Int J Recycl Org Waste Agricult (2016) 5:263–272
DOI 10.1007/s40093-016-0136-4

ORIGINAL RESEARCH

Recycling of sugarcane industries byproducts for preparation of enriched pressmud compost and its influence on growth and yield of rice (*Oryza sativa* L.)

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Received: 7 July 2015 / Accepted: 8 August 2016 / Published online: 13 August 2016

Abstract
Purpose Field experiment was conducted to investigate the effect of enriched pressmud compost prepared from sugarcane industries byproducts on soil nutrient availability, growth, yield parameters and yield of rice.
Method The effect of five levels of pressmud compost, viz., 0.00, 1.25, 2.50, 3.75 and 5.00 t ha^{-1} in two varieties, viz., ADT 36 and ADT 43 and a hybrid ADTRH 1 during the Kharif season of 2009 was studied. The experiment was conducted in a factorial randomized block design with three replications.
Results The results of the field experiment revealed that the hybrid ADTRH 1 manifested higher grain and straw yield, whereas the variety ADT 43 and ADT 36 registered lower grain and straw yields, respectively. With regard to the enriched pressmud compost, the application of 1.25 t ha^{-1} of enriched pressmud compost recorded higher straw and grain yields and it was comparable with 2.50 t ha^{-1} of enriched pressmud compost. Nutrient availability, growth, yield and efficiency parameters of rice were comparable with application of 1.25 and 2.50 t ha^{-1} of enriched pressmud compost.
Conclusion Considering the input cost, incorporation of 1.25 t ha^{-1} enriched pressmud compost as basal along with required remaining nitrogen through inorganic fertilizer as top dressing in three splits may be recommended for rice crop to realize maximum yield in kuruvai (kharif) season.

Keywords Growth · Mineral fertilizer · Nutrient availability · Pressmud compost · Rice · Yield

Introduction

India is the largest consumer and second largest producer of sugar in the world after Brazil. The sugar industry is the second largest agro-processing industries in India next to textiles industry with total sugar production of about 283 lakhs tonnes from 538 sugar factories during 2015–2016. The pressmud and molasses are the important by products of sugar industries, and the production is to the tune of 8.7 and 8.5 million tonnes per annum, respectively (National Federation of Co-operative Sugar Factories Ltd 2016; Dotaniya et al. 2016). The production of pressmud cake amounts to about 3 % of cane crushed in the sugar factory. Pressmud is the compressed sugar industry waste produced from the filtration of the cane juice. Molasses is utilized in the distillery for the production of alcohol. The distilleries release a huge quantity of spent wash. These waste products cause disposal and pollution problems. Pressmud cake (PMC) is one such source of organic matter and nutrients (rich in potassium and phosphorus) which can be profitably utilized for crop production. PMC like other organic manures has great potential to supply nutrients in addition to its favourable effects on physico-chemical and biological properties of soil. The value of pressmud as an organic manure has been well recognized for utilizing in agriculture, as it contains valuable plant nutrients in organic form besides being a very effective soil ameliorant (Singh et al. 2015a, b). Rice is the stable food crop in India with world ranking one in area (42.6 Mha) and second to China in production (104.80 Mt) during 2014–15. India needs to produce about 325 million tonnes of food grains to feed an expected population of about 1.5 billion by

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2025 (Swaminathan and Bhavani 2013). Keeping in view of the average annual population growth rate of 1.5 % and per capita consumption estimate of about 400 g of rice per day, demand of rice is expected to be around 140 Mt by 2025 (Singh et al. 2015a, b). As the pressmud and distillery effluents contain plant nutrients, these could be converted into nutrient-rich organic manure. Conversion of waste products into rich organic manures not only solves the problems of disposal and pollution, but also replenishes the soils and reduces the fertilizer cost (Selvamurugan et al. 2013). Although substantial work has been done on the utilization of raw pressmud in rice cultivation, the effect due to composting and enrichment of pressmud on nutrient availability, growth, yield parameters, yield and efficiency parameters of rice is very much limited. Hence a study was made to know the effect of enriched pressmud compost on growth, yield parameters and yield of rice.

