Influence Of Industrial Solid Wastes On Soil-Plant Interactions In Rice Under Acid Lateritic Soil

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ABSTRACT

An experiment using three industrial solid wastes *viz*. fly ash (FA), rice husk ash (RHA) and paper factory sludge (PFS) was conducted on wet season rice to study their potentials in augmenting crop yield and soil productivity under acid lateritic soil. The common source of soil amendment (lime) and plant nutrients like farmyard manure (FYM) and chemical fertilizers (CF) were used for comparison and or supplementing nutrient requirement of the crop. There was an increase in growth, yield attributes and yield (upto 110 and 23 per cent over control and CF respectively) of rice under integrated use of PFS or FYM as organic source, FA, RHA or L as soil amendment and CF. In addition, the uptake of N, P, K, Ca, Mg, Mn, Zn, Cu and Co increased under the integrated plant nutrient system. A marginal increase in content of heavy metals *viz*. Se, Cd and Ni in the plant tissue was also noted, although all these remained below the safe limit. Application of these industrial wastes resulted to improve the physico-chemical properties of soil in terms of decrease in bulk density and increase in pH, organic carbon and available nutrients. The radioactivity (Gross α and Gross β) in the treated plant and soil was either below the detection limit or remained under permissible limit. Usage of these wastes saved chemical fertilizers in rice cultivation to the extent of 36.3, 49.7 and 71.0 per cent of recommended N, P and K respectively with an added advantage of minimizing environmental pollution.

INTRODUCTION

Rice is commonly grown during wet season (June – October) in high rainfall regions of Eastern India. In intensive farming, supply of nutrients at a desired level is indispensable for exploiting the potential yield. But, indiscriminate and excessive usage of high analysis chemical fertilizers mostly N, P and K apart from their high cost may deteriorate the physical and chemical properties of the acidic soils. Hence, with intensification of cropping and use chemical fertilizers, the importance of supplementary and complementary roles of organic materials is being felt for retaining or regaining soil productivity.[5] Besides, in acid lateritic soil, availability of Fe, Al and Mn being high, these elements are at times available in excess causing toxicity and also fixation of available-P. Hence, periodic liming becomes essential to exploit the natural resources present in the soil by increasing its pH to the favourable range of 5.6 to 6.5.[9] Thus, integrated nutrient management using chemical fertilizers, organic sources and soil amendments is required for sustaining high crop yield.[12] The constraints in the integrated nutrient management are scarcity of organic nutrient source and high cost involved in liming. Some of the industrial wastes like fly ash, rice husk ash and paper factory sludge are capable of increasing pH besides being potential sources of plant nutrients.[1, 4, 10] Keeping these points in view, it becomes imperative to evaluate the role of these industrial wastes as components of integrated nutrient management in sustaining productivity of rice under acid lateritic soils.

MATERIALS AND METHODS

The experiment was conducted at the Experimental Farm of the Department of Agricultural and Food Engineering, Indian Institute Technology, Kharagpur intersected by 22^0 19' N Latitude and 87^0 19' E longitude to study the response of wet season rice to combined fertilization through organic source and chemical fertilizers with or without soil amendment. The climate of the region was warm and humid having averaged annual rainfall 1400 mm. The soil was acid lateritic (Haplustalf) and sandy-loam in texture having low in organic carbon (0.29 %) and N (150.6 kg ha^{-1}) and medium in P (14.31 kg ha^{-1}) and K (123.6 kg ha^{-1}) content. The availability of Ca, Mg, Fe, Mn, Zn and Cu in soil was 245.0, 54.3, 54.7, 7.5, 0.84 and 1.19 mg kg^{-1} respectively.

