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Evaluation of maize nutrient contents in a maize/cowpea intercropping systems in South Africa

Abstract

Field experiments were carried out at three localities in North West and Limpopo provinces at South Africa to assess the effects of planting density and planting patterns and their interaction effects on residual soil nutrient contents in maize/cowpea (M/C) sole and intercropped systems. The trial consisted of four planting densities (10000; 20000; 30000 and 40000 plants ha–1) and six planting patterns (1 rowM:1rowC; 1rowM:2rowsC; 2rowsM:2rowsC; 2rowM:4rowC; sole maize and sole cowpeas) at three sites. The experiment was a split–plot incorporated in randomized complete block design with four replications where maize plant density was the main factor and subplot factor was the planting pattern. The obtained results were as following: 1) Maize N, P, K, Ca and Mg concentration level showed a decreased pattern as the planting density increased at both trial sites. 2) Maize N content in planting density ranged from 1.28 to 1.65% at both locations. 3) Plant density of 10 000 plants ha–1 had higher N yield of maize by 22 and 11% relative to 40 000 plants ha–1 at Potchefstroom and Taung, respectively. However, N concentration in maize was significant at Taung, the 2rowsM:4rowsC pattern had higher N concentration and was 1.75% compared to all other intercropping planting patterns and sole maize. 4) The interaction of all intercropping planting patterns and plant density of 10 000 plants ha–1 gave higher nutrient concentration level than at higher plant density. 5) Sole cowpea had higher residual soil N–NO3– yield of 1.92, 1.66 and 1.23mgkg–1, whereas residual soil N–NH+4 was 3.28, 3.44 and 3.34mgkg–1 at Syferkuil, Potchefstroom and Taung, respectively, compared to all intercropping planting patterns and sole maize. 6) Cowpea has the ability to fix atmospheric N into the soil for subsequent crop use. and 7) The study indicates that intercropping system and lower plant density up to 30 000 plants ha–1 of maize had the potential of improving crop productivity and soil fertility status depending on the climate and available N in the soil.

Keywords: planting–density, planting–patterns, residual–soil–nutrients–content, intercropping, sole–cropping

Sanari Moriri,[1] Owoeye LG,[2] Mariga IK[1]

[1]Department of Plant Production, University of Limpopo, South Africa
[2]Agricultural Research Council– Institute for Industrial Crops (ARC–IIC), South Africa

Correspondence: Owoeye LG, Agricultural Research Council–Institute for Industrial Crops (ARC–IIC), Rustenburg 0300, South Africa, PBx82075, Tel +27736111127, Email OwoeyeL@arc.agric.za

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Introduction

Maize (*Zea mays* L) is the main staple and a cash crop for the majority of Small Holder (SH) farmers in South Africa. Low maize yield mainly in the SH sector is largely attributed to declining soil fertility and nutrient depletion resulting from continuous cropping with little or no nutrient inputs. Food production per capita is low and declining in many parts of South Africa. This is more pronounced in the dry regions, including Limpopo and North West Provinces, where rainfall is low and erratic and soils are predominantly sandy with low organic matter levels, low phosphorus and poor water holding capacity.[1] The most limiting nutrient to maize production is nitrogen (N) followed by phosphorus (P). The level of N can be improved through the use of inorganic fertilizers. However, SH farmers are resource–constrained and the incorporation of N–fixing legumes, whether used in rotation, sequential or intercropping with cereal crops, is a possible solution to the low N problem.[2]

Little or no fertilizer is used in most SH farmers' fields in Limpopo Province during planting and the soil is very low in organic matter content, hence the issue of transfer of N from legume to cereal is of great importance. Several investigators[3–5] have found no evidence that the presence of a cereal or grass has a specific effect on the release of N from actively growing roots, but other workers[6–8] have reported higher N contents and uptake in mixtures compared with sole crop systems.

Legumes are continuously shaded and hence their overall capacity to fix N is likely to be impaired since growth and photosynthesis will be limited.[8–9]

Most of the experiments involving exudation of N from legume roots have been conducted in greenhouse under reduced light; evidence has been obtained for considerable exudation.[5] It appears that legumes differ in their ability to benefit associated cereals that have the same growing period. In a comparative study with various legumes, Agboola et al.[10] reported an increase in maize grain yield over the control when mungbean (*Phaseolusaureaus*) was interplanted with the maize. The transfer of N from the legume to the maize was equivalent to 45kg ha–1. Cowpea did not have similar effect. Legumes are weak competitors for soil N if grown with grasses.[11] This will compel the legume to fix more N than in a situation in which it is growing alone, provided other factors, such as light and water, are not limiting.

