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Transformation of soil potassium affected by integrated nutrition of rice in an *Inceptisol*

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ABSTRACT

A field experiment was conducted during 2012 and 2013 to study the effect of integrated nutrition on transformation of soil potassium in rice-rice cropping system. The experiment was conducted with aromatic rice (cv. Gobindabhog) in split plot design with five organic matter levels in main plot and three inorganic fertilizer levels in subplots. Irrespective of treatment combinations a steady decline in the amount of both available and non-exchangeable K in soil with crop growth indicated that the doses of potassic fertilizer were suboptimal. Maximum straw yield was recorded with the application of mustard cake @1t ha^{-1} and inorganic fertilizer @ $N_{40}P_{20}K_{20}$. The highest grain (2.70 and 3.32 t ha^{-1}) and straw yield (4.96 and 3.97 t ha^{-1} during 2012 and 5.68 and 3.98 t ha^{-1}during 2013) were recorded with the application of mustard cake @ 1t ha^{-1} along with inorganic fertilizer @ $N_{40}P_{20}K_{20}$. Maximum K uptake by aromatic rice was also observed with the application of mustard cake @1t ha^{-1} plus inorganic fertilizer @ $N_{40}P_{20}K_{20}$ (O_5IN_3), while the lowest with O_1IN_1, where only inorganic fertilizer was applied @ N_{20} P_{10} K_{10}.

Keywords : Aromatic rice integrated nutrient management; potassium transformation

Rice is the major cereal crop of India and its contribution to the total food grain production in the country is around 43 per cent (Chaturvedi and Ali, 2002). Gobindabhog is an indigenous short grained aromatic rice variety mainly grown in Gangetic plains of West Bengal. It is very popular in domestic market and cultivated mostly following conventional chemical-based production technology leading to deterioration of soil quality and production grain of inferior quality. Deterioration of physical, chemical and biological environment of rice soil is not only due to continuous submergence and intensive tillage operation, but also because of imbalance nutrient management, high dose of chemical fertilizers and pesticides to cause decline in soil organic matter quality and quantity (Duxbury *et al*., 2000; Ladha *et al*., 2003).

Thus, emphasis has been paid to the sustainability and effect of crop management practices on resource quality of the rice-based production system in tropical and subtropical Asia (Dawe *et al*., 2000; Aggrawal *et al*., 2000). Integrated nutrient management is the most logical way to manage long term fertility and productivity in a sustainable manner. The basic concept of integrated nutrient management (INM) is the maintenance of soil fertility and of plant nutrient supply to achieve a given level of crop production through optimization of the benefits from all possible sources of organic, inorganic and biological components in an integrated manner appropriate to that cropping system and farming situation (Mahajan and Sharma, 2005; Subba Rao and Sammi Reddy, 2005).

Inherent K fertility especially in K deficient soils depends on the K release/fixation from/to non-exchangeable sites. Scanty information is available regarding the transformation of non-exchangeable K under waterlogged condition in presence of organic matter. The present field experiment was conducted to study the effect of integrated nutrient management on transformation of soil potassium as well as yield and potassium uptake by aromatic rice Gobindabhog in an Inceptisol.

MATERIALS AND METHODS

A field experiment was conducted during 2012 and 2013 in an *Inceptisol* at university farm of Bidhan Chandra Krishi Viswavidyalaya situated at (22.8^{0}N latitude and 88.30^{0}E longitude), Kalyani, Nadia to study the effect of integrated nutrient management on transformation of potassium in soil and yield and K-uptake in rice-rice cropping system. The experimental soil was loam in texture. The relevant physico-chemical properties of the soil are presented in table 1.

