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Soil fertility, macro and micro nutrient uptake and their use efficiencies under integrated nutrient management in groundnut (*Arachis hypogaea* L.)

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Abstract
A field experiment entitled "Soil Fertility, Macro and Micro Nutrient Uptake and their Use Efficiencies under Integrated Nutrient Management in Groundnut (*Arachis hypogaea* L.) was conducted during *kharif* season of 2017 at research farm, COA, Gwalior on sandy clay loam soil to study the response of groundnut fertilizers and biofertilizers. Four fertility levels *viz.*, 25, 50, 75 and 100% RDF and three biofertilizer inoculation *viz.*, no bio-formulations (B_1), liquid Bio-NPK + Zn solubilizing bacteria (B_2) and bio-grow (B_3) to groundnut in 12 treatment combinations replicated thrice in split plot design. The yield and nutrient uptake (N, P, K, Zn) was significantly highest with 100% RDF and liquid Bio-NPK + Zn solubilizing bacteria. Nutrient use efficiencies for macro nutrients were highest with 25% RDF and liquid Bio-NPK+ Zn solubilizing bacteria. Highest status of N, P and K in soil recorded with 100% RDF and bio-grow inoculation. Available zinc in soil was non-significant to different fertility levels but biofertilizer inoculation significantly improved Zn status of soil.

Keywords: Groundnut, integrated nutrient management, nutrient uptake, nutrient use efficiency, soil fertility

Introduction

Oilseed crops contribute significantly in the Indian agricultural economy in terms of both area and production. Groundnut is an important oilseed and cash crop of India occupying a predominant position among the oilseeds. India ranks first in area but average productivity is quite low and is nearly a third of those of USA and China and even lower than that of the world. Continuous cropping without proper nutrient management has led to many constraints such as stagnation or even decline in production and productivity of crops, deterioration of soil fertility, decline in factor productivity and increasing cost of production post green revolution.

Groundnut, being an exhaustive crop, removes large amount of macro-micronutrient. The area, production and productivity of the crop are higher in summer season than those of post-*kharif* and *kharif* seasons which might be due to sub-optimal rate of fertilizer, poor management and cultivation of groundnut in marginal and sub-marginal lands where deficiency of macronutrients such as nitrogen, phosphorus, potassium and micronutrient is predominant. In addition, use of high analysis chemical fertilizers indiscriminately triggers the deficiency of nutrients other than the applied thereby disturbing the natural equilibrium of soil nutrients. Therefore, NUE is a critically important concept for improving the performance of cropping systems and thus will contribute to sustainable agriculture without reducing the productivity.

All the above said constraints resulted in exploring alternative strategies which would help in maintaining soil fertility besides sustaining the yield of a crop. Thus, rational use of fertilizers is a pre requisite for increasing agricultural production and reduced environmental pollution. Liquid biofertilizers are such route to alternative strategy and many researchers have reported their beneficial effects on crop growth, yield and soil fertility when integrated with chemical fertilizers. Apart from providing a substrate for good crop growth, bio-fertilizers help to proliferate beneficial microbes in soil and also provide residual effect for subsequent crops. However, using these inoculants alone cannot give the expected result. Keeping these aspects in view, the present investigation was done to determine the influence of integrated nutrient management on yield, nutrient uptake, economics and post harvest soil nutrient status.

Materials and Methods

A field experiment was conducted at the research farm, College of Agriculture, Gwalior during *kharif* 2017. The soil of the experimental site was sandy clay loam in texture, neutral in pH (7.3) with low nitrogen (268.8 kg/ha), medium organic carbon (0.56%), and phosphorus (13.1 kg/ha), high potassium (554 kg/ha) and zinc (0.76 ppm) content. The experiment was laid out in split plot design with 12 treatment combinations replicated thrice. The treatment combinations comprised of four fertility levels *viz.* 25, 50, 75 and 100 % recommended dose of fertilizers (RDF) as main plots and three bioformulation applications *viz.* no bioformulations, NPK liquid formulation + Zn solubilizing bacteria and bio-grow as sub-plots. Variety 'JGN-23' of groundnut @ 100 kg/ha was sown at 30 x 10 cm spacing on 6th July 2017. The gross plot size was 5.0 m x 4.5 m. The recommended rate of fertilizers was applied in full as basal dose through urea, single super phosphate and muriate of potash, respectively. All the cultural practices were followed as per the recommended package of practices for groundnut.