Three soil amendments *viz*., fly ash (FA) @ 5 and 10 t ha^{-1}, rice husk ash (RHA) @ 5 t ha^{-1} and lime @ 2 t ha^{-1} and two organic sources viz., farmyard manure (FYM) and paper factory sludge (PFS) @ 30 kg ha^{-1} were used for treatment comparison. A uniform nutrient level of 90 kg N, 26.4 kg P and 33.2 kg K ha^{-1} through these materials and chemical fertilizers (CF) was maintained for all the treatments except in control plots. The experiment comprising thirteen treatment combinations was laid out in the randomized complete block design with three replications. The variety used for rice was IR 36 (SIAM x Chianan 8) which was photo-insensitive and of medium duration (110-120 days).

Periodic observations on number of tillers per hill, dry matter production and leaf area (by Licor LI - 3000A) were recorded. Grain and straw yield of rice were recorded from the harvest of the net plot area. Nutrient content was estimated from the harvested plant samples for grain and straw separately and total uptake was calculated accordingly. Soil samples from 0-15 cm depth were collected after harvest of crop and analyzed for organic carbon, pH, bulk density (BD) and available N, P, K, Ca and Mg content in soils as per standard procedures. The contents of Ca, Mg, Mn, Zn, Cu, Co, Se, Ni and Cd were measured by Atomic Absorption Spectrophotometer - GBC 932 AA using a Graphite Furnace with PAL 3000 auto sampler. The radioactivity of plant and soil samples was analyzed in the Department of Atomic Energy, Government of India, Kolkata and the Institute of Physics, Bhubaneswar, Orissa. The chemical composition of industrial wastes and farmyard manure was shown in Table 1.

RESULTS AND DISCUSSION

Growth

The tiller number per hill, leaf area index (LAI) and dry matter accumulation per hill were influenced by the treatments. In general, there was a sharp increase in tiller number up to 60 days after transplanting (DAT) and thereafter, a gradual decrease was noted (Fig. 1).

The decrease was most prominent where FA was applied alone. Combined application of FA and CF with either PFS or FYM helped in promoting the tiller number. Beneficial effect of FA and RHA was comparable to lime application when they were supplemented with organic and chemical fertilizers. Similar trend was noted in case of dry matter accumulation and LAI (Fig. 1 and Table 2**).** In general, combined application of organic materials (FYM or PFS) and soil amendment (FA, RHA or L) along with CF produced higher number of tillers, more dry matter and LAI than application of any of the organic materials and CF. Application of organic materials in conjunction with CF helped in improving nutrient supplying capacity of soil [5, 7] which was further increased when any of the soil amendments was added. Under adequate supply of nutrients, the dry matter, LAI as well as tiller number per hill were increased. A significant positive correlation between growth parameters and nutrient uptake further justifies the above findings (r = 89** to 93**).

Yield components

There was significant increase in the number of panicles and grains per panicle in all the treatments as compared to FA alone or control (Table 2). The increase was discernible when either FYM or PFS was applied with CF and FA, RHA or L. The effect of the treatments in increasing the test weight was not consistent. It has been mentioned earlier that acid lateritic soils are poor in organic matter. Hence, organic enrichment of the soil with any of the sources proved advantageous and increased panicle number per hill and grains per panicle. As a result, yield of rice increased under combined application of organic materials, soil amendment and chemical fertilizers. These findings are in conformity with that of Sajwan.[8]

Yield

The grain and straw yield under all the treatments except FA alone increased significantly over control. A marginal increase in yield was noted under FA over control. Further, there was some improvement in yield under the combined application of CF, FYM or PFS and soil amendment as compared to CF alone or its combination with organic sources only. Integrated fertilization with paper factory sludge proved superior to that with FYM. The FA or RHA in combination with CF and FYM or PFS was superior to L in similar combinations (Table 2). Due to addition of soil amendment, the pH of soil improved resulting which increase in availability and thereby utilization of nutrients.[11] Fly ash and rice husk ash having pH of 8.5 and 7.5 respectively added a large number of nutrients to soil.[3] Hence, the yield was higher with fly ash or rice husk ash combinations as compared to L combinations.