The experiment was laid out in split plot design with three replications in which main plots received different doses of organic manure from two sources *i.e.* farm yard manure (FYM) and mustard cake (MC) and subplots received different doses of inorganic fertilizers. The main plot treatments comprised of O_1: control (no organic manure), O_2: FYM @ 2.5 t ha^{-1}, O_3: FYM @ 5 t ha^{-1}, O_4: mustard cake @ 0.5 t ha^{-1} and O_5: mustard cake @ 1 t ha^{-1}. The sub-plot treatments included different levels of inorganic fertilizers *viz*., IN_1: $N_{20}P_{10}K_{10}$, IN_2: $N_{30}P_{15}K_{15}$ and IN_3: $N_{40}P_{20}K_{20}$. On dry weight basis the per cent nutrient composition (N: P_2O_5: K_2O) of organic manures was 0.6: 0.2: 0.5 and 4.5: 1.5: 1.0 for FYM and MC, respectively. Organic manures were applied as per treatment requirement before transplanting. Twenty days

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old rice seedlings (cv. Gobindabhog) were transplanted at a spacing of 15 x 15 cm in 4 x 2.5 m plots during second fortnight of July (Aman) and January (Boro) in both the year. The total amount of P and K and one half of nitrogen were applied before transplanting through single super phosphate and muriate of potash and urea, respectively and the remaining one half of N was applied three weeks after transplanting of rice. Standard agronomic practices including pest and disease control were followed and the crop was grown to maturity.

The initial surface (0-0.15 m) soil sample was collected from field and after processing analyzed for relevant physico-chemical properties. The experimental soil was silty clay in texture (38.5% sand, 37.0% silt and 24.5% clay) (Bouyoucos,1962), neutral in reaction (pH 6.8), normal in electrical conductivity (0.26 dS m^{-1}), cation exchange capacity 12.7 cmol (+) kg^{-1} and high in oxidizable organic carbon (7.6 g kg^{-1}) (Jackson, 1973), low in available N (116.3 mg kg^{-1}) (Bremner and Keeney, 1966), high in available phosphorus (16.3 mg kg^{-1}) (Olsen *et al.*, 1954), medium in available potassium (56.3 mg kg^{-1}) (Hanway and Heidel, 1952) and medium in non-exchangeable K. Non-exchangeable K was computed as the difference between 1N HNO_3-K (Wood and De Turk, 1941) and available K (IN NH_4OAc-K). The soil samples collected at different critical crop growth stages, *viz*. active tillering (AT), panicle initiation (PI) and harvest were analyzed for available K by 1N NH_4OAC (Jackson, 1973) and 1N HNO_3-K. Dry matter production at different growth stages and crop yield at harvest were recorded following standard methods. Potassium content in tri-acid digestion of oven-dry plant sample and in soil extract were measured using flame photometer (Jackson, 1973).

Pooled split plot analysis technique was applied over the years to compare stage, organic manure and inorganic fertilizer dose means and to test the related main and interaction effects by including stages, organic manure and chemical fertilizer treatments as additional source of variation, respectively. Means were compared at 5 per cent level of significance.

RESULTS AND DISCUSSION

Available potassium in soil

Available K content in soil declined steadily with crop growth in both the seasons and years (Table 1). Source and level of organic manure also revealed a significant response on the mean available K content in soil. The response of organic treatments with respect to maintaining available K content in soil followed the sequence of: $O_5 > O_4 > O_3 > O_2 > O_1$. Between two sources of organic manure mustard cake was found to be superior to FYM in maintaining available K content in soil. Again, with increase in the level of inorganic fertilizer, the available K content in soil increased consistently and significantly (Table 1).

The interaction effect of various treatment combinations on available K content in soil revealed that the highest amount of available K (52.76 and 47.87 mg kg^{-1} in 2012 and 46.77 and 45.63 mg kg^{-1} in 2013) was recorded in the treatment O_5IN_3, while the least (46.79 and 42.60 mg kg^{-1} in 2012 and 41.33 and 40.60 mg kg^{-1} in 2013) in the treatment O_1IN_1 (Table 1). The findings were in conformity to that of Kumar *et al.* (2010) and Urkurkar *et al.* (2010) who reported a higher available K content under integrated nutrient management than inorganic fertilizer alone. However, at the end of two year experimentation a net decline of 9.53 mg kg^{-1} in available K content was recorded in O_5IN_3 receiving 1 t ha^{-1} mustard cake along with inorganic fertilizer @ $N_{40}P_{20}K_{20}$, while of 15 mg kg^{-1} in O_1IN_1 receiving only inorganic fertilizer @ $N_{20}P_{10}K_{10}$.

