

Factors Affecting Nitrogen Fixation in Peanut at Varying Industrial and City Wastes

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ABSTRACT

Disposal of huge quantity of wastes generated from industrial and municipal activities are of major concern today due to associated soil, air and water pollution. Recycling of these wastes in agricultural land brings in the much-needed organic and mineral matter to the soil. However, the assimilative capacity of the soil with respect to its physical, chemical and biological properties and the performance of crop grown need thorough investigation. Field investigations were carried out to study the effect of fly ash and sewage sludge (treated city waste) applied to peanut (*Arachis hypogaea* L.) crop on changes in microbial status, nitrogen fixation and crop production in lateritic soil. Addition of such wastes in different doses and combination of wastes to agricultural lands alters the nutrient cycling processes particularly for leguminous crops, where nodulation, N_2 - fixation and N - uptake is mainly governed by a group of micro-organisms. Nodule number and N-accumulation in nodules was found to be higher in fly ash treated soil as compared to that of city waste. Effective nodule formation was increased with increase in dose of fly ash (alkaline in nature with pH 6.88). whereas reverse was true in case of city waste (acidic in nature with pH 4.02). There was increase in pod yield with application of fly ash, while, in the case of city waste maximum yield was obtained at lowest dose of 6.5 t ha^{-1} . Therefore, in acid lateritic soil, fly ash, a waste of Thermal Power Plant could be used for augmenting peanut production.

Introduction

With industrial progress, growing urban areas and resultant growth in urban solid wastes comprising mostly of industrial and municipal wastes are relatively new phenomenon in contemporary India the disposal of refuse presenting peculiar problems to soil, air and water. The three R's namely, Reduce, Recycle and Recover are oft-repeated phrases of waste management in Indian conditions. Recycle and Recover among the phrases can be well associated with Indian agriculture. Nutrients being the major constraint in Indian agriculture harvesting the nutrient energy from the biological and industrial waste are of prime importance. When these wastes are recycled through land for crop production, due to the degradative and assimilative capacity of the soil the pollution hazards of these wastes can be minimized to a greater extent as compared to direct disposing of at the sites.

Industrial wastes like fly ash (FA) from Thermal Power Plant and Sewage sludge from municipal and city activities (untreated and treated CW) are some such important organic based waste resources having a potentiality for recycling in the agricultural land. The characteristics of these wastes with respect to their pH, plant nutrient and heavy metals content differs. Fly ash being a burnt residue of coal is rich in essential mineral elements and also has capacity in neutralizing soil acidity and supplying the nutrients to the plants (Molliner and Street 1982). Sewage sludge application improves the organic carbon content of the soil and availability of nutrients Ca, K, and Mg, besides improving the physical properties of the soil. Much is known regarding the crop performance and changes in physical and chemical properties of soil due to application of such wastes. Little information however explored on the influence of various wastes on soil microbial population and its impact on nodulation and yield of peanut crop. Native

soil microbial population is responsible for decomposition of organic matter and recycling of nutrients such as C, N, S, and P in the biosphere. Addition of such wastes to agricultural land is likely to alter the nutrient cycling processes particularly for leguminous crops, where nodulation, N_2 - fixation and N - uptake is mainly governed by a group of microorganisms. The purpose of the study was, therefore, to investigate the influence of industrial, municipal and agricultural wastes on the performance of a leguminous crop like peanut with change in rhizosphere microbial population and thereby in N_2 -fixing parameters.

Materials and Methods

Field experiment was conducted in lateritic sandy loam soil (typic, acrothrox, kaolinitic, ultisols, pH 5.4, CEC 84 mmol kg^{-1} , OC 0.4%, total N 0.04%, available P 5.6 mg kg^{-1} , available K 99.4 mg kg^{-1}) at the Research farm of Agricultural and Food Engineering Department, Indian Institute of Technology, Kharagpur, India. Organic wastes, viz. industrial waste Fly Ash (FA) from Thermal Power Plant of Kolaghat, West Bengal, India and treated City Waste (CW) of Calcutta Corporation, West Bengal (India), were tested at four doses each of 6.5, 13, 26, and 52 t ha^{-1} . These treatments were compared with chemical fertilizer (CF) and an absolute control treatment.