Nutrient uptake

The uptake of N, K and Mg by grain and plant was increased appreciably in all the treatments except FA alone and control. The uptake of all the nutrients except Co under FA alone and control remained comparable. Fly ash alone recorded significantly higher total Co uptake by plant than that of control. The increase was discernible under the combined application of organic source with soil amendment and CF as compared to application of CF, FA, FYM+CF or PFS+CF. The extent of increase remained comparable in all the treatments of combined applications of PFS or FYM with FA and CF except in the treatment combinations with FA @ 5t ha^{-1} where uptake decreased. Among the soil amendments *viz*., FA, RHA and L, the uptake of different nutrients was at par with the exception that the uptake of Ca and Mg were higher in the treatment combinations with L than those with FA (Table 3). The beneficial effect of better nutrient utilization on growth, yield and yield attributes has already been explained. As a result, there was an increase in uptake of N, P, K, Ca and Mg under combined application as compared to chemical fertilizers alone.[2]

Uptake of different micronutrient varied significantly in different treatments. In case of Zn, Cu and Mn, a higher uptake was recorded where CF was supplemented by either FYM or PFS as compared to CF alone. But in case of Fe uptake, a reverse trend was noted. Among the soil amendments, when L was applied along with CF and FYM or PFS, the uptake of Fe, Zn, Cu and Co was significantly lower than the application of other two soil amendments *viz.* FA and RHA in similar combinations. With respect to Mn uptake, all three amendments remained comparable (Table 3).

Heavy metal

The content of heavy metals *viz.* Cd, Ni and Se in grain and straw of rice was studied. There was marginal increase in Se content when FYM+CF was applied with soil amendments like FA, RHA or L (2.29 ppm in grain and 3.36 ppm in straw) whereas the content decreased when PFS+CF was applied with those amendments (2.19 ppm in grain and 2.97 ppm in straw). In both grain and straw, the Cd content varied marginally (0.144 to 0.186 ppm in grain and 0.249 to 358 ppm in straw) among the different treatments. In case Ni content, no definite trend was found. However, marginal variation did not show any adverse effect on plant and remained under safe limit.[3]

Soil

Physical and chemical properties

The changes in bulk density (BD), organic carbon and pH of the top soil (0-15 cm) as affected by the different treatments are presented in Table 4. The bulk density was noticeably decreased under the treatments with combined application of organic source, soil amendment and CF as compared to control and only CF. Similar finding was observed by Yeledhalli *et al*.[12] The organic carbon content of the soil increased remarkably where FYM or PFS was applied with or without soil amendment and CF. Combined application of organic source, L and CF showed highest increase in pH. Fly ash alone also increased the pH as compared to CF, organic source and Control. The content of N, P and K was higher in soil where FYM or PFS was applied with CF and FA or RHA over the remaining treatments (Table 4). A marginal increase in the nutrient content under FA was noted as compared to control. A remarkable influence of the treatments was noted in Ca and Mg content. The highest Ca and Mg content were noted where organic source was applied with L and CF. This was mainly due to addition of Ca and Mg through L. A lower status of Ca and Mg in soil was found under CF and control than the FA treated plot.

Radioactivity

The radioactivity of fly-ash and soil treated with fly-ash @ 10 t ha^{-1} has been presented in Table 5. From the table it is clear that the radioactivity for most of the elements *viz.* ^{226}Ra, ^{228}Ac and ^{40}K was higher in fly-ash than the soil treated with fly-ash. Both fly-ash and treated soil retained more ^{40}K as compared to other radioactive elements. The radioactivity due to addition of fly-ash was subjected to dilution effect in the soil. However, the marginal variations remained within the safe limit.[6] Further, analysis of the plants grown in fly-ash treated soil revealed that the radioactivity (Gross α and Gross β) was either below detection limit remained under permissible limit.

