Grain yield and symbiotic activity of cowpea cultivars grown in sole and intercropping systems with maize in the Limpopo Province of South Africa

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Abstract

The smallholder cropping system in the Limpopo Province of South Africa is characterised by predominantly maize monoculture, low external input and poor soil fertility, particularly, nitrogen and phosphorous. Intercropping cereal and legume species is usually proposed to enhance nitrogen nutrition in the system. Alternate row intercropping studies of maize and four distinct cowpea cultivars were conducted during the 1998/99 and 1999/2000 growing seasons at two sites to determine the effect of the system on grain yield of the component crops, and symbiotic activities of the legume. Differences in maize grain yield were only observed at Syferkuil in 1999/00. With the exception of one cultivar where lower intercrop yield was recorded, seed yield of the cowpea cultivars were similar in the sole and intercrop systems. The amount of nitrogen fixed by the legumes ranged from 0 to 217 kg N ha^{-1} over the two seasons and on average, fixation was higher in the intercropped cowpea than the sole crops, except in 1999/00 at Syferkuil.

Media summary

Intercropping maize and cowpea cultivars for grain yields and symbiotic activities in the Limpopo Province of South Africa resulted in significant treatment differences in these parameters.

Key Words

Smallholder farmers, Nitrogen fixation.

Introduction

In the Limpopo province of South Africa, intercropping maize (*Zea mays*) with cowpea (*Vigna unguiculata*) and groundnut (*Arachis hypogeae*) is a common practice among smallholder farmers. The smallholder farming system is characterised by variable seasonal rainfall, predominantly maize monocultures, low soil organic matter levels, poor soil fertility, particularly in nitrogen and phosphorous and minimal external inputs into the farming system. It is also a system that had received minimal attention from the research community, as initial research efforts were focused on the large scale commercial farming sector of the country. The consequent effect is the reduction of crop yields to extremely low levels. Recent efforts to improve soil fertility have been through the introduction of leguminous species into the farming systems of many rural communities, mainly as intercrops with maize. Cowpea is a grain legume that is receiving much attention from researchers for its improved growth and yield. The nitrogen benefit from a legume in an intercropping system will depend on its active symbiotic activity under such a system. The importance of legume variety in nitrogen nutrition in maize-cowpea intercropping systems in the Limpopo Province and many parts of South Africa had not yet been documented. The objectives of this study were to determine the effects of intercropping maize with diverse cowpea cultivars on grain yields of component crops, and then nodulation and N_2 fixation of the cowpea varieties in the system.

Methods

Field experiments were carried out at two locations in the Limpopo Province of South Africa namely, the University of the North experimental farm at Syferkuil and a communal farmers' field at Thabina/Dan during the 1998/99 and 1999/2000 growing seasons. Syferkuil has relatively higher soil fertility than Thabina/Dan due to its long history of fertilization. The low soil fertility at the farmers' fields is typical of the smallholder systems in the province. Thabina/Dan receives higher annual rainfall (750 mm) compared to Syferkuil (500 mm).

The experiments were established as randomised complete block designs with four replications at each location under dryland conditions. Treatments examined four cowpea cultivars, namely, Pan311, Pan326 Bechuana White (BC White) and Agrinawa, which were either intercropped in alternate 90 cm rows with maize variety, SNK2147 or planted as sole cultures under four replications. Thus, the cowpea replaced a maize row in an alternate manner in the intercrop plots. Sole culture maize was included as treatment. The final densities were 30000 and 15000 plants/ha for the sole and intercropped maize respectively and 60000 and 30000 plants for the intercropped and sole crop cowpea respectively. At planting, 50 kg P/ha was applied in the form of single superphosphate at both locations whereas nitrogen fertiliser was applied as urea, at 40 kg N/ha to the maize at Thabina/Dan only. Pan311 and Pan326 are short duration types whereas Bechuana white and Agrinawa are medium and long duration cultivars respectively. The cowpea seeds were inoculated with a commercial Bradyrhizobium strain, CB756 just before planting. Symbiotic activities were assessed through nodulation and nitrogen fixation using the ^{15}N natural abundance technique, with sole maize as the reference crop (Unkovich et al., 1993). Delta (δ) ^{15}N values were determined using mass spectrometer model NA15000NC (CHNN) analyser.