In the inorganic fertilizer treatment, peanut (*Arachis hypogaea* L.) crop received a standard dose of nutrient i.e. 20 kg N, 60 kg P_2O_5 and 40 kg K_2O per hectare. The waste materials were incorporated at 10 days before sowing while the inorganic fertilizers were applied as basal at the time of sowing. Peanut crop (*Arachis hypogaea* L.) cultivar AK 12-24 was grown as a test crop for three seasons i.e. season-1 (S1) winter season (*rabi*, February 99 to May 99), Season-2 (S2) wet season (*kharif*, June 99 to October 99) and season-3 (S3) winter season (*rabi*, February 2000 to May 2000). Different fertilizer treatments were applied following three modes of application i.e. one time application (waste and fertilizer applied in season-1 and its residual effect was observed in season-2 and season-3 D-R-R*), two time application

(wastes and fertilizers applied in S1 and S2 and their residual effect were observed in S3, D-D-R**) and three time application (wastes and fertilizers applied in S1, S2 and S3, D-D-D***). The experimental design was split-plot where fertilizer treatments were taken in main plot and mode of application in the sub-plot with three replications.

Observations were made on total nodule, effective nodule, N-accumulation, pod yield and total microbial count at harvest. Total count and soil rhizobium count was measured using dilution plate count method (Walksman, 1922). Physical and chemical properties of the wastes are presented in Table 1.

Table 1. Physical and chemical properties of FA and CW used in the experiment

Particulars	FA	CW
Bulk density, g cc^{-1}	0.96	—
pH (1:2.5 material : water)	8.47	4.02
Organic carbon (%)	0.34	20.55
N (%)	0.05	1.66
P (%)	0.03	0.21
K (%)	0.18	0.22

Results and Discussions

Nodulation

Total nodule and effective nodule number at harvest is presented in Table 2. It is revealed that application of FA influenced in increasing both total and effective nodule number over control, while in case of CW the increase was noted only at lowest dose i.e. 6.5 t ha^{-1} . Nevertheless, higher doses of CW (13 t ha^{-1} or more) caused reduction in nodule number at decreasing order with increasing dosage. Addition of CW at higher doses reduced the soil pH from 5.4 to 4.4. Soil acidity affects the symbiotic association between *Rhizobium* and their host legumes (Munns, 1977). Acidity also caused reduction in growth and multiplication of rhizobia in soil (Mulder *et al.*,

*DRR - Direct-Residual-Residual, **DDR-Direct-Direct-Residual, ***DDD-Direct-Direct-Direct

Table 2. Nodules (number plant⁻¹) and effective nodulation (number plant⁻¹) in peanut as influenced by different fertilizer sources and their mode of applications

Fertilizer sources	Total nodulation (no. plant ⁻¹)				Effective nodulation (no. plant ⁻¹)			
	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean
Control	36.1	30.0	40.0	35.4	21.0	25.0	26.0	24.0
CF	43.0	55.0	101.0	66.3	26.0	34.0	48.0	36.0
FA _{6.5}	29.0	36.0	56.0	40.3	20.0	28.0	36.0	28.0
FA ₁₃	35.0	38.7	66.0	46.5	26.0	30.0	39.0	31.6
FA ₂₆	38.0	48.0	66.0	50.6	25.0	32.0	42.0	33.0
FA ₅₂	43.0	52.0	69.0	54.6	31.0	35.0	46.0	37.3
CW _{6.5}	59.0	67.0	52.0	59.0	36.0	42.0	28.0	35.3
CW ₁₃	46.0	35.0	30.0	37.0	29.0	26.0	19.0	24.6
CW ₂₆	40.0	24.0	6.0	23.3	28.0	22.0	4.0	18.0
CW ₅₂	23.0	18.0	1.0	14.0	16.0	10.0	0.5	8.8
Mean	39.0	39.4	45.2		25.8	27.8	26.7	26.7
	S	M	I		S	M	I	
S.Em±	1.59	0.69	2.30		0.66	0.26	0.859	
LSD (0.05)	4.70	1.98	6.57		1.95	0.74	2.447	

M₁=Mode 1 (fertilizer and waste applied in season 1 and residual effect studies in season 2 and season 3); M₂=Mode 2 (fertilizer and waste applied in season 1 and season 2 and residual effect studied in season 3); M₃=Mode 3 (fertilizer and waste applied in all the three seasons); CF=Chemical fertilizer, FA=Fly ash; CW=City waste; Suffix=Dosage in t ha⁻¹; S=Source; M=Mode; I=Interaction