Prior to sowing, the kernels were treated with the fungicides dithane M-45 @2g/kg seed, bavistin @1g/kg seed to prevent seed borne diseases and with biofertilizers as per the treatments. Chlorpyrifos @ 1.5 lit/ha was incorporated in soil before sowing and at 40 DAS to control termite infestation. An insecticide dimethoate 30 EC @ 2 ml/litre water was sprayed at 45 DAS to control the incidence of thrips and bud necrosis virus. Imidacloprid (@1 ml/litre water) + Mancozeb (@2 g/litre) at the time of disease occurrence was also applied against fungal diseases. The crop was irrigated three times and two hand weedings were done to control the weeds. Five plants selected randomly from each plot at harvest were dried in an electric oven at 65°C for 48 hours, ground and analyzed for concentration of N, P, K (Jackson, 1973) [8] and Zn (Lindsay and Norvell, 1978) [10] in kernel and haulm and the uptake of nutrients was computed by multiplying kernel/haulm yield of groundnut by their respective nutrient concentrations. Agronomic efficiency (AE), recovery efficiency (RE) and physiological efficiency were computed using the expressions as suggested by Baligar *et al*. (2001) [2]. Finally the crop was harvested and produce were dried, threshed, cleaned and weighed. The soil samples were collected from each treatment to assess the change in nutrient status after the harvest following standard methods (Jackson, 1973) [8]. Statistical analysis of the data was carried out using analysis of variance technique (Gomez and Gomez, 1984) [6].

Results and Discussion

Nutrient uptake

A glimpse of data revealed that treatments exerted significant influence on uptake of N, P, K and Zn wherein application of 100% RDF resulted in significantly higher uptake of N (72 and 166 kg/ha), P (10 and 11 kg/ha), K (6.5 and 97.8 kg/ha) and Zn ((36.5 and 134.8 g/ha) by kernel and haulm, respectively which remained statistically at par with 75% RDF application.

Among different bioformulations, Bio-NPK liquid formulation + Zn solubilizing bacteria application remained at par with bio-grow application and it resulted in significantly higher uptake of N (51 and 117 kg/ha), P (10 and 10 kg/ha), K (5.9 and 88.9 kg/ha) and Zn (35.9 and 133.4 g/ha) by kernel and haulm, respectively.

This significant increase in nutrient uptake might be ascribed to the fact that integrated application of chemical fertilizers and biofertilizers improved nutritional environment for plants. Application of biofertilizers enhances the soil nutrients by quick release of nutrients through production of organic acids leading to enhanced translocation, absorption and utilization of all other plant nutrients, thus resulting in more nutrient content in kernel and haulm (Kushwaha, 2013 [9] and Singh *et al.* 2013 [13]). The increased uptake of N, P, K and Zn might be attributed to their respective higher concentration in kernel and haulm uptake and thereby resulting in higher pod and haulm yields. These results are in line with the findings of Chaitanya Devi *et al.* (2003) [4], Basu *et al.* (2006) [3].

Table 1: Effect of nutrient management practices and bio formulations on uptake of nitrogen and phosphorus by kernel and haulm of groundnut

Treatment	N uptake (kg/ha)		Total N uptake (kg/ha)	P uptake (kg/ha)		Total P Uptake (kg/ha)	Kernel Yield (kg/ha)	Haulm yield (kg/ha)
	Kernel	Haulm		Kernel	Haulm			
Main Plots: Fertility levels								
F_1: 25% RDF	22	53	75	7	8	15	1158	5746
F_2: 50% RDF	38	85	123	9	9	17	1296	6049
F_3: 75 %RDF	55	131	187	10	11	21	1404	6962
F_4: 100 %RDF	72	166	237	10	11	22	1447	7006
S.Em±	1.1	4.0	4.6	0.2	0.4	0.5	24.3	262.4
LSD (P=0.05)	3.9	13.7	16.0	0.5	1.3	1.6	84.0	907.9
Sub Plots: Bio formulations								
B_1: No Bio-formulations	43	99	141	9	9	18	1266	6080
B_2:NPK liquid formulation + Zn solubilizing bacteria	51	117	168	10	10	20	1400	6676
B_3: Bio-grow	46	110	157	9	10	19	1313	6566
S.Em±	1.1	1.9	1.9	0.2	0.2	0.2	31.6	140.6
LSD (P=0.05)	3.3	5.7	5.6	0.7	0.6	0.7	94.8	421.7
Interaction								
S.Em±	2.2	3.8	3.7	0.4	0.4	0.5	63.3	281.3
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table 2: Effect of nutrient management practices and bio formulations on uptake of potassium and zinc by kernel and haulm of groundnut

