https://doi.org/10.56093/ijas.v90i10.107979

Indian Journal of Agricultural Sciences **90** (10): 1988–92, October 2020/Article

Influence of long term INM practices on the distribution of aluminium fractions in Acidic Inceptisol of North Eastern Himalaya Range and their relationship with NPK content in rice (*Oryza sativa*)

ABHIK PATRA[1], V K SHARMA*[2], D J NATH[3], T J PURAKAYASTHA[4], MANDIRA BARMAN[5], SARVENDRA KUMAR[6], KAPIL A CHOBHE[7], AJIN S ANIL[8] and R CHAKRABORTY[9]

ICAR-Indian Agricultural Research Institute, New Delhi 110 012, India

Received: 31 January 2020; Accepted: 18 February 2020

ABSTRACT

A long-term field experiment was commenced in 2006 with rice as a test crop under long-term integrated nutrient management (INM) practices at Instructional-cum-Research (ICR) farm of the Assam Agricultural University, Assam to study the distribution of aluminium (Al) fractions and their relationship with NPK content in different parts of rice plant under acidic Inceptisol. Results indicated that exchangeable Al and strongly organically bound and interlayer Al fractions effectively decreased whileweakly organically bound Al, amorphous Al and free Al fractions increased under integrated use of enriched compost @ 2 t/ha with 25% recommended doses of NP + 100% K over rest of the treatments. In rice, the integrated use of enriched compost @ 2 t/ha with 25% recommended doses of NP + 100% K showed significant increment in N and P content in grain, husk and straw over rest of the treatments. The K content in grain (0.36%), husk (0.37%) and straw (2.03%) was also found to be highest under application of 25% recommended doses of NP + enriched compost @ 2 t/ha + 100% K as compared to other treatments. There was a highly significant negative correlation was found between exchangeable Al and strongly organically bound and interlayer Al with N, P and K content of rice. Thus, integrated use of enriched compost with reduced dose of recommended nitrogen and phosphorus of rice reduced the toxic Al fractions in an acid soil which led to enhanced N, P and K content in rice grain, husk and straw.

Key words: Acidic soil, Aluminum fractions, Enriched compost, Long-term INM, Rice

In present agricultural scenario, long-term integrated nutrient management (INM) practices play an important role in improving soil physico-chemical properties apart from crop productivity. The application of organic amendments could conserve the nutrients in soil, and enhance the soil microbial biomass, activity and diversity, which have explicit relationships with soil quality and ecosystem sustainability (Wang *et al.* 2011). Organic and inorganic fertilizers are used primarily to increase nutrient availability to plants. The use of inorganic fertilizers increase nutrient contents of soil temporarily but their adverse effects on soil properties such as microbial activity, the humus fraction, soil structure and ion exchange system saturation are well known. The integrated nutrient management (INM) practice on the other hand gives superior performance over application of organic sources and inorganic fertilizers alone (Palaniappan and Annadurai 2007). Another study showed that it considerably increased rice yields by minimizing nutrient losses to the environment (Zhang *et al.* 2012). In developing countries in particular the implementation of INM practice can be considered as an effective agricultural practice to ensure food security and improve soil health as well as environmental sustainability.

In acidic soils, presence of aluminium (Al) is one of the limiting factors affecting plant growth and development. Long-term applications of lime and organic amendments significantly decrease the exchangeable Al content in soil and total Al in the soil solution (Rutkowska *et al*. 2015). Application of organic amendment and liming influences the formation of organic and mineral Al complexes in the soil solution. In acidic soils, complexes of Al with organic

*Corresponding author e-mail: vksharma.iari@gmail.com
[1]Ph D student (e-mail: abhik.patra88@gmail.com), SSAC, Institute of Agricultural Science, BHU, Varanasi, [2]Principal Scientist (e-mail: vksharma.iari@gmail.com), [4]Principal Scientist (e-mail: tpurakayastha@gmail.com), [5]Scientist (e-mail: mandira.ssaciari@gmail.com), [6]Scientist (e-mail: sarv.grandee@gmail.com), [7]Scientist (e-mail: chobhekapil27@gmail.com) SSAC, ICAR-IARI , New Delhi, [8]Ph D Scholar (e-mail: ajinsanil3829@gmail.com), [9]Ph.D. Scholar (e-mail: ranabir003@gmail.com) SS&AC, ICAR-IARI. [3]Principal Scientist (e-mail: ndhrubajyoti@yahoo.co.in) Department of Soil Science, Assam Agricultural University, Jorhat 785013.