1977). This resulted in increased number of ineffective rhizobia and reduced nodulation (Holdings and Lowe, 1971), or a reduction in infection and nodulation (Munns, 1977). This was further supported by a positive correlation between effective nodulation and *Rhizobium* population in the soil (Table 3). Soil pH was a major factor related to nodulation. Studies revealed that in low pH, regardless of any soil amendments, plants were devoid of nodules and when soil pH was above 6.0, effective N₂-fixation was observed (Ibekwe *et al.*, 1995; Sarkar, 2001). The residual fertility of FA amendment has shown differential response in nodule formation. FA application at highest dose i.e. 52 t ha⁻¹ has shown marginal increase in nodule number, both total and effective. In case of CW, the beneficial effect of residual fertility was observed only when applied at lower dose i.e. 6.5 t ha⁻¹.

Nitrogen content and accumulation in nodule

The concentration of N in nodule was strongly

Table 3. Correlation and regression between *Rhizobium* population and effective nodulation in peanut as influenced by different fertilizer sources and their mode of application

Y	X	Correlation and regression
Effective nodulation (no plant ⁻¹)	<i>Rhizobium</i> population (log no. g ⁻¹ soil)	R = 0.548 Y = -83.97 + 25.84 X

influenced by type of organic wastes used for peanut cultivation (Table 4). In case of CW, N-content was increased only when applied at lowest dose of 6.5 t ha⁻¹. There was marginal increase in N-content and N-accumulation in nodule with FA application was substantially low. This can be supported with low effective nodule produced under this treatment, which caused less N₂-fixation and thereby less N-content and accumulation in

Table 4. Nitrogen content (%) and Nitrogen accumulation (mg plant⁻¹) in nodules as influenced by different sources of fertilizers and their mode of application

Fertilizer sources	Nitrogen content (%)				Nitrogen accumulation (mg plant ⁻¹)			
	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean
Control	4.76	3.96	4.12	4.28	2.29	1.66	3.66	2.54
CF	4.35	4.41	4.93	4.56	2.48	4.80	5.51	4.27
FA _{6.5}	3.86	4.47	4.22	4.18	1.39	2.62	5.57	3.19
FA ₁₃	4.89	4.67	4.60	4.72	2.15	2.48	4.66	3.10
FA ₂₆	4.16	4.28	4.25	4.23	1.63	3.17	6.59	3.79
FA ₅₂	4.64	4.15	4.57	4.45	2.32	2.34	4.80	3.15
CS _{6.5}	4.44	4.73	4.92	4.70	2.35	2.83	5.70	3.63
CW ₁₃	4.48	4.63	4.79	4.63	3.49	3.38	3.84	3.57
CW ₂₆	4.49	4.60	3.57	4.22	4.57	3.45	0.76	2.93
CW ₅₂	4.83	4.74	1.90	3.82	3.47	2.71	0.15	2.11
Mean	4.51	4.43	4.22		2.70	3.06	3.98	
	S	M	I		S	M	I	
S.E.±	0.03	0.03	0.09		0.095	0.062	0.206	
LSD(0.05)	0.10	0.08	0.26		0.281	0.176	0.586	

M₁=Mode 1 (fertilizer and wastes applied i season 1 and residual effect studied in season 2 and season 3); M₂=Mode 2 (fertilizer and wastes applied in season 1 and season 2 and residual effect studied in season 3); M₃=Mode 3 (fertilizer and wastes applied in all the three seasons); CF=Chemical fertilizer; FA=Fly ash; CW=City waste; Suffix=Dosage in t ha⁻¹; S=Source; M=Mode; I=Interaction

nodule. Low pH affecting nodulation and N₂-fixation by legumes was reported by Ibekwe *et al.* (1995). In the present investigation, the low N-content in nodule and N-accumulation was probably due to poor N₂-fixation in acid soil under CW treatment. While comparing different growing seasons, N-content and accumulation in nodule was always lower during wet season as compared to dry season. This was mainly due to excess moisture, which impedes formation and development of nodule (Sarkar, 2001). Presence of a thin layer of water on the nodule surface impedes oxygen diffusion and thereby reduces N₂-fixation (Khan and Datta, 1982). Water logged condition results in the build up of carbon dioxide in the rhizosphere, which at higher concentration inhibits nodule formation (Bordeleau and Prevost 1994).