Treatment	K uptake (kg/ha)		Total K uptake (kg/ha)	Zn uptake (g/ha)		Total Zn Uptake (g/ha)	Kernel Yield (kg/ha)	Haulm yield (kg/ha)
	Kernel	Haulm		Kernel	Haulm			
Main Plots: Fertility levels								
F_1: 25% RDF	4.4	68.0	72.4	27.2	107.6	134.8	1158	5746
F_2: 50% RDF	5.4	79.4	84.9	31.8	114.8	146.6	1296	6049
F_3: 75 %RDF	6.1	95.2	101.3	35.1	130.5	165.6	1404	6962
F_4: 100 %RDF	6.5	97.8	104.3	36.5	134.8	171.2	1447	7006
S.Em±	0.13	3.64	3.73	0.57	5.19	5.42	24.3	262.4
LSD (P=0.05)	0.45	12.61	12.91	1.96	17.98	18.76	84.0	907.9
Sub Plots: Bioformulations								
B_1: No Bio-formulations	5.2	78.9	84.1	16.6	27.8	101.1	1266	6080
B_2:NPK liquid formulation + Zn solubilizing bacteria	5.9	88.9	94.8	19.9	35.9	133.4	1400	6676
B_3: Bio-grow	5.6	87.6	93.2	20.0	34.2	131.3	1313	6566
S.Em±	0.13	1.82	1.78	0.12	1.09	3.10	31.6	140.6
LSD (P=0.05)	0.39	5.45	5.33	0.36	3.26	9.30	94.8	421.7
Interaction								
S.Em±	0.26	3.63	3.55	0.24	2.18	6.20	63.3	281.3
LSD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Nutrient use efficiencies

Agronomic efficiency relates the grain yield to the amount of nutrient applied and physiological efficiency relates the biological yield per unit of nutrient accumulated by plants. The critical examination of data (Table 3) evince that agronomic efficiency (34.9, 11.6, 34.9 kg /kg, respectively) as well as the physiological efficiency (62.2, 436.8, 75.3 kg/kg, respectively) for NPK were significantly higher with the application 25% RDF. This might be ascribed to the fact that under 100% RDF application, the amount of nutrient applied and the increase in uptake of respective nutrients were relatively higher than increment in yield of crop which ultimately resulted in lower values of agronomic and physiological efficiencies compared to lower doses of NPK.

Table 3: Effect of nutrient management practices and bio formulations on agronomic, physiological and apparent recovery efficiency of NPK

Treatment	Agronomic efficiency (kg/kg)			Physiological efficiency (kg/kg)			Apparent recovery efficiency (%)		
	N	P	K	N	P	K	N	P	K
M1S1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
M1S2	34.9	11.6	34.9	62.2	371.2	75.3	386.6	21.6	319.1
M1S3	7.2	2.4	7.2	59.0	436.8	63.0	309.4	13.9	289.8
M2S1	17.5	5.8	17.5	14.8	297.7	43.1	449.0	7.4	154.2
M2S2	25.9	8.6	25.9	20.4	338.7	55.5	758.8	15.2	279.1
M2S3	19.2	6.4	19.2	21.1	295.9	49.8	580.5	13.8	246.1
M3S1	15.5	5.2	15.5	18.4	312.1	55.5	743.9	14.7	247.1
M3S2	23.4	7.8	23.4	16.3	282.0	54.9	875.1	16.9	260.0
M3S3	24.4	8.1	24.4	18.1	282.7	55.9	850.1	18.1	274.5
M4S1	15.4	5.1	15.4	12.0	279.4	53.3	780.6	11.1	175.1
M4S2	23.2	7.7	23.2	13.5	276.2	55.2	967.2	15.8	237.4
M4S3	15.3	5.1	15.3	13.1	294.3	52.1	865.6	12.9	218.2

