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Nutrient balance and economics of integrated nutrient management in groundnut (*Arachis hypogaea* L.) - mustard (*Brassica juncea* L.)

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Abstract: A 2-year field experiment was conducted to study the direct and residual effect of organic manure, phosphorus and gypsum on soil nutrient balance under groundnut-mustard crop sequence during 1997-99. Soil fertility measured in terms of available N, P and S content improved after groundnut crop over the initial levels. However, the final nutrient status after the mustard harvest declined. Application of FYM at 10 t ha^{-1} and poultry manure at 5 t ha^{-1} increased actual gain in N content with similar magnitude as compared to control and their effects of P content was less marked after groundnut harvest. Similar effect of above treatments was also noticed in actual loss of N and P content after mustard harvest. Increased rate of P application from 20 to 60 kg ha^{-1} to groundnut steeply increased actual gain in N and P content of soil after its harvest. Phosphorus application rate had marginal effect on actual loss of N and P content on final status of soil. Gypsum application at 250 kg ha^{-1} at sowing or in split dose increased the actual gain of N in soil after groundnut and minimizes the actual loss of N after the crop sequence but had no effect on P balance sheet.

Key words : Groundnut, Mustard, Nutrient balance, Nitrogen, Phosphorus, Sulphur.

Introduction

Groundnut and mustard are the most important *kharif* and *rabi* season oil seed crops of India and both the crops together contribute more than 70.0 per cent of the total oilseed production. Groundnut-mustard crop sequence is becoming very popular in the rainfed as well as irrigated tract of Rajasthan due to its economic viability. Nevertheless, the productivity of the system is low and has been ascribed to several constraints. Soils low in organic matter content and poor in fertility status are considered to be the major problem under semi-arid agro-climatic conditions of Rajasthan.

Integrated nutrient management involving the conjunctive use of chemical fertilizers and organic sources assumed great importance recently due to paucity of fertilizers and need to sustain productivity (Nambiar and Abrol, 1989). Since a current crop utilizes a limited part of applied nutrient, fertilizer requirement of the succeeding crop may be modified by the residual nutrients. Organic manure besides supplying nutrients to the current crop often have substantial residual effect on the succeeding crops (Gaur, 1982). The carry over effect of P is well known and first crop hardly utilized more than 15-20 per cent of applied P. Gypsum as S fertilizer, which is mostly applied to oilseeds, might benefit more than one crop in sequence due to its significant residual responses (Tandon, 1991). Thus, system approach to plant nutrition involving integrated use of all sources of plant nutrient is being attempted to study soil fertility building and balance sheet of major nutrients under groundnut-mustard crop sequence.

Materials and Methods

A field experiment was conducted for 2 years at Agronomy farm, Rajasthan College of Agriculture, Udaipur (Rajasthan) during 1997-99. The soil was sandy clay loam in texture, with pH 7.6, low in available N (247.8 kg ha^{-1}), medium in available P (16.4 kg ha^{-1}) and K (278.9 kg ha^{-1}). The experiment was laid out in split plot design with 4 replications. The combinations of 3 organic manure (control, 10 t FYM and 5 t poultry manure ha^{-1}) and 3 levels of P (20, 40 and 60 kg P_2O_5 ha^{-1}) were allotted to main plots. The 3 mode of gypsum application at 250 kg ha^{-1} *i.e.* control, full at sowing (single) and 1/2 at sowing + 1/2 at 35 DAS (split) were placed in sub

Table 1. Effect of organic manure, phosphorus and gypsum on available nutrient balance in soil after harvest of groundnut and mustard