Nitrogen uptake and yield of peanut

The nitrogen (N) uptake was significantly higher under CF and FA treatment at all doses

than control. However, in case of CW there was significant decrease in N-uptake when the dose was increased beyond 6.5 t ha⁻¹. The poor N-uptake by plant was mainly due to poor nodulation and N-accumulation in nodule. A positive correlation between N-accumulation in nodule and N-uptake by plant is observed (Table 5). Under residual fertility CW has shown greater N-uptake than other treatments. In this treatment higher residual organic carbon and available nutrients like N, P and K were responsible for increasing N-uptake in plant.

The pool analysis data (total pod yield of three seasons) showed that pod yield of peanut was influenced due to mode as well as type of fertilizer application (Table 6). Total cumulative yield was significantly higher under mode 3 followed by mode 2 and mode 1. Irrespective of mode of application there was significant increase in pod yield over control under all fertilizer treatments except in CW₅₂. CF application has produced maximum pod yield followed by CV₆₅ and CW₁₃. Application of CW beyond 13 t ha⁻¹ has resulted in decrease in

Table 5. Correlation and regression between N-accumulation and N-uptake in peanut as influenced by different sources and their mode of application

Y	X	Correlation and regression
N-uptake (g m ⁻²)	N-accumulation (mg plant ⁻¹)	R = 0.761** Y = 2.50 + 2.30 X

pod yield production. Interaction effect between mode and type of fertilizer treatments showed that in case of CF and FA, there was an increasing trend with repeat application. The increase in yield under FA treatments was to the extent of 48.4 per cent only at highest dose than control. On the other hand CW has shown the increasing trend only up to 13 t ha⁻¹ and beyond that the yield was significantly reduced. It may be mentioned that there was a decrease in yield with an increase in dose of CW and at highest level the extent of

reduction was 42 per cent as compared to control treatment. Such poor performance of peanut crop under CW treatment is mainly due to soil acidity, which was recorded as pH = 4.4 (Table 7) in this treatment and also probably due to the associated heavy metal contamination of sludge application (Banerjee *et al.*, 1997). Peanut is an acid-sensitive plant and pod formation takes place at pH level above 6.0. Increase in fruiting, pod filling and yield of peanut due to increase in soil pH was reported by Khan and Datta, 1990. Similarly alkaline FA at higher dose has also marginally improved the pH of soil (Table 7), which favoured in increasing the pod and haulm yield.

In three cropping sequences with peanut, application of organic wastes has shown considerable improvement in organic carbon content and available nutrients N, P, and K. Mineralization of these wastes released adequate quantity of nutrients in the soil and the available nutrients to the extent of 200 ppm N, 8.16 ppm P

Total 6. Total seed and haulm yield of peanut as influenced by different sources of fertilizer and their mode of application

Fertilizer sources	Pod yield (g m ⁻²)				Haulm yield (g m ⁻²)			
	M ₁	M ₂	M ₃	Mean	M ₁	M ₂	M ₃	Mean
Control	193.7	196.7	214.1	201.5	350.0	347.0	384.0	360.0
CF	331.3	379.5	487.7	399.5	283.0	563.0	864.4	670.0
FA _{6.5}	193.5	230.3	248.1	223.9	390.0	403.0	426.0	406.3
FA ₁₃	237.4	247.2	258.9	247.8	411.0	436.0	445.0	430.6
FA ₂₆	242.1	250.4	290.3	260.9	413.0	468.0	529.0	470.0
FA ₅₂	272.0	279.9	317.4	289.7	476.0	520.0	592.0	529.3
CW _{6.5}	315.4	381.2	398.9	365.1	576.0	668.0	708.0	650.6
CW ₁₃	328.3	376.2	378.9	361.1	596.0	666.0	687.0	649.6
CW ₂₆	302.4	231.4	187.5	240.4	572.0	450.0	340.0	454.0
CW ₅₂	147.6	115.0	87.6	116.7	303.0	224.0	187.0	238.0
Mean	265.2	272.9	286.5		428.0	486.3	518.5	
	S	M	I		S	M	I	
S.E.m.±	1.493	1.393	4.620		10.77	5.36	17.76	
LSD(0.05)	4.402	3.970	13.970		31.76	15.26	50.61	

M₁=Mode 1 (fertilizer and wastes applied in season 1 and residual effect studied in season 2 and season 3); M₂=Mode 2 (fertilizer and wastes applied in season 1 and season 2 and residual effect studied in season 3); M₃=Mode 3 (fertilizer and wastes applied in all the three seasons); CF=Chemical fertilizer, FA=Fly ash; CW=City waste; Suffix=Dosage in t ha⁻¹; S=Source; M=Mode; I=Interaction