Cowpea is tolerant to low soil fertility and can grow and produce well even on poor soils having more than 85% sand, less than 0.2% organic matter level and low levels of phosphorus.[12–13] Research results have shown that soil N levels increase, following cowpea in Limpopo Province and the crop does not deplete the natural reserves of soil nitrogen.[1,14–15]

However, Maluleke et al.[4] did not find significant changes in soil N due to symbiotic N fixation by lablab in Limpopo Province. Little is documented about the stover nutrient content and residual soil nutrient content in maize/cowpea intercrop planted at different densities and different planting patterns in dry environments such as Limpopo and North West provinces. Therefore, the objectives of this study were:

i. To determine the effect of planting patterns and planting densities of component crops on stover nutrient content and the residual soil nutrient content in maize/cowpea intercrop.

ii. To evaluate the interaction effect of component plant density and planting patterns on stover nutrient level in maize/cowpea intercrop, and the residual soil nutrient content.

Materials and methods

Site

A rainfed field experiment was conducted during 2007/2008 growing season at three locations namely, University of Limpopo experimental farm at Syferkuil, Agricultural Research Council–Grain Crop Institute (ARC–GCI) experimental farm at Potchefstroom and Taung Department of Agriculture experimental farm. Rainfall and temperature data for each trial site were collected at the research trial site weather station. The study sites are described in Table 1.

The trial was 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 (100x100cm), D2 (100x50cm), D3 (100x33cm) and D4 (100x25cm) and the subplot factor was planting pattern (row arrangements) namely sole maize (M), sole cowpea (C), 1:1 alternate intercropping (1 rowM: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 cowpea. PAN 6479 and PAN 311 are characterized by high yield, drought tolerance and short growth duration. Each plot consisted of seven rows of maize at 1m spacing in both intercrop and sole cropping, 6m long (42m^2) at all locations. For cowpeas, a plot consisted of seven rows in pure stand and in intercropping, 1rowM:1rowC and 2rowsM:2rowsC had six rows, 1rowM:2rowsC and 2rowsM:4rowsC had twelve rows within maize rows.

Leaf nutrient analysis

Samples of maize leaves that hold the ears were taken during reproductive stage at 80 DAP (days after planting) for nutrients analysis. Nitrogen concentration levels in plants were measured through tissue analysis of ground dry matter samples using the semi–micro Kjeldhal procedure and the results were read from an atomic adsorption spectrophotometer. Before analysis the plant tissue samples were oven dried at 65oc to constant weight and ground to pass through a 1.0 mm sieve. Magnesium, calcium and potassium were also measured by using dry ash methods and the results were read through an auto– analyser.

Soil nutrient analysis

Soil pH, nitrogen, phosphorus and potassium content were determined from samples taken prior to planting from 0–15cm and 15–30cm depths. Soil analytical data for the different sites is given in Table 2. At the end of the growing season, residual soil pH, nitrogen, phosphorus, potassium, magnesium, sodium, calcium and organic carbon were determined from 0–15cm depths using a hand auger at all trial sites. Nitrogen (NO_3–+ NH^4+) was determined on an auto–analyzer by the Kjeldhal method, available phosphorus was extracted using the Bray1 procedure and the phosphorus content of the extract was measured by the molybdate–blue method as described by Olsen et al.[16] A spectrophotometer with light band was used to determine the concentration of phosphorus in the soil extract, potassium, magnesium and calcium were determined using standard ammonium acetate (1normal pH7) by means of an atomic absorption spectrophotometer,[17] Organic carbon was measured by the wet chemical oxidation procedure of Walkey et al.,[18] and Soil pH (KCl) was measured using a pH meter.

Table 1 Description of the study sites

Location	Province	Soil Type	Latitude	Altitude
Syferkuil	Limpopo	Sandy loam, Glenrosa	-23^0 South and 20^0 East	1262m
Potchefstroom	North-West	Sandy clay	-26^0 South and 27^0 East	1347m
Taung	North-West	Sandy, Hutton	-27^0 South and 24^0 East	1000m

Table 2 Soil pH and nutrient content at the beginning of the trial

Location	Depth (Cm)	pH (KCL)	NH$_4$+ (mg kg^{-1})	N0-$_3$ (mg kg^{-1})	P (mg kg^{-1})	K (mg kg^{-1})
Syferkuil	0-15	6.13	3.2	2	25.8	187
	15-30	6.09	2.1	1.4	20.6	148
Potchefstroom	0-15	6.01	2.4	1.7	30.1	143.1
	15-30	6.02	2	1.3	22.1	76.5
Taung	0-15	6.01	1.2	1	21.5	108.5
	15-30	6.04	0.8	0.65	10.5	114.5

Experimental fields were ploughed a week before planting and at planting 44kg N ha^{-1} in the form of Limestone Ammonium Nitrate (LAN–28%N) and 50kg P ha^{-1} as a single super phosphates (10.5%P) were applied at all locations and hand hoes were used to incorporate the fertiliser. No fertilizer for topdressing was applied at all trial sites.