matter are the main dominating forms of Al. Long-term application of different mineral fertilizers or organic manure altered the soil reaction to a great extent (pH 3.58–6.78) and reduces the phytotoxic Al^{3+} ions in soil. The addition of organic amendments in acid soils can reduce the level of Al phytotoxicity by affecting the nature and quantity of different Al species. Thus, amendment of organic composts can be a significant and efficient management practice in acid soils for reducing Al toxicity. This is supported by the fact that the composts application significantly increased soil pH and reduced exchangeable Al, as measured by the KCl extraction, converting it to less active forms of Al such as organically bound Al and other non-crystalline fractions (Vieira *et al*. 2008). In the present study, an attempt was made to understand the impact of long-term integrated nutrient management (INM) practices on distribution of various fractions of Al pools in acidic Inceptisol of North–Eastern Himalayan region.

MATERIALS AND METHODS

Experiment was conducted using rice (cv. Ranjit) in the rainy season since, 2006 under long-term integrated nutrient management (INM) experiment at Instructional-cum-Research (ICR) farm of the Assam Agricultural University, Assam, located at latitude $26^0$43'N and longitude 94°11' E. The soil was highly acidic in reaction with pH value 4.70, non saline (EC 0.17 dS/m) and high in organic carbon content (9.6 g/kg) which belongs to clay loam texture. Available N, P and K content of experimental soil was 200 kg/ha, 21.9 kg/ha and 146 kg/ha, respectively and experimental soil is rated to be low in available N and P and medium in K status as per fertility ratings. The enriched compost used in experiment had pH: 7–7.5, EC: 3.57–3.80 dS/m, organic carbon: 19.2–19.6%, total N: 1.67–1.72%, total P: 1.15% and total K: 0.91%.The treatments consisted of T_1; absolute control, T_2;100% recommended doses (RDF) *w.r.t.* NPK, T_3; 50% recommended doses of NP + 100% K + biofertilizers, T_4; 50% recommended doses of NP + 100% K + enriched compost @1 t/ ha and T_5; 25% recommended doses of NP + 100% K + enriched compost @ 2 t/ha. The experiment was laid down in randomized block design and replicated four times with above treatments. The recommended dose of inorganic fertilizers for this region were 40:20:20 kg/ha (N: P_2O_5: K_2O) for rice. The sources of fertilizer for N, P and K were urea, single superphosphate (SSP) and muriate of potash, respectively. After harvest of rice crop, composite soil samples were collected from each plot. Soil samples from three different soil depths, *i.e.* 0–5 cm, 5–15 cm and 15–30 cm were collected for the study. These soil samples were air-dried then ground in wooden mortar and pestle and sieved through 2 mm sieve and used for chemical analysis. Aluminium fractions were determined by extracting the soil samples with different extractants, *viz.* 1 M KCl solution, 0.5 M $CuCl_2$ solution, 0.1 M sodium diphosphate tetrabasic ($Na_2P_4O_7$), 0.2 M ammonium acetate (NH_4-OAC) and Dithionite-citrate-bicarbonate buffer (Drabek *et al.* 2003) and Al concentration in different supernatant was determined by using ICP-MS (Walna *et al.* 2005). The plant samples were dried in hot air oven at 65^0C then ground in a Wiley mill for nutrient analyses. Nitrogen content in grain and straw samples was determined by micro-Kjeldahl method (Jackson 1973). For estimation of P and K content, grain and straw samples were digested with di-acid mixture (HNO_3:$HClO_4$ in 3:1 ratio) and phosphorus content in