Table 7. Residual fertility of soil at third season as influenced by sources and mode of fertilizer application

Treat- ments	Organic carbon (%)			pH			Available nitrogen (%)			Available phosphorous (%)			Available potassium (%)		
	M ₁	M ₂	M ₃	M ₁	M ₂	M ₃	M ₁	M ₂	M ₃	M ₁	M ₂	M ₃	M ₁	M ₂	M ₃
Control	0.26	0.28	0.28	5.5	5.6	5.4	0.0093	0.0096	0.0099	0.000197	0.000196	0.000313	0.0025	0.0030	0.0025
CF	0.28	0.29	0.29	5.2	5.2	5.0	0.0132	0.0105	0.0107	0.000392	0.000470	0.000470	0.0035	0.0033	0.0033
FA _{6.5}	0.25	0.3	0.30	5.0	5.1	5.2	0.0098	0.0099	0.0099	0.000196	0.000196	0.000313	0.0025	0.0035	0.0040
FA ₁₃	0.23	0.26	0.30	5.2	5.4	5.4	0.0114	0.0099	0.0106	0.000196	0.000313	0.000313	0.0025	0.0030	0.0033
FA ₂₆	0.21	0.21	0.29	5.2	5.7	5.3	0.0126	0.0111	0.0128	0.000313	0.000392	0.000392	0.0023	0.0025	0.0033
FA ₅₂	0.27	0.29	0.32	5.2	5.5	5.6	0.0114	0.0108	0.0119	0.000313	0.000392	0.000392	0.0030	0.0030	0.0040
CW _{6.5}	0.29	0.33	0.42	5.5	5.0	4.8	0.0096	0.0099	0.0108	0.000313	0.000392	0.000470	0.0025	0.0030	0.0033
CW ₁₃	0.37	0.4	0.43	4.8	4.6	4.6	0.0099	0.0119	0.0123	0.000313	0.000470	0.000860	0.0030	0.0030	0.0045
CW ₂₆	0.34	0.4	0.45	4.7	4.6	4.5	0.0097	0.0132	0.0132	0.000860	0.000860	0.000880	0.0033	0.0033	0.0045
CW ₅₂	0.27	0.37	0.59	4.6	4.6	4.4	0.0117	0.0115	0.0200	0.000470	0.000149	0.000220	0.0045	0.0045	0.0045

M₁=Mode (fertilizer and wastes applied in season 1 and residual effect studied in season 2 and season3); M₂=Mode 2 (fertilizer and wastes applied in season 1 and season 2 and residual effect studied in season 3); M₃=Mode 3 (fertilizer and wastes applied in all the three seasons); CF=Chemical fertilizer; FA=Fly ash; CW=City waste; Suffix=Dosage in t ha⁻¹.

and 45 ppm K under organic sources as against the corresponding nutrient content of 107, 4.17 and 33 ppm N, P and K, respectively under inorganic source and 99, 3.13 and 25 ppm N, P and K, respectively under control. Decomposition of organic matter generally increases the organic carbon in soil and available nutrients, as has been stated by Biswas *et al.* (1971) and Pandey *et al.* (1985). In case of inorganic fertilizer the low residual organic carbon content and available nutrients was mostly due to rapid mineralization and absence of formation of organo-mineral complexes (Yoshida and Padre, 1975).

Thus, the present study shows that loading of industrial wastes in agricultural lands exhibited differential response in microbial population in soil rhizosphere. Application of city wastes in lateritic soil has greatly affected the population of N-fixing bacteria, *Rhizobium*, particularly in case of leguminous crop like peanut and thereby affected the nodulation and N-accumulation in nodules. This resulted in reduction in N-uptake by plant and subsequently pod and haulm yield of peanut. Analysis of the soil has indicated that application of city wastes (treated sludge CS) has improved the organic carbon status in soil and available nutrients. However, its application has reduced the soil pH. Thus, city waste application although affected the biology of the soil, there seems to be little or no negative effects on the mineralization process. On the other hand, no such adverse effect was observed in case of FA application. There is ample scope to use the wastes like Fly Ash as a source of nutrients, which can be a substitute to chemical fertilizer but with appropriate cautions in acid lateritic soil.

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