Data were subjected to Analysis of Variance (ANOVA) using the General Linear Model procedure of Statistical Analysis System.[19] Differences between treatment means were separated using the Least Significant Difference (LSD0.05) procedure.[20] For interactions, LSD values were obtained by using Agrobase program.[21]

Results and discussion

The effects of planting density and planting patterns on maize nutrient content

Maize N content: The effects of planting density on maize N content were significant (P≤0.05) at both locations (Table 3). Maize N concentration showed a decreased pattern as the planting density increased at both locations. Maize N yield was consistently reduced at maize density of 40 000 plants ha^{-1} at the two sites. Plant density of 10 000 plants ha^{-1} had higher N yield of maize by 22 and 11% relative to 40 000 plants ha^{-1} at Potchefstroom and Taung respectively. Maize N content ranged with planting density from 1.28 to 1.65% at Taung and Potchefstroom, respectively. At Potchefstroom, N content in maize was similar at planting densities of 30 000 and 40 000 plants ha^{-1} and these attained the lowest maize N content. The 2rowsM:4rowsC row arrangement gave the highest Maize N content at Taung, whereas sole cropping had the lowest maize N content. The result at Potchefstroom was insignificant (Table 4).

Concentration levels of P, K and Mg in maize plants: At both locations, the analysis of variance did not show any significant differences on P, K and Mg concentration levels in maize plants in response to planting density and planting patterns (Tables 3) (Table 4).

Calcium (Ca) accumulation in maize plants: Ca accumulation in maize plants was only significant (P≤0.05) at Potchefstroom influenced by planting density, whereas planting pattern did not show any significant differences (Tables 3) and (Table 4). At Taung, the results on Ca concentration were uniform across treatments. Calcium content in maize plants ranged from 20% to 23 % at Potchefstroom due to planting density. The highest Ca accumulation in maize plant was detected at maize densities of 10000 and 20 000 plants ha^{-1} which were similar at Potchefstroom.

Planting density and planting pattern interaction effects on nutrient content in maize

Nitrogen concentration in maize plants: Nitrogen concentration levels during reproductive stage was significantly (P≤0.05) influenced by the interactions of planting density and planting patterns at the two locations (Table 4). In all planting patterns the N concentration in maize plants decreased as the planting density increased at both locations. The interactions between all planting patterns and maize density at 10 000plants ha^{-1} had higher N content in maize relative to the higher maize densities.

P concentration in maize plants: Significant (P≤0.05) differences in P concentration in maize plant tissue were detected due to interactions between planting density and planting pattern at Potchefstroom only (Table 4). Phosphorus concentration in maize plant tissue gradually

decreased with an increased in planting density at both locations, whereas at Taung, the interaction effects on P accumulation in maize plant tissue was uniform across treatments. At Potchefstroom, P accumulation by maize plants was similar in the 1rowM:2rowsC pattern and sole maize. Maize P accumulation followed similar pattern as in maize N content. The P concentration levels in maize plant tissue were higher in all planting patterns at lower maize density of 10 000 plants ha^{-1} with different cowpea densities.

K concentration in maize plants: Planting density and planting pattern interactions effect on K concentration in maize plant was significant at Taung only (Table 5), whereas at Potchefstroom the interactions effect was insignificant (P≤0.05). At Taung, the K concentration in maize plants was higher in the interactions between the 1rowM:1rowC, 2rowsM:4rowsC and maize density of 10 000 plants ha^{-1} with cowpea densities. The combination of sole cropping and 40 000 maize plants ha^{-1} maize had the highest K accumulation compared at all other planting densities and even higher when compared on average.

Ca content in maize plants: The highest Ca concentrations in maize plants was obtained in the interactions between all planting patterns including sole maize and maize density at 10 000 plants ha^{-1} with cowpea densities compared at higher maize and cowpea densities at Potchefstroom (Table 6).