Nutrient use efficiency

Use of combined fertilization sources was also advantageous with respect to nutrient use efficiency and saving of chemical fertilizers. It was observed that the nutrient use efficiency of all the three nutrients N, P and K increased over chemical fertilizers alone. The efficiency of N, P and K in rice was increased from 37.70 to 41.10, 128.5 to 140.9 and 102.2 to 111.4 kg grain per kg nutrient respectively as shown in Table 6. It is apparent from the Table that an increment in the efficiency under combined application of organic material, soil amendment and chemical fertilizers was recorded to the extent of 3.4, 11.6 and 9.2 kg grain per kg N, P and K respectively over the treatment where only chemical fertilizers were applied. In addition to this increase in nutrient use efficiency, there was an added advantage of saving of the chemical fertilizers. The extent of saving of chemical fertilizer with respect to N, P and K were 36.3, 49.7 and 71 per cent respectively.

CONCLUSION

It may be concluded that there is considerable scope for proper utilization of alkaline fly ash or rice husk ash in conjunction with paper factory sludge and chemical fertilizer in increasing rice production and improving soil productivity under acid lateritic soil. A substantial amount of high analysis chemical fertilizer may be saved through such utilization of industrial wastes under integrated plant nutrient system.

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Table 1 Physical and Chemical properties of FYM, PFS, FA and RHA used in experiment

Particulars	FYM	PFS	FA	RHA
Bulk density, Mg m^{-3}	0.51	0.60	0.96	0.45
pH (1: 2.5, material: water)	5.86*	5.48*	8.47	7.50
Org. C, %	21.60	19.61	0.34	4.97
N, %	1.16	0.76	0.05	0.06
P, %	0.38	0.14	0.03	0.26
K, %	0.76	0.40	0.16	0.12
Ca, %	0.19	0.15	0.42	0.27
Mg, %	0.15	0.14	0.22	0.18
Fe, %	0.49	0.33	0.92	0.07
Mn, ppm	286.85	350.50	288.20	282.50
Zn, ppm	140.70	335.15	25.80	35.50
Cu, ppm	46.90	28.70	21.50	18.80
Co, ppm	15.05	16.75	2.24	1.38

* Material: water, 1:5

Table 2 Effect of different fertilization sources on growth, yield components and yield of rice

Fertilization sources	LAI at 45 DAT	Panicles/ m^2	Grains/ panicle	Test weight (g)	Yield ($kg\ ha^{-1}$)	
					Grain	Straw
CF	5.15	399	67.7	21.81	3392	4965
FA_{10}	3.43	321	54.6	21.64	2192	3011
FYM+CF	5.10	381	62.6	21.94	3350	4536
FYM+FA_{10}+CF	5.23	437	68.5	22.27	3659	4944
FYM+FA_5+CF	5.11	416	68.6	22.31	3529	4549
FYM+RHA_5+CF	5.30	477	70.7	23.18	3902	5292
FYM+L_2+CF	5.27	421	71.3	22.50	3579	4823
PFS+CF	5.16	403	65.7	22.11	3450	4659
PFS+FA_{10}+CF	5.55	464	72.8	22.74	3816	5163
PFS+FA_5+CF	5.50	459	71.3	22.96	3646	4949
PFS+RHA_5+CF	5.73	448	68.4	22.79	3776	5125
PFS+L_2+CF	5.12	439	71.5	22.30	3675	4938
Control	2.86	291	49.1	20.62	1935	2740
LSD (P=0.05)	0.38	77	7.6	0.67	546	618

Values as suffix of FA, RHA and L denote $t\ ha^{-1}$

Table 3 **Effect of different fertilization sources on total uptake of nutrients by rice (mean of two years)**