Note: M1S1 = 25% RDF with no-bioformulation here for NUE calculations is treated as control

Apparent recovery efficiency for phosphorus and potassium was recorded highest with the application of 25% RDF while for nitrogen (967.2 %) it was recorded highest with 100% RDF application. It might be because the apparent recovery which is also referred to as nutrient acquisition effectiveness is expressed as the % increase in uptake per unit of nutrient applied (Adhikari *et al*., 2014) [1]. Thus, the uptake of nutrients although was significantly higher under 100% RDF application but was comparatively lower than the amount added in soil under the same treatment.

Different biofertilizer treatments showed remarkable influence on agronomic, physiological and apparent recovery efficiency of applied nutrients. Application of liquid NPK formulation + Zn solubilising bacteria resulted in highest agronomic efficiency (34.9 and 34.9 kg/kg, respectively), physiological efficiency (62.2 and 75.3 kg/kg, respectively) and apparent recovery efficiency (967.2 and 154.2%, respectively) for N and K. While for P, the highest agronomic efficiency (11.6 kg/kg) and apparent recovery efficiency (21.6%) was recorded with the application of Bio-NPK +Zn solubilising bacteria and the highest physiological efficiency (436.8 kg/kg) was recorded with bio-grow application. The results corroborate the findings of Hossain *et al.*, 2007 [7].

Post-harvest soil nutrient status

Data (Table 4) on soil nutrient status after harvest of groundnut evince that biofertilizers and fertilizer application marked a significant variation on soil available N, P, K and Zn indicating their build up in treated soil while organic carbon did not differ significantly due to various treatments. However, it was recorded superior (0.59% and 0.58%) with 100% RDF application along with Bio-grow, respectively over rest of the treatments. Since chemical fertilizers could not contribute to soil organic fraction, it is apparently the biofertilizers which contributed to increased organic carbon through greater mineralization of soil organic matter by enhanced microbial population. The result is in accordance with the findings of Thakur *et al.* (2011) [14]. Further the data revealed that application of 100% RDF significantly increased the available N P K (163.1, 14.2 203.8 kg/ha, respectively) after harvest of the crop.

A perusal of data showed that among different bioformulations, bio-grow resulted in highest available N P K (155.3, 12.8, 194.3 kg/ha, respectively). This might be due to effect of *Rhizobium* which is prominent in fixing nitrogen, phosphate solubilizers and potash mobilizers. Our result agree with Meshram *et al*. (2004) [11], Singh *et al*. (2011) [12] and Sireesha and Prasuna Rani (2014) [14]. However, available zinc status of soil remained unaffected due to fertilizer application but application of liquid Bio-NPK formulation + Zn solubilizing bacteria and Bio-grow significantly enhanced the zinc content in soil after harvest. The lowest value was recorded under the treatment where no bioformulation was applied. This result is in agreement with Ipsita and Singh (2014) [5] who found that application of PGPR was beneficial showing higher nutrient content in soil.

The apparent nitrogen balance was highly negative (-193 kg/ha) for the treatment 100% RDF with liquid bio-NPK + Zn solubilizing bacteria and rest of the treatments except for absolute control. The apparent P balance was highly positive (39.1 kg/kg) in treatments where 100% RDF and no Bio-formulations was applied The K balance was also highly positive (57 kg/kg) for the treatment 25% RDF with no bio-formulations and highly negative (-31 kg/kg) for the treatment 100% RDF with bio-grow. Similarly, Zn balance was also highly positive with application of 25% RDF with no bio-formulations (Figure 1).