Mg accumulation in maize plants: Mg accumulation in maize responded positively to interactions effect at the reproductive stage generally declined linearly with an increase in planting density at Potchefstroom (Table 6). The interaction effects between the 1rowM:1rowC and all planting densities of maize with cowpea were statistically similar in Mg concentration in maize plants. Although the interactions between 1row M :1row C pattern and planting density of 10 000 plants ha^{-1} of maize and cowpea had higher Mg yield. At Taung, sole maize at 20 000 and 30 000 plants ha^{-1} had higher maize Mg concentration compared at 10 000 and 40 000 plants ha^{-1}. In 1rowM:1rowC arrangement and 10 000 plants ha^{-1} of maize and cowpea density maize had lesser Mg content compared at higher densities of both crops.

A non–significant difference between locations on maize N content was also observed (Table 7). Potchefstroom achieved 6% higher on N yield by maize compared to Taung, although the results on plant N yield were statistically similar at the two locations. The analysis of variance showed a significant difference on P, K, Ca and Mg accumulation in maize between locations. Content of all nutrients in maize plants (P, K, Ca and Mg) was higher at Potchefstroom than at Taung.

The effects of planting density on residual soil pH and nutrient content after crop harvest residual soil organic carbon

The results on the effect of plant density on residual soil organic carbon percentage were non–significant at Syferkuil and Potchefstroom, whereas at Taung the results were significant (Table 8). Residual soil organic carbon percentage ranged (0.34 to 0.98%) at all sites. The highest residual soil organic carbon was found in 20 000 plants ha^{-1} and was 38% higher than all other planting densities at Taung. Higher planting density of 40 000 plants ha^{-1} had lower residual soil organic carbon compared to lower plant densities at Taung. Despite insignificant differences (P≤0.05) in residual soil pH

and mineral nutrient caused by planting density, higher maize density of 40 000plants ha^{-1} had lesser amount of residual soil nutrient content compared to lower densities at all sites.

The results demonstrate that higher planting density of maize utilize higher amount of soil nutrient and also requires sufficient amount of water. The result findings support that of Herdy et al.,[22] who found a reduction in N$_2$ fixation per plant at increasing plant density. Low planting density had higher residual soil organic carbon than higher plant density of 40 000 plants ha^{-1}. This indicates that at higher density of maize, organic carbon is depleted at a higher rate and competition for nutrients is higher than at lower plant density.

The effects of planting pattern on residual soil pH and nutrient content after crop harvest residual soil pH

Significant differences (p≤0.05) on residual soil pH caused by planting patterns were detected at all locations (Table 9). Residual soil pH was higher in the 2rowsM:4rowsC pattern with pH 7.54 and 7.24 at Syferkuil and Taung respectively, whereas at Potchefstroom, sole maize resulted in higher residual soil pH of 6.64.

Residual soil N–NO$_3$: Statistical differences on residual soil N–NO$_3$ resulting from planting patterns were insignificant at Syferkuil and Taung, but at Potchefstroom significant differences were observed between treatments (Table 9). At Potchefstroom, sole cowpea gave higher residual soil N–NO$_3$ content of 1.66mg kg^{-1} compared to intercropping planting patterns and sole maize.

Residual soil N–NH$_4$: The effect of planting patterns on residual soil N–NH$_4$ was significant at all locations (Table 9). Sole cowpea resulted in greater amount of residual N–NH$_4$ than in intercropping and sole maize at the three sites. Sole maize resulted in low residual soil N–NH$_4$ than in intercropping and sole cowpea and was 2.46, 2.40 and 2.38mg kg^{-1} at Syferkuil, Potchefstroom and Taung, respectively.

Residual soil P: Planting patterns significantly influenced residual soil P content at Potchefstroom and Taung. At Syferkuil, the results on residual soil P were non significant (Table 9). Sole maize resulted in low residual soil P content relative to intercropping and sole cowpea at Potchefstroom and Taung.

Residual soil K: Insignificant differences were obtained on residual soil K due to planting patterns at Syferkuil and Potchefstroom (Table 9). At Taung the residual soil K content was higher in 1rowM:1rowC pattern compared to all other planting patterns. The 1row M:2 rows C, 2 rows M:2 rows C patterns and sole cowpeas were similar in residual soil K, whereas the 2 rows M: 4rows C arrangement attained the lowest residual soil K content.

Residual soil Ca: There were no significant differences in residual soil Ca content at Syferkuil and Taung but at Potchefstroom there were significant differences in residual soil Ca. There was a narrow range of 998.25 to 1068.19 mg kg– in residual Ca content in the soil and the highest was attained by sole maize.