Treatment	After groundnut harvest				After mustard harvest	
	Nitrogen	Phosphorus	Sulphur	Calcium	Nitrogen	Phosphorus
Organic manure (ha^{-1})						
Control	249.2	19.5	22.7	334.1	212.9	15.0
FYM 10t	263.3	20.8	24.1	341.5	221.1	15.5
PM 5t	263.4	21.5	24.2	347.7	219.4	15.7
S.Em±	2.6	0.3	0.3	2.9	2.5	0.2
CD (P=0.05)	7.3	0.9	0.8	8.2	7.0	0.5
Phosphorus (kg P_2O_5 ha^{-1})						
20	251.7	19.5	22.9	335.9	216.9	15.1
40	259.2	20.7	23.9	341.6	216.2	15.3
60	265.1	21.7	24.1	345.9	220.3	15.7
S.Em±	2.6	0.3	0.3	2.9	2.5	0.2
CD (P=0.05)	7.3	0.9	0.8	8.2	7.0	0.5
Gypsum (250 kg ha^{-1})						
Control	253.4	20.3	20.7	328.1	214.1	15.4
Full at sowing	260.9	20.7	24.3	346.0	219.2	15.5
Half at sowing + half at 35 DAS	261.6	20.7	25.9	349.3	220.1	15.4
S.Em±	1.5	0.2	0.2	1.7	1.6	0.1
CD (P=0.05)	4.1	NS	0.6	4.9	4.3	NS

plots. FYM and poultry manure was applied 15 days before sowing. P was applied through DAP. Finely grounded gypsum was applied in furrows at sowing and on both sides of crop rows at 5 cm depth at 35 DAS as per treatment. FYM used contained 0.45% N, 0.23% P, 0.5% K and pH 7.1. The poultry manure contained 1.4% N, 1.6% P, 1.0% K and pH 8.0. Gypsum was having 14.0% S and 18.0% Ca.

The amount of rainfall received during groundnut crop growth was 483.7 mm and 537.5 mm in the year 1997 and 1998 respectively. The groundnut crop was raised as rainfed and sowing was done with the onset of monsoon rains on July 18, 1997 and July 7, 1998. A seed rate of 100 kg kernel ha^{-1} of variety JL-24 (SB) was used at a spacing of 30 x 10 cm. All the plots were uniformly fertilized with 24 kg N ha^{-1} at sowing after compensating N supply through DAP. Mustard crop was sown as a sequence in the *rabi* season on residual soil fertility without disturbing original layout plan of main crop. The Indian mustard variety *Pusa bold* was sown on Nov.9, 1997 and Nov.2, 1998 in rows 30 cm apart. Plant samples at harvest were analyzed for groundnut (separately for haulm, kernel, and shell) and mustard (seed and stover) for total uptake of N, P and S following standard methods. Soil samples (0-15 cm soil depth) before and after harvest of each crop were collected and analyzed for plant available nutrients followed standard methods (Page *et al.* 1982).

Results and Discussion

Changes in available nutrient status

Alkaline $KMnO_4$ oxydisable N : Application of organic manure had significant effect on available N content. Farmyard manure at 10 t ha^{-1} and poultry manure at 5 t ha^{-1} brought significant improvement in the post harvest available N content in the soil over control (Table 1). Application of 60 kg P_2O_5 ha^{-1} to

Table 2. Nitrogen balance sheet after 2 years of cropping (Mean of 2 years)

A. Fate of nitrogen during groundnut crop (kg ha^{-1})

Treatment	Initial status	Nutrient added	Crop uptake	Expected balance	Actual balance	Apparent gain/loss	Actual gain/loss
Organic manure (ha^{-1})							
Control	247.6	24.0	97.2	174.5	249.2	74.8	1.6
FYM 10t	247.6	69.0	116.7	199.9	263.3	63.3	15.6
PM 5t	247.6	94.0	114.7	226.9	263.4	36.5	15.7
P Levels (kg P_2O_5 ha^{-1})							
20	247.6	62.3	99.9	210.0	251.6	41.6	4.0
40	247.6	62.3	111.4	198.5	259.2	60.6	11.5
60	247.6	62.3	117.2	192.7	265.1	72.3	17.4
Gypsum (250 kg ha^{-1})							
Control	247.6	62.3	100.9	208.9	253.4	44.4	5.8
Single dose	247.6	62.3	112.9	197.0	260.9	63.8	13.2
Split dose	247.6	62.3	114.7	195.3	261.6	66.4	13.9