Grain yield samples were taken from the middle rows of each plot and data were analysed using the Statistical Analysis System (SAS). Differences between treatment means were separated using the least significant difference (LSD) procedure (Gomez and Gomez, 1984).

Results

Maize grain yield

Maize grain yield was significantly ($p<0.05$) affected by the treatment only in 1999/00 at Syferkuil. The yield at this location ranged from 4956 to 7757 kg ha^{-1} with the highest occurring under intercropped maize with Pan311 (Table 1). Maize intercropped with Pan311 was 42% superior to the sole maize whereas those intercropped with Pan326, Agrinawa and Bechuana White was similar to the sole maize. Maize yield in 1999/2000 at Thabina/Dan was unavailable due to excessive rainfall damage.

Table 1. Seed yield of intercropped and sole maize at Syferkuil and Thabina/Dan during the 1998/99 and 1999/00 growing seasons.

	Syferkuil		Thabina/Dan
	1998/99	1999/00	1998/99
Treatment	……kg/ha……..		
M + Pan311	2155	7757 [a]	4008
M + Pan326	3074	6083 [abc]	3848

M + BC White	3397	4956 [c]	2947
M + Agrinawa	2239	6958 [ab]	3130
Sole Maize	3203	5476[b]	2956
Lsd $_{(0.05)}$	ns	1775	Ns

ns: Non significant

The highest performance of maize intercropped with Pan311 could be due to the fact that this cultivar is small structured and generally early maturing, and thus offered minimal competition to the maize. The above results agree with other researchers' findings that yield advantages in intercrops may arise when the component crops have different growth durations. Each crop will be exposed to higher resources, because they will make major demands for resources at different times (Ayisi and Poswall, 1997; Ofori and Stern, 1987; Putnam and Allan, 1992).

Cowpea grain yield

Cowpea grain yield was influenced by cropping system in both the 1998/99 and 1999/00 trials at Syferkuil, but only in 1998/99 at Thabina/Dan. At Syferkuil in 1998/99, the highest seed yield was recorded in sole Pan311, followed by intercrop with Pan311 and Pan326 (Table 2).

During the 1999/2000 growing season at this location, the highest yields were recorded in Bechuana White under both sole and intercropping system followed by sole and intercrop Pan311 and Agrinawa (Table 2). Yield of Pan311 was however reduced by 53% when intercropped. Yield reduction of intercropped Pan311 could be attributed to the increased competitiveness of the associated maize crop as indicated by its superior yield performance.

At Thabina/Dan, significant difference was only recorded in 1998/99 and not in 1999/00. In 1998/99, the highest seed yield of 1547 kg ha^{-1} was recorded in sole cropped Pan311. This was similar to the results at Syferkuil during the same year (Table 2). The seed yield of the above mentioned cultivar was reduced by 24% when intercropped. Similar to Syferkuil, yield of Pan326, Bechuana White and Agrinawa remained unchanged whether they were intercropped or grown as sole crop at all locations and seasons. The consistent performance of cultivars Pan326, Bechuana White and Agrinawa indicates their abilities to maintain high productivity under intercrop situations and hence revealing their potential as intercrop cultivars in the maize-legume intercropping system.

Table 2. Seed yield of cowpea at Syferkuil and Thabina/Dan during the 1998/99 and 1999/00 growing seasons.

	Syferkuil		Thabina/Dan	
	1998/99	1999/00	1998/99	1999/00
Treatment	……kg/ha……..			