Residual soil Mg and Na: The 2rows M: 4rows C and 2 rows M: 2rows C arrangements resulted in low amount of Mg content after crop harvest than all other planting patterns including sole maize and cowpea at Potchefstroom and Taung, respectively. No significant differences were obtained on residual soil Na caused by planting patterns at the three sites. The interaction of planting density and planting pattern did not show any significant differences across treatments at the three sites. The results were inconsistent in all the interaction treatments across locations.

The results also indicate that cropping patterns increased residual soil pH from 6.1 to 7.4 at Syferkuil, from 6.1 to 6.6 at Potchefstroom, whereas at Taung was increased from 6.1 to 7.1 relative to initial soil pH. Higher residual soil pH reduces soil acidity, and thus reducing lime applications to raise soil pH and input costs are reduced. More studies are needed to find out whether high soil pH and nutrient in subsoil might have allowed roots to exploit the available soil nutrient stored in the soil to enhance crop growth and yields.

Significant differences were low on residual soil K, Mg, Ca and Na after crop harvest, intercropping retained soil nutrient than maize sole cropping. The result also indicates that sole cowpea and intercropping resulted in high residual soil organic carbon at all locations. Sole maize depletes and requires higher nutrient content and it is severe at higher planting density. Taung had lower residual soil nutrient and organic carbon, this locality is characterised by sandy soils, low fertility and low levels of organic matter, all of these might attributed to low growth rate. The differences in planting density and planting patterns on residual soil nutrient strongly indicate that there is a need to have a uniform crop after intercrop trials as they created variation in soil fertility.

Cowpea plants were strongly dependent on soil N during growing season at Syferkuil and Potchefstroom only (Table 10). These experimental sites had higher available soil N before planting compared to Taung (Table 2). Higher dependence of cowpea plants on soil N under high N conditions was reported by Ayisiet al.,[1] Mpangane et al.,[4] Ayisiet al.[14] There was no N yield due to cropping systems at Syferkuil; the result shows that residual soil N was lower compared with the initial soil N content. In intercropping, residual soil N had a 12% reduction in soil N yield relative to initial available soil N. The initial soil mineral N before planting was the same compared to residual mineral soil N after crop harvest in sole cowpea. This shows that cowpea did not depend on available soil N for growth.

At Potchefstroom, intercropping and sole maize did not increase residual soil N, demonstrating that initial soil N was higher compared to the residual soil N. However, sole cowpea had shown to increase soil N yield with 1.8 kg ha^{-1}, this might be due to the fact that cowpeas has the ability of fixing atmospheric N into the soil[2] and will be available to be used by the subsequent crop.[23,24]

The data from this study also show that cowpea had used atmospheric N for crop growth and also fixed the nutrient into the soil for subsequent crop use. The percentage N of cowpea depending on symbiotic fixation was much higher at Taung only. Soil N yield was 3.6, 2.5 and 4.9kg ha^{-1} in intercropping, sole maize and sole cowpea respectively. This demonstrates that symbiotic N$_2$ fixation by cowpeas had the ability to replenish the available N used by both crop for growth and also fixed for future crop use. Lower initial soil N at Taung had influenced cowpea plants to depend on symbiotic N$_2$ fixation, and increased residual mineral soil N by 82% compared with initial soil N at that trial site. Sole maize resulted in increased residual soil N, which was not expected and that needs further investigation.

Despite higher temperatures and excessive rainfall at Taung which are reported to inhibit the symbiotic N$_2$ fixation by cowpea[25] the trial site resulted in higher residual mineral N. Lower concentrations of residual mineral soil N in intercropping compared to sole cowpea was

also observed in the three trial sites. The results indicate that shading or competition for light reduced photosynthesis and subsequently N_2 fixation in cowpea. Similar results were also observed by numerous scientists Trang et al.,[8] Wahua et al.,[26] andVan Kessel et al.[9] The results disagree with the findings of Marschner et al.,[27] who found that growing non legumes with legumes encourages legumes to respond by fixing more N than they might do in sole cropping. This may be that the non legume lowers soil N to stimulate higher rates of N fixation.