B. Fate of nitrogen during mustard crop (kg ha^{-1})

Treatment	Initial status	Nutrient added	Crop uptake	Expected balance	Actual balance	Apparent gain/loss	Actual gain/loss
Organic manure (ha^{-1})							
Control	249.3	-	91.47	157.8	213.0	55.2	-36.3
FYM 10t	263.3	-	101.3	162.0	221.1	59.1	-42.2
PM 5t	263.4	-	106.9	156.5	219.5	63.0	-43.9
P Levels (kg P_2O_5 ha^{-1})							
20	251.7	-	95.4	156.3	216.9	60.6	-34.8
40	259.2	-	98.7	160.5	216.2	55.8	-42.9
60	265.1	-	105.6	159.5	220.4	60.9	-44.7
Gypsum (250 kg ha^{-1})							
Control	253.5	-	95.2	158.3	214.2	55.9	-39.5
Single dose	260.9	-	101.9	159.0	219.2	60.2	-41.7
Split dose	261.6	-	102.6	156.9	220.1	61.2	-41.5

preceding groundnut crop significantly increased post-harvest available N content of soil as compared to 20 kg P_2O_5 ha^{-1} was not statistically significant. Application of gypsum at 250 kg ha^{-1} either in single or in split dose to preceding groundnut crop significantly increased post-harvest available N content as compared to control.

Olsen's extractable P : The effect of FYM on available P was significant during 1997. The effect of poultry manure on available P was significant during both the years (Table 1). Results showed that available P content in soil increased significantly from 19.5 kg ha^{-1} under control to 20.8 and 21.5 kg ha^{-1} with 10t FYM and 5t poultry manure ha^{-1} respectively. Application of P at 60 kg ha^{-1} to groundnut significantly increased post harvest available P content in soil by 11.5 per cent over 20 kg ha^{-1} (19.5 kg ha^{-1}). Gypsum at 250 kg ha^{-1} when applied either in single or in split dose to groundnut crop had no significant effect on available P content in soil after its harvest.

Table 3. Phosphorus balance sheet after 2 years of cropping (Mean of 2 years)

A. Fate of phosphorus during groundnut crop (kg ha^{-1})

Treatment	Initial status	Nutrient added	Crop uptake	Expected balance	Actual balance	Apparent gain/loss	Actual gain/loss
Organic manure (ha^{-1})							
Control	16.3	18.03	14.77	19.56	19.50	-0.06	3.2
FYM 10t	16.3	28.03	17.15	27.19	20.80	-7.48	4.5
PM 5t	16.3	50.03	17.26	52.07	21.50	-30.57	5.2
P Levels (kg P_2O_5 ha^{-1})							
20	16.3	24.43	15.08	25.65	19.45	-6.20	3.15
40	16.3	33.03	16.45	32.89	20.65	-12.23	4.35
60	16.3	41.63	17.65	40.28	21.69	-19.68	5.39
Gypsum (250 kg ha^{-1})							
Control	16.3	32.20	15.39	33.11	20.33	-12.77	4.03
Single dose	16.3	34.45	16.73	33.02	20.74	-12.28	4.44
Split dose	16.3	34.45	17.06	32.69	20.72	-11.96	4.42

B. Fate of phosphorus during mustard crop (kg ha^{-1})

Treatment	Initial status	Nutrient added	Crop uptake	Expected balance	Actual balance	Apparent gain/loss	Actual gain/loss
Organic manure (ha^{-1})							
Control	19.50	-	18.00	1.50	14.96	13.46	-4.54
FYM 10t	20.80	-	19.62	1.18	15.52	14.34	-5.28
PM 5t	21.50	-	20.07	1.43	15.66	14.23	-5.84
P Levels (kg P_2O_5 ha^{-1})							
20	19.45	-	18.23	1.22	15.14	13.92	-4.31
40	20.65	-	19.15	1.50	15.28	13.78	-5.38
60	21.69	-	20.31	1.38	15.71	14.33	-5.97
Gypsum (250 kg ha^{-1})							
Control	20.33	-	18.13	2.20	15.34	13.14	-4.99
Single dose	20.74	-	19.63	1.10	15.44	14.33	-5.30
Split dose	20.72	-	19.93	0.80	15.36	14.56	-5.37

Ammonium acetate extractable S : Results showed that application of FYM at 10t ha^{-1} and poultry manure at 5t ha^{-1} significantly increased the available S from 22.7 kg ha^{-1} (control) to 24.1 and 24.2 kg ha^{-1}, respectively on pooled basis (Table 1). P application rate to groundnut had no significant effect on post harvest available S content in soil. Application of gypsum at 250 kg ha^{-1} either in single or in split dose to groundnut crop caused significant improvement in available S content in soil after harvest. It increased from 20.7 kg ha^{-1} (control) to 24.3 kg ha^{-1} with gypsum applied full at sowing and 25.9 kg ha-1 with gypsum applied half at sowing and half at 35 DAS. The difference between two modes of gypsum application was significant in this respect.

