Phosphorus application to Maize-Cowpea sequences in smallholder farming systems of Zimbabwe

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Abstract

Cowpea can increase the on-farm nitrogen (N) budgets through the biological N fixation. However, legumes require adequate phosphorus (P) for efficient N fixation to occur and to reduce the cost of purchased nitrogen fertilizers. Field experiments were conducted on P application effects in maize-cowpea sequences. In the first season, 20 kg/ha of P_2O_5 increased both maize and cowpea yields significantly ($P<0.05$) on P-deficient sandy soils. There was a decline in the kg grain/kg P applied with fertilizer P rates beyond 20 kg/ha P_2O_5 in the first and the second (residual) year on both maize and cowpea. The relative effect of each kg of P was higher on maize than on cowpea in the residual year. Yields in the second season were higher from plots where higher P levels were previously applied, with the residual treatments being statistically significant ($P<0.05$). Total grain yields for the rotation were highest when the P fertilizer was applied to cowpea, followed by maize grown on the residual P and the incorporated cowpea residues.

Media summary

In maize-cowpea farming systems, higher yields are achieved from crop sequences when phosphorus is applied to cowpea in the first season and followed by maize in the second season.

Keywords

Crop sequences, residual phosphorus effects, legumes, maize-cowpea rotations, sandy soils

Introduction

Crop sequences are utilized by the majority of farmers in rural Zimbabwe. Cowpea is a widely grown legume in both the high and low rainfall smallholder farming areas of Zimbabwe (Shumba et al. 1990). Although maize is the staple crop in Zimbabwe, the popularity of cowpea with farmers can be attributed to its multiple uses and its adaptability to different environments. It is often used for relish so it an important source of proteins for humans, as livestock feed, and for enhancing soil fertility through biological N fixation (Giller 2001; Johnson 1970). However, the lack of appropriate fertilizer recommendations, poor seed availability, and a limited product market were identified as major constraints to the expansion of cowpea production in Zimbabwe (Nhamo et al. 2003). The aim of this study was to determine an agronomic rationale for P application rates and strategies in maize-cowpea sequences.

Materials and methods

The experiments were conducted on-farm on sandy soils in two smallholder farming areas of Zimbabwe, Shurugwi and Zimuto, where the average annual rainfall ranges from 450 to 600 mm. Phosphorus was broadcast at rates of 0, 20, 40 and 60 kg/ha of P_2O_5 on all maize and cowpea plots in the first season. In the second season, the crops were rotated and grown on residual P from the previous year's application. Nitrogen (60 kg N/ha) was applied to the maize, whilst K was applied in both years to cowpea and maize at 45 kg K/ha. Cowpea residues from the first season were incorporated into the soil, but the maize residues were fed to livestock. Grain yields were measured at the end of each season. The relative P effect was calculated as the ratio of the yield benefit of each P treatment to the control (0P).

Results

Selected properties of the soils at the trial sites are given in Table 1. Most of the soils had a low pH (less than 6.2), low clay and organic matter contents, and hence low total exchangeable bases and CEC. Soils from homestead fields (e.g. at the Maganyani site in Zimuto) had higher nutrient contents than the soils from topland fields in their respective areas.

Table 1. Selected properties of the sandy soils (0-20cm) at the trial sites in Zimbabwe.

Site	PH ($CaCl_2$)	N (%)	P (mg/kg)	Ca	Mg	K	CEC	OC (g/kg)	Clay (%)	Sand (%)	Silt (%)
					Cmol$_+$/kg						
Mapfidza (Shg, H)	6.2	0.78	6.2	2.3	0.6	0.02	2.6	10.10	8	88	4
Shanyurai (Shg, T)	4.9	0.56	3.8	1.6	0.4	0.30	1.9	7.20	2	92	6
Shava (Shg, H)	5.2	0.60	5.3	1.5	0.5	0.05	2.0	9.80	2	93	5
Chibango (Zmt, H)	5.9	0.61	4.9	1.8	0.5	0.09	2.2	8.60	5	88	7
Maganyani (Zmt, H)	5.1	0.59	3.6	1.5	0.3	0.10	1.8	7.00	5	89	6
Steama (Zmt, T)	4.8	0.49	2.9	1.0	0.2	0.06	1.3	5.40	4	93	3

Abbreviations: locality; Shg, Shurugwi; Zmt, Zimuto; field type; H, homestead; T, topland.

Cowpea yields from the sites in Zimuto were significantly ($P<0.05$) higher than those in Shurugwi. However, average yields at each of the regions relative to the country average of 200 kg/ha were high, 816 kg/ha and 1212 kg/ha for Shurugwi and Zimuto, respectively (Tables 2 and 3). Maize yields at Shurugwi (1556 kg/ha) were higher than those at Zimuto (885 kg/ha) in the first season. In the second season, yields of cowpea and maize from the 0P control plots were significantly lower than from the plots that previously received the higher rates of P fertilizer (Tables 4 and 5).