Table 3 The effects of planting density on nutrient accumulation in maize at different places

Planting density of maize at Potchefstroom in the North West Province					
Planting density	**N**	**P**	**K**	**Ca**	**Mg**
Plants ha^{-1}	**%**	**%**	**%**	**%**	**%**
10 000	1.65a	0.35	1.84	0.23a	0.19
20 000	1.45ba	0.36	1.84	0.22a	0.19
30 000	1.36b	0.33	1.83	0.21ba	0.18
40 000	1.35b	0.32	1.76	0.20b	0.19
LSD (0.05)	0.22	ns	ns	0.02	Ns
CV (%)	25.8	23.8	8.1	17.4	17.7
Planting density of maize at Taung in the North West Province					
10 000	1.42a	0.14	1.97	0.27	0.12
20 000	1.42a	0.19	1.9	1.27	0.12
30 000	1.38ba	0.15	1.97	0.28	0.11
40 000	1.28b	0.13	1.99	0.26	0.11
LSD (0.05)	0.13	ns	ns	ns	ns
CV (%)	16	20.8	12.4	19.1	22.6

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 Maize nutrient accumulation response to planting patterns at different places

Planting patterns at Potchefstroom in the North West Province					
Planting patterns	**N (%)**	**P (%)**	**K (%)**	**Ca (%)**	**Mg (%)**
1rowM:1rowC	1.84	0.4	2.2	0.27	0.23
1rowM:2rowsC	1.81	0.44	2.16	0.27	0.22
2rowsM:2rowsC	1.76	0.4	2.19	0.25	0.22
2rowsM:4rowsC	1.7	0.4	2.21	0.26	0.22
Sole cropping	1.59	0.39	2.14	0.25	0.22
LSD (0.05)	ns	ns	ns	Ns	ns
CV (%)	25.8	23.8	8.1	17.4	17.7
Planting patterns at Taung in the North West province					
1rowM:1rowC	1.62ba	0.17	2.3	0.31	0.13
1rowM:2rowsC	1.66ba	0.18	2.43	0.32	0.14
2rowsM:2rowsC	1.64ba	0.18	2.37	0.32	0.13
2rowsM:4rowsC	1.75a	0.18	2.39	0.34	0.14
Sole cropping	1.56b	0.16	2.27	0.3	0.13
LSD (0.05)	0.15	Ns	ns	Ns	ns
CV (%)	16	20.8	12.4	19.1	22.6

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 5 Nutrient accumulation in maize as influenced by planting density and planting pattern interaction at Potchefstroom in the North West province

Planting Patterns	Plant Density(Plants103 ha⁻¹)		N	P	K	Ca	Mg
	Maize	Cowpea	%	%	%	%	%
1rowM:1rowC	10	10	2	0.45a	2.3	0.30a	0.25
	20	20	1.88	0.40a	2.25	0.25ba	0.23
	30	30	1.8	0.38a	2.15	0.28a	0.23
	40	40	1.7	0.35b	2.15	0.23b	0.23
Mean			1.85	0.4	2.21	0.27	0.24
1rowM:2rowC	10	30	2.03a	0.45	2.23	0.30a	0.28a
	20	60	1.88a	0.45	2.15	0.25ba	0.23b
	30	92	1.88a	0.4	2.13	0.25ba	0.23b
	40	121	1.50b	0.43	2.1	0.23b	0.20b
Mean			1.81	0.43	2.15	0.26	0.21
2rowM:2rowC	10	30	2.08a	0.43a	2.3	0.30a	0.23a
	20	60	1.90a	0.45a	2.28	0.30a	0.25a
	30	92	1.78a	0.38a	2.25	0.20b	0.23a
	40	121	1.30b	0.35b	1.93	0.23b	0.20b
Mean			1.76	0.4	2.2	0.25	0.22
2rowM:4rowC	10	40	1.90a	0.48a	2.28	0.3	0.25a
	20	80	1.58a	0.40a	2.25	0.28	0.23a
	30	121	1.55a	0.40a	2.23	0.28	0.23a
	40	160	1.35b	0.38b	2.15	0.25	0.20b
Mean			1.59	0.41	2.22	0.27	0.22
Sole cropping	10	10	2.03a	0.43	2.23	0.3	0.25a
	20	20	1.73a	0.43	2.13	0.28	0.25a
	30	30	1.65a	0.4	2.13	0.28	0.23a
	40	40	1.40b	0.4	2.13	0.25	0.20b
Mean			1.7	0.41	2.15	0.27	0.23
LSD (0.05)			0.44	0.09	Ns	0.05	0.04
CV (%)			25.8	23.8	8.1	17.4	17.7
Density			*	ns	Ns	*	ns
Planting Patterns			ns	ns	Ns	ns	ns
Interaction			*	*	Ns	*	*