Ammonium acetate extractable Ca : Application of organic manure marginally increased extractable Ca content in soil during both the years except the effect of poultry manure during 1998 wherein

Table 4. Effect of organic manure, phosphorus and gypsum on net return and B:C ratio (Pooled data)

Treatment	Groundnut pod yield (q ha^{-1})	Mustard seed yield (q ha^{-1})	Net returns (Rs.)			B:C ratio	
			Ground-nut	Mustard	Groundnut - Mustard	Ground-nut	Mustard
Organic manure (ha^{-1})							
Control	16.2	15.0	20211	16266	36477	2.33	5.11
FYM 10t	18.5	16.4	22112	17999	40111	2.06	5.66
PM 5t	18.1	16.8	21388	18537	39926	1.99	5.83
S.Em±	0.3	0.3	418	291	574		-
CD (P=0.05)	0.7	0.7	1192	830	1637		-
Phosphorus (kg P_2O_5 ha^{-1})							
20	16.3	15.4	19540	16713	36153	2.02	5.25
40	17.9	16.0	21729	17524	39253	2.18	5.51
60	18.5	16.9	22544	18564	41108	2.18	5.84
S.Em±	0.3	0.3	418	291	574	-	-
CD (P=0.05)	0.7	0.7	1192	830	1637	-	-
Gypsum (250 kg ha^{-1})							
Control	16.6	15.1	19725	16410	36135	2.01	5.16
Full at sowing	18.1	16.3	21977	17912	39890	2.19	5.63
Half at sowing + half at 35 DAS	18.1	16.8	22010	18479	40490	2.18	5.81
S.Em±	0.2	0.2	295	218	367	-	-
CD (P=0.05)	0.5	0.5	826	610	1027	-	-

t was statistically significant over control (Table 1). An increased rate of P application had no significant effect on extractable Ca content in soil. Application of gypsum at 250 kg ha^{-1} increased extractable Ca content in soil significantly over control. Gypsum applied full at sowing and half at sowing + half at 35 DAS increased extractable Ca by 6.2 and 6.9 per cent over control, respectively.

Addition of organic manure caused favourable effect on post harvest available nutrients. This may be assigned to increased release of nutrient in soil from native pool as well as their residual effect. Organic matter provides energy for nodulation and N_2 fixation by micro-organism. Organic acids and chelates are produced during decomposition of organic residues and phosphorus tied up as insoluble Ca, Fe and Al form may be released as soluble form (Dhillon and Dev, 1979). The solubility of Ca and Mg phosphate may be increased due to production of carbonic acid from CO_2 released during decay of organic matter (Stevenson, 1982). Similarly there was build up of available S and Ca content in the soil due to increased availability from native pool. Das *et al.* (1992) reported that application of FYM and poultry manure to groundut crop increased post harvest soil organic C and available Ca contents. Ismail *et al.* (1998) reported significant increased in organic C, available N and P content of the soil with application of FYM possibly due to the increase in decomposition product of organic matter. The acidulating effect of FYM on applied and native phosphorus might have also enhanced the P availability.

Application of 60 kg P_2O_5 ha^{-1} to groundnut crop significantly increased post harvest available N and P content in soil over 20 kg P_2O_5 ha^{-1}. However, available S and extractable Ca

content remain unaffected. Phosphorus application to legume benefitted the following crop on two counts, that is usual residual effect of P and N advantages as a result of better N_2 - fixation under optimum P. Besides this, roots of legumes excrete certain acidic substances that dissolve insoluble P converting into easily assimilable (Subba Rao, 1982). Kalita and Kalita (1992) reported available P and exchangeable Ca^{2+} content in soil increased after harvest of greengram with increasing rate of P added to greengram through single super phosphate (SSP). The increase in P content might be attributed to the humic substances secreted by roots, mineralization effect of soil microflora and CO_2 production by greengram roots and associated microorganisms which may promote solubilization of native soil P. The increase in exchangeable Ca^{2+} content in soil after harvest of greengram might be related to the fact that the $CaSO_4$ is a major component of SSP.

