making, which are some of the common uses of maize residues. These results agree with the findings of Morgado and Willey (2008) that total biomass yield of intercropped maize per unit area increased with increase in population from 20000 plants/ha to 40000 plants/ha. Molatudi and Mariga (2012) also reported that intercropped maize at 37 000 plants/ha achieved a significantly higher total above ground dry matter than maize at 24 700 plants/ha. Moriri *et al.* (2010) reported high dry matter production in all maize/cowpea patterns at 30 000 maize plants/ha than at maize plant densities of 10 000, 20 000 and 40 000 plants/ha and further concluded that the 1rowM: 2rowsC arrangement has the potential to increase dry matter yield under dryland production.

Harvest index followed the same pattern as biomass in 2009/10 season. In 2010/11 season maize density of 37 000 plants/ha achieved the highest harvest index of 0.54, which was significantly higher than at 24 700 and 18 500 plants/ha. The results agree with Moriri (2008) who reported harvest indices in range of 27.3 to 44.6% in maize/cowpea intercropping trials at Syferkuil which increased with increase in maize density. The dry bean arrangement did not significantly influence maize biomass and harvest index in both seasons. The maize biomass was however higher in the double row arrangement in both seasons, suggesting that the treatment could have influenced maize growth through enhanced moisture conservation and/or reduced weed competition achieved by better ground cover.

Table 7. The effect of crop aggressivity (A) on the maize/ dry bean intercropping.

	2009/10 growing season		2010/11 growing season	
	Aggressivity			
Treatment	Maize	Dry bean	Maize	Dry bean
M_1L_1	-0.13	0.13	-0.06	0.06
M_1L_2	-0.11	0.11	-0.1	0.1
M_2L_1	-0.12	0.12	-0.16	0.16
M_2L_2	-0.13	0.13	-0.13	0.13
M_3L_1	-0.12	0.12	0.03	-0.03
M_3L_2	-0.15	0.15	-0.12	0.12

Maize grain yield declined with decrease in plant density, although the yield at the higher two densities were not significantly (P<0.05) different (Table 4). The lowest density obtained the lowest maize grain yield in both seasons. These results are in agreement with Muoneke *et al.* (2007) who reported that maize grain yield increased as maize plant density increased in maize/soybean intercropping. Since maize is the staple food for many rural families in South Africa, that maize density (18500 plants/ha) yields too lowly and should not be recommended even for intercropping. Dry bean arrangement also did not affect maize grain yield in 2009/10 but the yield of the two bean row arrangement was higher than with the single row arrangement. From a competition perspective, this was a confusing result since more bean plants are expected to compete more with the maize for growth factors. However, it is possible that the improved ground cover from the two row arrangement may have conserved more moisture by improved ground cover and reduced weeds and thus facilitated better maize growth.

Maize density influenced maize stand in both seasons (Table 5). The three maize densities significantly (P<0.05) differed from each other in the expected declining order from (90 x 30 cm to 90 x 60 cm). Maize plant height responded to maize density in the second season only. Plants were taller in the higher densities with significant differences (P<0.05) between 37 000 and 18 500 plants/ha treatments, 24 700 plants/ha density being intermediate (Table 5). This was expected. Dry bean arrangement did not influence maize cob height and maize density in 2009/10 and maize plant height in 2010/11, but significantly influenced plant height in 2009/10 and cob height and plant density in the second season (Table 5). Maize plants were taller in the single row bean arrangement but cob height and maize plant density were higher in the double row bean arrangement.

Maize density x dry bean arrangement interaction significantly (P<0.05) affected, biomass, grain yield, harvest index, plant height and maize density in both seasons and maize cob height in 2010/11 season

(Table 4 and 5).Maize plants were generally taller with the single row arrangement under 24700 plants/ha in 2009/10 and were only significantly shorter in the single row arrangement under 18 500 plants/ha. In 2010/11 season, the maize plants were significantly taller in double row arrangement under 37000 plants/ha.

Table 8. Monetary value of sole and intercropped bean and maize as influenced by dry bean arrangement and maize density at Syferkuil.

Treatments	2009/10 growing season			2010/11 growing season		
	Monetary value (R/ha)					
	Maize	Dry bean	Total	Maize	Dry bean	Total
Sole maize-37000(M_1)	3045[a]	-	3045[de]	3462.1[a]	-	3462.1[ef]
Sole maize -24700(M_2)	2949.8[a]	-	2949.8[de]	2495.7[bc]	-	2495.7[f]
Sole maize - 18500(M_3)	2058.9[ab]	-	2058.9[e]	1274.8[d]	-	1274.8[g]
Sole legume (L)	-	3106.7[a]	3106.7[de]	-	3185[a]	3185[ef]
M_1L_1	2365.5[a]	2607.5[ab]	4973a[b]	2541.2[b]	1894.2[cd]	4435.4[c]
M_1L_2	2811.7[a]	2625.1[ab]	5436.8[a]	2862.7[ab]	2491[bc]	5353.7[a]
M_2L_1	2188.1[ab]	2545.4[ab]	4733.5[abc]	1789[cd]	2920[ab]	4709b[c]
M_2L_2	2471.3[a]	2822.3[ab]	5293.6[a]	2319[bc]	3005.3[ab]	5324.3[ab]
M_3L_1	1203.1[b]	2283.7[b]	3486.8[cd]	1249[d]	1217.9[d]	2466.9[f]
M_3L_2	1239.4[b]	2616.9[ab]	3856.3[bcd]	1254.7[d]	2996.3[ab]	4251[c]
$LSD_{(0.05)}$	1112	735.6	1252.9	682	683.06	785.77
$CV_{\%}$	30.28	15.55	18.85	19.16	15.18	12.42