Non-exchangeable potassium in soil

A steady decline in the amount of non-exchangeable K was also observed with crop growth, thus indicated the release of K from non-exchangeable source to replenish available K pool exhausted by crop removal and other means. The response of inorganic fertilizer dose was quite consistent and a gradual significant increase in non-exchangeable K content of soil was recorded with increase in dose of K-fertilizer, but the magnitude of response was not so remarkable (Table 1). Data also revealed that at the end of 2nd year experimentation greatest decline in non-exchangeable K (107 mg kg^{-1}) was recorded in the treatment O_1IN_1 receiving only inorganic fertilizer @ $N_{20}P_{10}K_{10}$, not only due to suboptimal dose of K-fertilizer addition but also due to lack of contribution from organic manure. Ramanathan (1977) also reported that the extent of non-exchangeable K used by crop reduced when K fertilizer was applied and higher the extent of non-exchangeable K utilized, lesser was the K uptake. The result thus revealed that K nutrition of rice in this soil with existing nutrient management practice was largely dependent on release of K from non-exchangeable sites.

Crop yield

The highest straw yield (4.83 and 3.87 t ha^{-1} in 2012 and 5.65 and 3.89 t ha^{-1} in 2013) was recorded with O_5 (1t ha^{-1} MC) and the least (4.09 and 3.17 t ha^{-1} in 2012 and 4.56 and 3.20 t ha^{-1} in 2013) with O_1 (control) in both the years (Table 2). Straw yield in both the years was lesser in *Boro* rice than in Aman rice, possibly due to its response to cooler climate. Superiority of mustard cake over FYM and increase in the dose of organic manure on the increase in straw yield of rice were

Table 1: Effect of integrated nutrition on available and non-exchangeable K content (mg kg^{-1}) in soil

Stages	Available K				Non-exchangeable K			
	2012		2013		2012		2013	
	Aman	***Boro***	***Aman***	***Boro***	***Aman***	***Boro***	***Aman***	***Boro***
28 DAT	53.45	48.21	46.62	45.77	1037	995	955	901
56 DAT	51.19	46.18	44.49	43.31	1021	987	935	890
At harvest	46.67	42.12	41.12	40.55	998	958	912	866
LSD (0.05)	**0.15**	**0.17**	**0.16**	**0.8**	**0.85**	**0.77**	**0.53**	**0.57**
O_1	47.40	43.13	41.80	40.97	1020	981	931	881
O_2	49.41	44.82	42.93	42.38	1021	981	931	880
O_3	51.07	45.67	44.00	43.18	1021	984	936	888
O_4	51.87	46.47	45.20	44.23	1016	976	932	888
O_5	52.44	47.42	46.45	45.29	1016	978	934	890
LSD (0.05)	**0.20**	**0.22**	**0.20**	**0.1**	**1.10**	**1.00**	**0.60**	**0.74**
IN_1	49.81	44.91	43.64	42.79	1017	979	932	885
IN_2	50.45	45.56	44.02	43.25	1018	980	933	885
IN_3	51.04	46.03	44.57	43.59	1020	981	934	887
LSD (0.05)	**0.19**	**0.25**	**0.30**	**0.14**	**1.74**	**1.00**	**0.60**	**0.78**
O_1IN_1	46.79	42.60	41.33	40.60	1018	980	930	880
O_1IN_2	47.44	43.10	41.63	40.93	1020	981	931	881
O_1IN_3	47.96	43.70	42.43	41.37	1022	982	932	882.
O_2IN_1	48.27	43.97	42.57	41.97	1020	980	929	879
O_2IN_2	49.23	44.97	42.87	42.40	1020	981	931	880
O_2IN_3	50.73	45.53	43.37	42.77	1023	982	932	882
O_3IN_1	50.53	45.07	43.53	42.73	1019	983	935	887
O_3IN_2	51.03	45.80	44.00	43.23	1020	984	936	888
O_3IN_3	51.63	46.13	44.47	43.57	1022	986	937	889
O_4IN_1	51.40	46.03	44.63	43.77	1015	975	931	888
O_4IN_2	52.07	46.43	45.17	44.33	1016	976	932	888
O_4IN_3	52.13	46.93	45.80	44.60	1017	977	933	890
O_5IN_1	52.08	46.90	46.13	44.87	1015	977	933	890
O_5IN_2	52.48	47.50	46.46	45.37	1016	978	934	890
O_5IN_3	52.76	47.87	46.77	45.63	1017	979	935	891
LSD (0.05)	**0.74**	**0.96**	**1.17**	**0.56**	**6.73**	**3.86**	**1.89**	**3.02**