Gypsum application to groundnut caused significant increase in post harvest available N, S and extractable Ca but had no effect on available P content in soil. Further, the application of gypsum half at sowing + half at 35 DAS showed marginal gain in available S and extractable Ca content over its full application at sowing. Gypsum application to peanut at 200 kg ha^{-1} increased organic C content of soil but suppressed available P content of soil (Giri, 1998). More and Nalawade (1993) reported that gypsum application to groundnut at 400 kg ha^{-1} significantly increased post harvest available S and Ca content in soil.

Final nutrient status

As sequential crop, mustard was raised on residual soil fertility of groundnut (which was fertilized with organic manure, phosphorus and gypsum) skipping the direct application of any fertilizer. Results show that available nutrients content of soil depleted after completion of crop sequence as compared to their initial level (before mustard). The variation between different treatments means in available N, P and S content was not significant over their respective control after the harvest of mustard crop during both the years (Table 1). This may be due to heavy uptake of nutrients by the succeeding mustard crop. As also, the rapeseed and mustard crop is known for efficient extraction of nurients through its extensive and deep root system.

Nutrient balance

Nitrogen : Results showed apparent gain in N content during groundnut crop (Table 2). Application of organic manure decreased this apparent gain and it was maximum under control followed by FYM and poultry manure. The actual gain in N content of soil after harvest of groundnut increased with organic manure treatments. The effect of FYM and poultry manure was similar but larger than control. Further during mustard crop, N content alsc underwent apparent gain. Residual effect of organic manure had little interference in this apparent gain. However, there was actual loss of N in soil after harvest of mustard crop The increased rate of P application increased apparent gain in N content during groundnu crop and actual gain in N status of soil afte harvest of groundnut. Further during mustar crop, N content showed apparent gain wit P application rates and actual loss in N conter of soil after harvest of mustard crop. Applicatio of gypsum treatments increased apparent gai in N content during groundnut crop as compare to control. There was actual gain in N statu of soil after harvest of groundnut crop. Gypsu treatments increased actual gain of N in soi During mustard crop, N balance showed appare gain but there was actual loss of N from soi

Phosphorus : Application of organic manu caused apparent loss of P during groundn crop in comparison to control (Table 3). was quite higher under poultry manure th FYM. There was actual gain in available content of soil after harvest of groundnut cro The magnitude of gain in available P w in the order of poultry manure > FYM control. Further during mustard crop, there w apparent gain in available P at all levels organic manure with similar quantum. Tl apparent gain in available P results in act loss of P from soil after harvest of must crop. Increased rate of P application progressiv increased its apparent loss and there was act gain in available P status of soil after harv of groundnut crop. The magnitude of g in P content was increased with increase

P level upto 60 kg P_2O_5 ha^{-1}. Further during mustard crop, P content showed apparent gain. This results in depletion of final P status of soil after harvest of mustard crop. Application of gypsum treatments had no effect on P balance during groundnut-mustard cropping in two years.

Economics : Application of organic manure to preceding groundnut significantly increased net return of mustard crop as well as groundnut-mustard cropping system during both the years (Table 4). In mustard crop, residual effect of 10t FYM and 5t poultry manure ha^{-1} recorded higher net return by a mean of Rs.1731/- and Rs.2271/- ha^{-1}, over control. For groundnut-mustard cropping system, application of 10t FYM and 5t poultry manure recorded net return by a mean of Rs.40,111/- and Rs.39,926/- as against Rs.36,477/- ha^{-1} recorded under control. Application of P at 60 kg P_2O_5 ha^{-1} to preceding groundnut crop significantly increased net return by mustard crop as well as groundnut-mustard cropping system during both the years. Its application caused additional net return of Rs.1851/ ha^{-1} in mustard crop and Rs.4955/- ha^{-1} in groundnut-mustard cropping system over 20 kg P_2O_5 ha^{-1} on mean basis.

Application of gypsum treatments to groundnut crop significantly increased net return by the following mustard crop and over all cropping system during both the years. Gypsum applied in single and in split dose caused additional net return of Rs.1502/-ha^{-1} and Rs.2069/-ha^{-1} by mustard crop over control. The corresponding increase in net return by groundnut- mustard cropping system was Rs.3775/- ha^{-1} and Rs.4355/ - ha^{-1} respectively, over control on mean basis.

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