Fertilization sources	N kg ha^{-1}	P kg ha^{-1}	K kg ha^{-1}	Ca kg ha^{-1}	Mg kg ha^{-1}	Fe g ha^{-1}	Mn g ha^{-1}	Zn g ha^{-1}	Cu g ha^{-1}	Co g ha^{-1}
CF	97.02	23.33	83.58	9.79	8.61	2192.20	1118.35	354.65	75.85	11.16
FA_{10}	50.92	15.32	46.83	6.54	5.58	1140.85	646.85	193.65	41.10	8.64
FYM+CF	78.74	22.31	80.74	11.08	9.05	1706.95	1379.50	385.35	91.95	11.84
FYM+FA_{10}+CF	100.76	26.01	89.32	13.23	11.86	1574.55	1702.40	438.10	94.20	18.18
FYM+FA_5+CF	88.55	23.91	62.73	11.81	10.30	1589.35	1436.05	393.95	93.40	16.29
FYM+RHA_5+CF	113.36	29.05	98.02	15.04	14.83	2316.30	1733.95	512.15	102.10	17.27
FYM+L_2+CF	101.76	23.78	88.21	17.41	13.36	1235.30	1546.85	374.65	71.75	11.81
PFS+CF	83.81	22.42	82.22	12.11	8.61	1710.20	1327.45	411.70	105.20	14.69
PFS+FA_{10}+CF	105.74	26.24	92.76	15.16	11.49	1763.65	1529.55	473.80	106.55	21.53
PFS+FA_5+CF	97.85	24.82	88.24	13.85	10.48	1750.85	1384.40	444.45	107.40	19.45
PFS+RHA_5+CF	105.12	25.75	90.19	16.32	13.22	2021.65	1586.40	502.25	95.65	19.27
PFS+L_2+CF	108.16	25.19	89.06	18.05	13.50	1331.90	1507.95	403.70	78.55	12.92
Control	42.84	11.74	42.89	5.07	4.25	1052.25	615.80	182.00	36.80	5.84
LSD (P=0.05)	15.31	3.92	13.74	2.18	1.78	272.75	252.20	69.85	15.01	2.64

Values as suffix of FA, RHA and L denote t ha^{-1}

Table 4 Effect of different modes fertilization sources on physico-chemical properties of soil after rice

Fertilization sources	Bulk density Mg m^{-3}	pH	Organic C %	N kg ha^{-1}	P kg ha^{-1}	K kg ha^{-1}
CF	1.64	5.40	0.31	218.0	21.80	159.7
FA_{10}	1.61	5.85	0.48	186.3	16.79	142.3
FYM+CF	1.58	5.60	0.48	251.2	25.17	161.5
FYM+FA_{10}+CF	1.50	6.15	0.46	261.3	27.42	166.3
FYM+FA_5+CF	1.51	6.00	0.56	255.8	26.36	154.5
FYM+RHA_5+CF	1.49	6.10	0.54	251.4	26.50	163.2
FYM+L_2+CF	1.54	6.60	0.38	252.5	27.90	159.1
PFS+CF	1.55	5.55	0.33	242.8	24.73	164.8
PFS+FA_{10}+CF	1.51	5.95	0.52	259.3	27.12	167.3
PFS+FA_5+CF	1.53	5.90	0.49	254.5	26.24	158.5
PFS+RHA_5+CF	1.50	6.00	0.49	256.5	26.68	168.0
PFS+L_2+CF	1.54	6.60	0.41	253.4	27.80	163.6
Control	1.66	5.30	0.47	161.9	14.48	121.8
Initial	1.65	5.32	0.29	150.6	14.31	123.6

Values as suffix of FA, RHA and L denote t ha^{-1}

Table 5 Comparative radioactivity of fly ash and soil treated with fly ash in rice

Radioactive elements	Radioactivity (Bq kg^{-1})	
	Fly ash	Soil treated with fly ash
^{226}Ra (through 186 KeV)	64 ± 3	32 ± 2
^{226}Ra (through 1765 KeV of ^{214}Bi)	57 ± 2	35 ± 2
^{226}Ra (through 238 KeV of ^{212}Pb)	58 ± 1	44 ± 1
^{228}Ac (through 911 KeV)	71± 2	49 ± 2
^{40}K (through 1481 KeV)	212 ± 30	74 ± 22

Table 6 Saving of chemical fertilizers and nutrient use efficiency under different modes of fertilization sources in rice