possibly due to greater as well as the ready release of nutrients from the former than the later. The result was in conformity with those of Sudha and Chandini (2002) and Bhadoria and Prakash (2003). However, the response of inorganic fertilizer doses on straw yield of rice was not significant in any year. Interaction effect of organic manure and inorganic fertilizer doses revealed that application of mustard cake @1t ha^{-1} along with inorganic fertilizer @ $N_{40}P_{20}K_{20}$ (O_5IN_3) recorded maximum straw yield (4.96 and 3.97 t ha^{-1} in 2012 and 5.68 and 3.98 t ha^{-1} in 2013) and the lowest (4.00 and 3.10 t ha^{-1} in 2012 and 4.44 and 3.13 t ha^{-1} in 2013) with only inorganic fertilizer application @ $N_{20}P_{10}K_{10}$ (O_1IN_1). Higher straw yield and grain yield was also reported by Hossain *et al.* (2003) with the application of 50 per cent chemical fertilizer plus 50 per cent organic manure.

The highest grain yield (2.48 and 3.25 t ha^{-1}) of aromatic rice was achieved with the application of 1t ha^{-1} mustard cake, which was *at par* with 0.5 t ha^{-1} mustard cake, but significantly superior to FYM in both the years. Unfortunately, no grain yield was received during boro season in both years possibly due to varietal response towards temperature particularly during panicle initiation stage. Beneficial role of organic manure on crop productivity was again established with higher grain yields as observed in treatments comprising of organic manure than in control (no organic manure). The interaction effect of organic manure and inorganic fertilizer levels revealed that the highest grain yield of rice (2.70 and 3.32t ha^{-1}) was recorded in treatment receiving 1t ha^{-1} mustard cake along with inorganic fertilizer @ $N_{40}P_{20}K_{20}$ (O_5IN_3), which was on par with treatments receiving 0.5 t ha^{-1} mustard cake and same dose of inorganic fertilizer (Table 2). However, in both the year the lowest grain yield (2.00 and 2.14 t ha^{-1}) was found in treatment O_1IN_1 (no organic manure and with

Table 2: Effect of integrated nutrient management on straw and grain yield (t ha^{-1}) of aromatic rice

Main plot	Straw yield				Grain yield	
	2012		2013		2012	2013
	Aman	*Boro*	*Aman*	*Boro*	*Aman*	*Aman*
O_1	4.09	3.17	4.56	3.20	2.09	2.28
O_2	4.22	3.25	5.12	3.30	2.17	2.78
O_3	4.19	3.55	5.42	3.61	2.22	2.95
O_4	4.52	3.72	5.45	3.71	2.48	3.17
O_5	4.83	3.87	5.65	3.89	2.47	3.25
LSD (0.05)	**0.39**	**0.27**	**0.47**	**0.16**	**0.17**	**0.13**
IN_1	4.28	3.41	5.23	3.45	2.27	2.81
IN_2	4.40	3.51	5.22	3.54	2.38	2.88
IN_3	4.43	3.62	5.27	3.63	2.29	2.97
LSD (0.05)	**NS**	**0.07**	**NS**	**0.05**	**0.20**	**0.16**
O_1IN_1	4.00	3.10	4.44	3.13	2.00	2.14
O_1IN_2	4.05	3.16	4.56	3.20	2.06	2.28
O_1IN_3	4.23	3.25	4.69	3.27	2.22	2.42
O_2IN_1	4.15	3.11	5.08	3.15	2.15	2.74
O_2IN_2	4.45	3.23	5.15	3.28	2.25	2.79
O_2IN_3	4.05	3.40	5.13	3.47	2.10	2.80
O_3IN_1	4.06	3.42	5.43	3.51	2.11	2.89
O_3IN_2	4.42	3.58	5.41	3.63	2.34	2.90
O_3IN_3	4.09	3.65	5.43	3.68	2.20	3.06
O_4IN_1	4.42	3.60	5.53	3.65	2.39	3.08
O_4IN_2	4.32	3.71	5.40	3.73	2.34	3.19
O_4IN_3	4.82	3.84	5.41	3.75	2.69	3.25
O_5IN_1	4.76	3.80	5.69	3.81	2.35	3.20
O_5IN_2	4.76	3.85	5.58	3.88	2.38	3.22
O_5IN_3	4.96	3.97	5.68	3.98	2.70	3.32
LSD (0.05)	**0.94**	**0.16**	**0.20**	**0.12**	**0.46**	**0.36**