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 6 Plant nutrient accumulation in maize as influenced by planting density and planting pattern interactions at Taung in the North West province

Planting Patterns	Plant Density (Plants103 ha⁻¹)		N	P	K	Ca	Mg
	Maize	Cowpea	%	%	%	%	%
1rowM:1rowC	10	10	1.61	0.18	2.43a	0.3	0.11b
	20	20	1.67	0.19	1.95b	0.32	0.13ba
	30	30	1.66	0.17	2.35a	0.31	0.16a
	40	40	1.56	0.16	2.46a	0.33	0.14a
Mean			1.63	0.18	2.3	0.32	0.14
1rowM:2rowC	10	30	1.61	0.17	2.23	0.32	0.14
	20	60	1.62	0.16	2.23	0.3	0.14
	30	92	1.51	0.16	2.25	0.34	0.14
	40	121	1.49	0.15	2.36	0.31	0.14
Mean			1.56	0.15	2.27	0.32	0.14
2rowM:2rowC	10	30	1.58a	0.18	2.31	0.29	0.13
	20	60	1.70a	0.42	2.4	0.32	0.14
	30	92	1.78a	0.17	2.43	0.33	0.13
	40	121	1.49b	0.17	2.35	0.3	0.13
Mean			1.64	0.24	2.37	0.31	0.13
2rowM:4rowC	10	40	1.88a	0.2	2.46	0.35	0.15
	20	80	1.88a	0.2	2.39	0.35	0.15
	30	121	1.70a	0.17	2.42	0.36	0.15
	40	160	1.56b	0.16	2.31	0.31	0.13
Mean			1.76	0.18	2.4	0.34	0.15
Sole cropping	10	10	1.62a	0.16	2.37	0.34	0.12b
	20	20	1.64a	0.18	2.45	0.33	0.17a
	30	30	1.85a	0.21	2.44	0.35	0.15a
	40	40	1.55b	0.16	2.49	0.29	0.12b
Mean			1.67	0.18	2.44	0.33	0.14
LSD (0.05)			0.26	ns	0.29	Ns	0.03
CV (%)			16.02	20.8	12.38	19.1	22.6
Density			*	ns	ns	Ns	Ns
Planting Patterns			*	ns	ns	Ns	Ns
Interaction			*	ns	*	Ns	*

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 7 The effects of plant nutrient accumulation in maize across locations

Location	N (%)	P (%)	K (%)	Ca (%)	Mg (%)
Potchefstroom	1.45	0.34a	1.96a	0.27a	0.19a
Taung	1.37	0.16b	1.82b	0.22b	0.11b
LSD (0.05)	ns	0.03	0.06	0.01	0.01
CV (%)	21.3	41.9	10.8	19.1	22.9

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 8 The effects of planting density on residual soil pH and mineral nutrient (0 – 15cm) after crop harvest at Taung in the North West province

Planting Density	pH (KCL)	N-NO₃	N- NH+4	P	K	Ca	Mg	Na	%C
Plants ha⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹
10 000	7.14	1.10	2.79	16.08	119.17	396.63	128.92	12.67	0.37ba
20 000	7.08	1.26	3.00	16.46	120.13	386.13	129.38	11.58	0.38a
30 000	7.11	0.94	3.14	15.5	123.79	384.63	128.08	14.50	0.36ba
40 000	7.05	1.00	2.82	14.67	118.38	399.88	129.88	11.88	0.34b
LSD (0.05)	ns	Ns	ns	ns	ns	ns	ns	ns	0.02
CV (%)	4.62	85.25	40.32	37.77	13.59	11.12	9.86	45.95	10.98

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 9 Residual soil pH and mineral nutrient content (0-15cm) response to planting patterns after crop harvest at different places

Planting Patterns After Crop Harvest at Syferkuil in the Limpopo Province

Planting patterns	pH KCL	N-NO³-	N-NH⁴+	P	K	Ca	Mg	Na	%C
Plants ha⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹
1rowM:1rowC	7.31b	1.69ba	2.89a	20.44	197.19	839.56	456.19	55.94	0.81
1rowM:2rowsC	7.38b	1.53ba	3.23a	18.94	181.19	847.19	462.81	57	0.85
2rowsM:2rowsC	7.35b	1.54ba	3.00a	19	188.19	804.5	457.94	55.44	0.79
2rowsM:4rowsC	7.54a	1.59ba	2.78a	19.31	192.56	864.31	476.13	62.13	0.8
Sole maize	7.41a	1.14b	2.46b	21.25	198.88	803.75	455.25	58.44	0.8
Sole cowpea	7.42a	1.92a	3.28a	18.81	196.94	813.17	458.56	54.94	0.82
LSD (0.05)	0.15	0.75	0.63	ns	ns	ns	ns	ns	ns
CV (%)	3.32	68.15	36.45	26.7	20.89	13.58	11.53	28.11	9.3