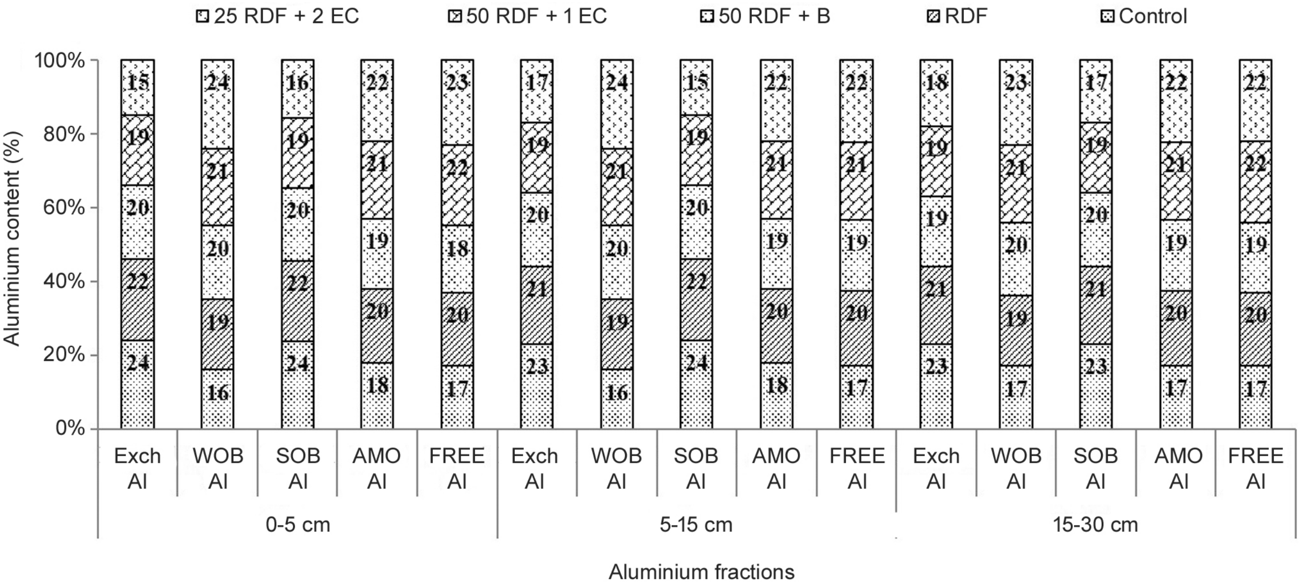

Fig 1 Distribution of aluminium fractions (%) in post-harvest soil as influenced by manuring and fertilization at different soil depths Aluminium fractions: Exch Al: Exchangeable Al; WOB Al: Weakly organically bound Al; SOB Al: Strongly organically bound and interlayer Al; AMO Al:Amorphous Al and Free Al. Treatments: Control, RDF:100% NPK, 50 RDF+B: 50% NP + 100% K + biofertilizers, 50RDF+1EC: 50% NP + 100% K + enriched compost @ 1 t/ha and 25RDF+2EC: 25% NP + 100% K + enriched compost @ 2 t/ha.

the acid digest was estimated by vanado-molybdo yellow colour method (Tandon 2001) by a spectrophotometer and potassium content using ICP-MS.

RESULTS AND DISCUSSION

Distribution of Al fractions in soil

Distribution of various fractions of Al in experimental soil at 0-5 cm depth under different treatments is given in Fig 1. Results indicated that among the treatments, exchangeable Al fraction was mainly dominated in T_1 (24%) followed by T_2 (22%) and T_3 (20%) which were more or less similar to each other. The lower concentration (15%) of exchangeable Al was observed in the treatment which had received enriched compost @ 2 t/ha with reduced doses of NP (T_5) compared to other treatments. Similar trend was also observed for strongly organically bound and interlayer Al fractions, where T_1, T_2 and T_3 assimilated most of this Al fraction which were 24, 22 and 20%, respectively with lowest (16%) under T_5 treatment compared to other treatments. In weakly organically bound Al, amorphous Al and free Al similar results were observed wherein, treatment T_5 contained maximum of these fractions followed by T_4 and T_3. At 5–15 cm soil depth, the phytotoxic Al fractions, *i.e.* exchangeable Al and strongly organically bound and interlayer Al fraction was found highest in T_1 over rest of the treatments where Al fractions were 23 and 24%, respectively. These bio-available fractions of Al were significantly declined in T_5 with lowest value of 17 and 15%, respectively. The per cent contribution of rest three Al fractions was found maximum in treatment T_5 which contributed 24% in weakly organically bound Al, 22% each in amorphous Al and 22% in free Al. In case of 15 – 30 cm soil depth, the exchangeable Al and strongly organically bound and interlayer Al fraction was maximum (23% each) in T_1 whereas minimum in T_5 (18 and 17%, respectively). The less phytotoxic pools of Al, *i.e.* weakly organically bound Al, amorphous Al and free Al were found highest (23, 22 and 22%, respectively) in T_5 treatment.