inorganic fertilizer @ $N_{20}P_{10}K_{10}$). Increase in the yield of rice with integrated nutrient management was possibly due to improvement of soil physical, chemical and biological environment and thereby increased nutrient use efficiency. The result was well corroborated with the findings of several authors (Chaudhury *et al*., 2011; Kumar *et al*., 2011).

Potassium uptake by aromatic rice plant

Comparison of the response of organic manure treatments on total uptake of K by rice plant revealed that as a source of organic matter mustard cake was superior to FYM (Table 3). Furthermore, K uptake by rice plant increased with increase in the dose of both organic manure and inorganic fertilizer and was consistent with the increase in dry matter production, thus suggested that the native available pool of nutrients especially potassium in this case was insufficient to meet up the crop demand. The interaction effect showed that maximum K uptake (83.95 and 56.50 kg ha^{-1} in first year 87.32 and 56.65 kg ha^{-1} in second year) by aromatic rice Gobindabhog was recorded in O_5IN_3 (1 t ha^{-1} mustard cake along with inorganic fertilizer @ $N_{40}P_{20}K_{20}$), while minimum (65.22 and 43.60 kg ha^{-1} in 2012 and 68.41 and 44.02 kg ha^{-1} in 2013) in O_1IN_1 (only inorganic fertilizer @ $N_{20}P_{10}K_{10}$). Highest nutrient uptake as well as the highest crop yields were achieved in treatment combination receiving the highest dose of organic manure (mustard cake) along with the highest dose of inorganic fertilizer. The results thus corroborated the beneficial effect of integrated nutrient management on nutrient uptake and crop productivity. The result also indicated suboptimal level of K fertilizer addition in all the treatments, which triggered the release of K from non-exchangeable sites to meet up crop demand and to establish new equilibrium with soil available K pool. Chaudhury *et al.* (2011) also reported higher yield and nutrient accumulation under integrated nutrient management than inorganic fertilizer alone.

The results revealed that none of the treatment combination could satisfy the crop demand for potassium leading to depletion in native available K status of rice soil. A steady decline in non-exchangeable K in all the treatments from its initial amount suggested that the

Table 3: Effect of Integrated nutrient management on total uptake of potassium (kg ha^{-1}) by aromatic rice