Fertilization sources	Saving of chemical fertilizers (%)			Nutrient use efficiency kg grain / kg nutrient		
	N	P	K	N	P	K
Chemical fertilizers (CF)	-	-	-	37.69	128.49	102.17
Organic[1] + CF	33.3	29.3	48.0	37.78	128.79	102.41
Organic[1]+Amendment[2]+ CF	36.3	49.7	71.0	41.09	140.07	111.38

Organic[1] = Mean of FYM and PFS @ 30 kg N ha^{-1} and Amendment[2] = Mean of FA @ 10 t ha^{-1}, RHA @ 5 t ha^{-1} and L @ 2 t ha^{-1}

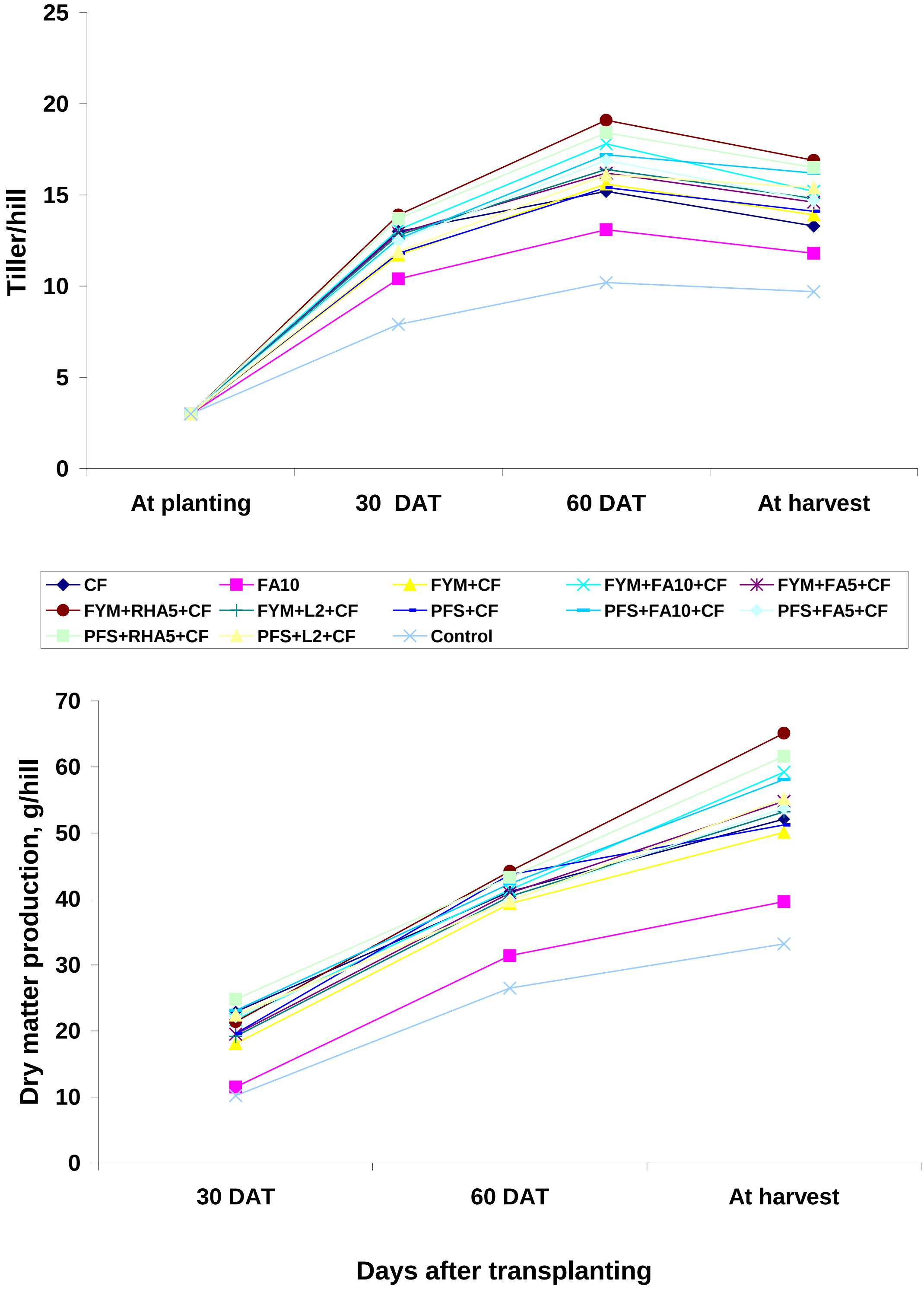

Fig. 1 Effect of fertilization sources on tiller number and dry matter production per hill of rice

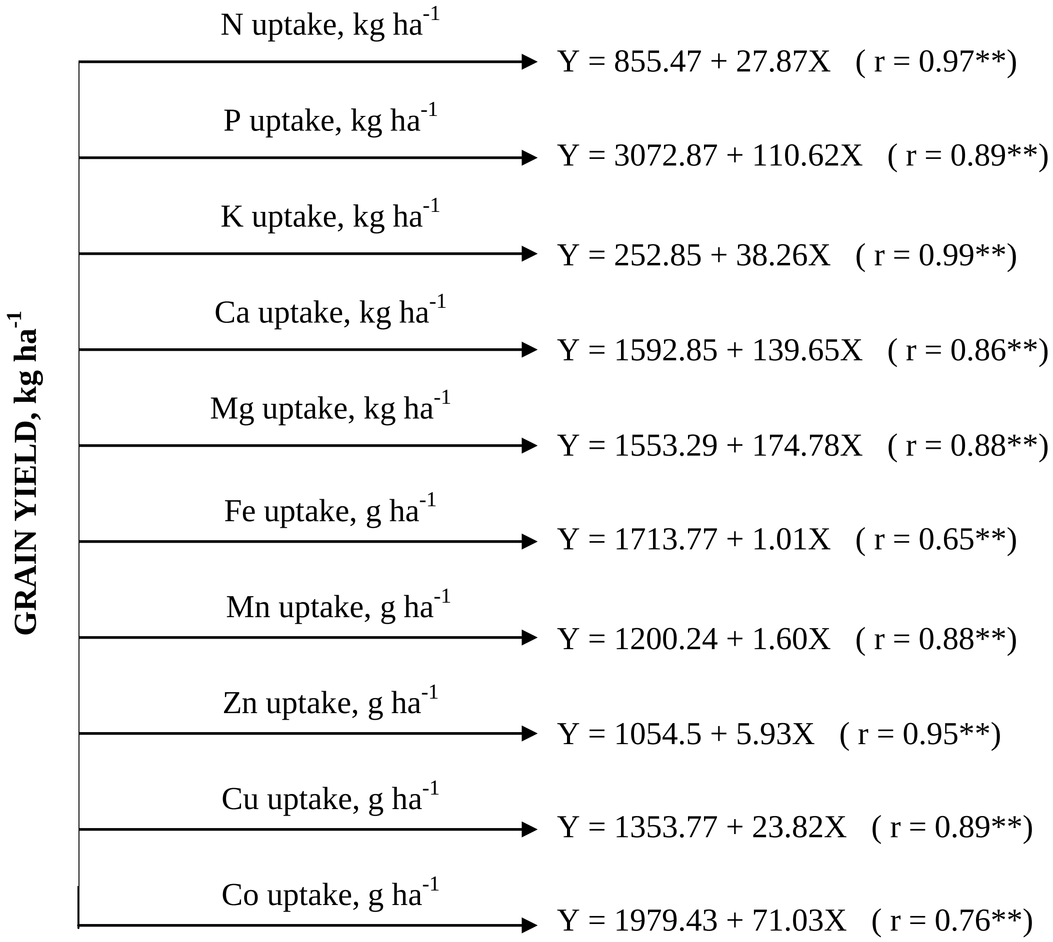

Fig. 2 Correlation and regression between grain yield and nutrient uptake of rice under different fertilization sources