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Full Length Research Paper

Influence of component crop densities and planting patterns on maize production in dry land maize/cowpea intercropping systems

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An experiment was conducted to test the effect of four plant densities (10, 20, 30 and 40,000 plants ha^{-1}) and four planting patterns (1rowM:1rowC, 1rowM:2rowsC, 2rowsM:2rowsC and 2rowsM:4rowsC) on the growth and dry matter production of a dryland maize/cowpea intercrop at three sites in Limpopo and North West province. The experiment was a split plot incorporated in randomized complete block design with four replications, where maize plant density was the main plot factor and subplot factor was the planting pattern. Sole maize flowered and reached physiological maturity later than intercropped maize, while sole cowpea flowered and matured earlier than under intercropping. Higher plant densities of 30 000 and 40 000 maize plants ha^{-1} delayed flowering and maturity of both component crops in sole and intercropped arrangements. Significant differences in maize and cowpea dry matter yields were observed at all trial sites. The 1rowM:2rowsC pattern and plant density of 30 000 plants ha^{-1} with 92 000 plants ha^{-1} of cowpeas was superior in maize dry matter production at all trial sites, whereas sole cowpea at 40 000 plants ha^{-1} gave the highest dry matter yield than the intercrop arrangements. The results of this study show that high plant density causes stress to plants and reduces plant growth, whereas intercropping has a negative influence on cowpea plant growth.

Key words: Planting density, planting patterns, plant growth, maize/cowpea intercrop.

INTRODUCTION

Maize (*Zea mays*) is a priority crop to farmers because it is a staple food in many rural communities of South Africa. 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. Cowpea (*Vigna unguiculata* [L.] Walp.) is an important grain legume and a good source of dietary proteins for millions of people in Africa (Bressani, 1985). In Limpopo Province of South Africa cowpea has received much attention from researchers for its ability to ameliorate soil fertility problems (Mpangane, 2001; improved growth and yield under intercropping and in sole cropping. Smallholder (SH) farmers usually intercrop Maluleke, 2004 and Ayisi et al., 2004), and for its cowpea with maize or grain sorghum (*Sorghum bicolor)* suggesting that it is better adapted to local conditions but the proportion of the legume in the mixture is often too low to constitute a true intercropping system (Mpangane, 2001).

High biomass of maize in intercrops, compared to their respective sole crop has been reported by Rerkasem and Rerkasem (1998), and higher biomass production is due to the enhanced growth of the non-legume crop. Competition between component crops for growth - limiting factors is regulated by factors such as the proportion of crops in the mixture and fertilizer application (Trenbath, 1976; Russell and Caldwell, 1989). Information from previous studies indicates that shade effects on growth

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Abbreviations: SH, Smallholder; **PM,** physiological maturity.

and yield of legume crops decrease dry matter yield and

increase plant height (Hang et al., 1984; Stirling et al., 1990). The adoption of intra-row intercropping by SH farmers in Limpopo and North West provinces is limited because the practice is labour intensive. Planting patterns or row arrangement of component crops in separate rows are also known to improve the amount of light transmitted to the lower legume canopy, especially in alternate rows (Mohta and De, 1980; Waghamere et al., 1982; Oljaca et al., 2000). Therefore, the objectives of this study were to determine the effect of planting densities and planting patterns and their interactions on dryland maize/cowpea growth and biomass production.

MATERIALS AND METHODS

A rainfed field experiment was conducted during 2005/2006 growing season at three locations namely, University of Limpopo experimental farm at Syferkuil, Agricultural Research Council (ARC-GCI) experimental farm at Potchefstroom and Taung Department of Agriculture experimental farm. Rainfall and temperature data for each trial site were collected at its weather station. The experiments were established as split-plots incorporated in randomised complete block design (RCBD) with four replications at each location. The main plot factor was maize plant density at four levels: D1 (100 x 100 cm), D2 (100 x 50 cm), D3 (100 x 33 cm) and D4 (100 x 25 cm) and the subplot factor was planting pattern (row arrangements) namely sole maize (M), sole cowpea (C), 1:1 alternate intercropping (1rowM:1rowC), 1:2 alternate intercropping (1rowM:2rowsC), 2:2 alternate intercropping (2rowsM:2rowsC) and 2:4 alternate intercropping (2rowsM:4rowsC). Varieties used in the trial were PAN 6479 for maize and PAN 311 for cowpeas both of which are drought tolerant.