Table 2. Cowpea grain yields (kg/ha) in the first season for application of different P rates in the Shurugwi and Zimuto smallholder farming areas of Zimbabwe.

Site	Cowpea yields at different P rates (kg/ha P_2O_5)				
	0	20	40	60	SED
Mapfidza	1389	1521	1678	1675	108
Shanyurai	319	422	459	495	25

Shava	834	866	997	1012	195
Chibango	964	1350	1536	2088	650
Maganyani	1358	1476	1632	1899	325
Steama	466	488	546	737	348

See Table 1 for locality and field type of each site

Table 3. Maize grain yields (kg/ha) in the first season of application of different P levels in the Shurugwi and Zimuto smallholder farming areas of Zimbabwe.

Site	Maize yields at different P rates (kg/ha P_2O_5)				
	0	20	40	60	SED
Mapfidza	3318	4038	4320	4760	1524
Shanyurai	618	811	745	987	79
Shava	1430	1655	2038	1651	419
Chibango	1040	1136	1151	1137	446
Maganyani	821	1026	1058	1266	208
Steama	398	495	561	525	125

See Table 1 for locality and field type of each site

Discussion

There was an increase in the total grain yield of both crops over the two years at each site due to the P applied in the first year. In maize, the 0P control received the blanket N and K application and this resulted in yields that were usually not significantly different from the treatments with applied P. However, the rate of N may have been inadequate, and the low yield responses of maize to P at some sites could be a result of N deficiency masking the effects of the applications of P since N is the main limiting nutrient on sandy soils in the Shurugwi and Zimu regions.

Table 4. Cowpea grain yields (kg/ha) in the second season (residual P effects) to the rates of P fertilizer applied in the previous season in the Shurugwi and Zimuto smallholder farming areas of Zimbabwe.

Site	Cowpea yield response to residual P from rates (kg/ha P_2O_5) applied in previous season				
	0	20	40	60	SED
Mapfidza	1196	1567	1876	1765	119
Shanyurai	290	513	662	700	39
Shava	624	909	1099	1007	206
Chibango	708	1077	1164	1979	559
Maganyani	1290	1185	1236	1675	327
Steama	333	491	569	963	314

See Table 1 for locality and field type of each site

Table 5. Maize grain yields (kg/ha) in the second season (residual P effects) to the rates of P fertilizer applied in the previous season in the Shurugwi and Zimuto smallholder farming areas of Zimbabwe.

Site	Maize yield response to residual P from rates (kg/ha P_2O_5) applied in previous season				
	0	20	40	60	SED
Mapfidza	4482	5154	5212	5984	608.7
Shanyurai	2492	3143	3256	3325	626.9
Shava	4178	4333	5313	5872	769.3
Chibango	821	1238	1265	1280	191.8
Maganyani	980	1199	1387	1400	227
Steama	937	1589	1598	1630	118

See Table 1 for locality and field type of each site

Fertility of different field types

The higher yields of cowpea and maize at Mapfidza, Shava, Chibango and Maganyani reflect the higher fertility of the soils at these homestead sites (Table 1). Homestead fields (those close to the home) are better managed and more fertile than topland fields as they receive additional inputs such as kitchen refuse, composts and ash. However, the higher fertility levels of the homestead fields had the effect of reducing the yield per unit P applied in all the treatments relative to the control.

Nutrient interactions

In crop sequences in Zimbabwe, the major nutrient inflows are a result of nutrient cycling and biological N fixation by legumes. Maize following cowpea benefited from residual fertilizer P, and P and other nutrients from the decomposing above- and below-ground cowpea residues. However, cowpea following maize only benefited from the residual fertilizer P, since most of the maize residues were removed to feed animals and maize does not improve the N budget through N fixation. This effect shows the importance of small applications of P on the crop sequences, as there was a positive correlation between P application rate and the yield responses in both the first and the second year. Hardter et al. (1991) reported higher yields and land-use efficiencies from maize-cowpea sequences following application of both N and P fertilizers. Hence, in these systems management of crop residues can play a significant role in the cycling of nutrients and improvement of the soil fertility (Giller 2001; Kouyate et al. 2000).

Targeting phosphorus application

The major benefit of applying P to cowpea is the increased leaf and root biomass that can be incorporated into the soil. The increased maize yields obtained when planted after cowpea show this effect (Table 5). Eagleton et al. (1991) also found that P application increased both cowpea and maize yields. With the application of N, maize uses more P in the first year, leaving much less residual P in the soil for the subsequent crop, in contrast to cowpea which recycles both P and N. The higher relative P effect obtained with maize following cowpea is a result of the recycling of nutrients from the decomposition of the cowpea biomass.

Conclusions

The application of P to cowpea increases biomass production, and thus the benefit to the following maize crop through the efficient recycling of both N and P. The unit grain to unit P ratio favoured the application of P to cowpea, with the following maize crop benefiting from the residual effects. In maize-cowpea sequences in the Shurugwi and Zimu regions, adding a small amount of P is important, and it is better applied to cowpea than to maize.

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