The findings of the present study was lined with findings of Vieira *et al.* (2008) and Karak *et al.* (2015), that application of organic compost and municipal solid waste compost significantly reduces the exchangeable Al fraction from soil. The decrease in another less phytotoxic fraction of Al (strongly organically bound and interlayer Al fraction) due to integrated application of organic and inorganic fertilizers had also been reported by Vieira *et al.* (2008). Increase in amorphous Al in soil due to application of bio-fertilizer and enriched compost may be due to reactive nature of organic matter and increased amount of amorphous oxides and hydroxides of Al in soil. Free Al was most non-reactive pool of Al that does not cause any toxic effect on plants while combined application of organic and inorganic fertilizers enhances this pool during immobilizing more phytotoxic Al pools to less phytotoxic pool.

Major nutrients content in different plant parts of rice

Nitrogen (N) content in different parts of rice as influenced by INM treatments was presented in Table 1. Results indicated that the N content in different parts of rice increased due to application of enriched compost and fertilizer used in integration or alone compared to control. The N content in grain, husk and straw of rice ranged from 1.96 to 2.17%, 0.37 to 0.66% and 0.67 to 0.91%, respectively. The maximum N content 2.17, 0.66 and 0.91% was observed in grain, husk and straw of rice, respectively, under application of enriched compost @ 2 t/ha along with reduced doses of NP (T_5). It was also recorded that N content in different plant parts of rice was significantly increase under treatment T_5 in tune of 10.7%, 78.4% and 35.8% in grain, husk and straw, respectively over control. Increase in N content in plant may be the results of positive inter-relationship between nutrients with enriched compost that had exerted beneficial effects in the release of ammonical and nitrate nitrogen. Similar results have been reported (Patra et al., 2018) where the addition of nitrogenous fertilizer along with FYM helped in narrowing down of C:N ratio,, increased mineralization and also resulted in rapid conversion of organically bound N to inorganic forms.

Table 1 Effect of manuring and fertilization on major nutrients (N, P and K) content (%) in rice

Treatment	Nitrogen (%)			Phosphorus (%)			Potassium (%)		
	Grain	Husk	Straw	Grain	Husk	Straw	Grain	Husk	Straw
T_1: Control	1.96^{B}	0.37^{D}	0.67^{D}	0.23^{C}	0.05^{C}	0.04^{D}	0.27	0.32	1.59^{B}
T_2: 100% NPK	2.02^{B}	0.54^{C}	0.80^{BC}	0.40^{B}	0.08^{B}	0.06^{C}	0.31	0.34	1.87^{A}
T_3: 50% NP + 100% K + bio-fertilizers	1.99^{B}	0.49^{C}	0.76^{C}	0.42^{B}	0.10^{B}	0.08^{B}	0.35	0.36	1.82^{A}
T_4: 50% NP+100% K+ enriched compost @ 1 t ha^{-1}	2.08^{AB}	0.59^{B}	0.84^{B}	0.44^{AB}	0.08^{B}	0.06^{BC}	0.35	0.37	1.95^{A}
T_5: 25% NP + 100% K + enriched compost @ 2 t ha^{-1}	2.17^{A}	0.66^{A}	0.91^{A}	0.50^{A}	0.15^{A}	0.10^{A}	0.36	0.37	2.03^{A}
Mean	2.05	0.55	0.81	0.42	0.10	0.07	0.33	0.35	1.86
SE (±)	0.06	0.02	0.03	0.03	0.01	0.01	0.03	0.02	0.10
LSD (P=0.05)	0.13	0.05	0.07	0.06	0.02	0.02	NS	NS	0.22

Table 2 Pearson's correlation coefficients (r) of different aluminium fractions with major nutrients content in different plant parts of rice