Phenological development

Days to flowering were recorded when 50% of the plants on a plot had flowered. Physiological maturity (PM) of cowpea was scored when 90% of pods on a plot had attained a brownish appearance, and for maize when the kernel milk line disappeared and just before the kernel black layer formed at the tip of the kernels. Cowpeas were harvested when 90% of the plants on a plot revealed pods that rattle when shaken (Stoskopf, 1981) and for maize when 90% of the plants had no milk line.

Dry matter production

Above ground plant samples were taken for cowpea and for maize at harvest maturity in all locations. Dry matter samples of the crops were taken from a 16 m^2 area from each plot at harvest at all locations. Maize and cowpea plants were cut at ground level to determine aboveground dry matter. Both maize and cowpea plant materials were oven dried at 65°C for 72 h before weighing.

Data analysis

Data were subjected to analysis of variance (ANOVA) using the General Linear Model procedure of Statistical Analysis System (SAS, 2000). Differences between treatment means were separated using the Least Significant Difference ($LSD_{0.05}$) procedure (Gomez and Gomez, 1984). For interactions, LSD values were obtained by using Agrobase program (2000).

RESULTS AND DISCUSSION

Rainfall and temperatures

Rainfall and monthly temperature means recorded during the 2005/2006 growing season at Syferkuil, Potchefstroom and Taung, respectively, are given in Figure 1 and Table 1. The 2005/06 seasonal rainfall totals for Syferkuil, Potchefstroom and Taung were 399.4, 648.1 and 840 mm, respectively (Figure 1). This translates to 20 and 7.4% less of the long term averages at Syferkuil and Potchefstroom, respectively. At Taung, seasonal rainfall was 31% higher compared to the long term average. Closer observation of the rainfall data between the three locations reflected a comparatively higher rain in the first three months of the 2006 growing season. The peak at Syferkuil and Taung was in February, whereas at Potchefstroom it was in March. Despite the early peak at Syferkuil, crop growth of both crops was not affected at this experimental site. Syferkuil and Potchefstroom had comparable ranges of maximum and minimum temperature but Taung had much higher maximum temperatures and bigger diurnal ranges, especially in February and March. The maximum seasonal temperature was 3°C lesser than the long term maximum temperatures of 28°C at Syferkuil, while the minimum temperatures were the same at 12°C. At Potchefstroom, maximum temperature was similar compared to long-term temperature of 26°C, whereas the minimum temperatures differed by 1°C. Maximum and minimum seasonal temperatures at Taung were 29°C and 13.7°C, respectively, and were higher compared to long term temperatures of 24 and 10°C, respectively.

Phenological development

Maize flowering and physiological maturity

Phenological data for the three sites are presented in Table 2. Highly significant differences (P<0.0001) in number of days to flowering and physiological maturity (PM) resulted from planting density at all sites. Flowering of maize ranged from 54 to 66 DAP at Syferkuil, 63 to 69 DAP at Potchefstroom, whereas at Taung the ranged was 69 to 71 DAP. Maize plants at lower planting density tended to flower and matured earlier than those planted at higher density at the three sites. Similar results were observed by Takatlidis and Koutroubas, (2004) on maize and reported that high planting densities from 5 to 20 plants m^2 increased number of days to flowering, pollen shedding and silk emergence. Hashemi - Dzefouli and Herbert (1992) working on maize also reported similar results. The results in the current study also show that competition for resources was severe at higher planting densities of both crops and this delays both flowering and maturity at all sites. Days to flowering responded highly significantly (P<0.0001) to planting patterns at Potchefstroom only (Table 3). PM was