Treatments	2012			2013			2012			2013		
	Aman			*Boro*			*Aman*			*Boro*		
	28 DAT	56 DAT	At harvest	28 DAT	56 DAT	At harvest	28 DAT	56 DAT	At harvest	28 DAT	56 DAT	At harvest
O_1	24.83	37.71	68.10	16.29	21.64	45.08	25.79	39.08	70.24	16.01	20.42	45.51
O_2	25.16	38.24	70.67	18.30	24.40	46.42	26.30	39.21	77.52	18.30	23.96	47.18
O_3	27.35	39.51	70.80	21.52	25.86	50.85	26.55	39.00	79.66	20.50	24.69	51.66
O_4	26.36	38.85	74.96	22.84	27.80	53.15	26.94	39.77	81.72	21.93	26.50	53.03
O_5	27.31	39.97	81.36	25.62	30.49	55.41	28.34	41.06	85.60	24.18	29.29	55.65
LSD (0.05)	**1.96**	**1.97**	**0.31**	**0.18**	**0.66**	**3.96**	**2.00**	**2.16**	**1.22**	**0.17**	**0.43**	**2.30**
IN_1	25.00	37.95	71.22	19.79	25.47	48.56	25.37	38.46	76.91	18.99	24.33	49.18
IN_2	26.23	38.56	72.47	21.06	25.70	50.18	26.85	39.28	78.88	20.45	24.75	50.72
IN_3	27.37	40.06	75.84	21.89	26.95	51.81	28.13	41.12	81.05	21.12	25.82	51.91
LSD (0.05)	**0.52**	**0.55**	**0.41**	**0.28**	**0.39**	**1.00**	**0.01**	**0.48**	**1.13**	**0.22**	**0.32**	**0.76**
O_1IN_1	23.52	36.89	65.22	15.04	21.03	43.60	24.16	37.92	68.41	14.75	19.72	44.02
O_1IN_2	25.05	37.72	67.98	16.55	21.64	45.15	25.90	38.92	70.11	16.53	20.47	45.72
O_1IN_3	25.93	38.51	71.11	17.28	22.26	46.49	27.30	40.39	72.20	16.76	21.08	46.78
O_2IN_1	24.37	37.39	68.55	16.94	23.42	44.48	24.72	37.73	75.45	17.28	23.17	45.05
O_2IN_2	25.03	38.41	69.71	18.84	24.35	46.18	26.40	39.27	76.66	18.40	24.54	46.90
O_2IN_3	26.07	38.93	73.74	19.13	25.42	48.60	27.78	40.64	80.45	19.22	24.16	49.60
O_3IN_1	26.65	39.25	68.58	20.55	25.80	48.84	25.29	38.23	76.57	19.42	24.67	50.12
O_3IN_2	27.36	38.64	69.93	21.58	24.91	51.18	26.33	37.79	79.98	20.89	23.84	51.90
O_3IN_3	28.04	40.64	73.90	22.44	26.88	52.54	28.03	40.98	82.42	21.17	25.57	52.97
O_4IN_1	24.72	37.92	73.94	21.64	27.59	51.50	25.75	38.95	79.78	20.25	26.12	52.22
O_4IN_2	26.75	38.50	74.44	22.89	27.25	53.03	26.92	39.17	82.52	22.23	25.99	53.32
O_4IN_3	27.62	40.14	76.49	23.99	28.55	54.91	28.13	41.17	82.87	23.32	27.38	53.57
O_5IN_1	25.75	38.29	79.82	24.81	29.51	54.36	26.95	39.49	84.33	23.24	27.99	54.51
O_5IN_2	26.97	39.53	80.31	25.44	30.34	55.36	28.68	41.23	85.15	24.18	28.94	55.79
O_5IN_3	29.21	42.11	83.95	26.60	31.62	56.50	29.38	42.45	87.32	25.13	30.93	56.65
LSD (0.05)	**0.22**	**0.31**	**0.36**	**0.63**	**0.86**	**0.76**	**0.23**	**0.28**	**0.81**	**0.50**	**0.71**	**1.69**

nutrient doses were suboptimal and K nutrition of rice in this soil was largely dependent on the release of K from non-exchangeable sites. Mustard cake was a better source of organic manure than FYM. This variety was not at all suitable for growing during *Boro* season.

REFERENCES

Aggarwal, P. K., Bandopadhyay, S. K., Pathak, H., Kalra, N., Chander, S. and Kumar, S. 2000. Analysis of yield trends of the rice-wheat system in north-western India. *Outlook Agric.*, **29**: 259-68.

Bhadoria, P. B. S. and Prakash, Y. S. 2003. Relative influence of organic manures in combination with inorganic fertilizers in improving rice productivity of laterite. *J Sustainable Ag.*, **23** (1): 77-87.

Bouyoucos, G. J. 1962. Hydrometer method improved for making particle size analysis in soils. *Agron. J*, **54** : 464-65.

Chaturvedi, S. K. and Masool, A. 2002. "Poor man's meat" needs fresh fillip. *The Hindu*: 63-69.

Chaudhary, S. K., Singh, J. P. and Jha, S. 2011. Effect of integrated nutrient management on yield quality and nutrient uptake of rice (*Oryza sativa*) under different dates of planting. *Indian J. Agron.*, **56** (3): 228-31.