The highest grain yield was obtained from interaction between 37000 plants/ha of maize and double rows arrangement of dry bean in both seasons, however this was not significantly different from that at 24700 plants/ha in 2009/10. The interaction of 18500 plants/ha maize and single row arrangement achieved the lowest yield in both seasons (Tables 4 and 5). Although some reports indicated that high plant population resulted in high competition for growth resources, thus lowering grain yield, the results from this study show that the high maize density of 37000 plants/ha, which is recommended for dryland areas, with double row of dry bean arrangement attained high maize yield and this could be due to improved radiation interception and through complete ground cover which is the key to conservation of soil moisture. In addition, the increased legume density could have fixed more nitrogen.

Evaluation of intercrop productivity

The evaluation of maize and dry bean productivity in different treatment is given in Table 6 and the results showed modest reduction of maize and dry bean yields due to intercropping in both seasons. Maize yield reduction was positively correlated with maize density (Table 6). Maize yield in the intercrops, at all maize densities, was much higher with the double dry bean row arrangement than with the single row arrangement. Dry bean yield response to intercropping was variable. The dry bean yield was least affected by intercropping under 24700 plants/ha in both bean row arrangements and in double row arrangement under 18500 plants/ha. Maize yield generally increased with increase in maize density. The most productive combination of intercropping was achieved from double row arrangement at 37000 plants/ha in 2009/10 season with LER value of 1.76 while in 2010/11 it was at 18 500 plants/ha with the same row arrangement, with an LER value of 1.87 (Table 6). LER values ranged from 1.32 to 1.76 in 2009/10 season and 1.32 to 1.92 in 2010/11 season. The lowest LER values of 1.32 were recorded for the single row dry bean with 18 500 plants/ha in 2009/10 and with 37 000plants/ha in 2010/11. Similar results were reported for mix-proportions of cowpea/common bean- maize (Yilmaz *et al.,* 2008) and maize-faba bean (Li *et al.*, 1999). These results thus indicate that intercropping maize with dry bean at the maize densities and dry bean arrangements tested in this study was more productive than growing monocrops of the two component crops.

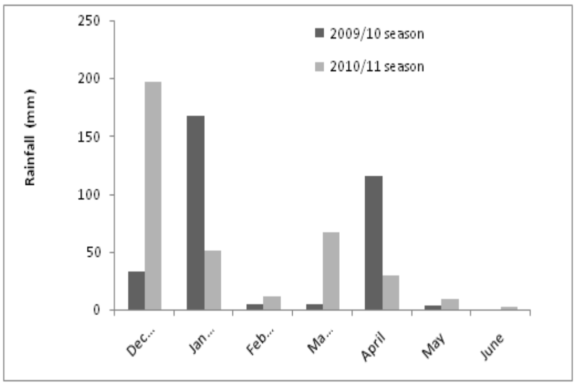

Fig. 1. Total monthly rainfall (mm) recorded between December and June 2009/10 and 2010/11 growing seasons.

The PLER values for dry bean were high in both seasons (Table 6). Dry bean yields in the intercrop were quite comparable to those from the sole crop. This was surprising given the poor rainfall recorded in the two growing seasons. The PLER showed that, compared to single row arrangement, the double row arrangement of dry bean appears to have more beneficial land use efficiency in all intercropping combinations tested in this study. Maize PLER values were also high in both seasons. This is in agreement with the results reported by Kipkemoi *et al.* (2002), who reported that two rows of soybean planted between two rows of maize resulted in superior LER.

In all treatments dry bean attained positive aggressivity (A) values in both seasons and negative value in 2010/11 season under 18500 plants/ha and single row arrangement (M_3L_1) as indicated in Table 7. The aggressivity (A) parameters indicated a definite tendency for maize to be dominant. This signifies that maize was dominated while dry bean was dominant to maize, however maize was only dominant in the 2010/11 at 18500 plants/ha with single row arrangement. The results of aggressivity conformed to those of PLER. Dry bean is considered to be more competitive for growth limiting factors than maize, since it obtained higher PLER. The results are supported by Aynehband and Behrooz (2011), who reported that maize was the non-dominant species as measured by the negative value of aggressivity in a maize-mung bean intercropping system. The results disagree with those reported by Moriri *et al.* (2010), which suggested that maize was a more aggressive crop in maize/ cowpea intercrop system.

From a monetary value perspective, intercropping maize with dry bean obtained higher total monetary value than sole cropping (Table 8). Double bean row arrangement with 37000 plants/ha of maize was the most profitable with the total return of R5437/ ha and R5354 /ha in 2009/10 and 2010/11, respectively. However, this was not significantly different from 24700 plants/ha of maize with double bean row arrangement in 2009/10 season. The results show that in both seasons intercropping had the potential to double returns to the farmers if they sold all their produce. This clearly shows that intercropping of maize/dry bean was more profitable that sole cropping. Intercropping reduces the risk of crop failure, increases crop diversification and has significant impact on the profitability of cropping systems. These crop combinations can be easily adopted by SH famers as they are more profitable and can thus enhance the farming progression among farmers. The results are in agreement with Molatudi and Mariga (2012) who concluded that maize/bean intercropping was clearly superior to sole maize in terms of monetary value.

Future studies should consider evaluating the weed and soil moisture profiles under the same treatments used in the current study, and should also include on-farm sites to facilitate farmer evaluation.

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