Depth	Aluminium fractions	N content in rice		P content in rice		K content in rice	
		Grain	Straw	Grain	Straw	Grain	Straw
0 – 5 cm	Exch Al[#]	-0.59**	-0.78***	-0.82***	-0.71***	-0.48*	-0.57**
	WOB Al	0.61**	0.82***	0.86***	0.79***	0.56**	0.70***
	SOB Al	-0.61**	-0.77***	-0.83***	-0.81***	-0.60**	-0.64**
	Amo Al	0.54*	0.78***	0.83***	0.70***	0.53*	0.88***
	Free Al	0.76***	0.92***	0.82***	0.59**	0.57**	0.74***
5 – 15 cm	Exch Al	-0.31	-0.58**	-0.55*	-0.71***	-0.42	-0.46*
	WOB Al	0.60**	0.84***	0.80***	0.81***	0.51*	0.71***
	SOB Al	-0.56**	-0.73***	-0.70***	-0.78***	-0.44*	-0.81***
	Amo Al	0.49*	0.76***	0.72***	0.66**	0.44*	0.85***
	Free Al	0.52*	0.83***	0.82***	0.67**	0.54*	0.77***
15 – 30 cm	Exch Al	-0.15	-0.50*	-0.57**	-0.54*	-0.50*	-0.58**
	WOB Al	0.58**	0.80***	0.80***	0.81***	0.60**	0.74***
	SOB Al	-0.62**	-0.78***	-0.79***	-0.75***	-0.61**	-0.84***
	Amo Al	0.60**	0.84***	0.80***	0.64**	0.46*	0.91***
	Free Al	0.65**	0.88***	0.74***	0.58**	0.51*	0.72***

*Significance at $p<0.05$ level, **significance at $p<0.01$ level and ***significance at $p<0.001$ level. [#]Exch Al: Exchangeable Al; WOB Al: Weakly organically bound Al; SOB Al: Strongly organically bound and interlayer Al; and Amo Al:Amorphous Al

Phosphorus content in grain, husk and straw of rice ranged between 0.23 to 0.50%, 0.05 to 0.15% and 0.04 to 0.10%, respectively. Significant highest P content in grain, husk and straw was recorded 0.50%, 0.15% and 0.10%, respectively with application of enriched compost @ 2 t/ha along with reduced doses of NP (T_5) which was statistically on par with application of enriched compost @ 1 t/ha along with reduced doses of NP (T_4) in respect of grain P content. Compared to the control, phosphorus content in plant increased by 117% in grain, 200% in husk and 150% in straw under the treatment where enriched compost @ 2 t/ha with reduced doses of NP application (T_5) was applied. The possible reason behind this was release of various organic acids during decomposition of organic matter and their reaction with inert rock phosphate to give inorganic P (Babana and Antoun 2006). Chelation of H^+ or Al^{3+} ions might be another reason for enhancement of P mobilization (Reyes *et al*. 2006).

The potassium (K) content in grain, husk and straw ranged from 0.27 to 0.36%, 0.32 to 0.37% and 1.59 to 2.03%, respectively (Table 1). Among grain, husk and straw, highest value of 2.03% (straw) and lowest value of 0.27% (grain) K content was recorded with T_5 and T_1, respectively. The application of organic or inorganic fertilizers effectively increased K content in plant particularly in straw over control and the increase was 17.6% in 100% NPK treated plot to 27.7% in enriched compost @ 2 t/ha along with reduced doses of NP treated plot. The significant increase in K content in straw due to application of equal dose of K fertilizer in all treatments except control and may be due to release of organic acids from the microbes and enhancement of K solubilization (Biswas *et al*. 2009).

Correlation coefficients (r) between aluminium fractions with major nutrient content in rice

Correlation analysis between different Al fractions and N, P and K content in different tissue parts of rice plant was carried out and is presented in Table 2. There was a highly significant negative correlation was found between exchangeable Al and strongly organically bound and interlayer Al with N, P and K content of rice. This phytotoxic pool of Al inhibits root elongation by destroying the root apex, resulting in inefficient uptake of water and nutrients and high Al concentration restricts plant growth because Al ion can easily form complex with intracellular substances and thus inhibit plant metabolism (Matsumoto 2000). The other three Al fractions *i.e.* weakly organically bound Al, amorphous Al and free Al had highly significant positive correlation with N, P and K content in rice grain and straw. This may be due to the fact that plant does not take Al present in these forms. These forms of Al did not compete with other nutrients for root's absorption site. This finding was in agreement with the earlier research of Karak *et al.* (2015).