Dawe, D., Doberman, A., Moya, P., Abdulrachman, S., Singh, B., Lal, P., Li, S. Y., Lin, B., Panullah, G., Sairam, O., Singh, Y., Swarup, A., Tan, P. S. and Zhen, Q. X. 2000. How wide-spreads are yield declines in long-term rice experiment in Asia? *Field Crops Res.*, **66** :175-93.

Duxbury, J. M., Abrol, I. P., Gupta, R. K. and Bronson, K. F. 2000. Analysis of long term soil fertility experiments with rice-wheat rotations in South Asia : *Long-term Soil Fertility Experiments with Rice-Wheat Rotations in South Asia.* I.P. Abrol (ed) In : Rice-wheat consortium paper series No. 6. New Delhi, India.

Hossain, M. Z., Hossain, S. M. A., Anwar, M. P., Sarkar, M. R. A. and Mamun, A. A. 2003. Performance of BRRI Dhan 32 in SRI and conventional methods and their technology mixes. *Pak. J.Agron.*, **2** (4): 195-200.

Jackson, M. L. 1973. *Soil Chemical Analysis*. Prentice Hall of India Private Ltd. New Delhi, India.

Kumar Vipin and Singh, A. P. 2010. Long-term Effect of Green Manuring and Farm Yard Manure on Yield and Soil Fertility status on Rice-Wheat cropping system. *J. Indian Soc. Soil Sci.*, **58 (4)**: 409-12.

Kumar, V., Prasad, R. K., Suman, S. K. and Tiwari, S. 2011. Integrated nutrient management for better soil fertility and rice productivity. *Oryza*, **48** (4): 335-38.

Ladha, J. K., Dawe, D., Pathak, H., Padre, A. T., Yadav, R. L., Singh, B., Singh, Y., Singh, P., Kundu, A. L., Sarkar, R., Ram, N., Regmi, A. P., Gami, S. K., Bhandari, A. L., Amin, R., Yadav, C. R., Bhattarai, E. M., Das, S., Aggarwal, H. P., Gupta, R. K. and Hobbs, P. R. 2003. How extensives are yield declines in long-term rice-wheat experiments in Asia. *Field Crops Res*, **81**: 159-80.

Mahajan, A. and Sharma, R. 2005. Integrated nutrient management (INM) system – concept, need and future strategy. *Agrobios Newsletter*, **1** (3): 29-32.

Olsen, S. R., Cole, C. V., Watanabe, F. S., Dean, L. A. 1954. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. *U.S. Department of Agriculture Circular* 939.

Ramanathan, K. M. 1977. Studies on dynamics of soil potassium. Unpublished *Ph. D. Thesis*, Tamil Nadu Agriculture University, Coimbatore.

Subba Rao, A. and Sammi Reddy, A. 2005. Emerging strategies for sustaining higher productivity and ensuring soil quality under intensive agriculture. *Indian J. Fert.*, **1** (4): 61-76.

Sudha, B. and Chandini, S. 2002. Nutrient management in rice (*Oryza sativa* L.). *J. Trop. Ag.*, **40** (1-2): 63-64.

Urkurkar, J. S., Tiwari, Alok., Chitale, Shrikant. and Bajpai, R. K. 2010. Influence of long-term use of inorganic and organic manures on soil fertility and sustainable productivity of rice (*Oryza sativa*) and wheat (*Triticum aestivium*) in Inceptisols. *Indian J. Agril. Sci*, **80** (3) : 208-12.

Walkley, A. and Black, I. A. 1934. An examination of Degtjareff method for determining soil organic matter and proposed modification of the chromic acid titration method. *Soil Sci.*, **37**: 29-38.

Wardana, I. P., Gani, A., Abdulrachman, S., Bindraban, P. B. and Keulen Van, H. 2010. Enhancing water and fertilizers saving without compromising rice yield through integrated crop management. *Indonesia J. Agril. Sci*, **11** (2): 65-73.

Wood, L. K. and De Turk, K. K. 1941. The absorption of potassium in soil in non-exchangeable form. *Soil Sci. Soc. Amer. Proc.*, **5**: 152-61