Table 4: Effect of nutrient management practices and bio formulations on post harvest nutrient status of soil

Treatment	Organic carbon (%)	Available N (kg/ha)	Available P (kg/ha)	Available K (kg/ha)	Available Zn (ppm)
Main Plots: Fertility levels					
F_1: 25% RDF	0.54	138.8	10.1	162.2	0.65
F_2: 50% RDF	0.57	148.9	11.9	178.0	0.66
F_3: 75 %RDF	0.57	156.8	12.9	196.2	0.65
F_4: 100 %RDF	0.59	163.1	14.2	203.8	0.66
S.Em±	0.012	3.99	0.27	3.37	0.008
LSD (P=0.05)	NS	13.80	0.92	11.67	NS
Sub Plots: Bioformulations					
B_1: No Bio-formulations	0.56	147.7	11.5	176.4	0.62
B_2:NPK liquid formulation + Zn solubilizing bacteria	0.57	152.7	12.5	184.4	0.67
B_3: Bio-grow	0.58	155.3	12.8	194.3	0.67
S.Em±	0.007	3.27	0.05	1.41	0.001
LSD (P=0.05)	NS	NS	0.15	4.22	0.004
Interaction					
S.Em±	0.015	6.53	0.10	2.81	0.003
LSD (P=0.05)	NS	NS	0.30	NS	NS

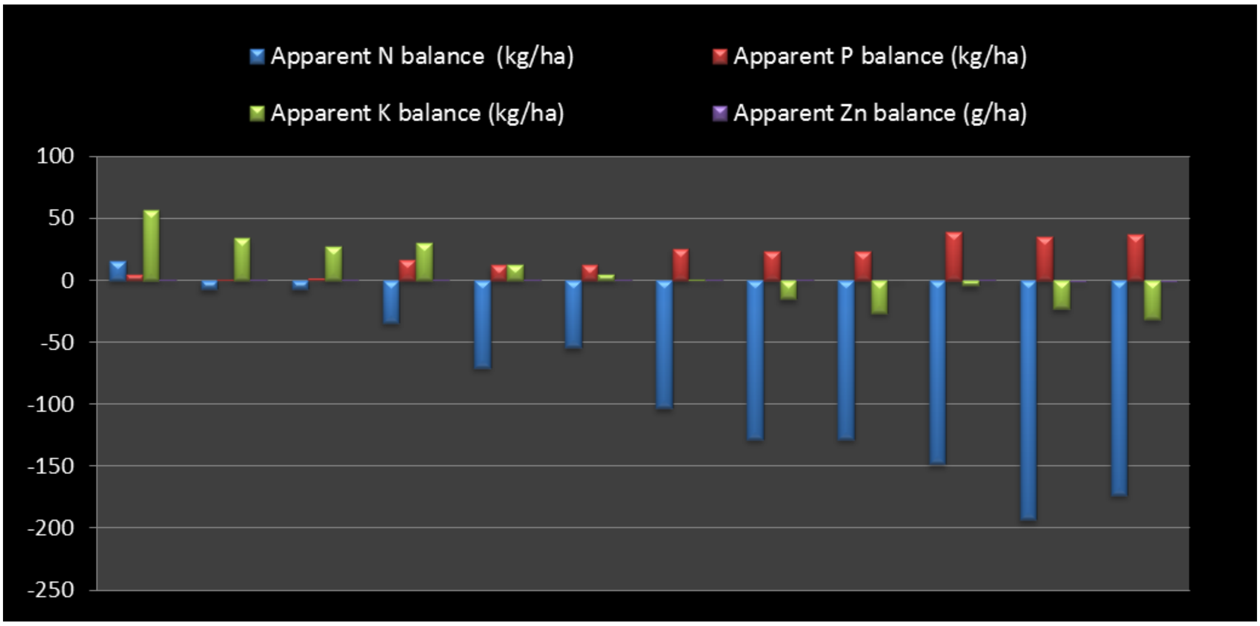

Fig. 1: Apparent nutrient balance sheet of nutrients in soil after harvest of groundnut

Based on the experimental results, it can be concluded that an integrated supply of 100% RDF with liquid Bio-NPK formulation + Zn solubilizing bacteria in *kharif* groundnut favored for better nutrient uptake resulting in higher yield which in turn secured higher net returns and B: C ratio and improved post-harvest nutrient status of soil.

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