Thus, the present investigation proved that enriched compost was a good amendment for reducing Al toxicity in highly acidic soils wherein the integrated application of enriched compost with 75% reduction of inorganic fertilizers effectively reduced not only phytotoxic Al fraction in soil but also improved the N, P and K content in rice grain under acidic Inceptisol of North-Eastern Himalayan Region.

REFERENCES

Babana A H and Antoun H. 2006. Biological system for improving the availability of Tilemsi phosphate rock for wheat (*Triticum aestivum* L.) cultivated in Mali. *Nutrient Cycling in Agroecosystems* **76**: 285–295.

Biswas D R, Narayanasamy G, Datta S C, Singh G, Begum M, Maiti D and Basak B B. 2009. Changes in nutrient status during preparation of enriched organomineral fertilizers using rice straw, low grade rock phosphate, waste mica, and phosphate solubilizing microorganism.*Communications in Soil Science and Plant Analysis* **40**: 2285–2307.

Drabek O, Boruvka L, Mladkova L and Kocarek M. 2003.Possible method of aluminium speciation in forest soils. *Journal of Inorganic Biochemistry* **97**: 8–15.

Jackson M L. 1973. *Methods of Chemical Analysis.* Prentice Hall of India (Pvt) Ltd, New Delhi.

Karak T, Sonar I, Paul R K, Frankowski M, Boruah R K, Dutta A K and Das D K. 2015. Aluminium dynamics from soil to tea plant (*Camellia sinensis* L.): Is it enhanced by municipal solid waste compost application? *Chemosphere* **119**: 917–926.

Matsumoto H. 2000. Cell biology of aluminum toxicity and tolerance in higher plants. *International Review of Cytology* **200**: 1–46.

Palaniappan S P and Annadurai K. 2007. *Organic Farming: Theory and Practices.* Jodhpur: Scientific Publishers.

Patra A, Sharma V K, Purakayastha, T J, Barman M, Kumar S, Chakraborty D, Chobhe Kapil A and Nath D J. 2018. Long-term effect of integrated nutrient management on yield and nutrients uptake by rice (*Oryza sativa*) in acid soil. *Indian Journal of Agricultural Sciences* **88**: 579–583.

Reyes I, Valery A and Valduz Z. 2006. Phosphate-solubilizing microorganisms isolated from rhizospheric and bulk soils of colonizer plants at an abandoned rock phosphate mine. *Plant and Soil* **287**: 69–75.

Rutkowska B, Szulc W, Hoch M and Spychaj Fabisiak E. 2015. Forms of Al in soil and soil solution in a long term fertilizer application experiment. *Soil Use and Management* **31**: 114–120.

Tandon H L S. 2001. *Methods of Analysis of Soils, Plants, Waters, and Fertilisers*. Fertiliser Development and Consultation Organization, New Delhi, India.

Vieira F C, He Z L, Bayer C, Stoffella P J and Baligar V C. 2008. Organic amendment effects on the transformation and fractionation of aluminum in acidic sandy soil. *Communications in Soil Science and Plant Analysis* **39**: 2678–2694.

Walna B, Spychalski W and Siepak J. 2005. Assessment of potentially reactive pools of aluminium in poor forest soils using two methods of fractionation analysis. *Journal of Inorganic Biochemistry* **99**: 1807–1816.

Wang B, Liu G B, Xue S and Zhu B. 2011. Changes in soil physico-chemical and microbiological properties during natural succession on abandoned farmland in the Loess Plateau. *Environmental Earth Sciences* **62**: 915–925.

Zhang F, Cui Z, Chen X, Ju X, Shen J, Chen Q, Liu X, Zhang W, Mi G, Fan M and Jiang R. 2012. Integrated nutrient management for food security and environmental quality in China. *Advances in Agronomy* **116**: 1–40.