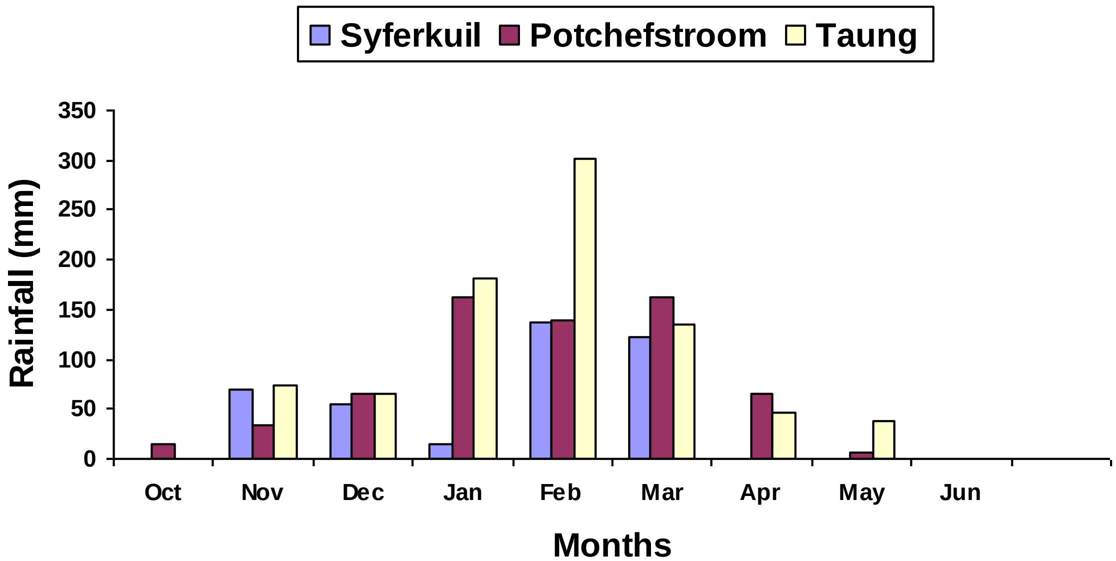

Figure 1. Monthly rainfall (mm) during the 2005/2006 growing season at Syferkuil, Potchefstroom and Taung.

Table 1. Mean monthly maximum and minimum temperatures during the 2005/2006 growing season at the three trial sites.

Months	Syferkuil		Potchefstroom		Taung	
	Max (°C)	Min (°C)	Max (°C)	Min (°C)	Max (°C)	Min (°C)
October	28.4	13.7	29.8	13.2	32.8	16.2
November	28.6	15.6	30.2	14.4	34.4	17.5
December	26.5	15.6	30.3	15.7	32.1	16.7
January	28.4	18.1	27.7	17.7	33.6	18.1
February	27.5	17.0	27.1	17.0	30.2	13.5
March	24.6	14.5	24.8	13.7	28.5	11.3
April	21.3	5.7	23.8	10.2	28.0	10.8
May	21.8	3.2	19.9	2.9	25.3	10.2
June	21.0	3.0	19.9	0.6	20.5	8.6

Table 2. Number of days to flowering and physiological maturity (PM) of maize grown at different planting densities at the three locations.

Planting densities	Syferkuil		Potchefstroom		Taung	
	Days to 50% Flowering	Days to PM	Days to 50% Flowering	Days to PM	Days to 50% Flowering	Days to PM
Plants ha^{-1}	……………………….# of DAP…………………………….....					
10 000	54b	120c	63c	121b	70c	126c
20 000	56b	122b	65b	123a	69d	128bc
30 000	63a	125a	68a	123a	72a	129ba
40 000	66a	125a	69a	123a	71b	130a
LSD $_{(0.05)}$	3.0	1.0	0.6	1.2	0.6	1.7
CV (%)	12.7	1.7	2.3	1.9	2.1	4.1

DAP = Days after planting, PM = Physiological maturity, # = Number, LSD= Least significant difference, CV (%) = Coefficient of variation.

Table 3. Days to flowering and physiological maturity of maize grown under different planting patterns at three locations.

Planting pattern	Syferkuil		Potchefstroom		Taung	
	Days to 50% flowering	Days to PM	Days to 50% flowering	Days to PM	Days to 50% flowering	Days to PM
1rowM:1rowC	63	124b	69b	124b	68	129b
1rowM:2rowsC	65	122b	67c	123b	68	129b
2rowsM:2rowsC	65	123b	68b	123b	68	129b
2rowsM:4rowsC	64	123b	69b	124b	68	130b
Sole cropping	67	126a	70a	128a	69	132a
LSD $_{(0.05)}$	ns	1.3	0.7	1.4	ns	2.0
CV (%)	7.5	1.7	2.3	1.9	2.1	2.6

PM = Physiological maturity, LSD= Least significant difference, CV (%) = Coefficient of variation, ns = non significant (P≤0.05).
Means followed by the same letter in the same column are not significantly different from each other at 5% level.

Table 4. The effects of planting patterns on cowpeas flowering date and PM at three locations.

Planting pattern	Syferkuil		Potchefstroom		Taung	
	Days to 50% flowering	Days to PM	Days to 50% flowering	Days to PM	Days to 50% flowering	Days to PM
1rowM:1rowC	56b	89a	59ab	95a	61b	99a
1rowM:2rowsC	58ba	89a	58b	95a	61b	98a
2rowsM:2rowsC	57b	90a	60a	96a	61b	99a
2rowsM:4rowsC	59a	90a	61a	96a	64a	99a
Sole cropping	50c	75b	52c	80b	56c	88b
LSD $_{(0.05)}$	2.0	1.8	1.1	2.3	0.6	2.0
CV (%)	11.1	3.1	4.1	3.8	2.2	2.7