Sole Pan311	532	1051	1547	71
Sole Pan326	279	500	1126	115
Sole BC White	40	1370	567	101
Sole Agrinawa	2	872	467	89
Intercropped Pan311	387	497	1175	158
Intercropped Pan326	335	472	1167	210
Intercropped BC White	12	1110	394	97
Intercropped Pan Agrinawa	6	984	521	138
Lsd $_{(0.05)}$	79	296	324	ns

Nodule mass

Nodule mass differed among the cowpea varieties, location, season and also whether they were grown as intercrop or sole cultures. The highest nodule weights were generally recorded in Bechuana White and Agrinawa across locations and seasons. The nodules produced by these two cultivars were also on average, 25 to 45% heavier in the intercrop system than when grown as sole crops except for the 1999-2000 season at Syferkuil. Generally, the cultivar Bechuana White appeared consistent in terms of nodule weight and might be the cultivar with the highest potential for improving soil fertility.

Percent N derived from fixation

The $\delta\ ^{15}N$ value enables one to determine the extent of a plant's dependence on soil and atmospheric nitrogen. The percentage of nitrogen derived from fixation ranged from 4.3 to 11.7 and 16.8 to 50.0 in 1998/99 and 1999/00 growing seasons respectively at Syferkuil whereas at Thabina/Dan, the range was 19.3 to 50.6 and 71.3 to 92.7 respectively during the two seasons (Table 3). The legumes at Syferkuil (experimental farm) were largely dependent on soil nitrogen during the 1998/99 growing season but this dependence was relatively less in 1999/2000. Higher dependence of cowpea on soil N under high N conditions had been reported by Ayisi et al., 2000). In general the percentage dependence on symbiotic fixation was much higher at Thabina/Dan (farmer's field) than at Syferkuil, which could partly be attributed to the relatively higher initial soil N at the experimental station.

Amount of N fixed

A wide variation in the amount of nitrogen fixed by the legumes was observed, ranging from as low as 19.5 to 217 kg N ha^{-1} across locations and seasons (Table 3). There were also inconsistencies in the amount of N fixed by the individual cultivars but Pan326 generally appears to be a lower N fixer compared to the other cultivars. Comparing sole and intercropped cowpea, the amount of N fixed was on average 6 to 15% greater in the intercropping system than in the sole cultures. Such observation is partly similar to the findings of Patra et al. (1986), who reported higher amounts of nitrogen fixed by legumes under intercropping conditions.

Table 3. Percent nitrogen derived from fixation (%Ndfa) and the amount of N fixed by the sole and intercropped cultivars of cowpea at Syferkuil and Thabina/Dan during the 1998/99 and 1999/00 growing seasons.

	1998/99				1999/00			
	Thabina/Dan		Syferkuil		Thabina/Dan		Syferkuil	
Treatment	%Ndfa	N Fixed	%Ndfa	N Fixed	%Ndfa	N Fixed	%Ndfa	N Fixed
Sole Pan311	6.3	63.3	20.2	168	31.0	124	92.7	124
Sole Pan326	8.4	28.2	32.6	103	16.8	87	89.3	83
Sole BC White	4.3	19.5	41.8	175	29.5	217	80.7	99
Sole Agrinawa	-	-	36.1	107	23.0	167	84.4	147
*Inter Pan311	11.7	68.5	19.3	151	12.7	136	71.3	123
*Inter Pan326	5.3	24.7	50.6	170	33.8	121	78.1	117
*Inter BC White	5.7	24.3	44.8	169	28.2	144	84.3	146
Inter Agrinawa	-	-	32.9	148	50.0	148	79.7	136

* Intercropped

Conclusion

The cowpea species, Pan-311, Pan326, Bechuana White and Agrinawa can be generally incorporated into maize in the alternate intercropping system without depressing the maize growth.

Nodule formation also differed among the cultivars with Bechuana White and Agrinawa producing many more nodules than the short duration type. In terms of the cultivars' dependence on symbiotic nitrogen fixation, plants grown under farmer field conditions depended more on symbiotic nitrogen for their N requirement than those grown at the experimental farm. The actual amount of nitrogen fixed by the legumes ranged from about 20 to 217 kg ha^{-1} depending on season, location and whether grown as intercrop or sole crop.

Acknowledgements

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