Planting patterns after crop harvest at Potchefstroom in the North West province

Planting patterns	pH KCL	N-NO₃-	N-NH⁴+	P	K	Ca	Mg	Na	%C
Plants ha⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹
1rowM: 1rowC	6.56b	1.01b	2.76a	30.38a	152.75	1027.38a	364.19a	18.81	0.96
1rowM: 2rowsC	6.56b	1.21b	2.93a	28.63a	162.38	1049.13a	370.25a	18.94	0.98
2rowsM: 2rowsC	6.61a	0.89b	2.76a	28.13a	165.65	1077.19a	379.06a	18.13	0.97
2rowsM: 4rowsC	6.58ba	1.11b	2.89a	30.63a	161.06	998.25b	352.19b	17.63	0.97
Sole maize	6.64a	0.89b	2.40b	27.19b	157.06	1068.19a	378.44a	15.13	0.94
Sole cowpea	6.54b	1.66a	3.34a	28.25a	163.88	1043.38a	369.88a	18	0.99
LSD (0.05)	0.06	0.41	0.64	3.09	ns	71.2	21.61	ns	ns
CV (%)	1.54	62.52	38.64	21.07	20.87	11.55	9.92	42.59	9.48

Planting Patterns After Crop Harvest at Taung in the North West Province

Planting patterns	pH KCL	N-NO₃-	N-NH⁴+	P	K	Ca	Mg	Na	%C
Plants ha⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹	mg kg⁻¹
1rowM: 1rowC	7.16a	1.22	3.09a	14.75a	130.88a	407.94	135.50a	13.13	0.38
1rowM: 2rowsC	7.13a	0.9	3.05a	15.81a	121.19b	389.5	126.69b	11.31	0.36
2rowsM: 2rowsC	6.94b	1.11	2.72b	16.50a	119.25b	385.94	123.50b	13	0.36
2rowsM: 4rowsC	7.24a	0.93	2.96a	15.06a	108.88c	389.69	129.44a	13.38	0.36
Sole maize	7.08a	1.06	2.38b	14.38b	122.13ab	388.38	128.94a	12.63	0.35
Sole cowpea	7.04b	1.23	3.44a	17.56a	119.88b	389.44	130.31a	12.5	0.37
LSD (0.05)	0.19	ns	0.69	3	9.66	Ns	7.51	ns	ns
CV (%)	4.62	85.25	40.32	37.77	13.59	11.12	9.86	45.95	10.98

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 10 Mineral soil nutrient at 0-15 cm depth influenced by cropping systems at the three experimental sites

Location	Cropping system	N		P	
		Initial kg ha^{-1}	Residual kg ha^{-1}	Initial kg ha^{-1}	Residual kg ha^{-1}
Syferkuil	Intercropping	10.4	9.2	56.8	42.7
	Sole maize	10.4	7.2	56.8	46.8
	Sole cowpea	10.4	10.4	56.8	41.4
Potchefstroom	Intercropping	8.2	7.9	66.2	64.8
	Sole maize	8.2	6.6	66.2	59.8
	Sole cowpea	8.2	10	66.2	62.2
Taung	Intercropping	4.4	8	47.3	34.1
	Sole maize	4.4	6.9	47.3	31.6
	Sole cowpea	4.4	9.3	47.3	38.6

Initial = soil nutrient status before planting; Residual = soil nutrient status after crop harvest

Conclusion

Generally, intercropping system at Syferkuil and Potchefstroom did not improve soil fertility status at the two experimental sites and had mined available soil N and P, even though residual mineral N was lower in sole maize, suggesting that soil nutrient mining was more severe compared to intercropping. Data from these experiments show that symbiotic fixation of cowpea depends on soil nutrient status, plant density and cropping systems and environment within locality. In situations where there are limited resources, it is advisable for a SH farmer to plant at low density to minimise the demand for soil nutrient and moisture by maize plants. Increasing cowpea density in intercropping did not show any significant influence on residual soil mineral nutrient. This study shows that intercropping with cowpeas in low rainfall areas is unlikely to sustain crop productivity without soil fertilization.

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Conflict of interest

The author declares no conflict of interest.

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