PM = Physiological maturity, LSD= Least significant difference, CV (%) = Coefficient of variation.
Means followed by the same letter in the same column are not significantly different from each other at 5% level.

significantly influenced by planting patterns at all locations. Maize flowering ranged from 63 to 70 DAP at all sites. Maize PM ranged from 122 to 132 DAP at all locations. Delay in flowering periods due to plant stress were also reported by Muchow (1989) working on maize, where four days differences were observed in plants that were under stress. Modiba (2002), working on maize, also indicated that stress on a maize plant delayed flowering at Syferkuil. The results from these experiments indicate that competition for resources in intercropping were less, and severe in sole cropping. However, the study findings was contrary to the finding of Rengel and Graham (1995) who observed that stressed maize plants flower earlier. The effect of planting density x planting pattern interactions did not influence maize phenological development at all locations.

Flowering and physiological maturity of cowpeas

Cowpeas that were planted in intercropping flowered later than those in sole crops at all sites (Table 4). Floral appearance was delayed in 2rowsM:4rowsC arrangement compared to all other planting patterns and sole cowpeas at all sites. Sole cowpea reached PM earlier than those planted in intercropping planting patterns and ranged from 75, 80 to 88 DAP at Syferkuil, Potchefstroom and Taung, respectively. The results show that the shading effects caused by taller maize plants delay flowering and maturity of cowpeas. However, Mpangane (2001) observed that days to flowering and maturity of all cowpea cultivars did not differ between the sole and intercrops with maize. The results also pointed out that number of days to 50% flowering and PM was different at the three locations. Syferkuil cowpea flowered and reached PM earlier than at Potchefstroom and Taung, respectively. This might be as a result of differences in heat units and rainfall distribution between the three locations.

Maize dry matter production response to interaction effects

Maize dry matter increased with densities up to 30 000 plants ha^{-1} and decreased at 40 000 plants ha^{-1} in all planting patterns, including sole cropping at all sites

Table 5. The interaction effects on maize whole plant dry matter production grown at three locations.

Planting patterns	Plant density (Plants10^3 ha^{-1})		Dry matter production at harvest (kg ha^{-1})		
	Maize	Cowpea	Syferkuil	Potchefstroom	Taung
1rowM:1rowC	10	10	6016c	4111c	4480
	20	20	13234b	9556b	9872
	30	30	17938a	13806a	10954
	40	40	16906a	12618a	9875
Mean			13524	10023	8795
1rowM:2rowC	10	30	5719c	4375bd	4457
	20	60	13969b	12410b	9542
	30	92	17531a	15064a	11040
	40	121	16453a	10507c	9983
Mean			13418	10589	8756
2rowM:2rowC	10	30	6234d	5222d	4993
	20	60	13531c	10445b	9754
	30	92	18134a	11479a	10784
	40	121	15296b	9401bc	9034
Mean			13299	9137	8641
2rowM:4rowC	10	40	6594d	6632d	5132d
	20	80	14453c	10437c	8507c
	30	121	18685a	14299a	10333a
	40	160	16953b	11701b	9875b
Mean			14171	10767	8462
Sole cropping	10	10	6297c	6389c	5076c
	20	20	12578b	10011b	7840b
	30	30	14891a	12903a	9481a
	40	40	13422b	9569b	7438b
Mean			11796	9718	7459
LSD $_{(0.05)}$			1577	857	447
CV (%)			12.1	18.04	8.7
Density			**	**	**
Planting Patterns			**	**	**
Interaction			**	**	**

LSD= Least significant difference, CV (%) =Coefficient of variation, ** = Highly significant (P<0. 0001).
Means followed by the same letter in the same column are not significantly different from each other at 5% level.

(Table 5). The interactions between all planting patterns and 30 000 plants ha^{-1} maize density resulted in more dry matter production than at planting density of 10 000, 20 000 and 40 000 plants ha^{-1}. At Syferkuil, the interactions between 2rowsM:4rowsC pattern and maize density of 30 000 plants ha^{-1} and 121 000 plants ha^{-1} of cowpea had produced higher dry matter yield of 18685 kg ha^{-1}. The increase in dry matter production of maize in inter-cropping compared to sole maize might be attributed to the fact that maize is a more aggressive component crop in the cereal cereal/legume intercrop system. Similar results had been reported by numerous investigators (Searle et al., 1981; Clement et al., 1992 and Rerkasem and Rerkasem, 1998) Who found that dry matter production increased when maize is intercropped relative to sole maize.

Table 6. The interaction effects on maize whole plant dry matter production grown at three locations.

Planting patterns	Plant density (Plants10^3 ha^{-1})		Dry matter production at harvest (kg ha^{-1})		
	Maize	Cowpea	Syferkuil	Potchefstroom	Taung
1rowM:1rowC	10	10	2777c	2921c	3981c
	20	20	4185a	3932a	6097a
	30	30	4084a	3232b	5638ab
	40	40	3872b	2886c	5484b
Mean			3730	3244	5300
1rowM:2rowC	10	30	2099d	2125b	3906c
	20	60	4063a	3118a	5419a
	30	92	3888b	2816a	4834b
	40	121	3576c	2507b	4438bc
Mean			3407	2624	4649
2rowM:2rowC	10	30	2103d	2234b	3766c
	20	60	3849a	2879a	4491a
	30	92	3452b	2501a	4323a
	40	121	3051c	2468ba	3831b
Mean			3114	2521	4128
2rowM:4rowC	10	40	2110d	2071b	3059b
	20	80	3120a	2502a	4510a
	30	121	2915b	2368b	4300a
	40	160	2640c	1456c	3450b
Mean			2696	2099	3829
Sole cropping	10	10	3402d	3181d	5581c
	20	20	6358c	4291c	6997b
	30	30	7373b	6067b	7538a
	40	40	9256a	6732a	7884a
Mean			6597	5068	7000
LSD $_{(0.05)}$			131	457	580
CV (%)			21.1	39.06	32.8
Density			**	**	Ns
Planting Patterns			**	**	**
Interaction			**	ns	Ns

LSD= Least significant difference, CV (%) =Coefficient of variation, Ns = Non significant ($P \leq 0.05$), ** = Highly significant ($P < 0.0001$). Means followed by the same letter in the same column are not significantly different from each other at 5% level.

Cowpea dry matter production influenced by interaction effects

Cowpea dry matter production in sole cropping increased with increasing cowpea density and produced more dry matter compared to intercropping planting patterns at all locations (Table 6). Cowpea dry matter production under all intercropping planting patterns increased up to 20 000 maize plants ha^{-1} and decreased as the planting density increased to 30 000 and 40 000 plants ha^{-1} at all locations. The combinations of 2rowsM:4rowsC arrangement and maize density of 40 000 plants with cowpea density

of 160 000 plants ha^{-1} had lower dry matter production compared to all other intercropping planting patterns and sole cropping at all trial sites. The above combinations on average had reduced cowpea dry matter by 59% at both Syferkuil and Potchefstroom and 45% at Taung. This indicates that competition for resources in intercropping reduces cowpea growth and also results in a decrease in growth rates. Legume growth suppression by maize in intercropping systems has been reported (Clement et al., 1992; Ayisi et al., 2004).

In intercropping, the 1rowM:1rowC was superior in dry matter compared to other intercropping patterns. The same planting pattern in intercropping has the potential to increase cowpea growth rates by reducing competition for resources such as light, water and nutrient. The study results disagree with that of Ofori and Stern (1987b) who found that double rather than single alternate row arrangement improves growth and light penetration of the legume component. Trenbath (1976) believed that competition between component crops for growth limiting factors might be regulated by proportions of crop in the mixture. This study also shows that higher density of maize in intercropping shades the cowpea, caused by higher maize height, and reduced cowpea growth. These were severe in the 2rowsM:4rowsC pattern and maize density at 40 000 plants ha^{-1}. Similar results were also obtained by several researchers, Ofori and Stern, (1987b); Henriet et al. (1997); Russell and Caldwell (1989) working on cereal/legume intercropping.

Conclusions

The 1rowM:2rowsC arrangement is the suitable planting pattern and has the potential to increase dry matter yield of maize under dryland production thereby also enhancing crop growth. In cowpea, sole cropping produced more dry matter than in intercropping systems. The 2rowsM:4rowsC pattern has the lowest cowpea dry matter, and taller cowpea plant height, all of these being attributed to reduced cowpea growth. Maize density of 20 000 plants ha^{-1} and 1rowM:1rowC pattern is the best combination of component crops in intercrop due to higher dry matter production. This combination of the component crops proved to increase crop growth rates of both crops in this study at all locations. In both provinces, maize is a staple, cash crop and fodder for livestock. Thus improved cropping systems that increase growth of the secondary crop (cowpea) but reduced growth of the main crop are unlikely to be adopted by SH farmers. However, the results from this study show that intercropping has the potential to increase maize growth due to an increase in dry matter production than their respective sole crops at all locations. From this study it was found that the 1rowM:1rowC and 1rowM:2rowsC arrangements have the potential for enhancing cowpea and maize growth and also reducing weed growth.

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