Materials and methods

Preparation of enriched pressmud compost

Enriched pressmud compost was prepared from raw pressmud using windrow composting technique and enriched by adding rock phosphate, $ZnSO_4$, $MgSO_4$, *Azospirillum*, *Phosphobacteria*, *Pseudomonas*, gypsum and cow dung slurry.

Preparation of pressmud compost from raw pressmud

Raw materials, viz., pressmud and spent wash from local sugar industries and fly ash from local thermal power plant were procured and utilized for preparation of pressmud compost. The raw pressmud was kept in an open hard place for the period of 2 months after receiving the pressmud from sugar industry for minimizing the temperature of raw pressmud. Initially the temperature of raw pressmud was around 80 °C. The raw pressmud after attaining the normal temperature was piled in long rows of 1.2–2.4 m width and 1–1.2 m height on a hard surface and usually in the open area. Hard surface area was selected for composting to prevent leaching of water or nutrients from the compost. These long rows of pressmud were turned at regular interval to improve porosity and oxygen content, mix in or remove moisture, and redistribute cooler and hotter portions of the pile. Spent wash was sprayed on the surface of pressmud rows in every 15 days. Then, the aero-tiller was allowed 4–5 times over the surface of pressmud row on 15th, 20th, and 25th likewise up to 40th day at an interval of 5 days for reducing the height of pressmud row from 4 to 2 feet, for breaking the hard blocks present in the pressmud row and also for uniform composting. Afterwards, row dressing was made at 1 m width and to 50 m length by using aero-tiller. Fifty days after row dressing, fly ash was added at the rate of 50 kg per tonne of pressmud for reducing the fibre content of pressmud. The moisture level was maintained at 60 % level throughout the composting period. Finally, the pressmud compost was changed to black colour after 60 days of application of fly ash with an earthy odour and it was used for further enrichment.

Enrichment of pressmud compost

Before doing enrichment, the total weight of pressmud compost in a single row was calculated by assessing the weight of pressmud compost in 1 m^2 at three places and by taking the average weight of pressmud compost in 1 m^2 areas, the total weight was arrived with multiplying the length of pressmud compost row in metres. The following materials were used for preparing 1 tonne of enriched pressmud compost and they were mixed systematically to pressmud compost one after the other.

Rock phosphate	25 kg
$ZnSO_4$	10 kg
$MgSO_4$	10 kg
Azospirillum	1 l
Phosphobacteria	1 l
Pseudomonas	1 l
Gypsum	100 kg
Cow dung slurry	240 l
Fly ash	50 kg

The enriched pressmud compost was ready after 30 days of the preparation of pressmud compost. A detailed chemical composition of raw pressmud; pressmud compost and enriched pressmud compost are given in Table 1.

Field experiment

Field experiment was conducted at Pandit Jawaharlal Nehru College of Agriculture and Research Institute, Karaikal, in the Union Territory of Pondicherry to study the effect of enriched pressmud compost on soil nutrient availability, growth and yield of rice in kuruvai (Kharif) season during the year 2009. The experimental soil (Fluventic Haplustept) was with pH of 7.80 and EC of 0.22 dS m^{-1}. The available N, P, K status was 153, 12.4 and 220 kg ha^{-1}, respectively. The organic carbon content was 4.5 g kg^{-1} with CEC of 13.2 cmol (p^+) kg^{-1}. The textural classification revealed loamy type of soil with 20.9 % of clay, 40.0 % of silt, 23.4 % of fine sand and 15.6 % of coarse sand. The experiment was conducted in a factorial randomized block design (fRBD) with three cultivars and five treatments in three replications. The treatments adopted were

Table 1 Chemical composition of raw pressmud, pressmud compost and enriched pressmud compost

Parameter	Raw pressmud	Pressmud compost	Enriched pressmud compost
pH	7.27	7.28	7.44
EC (dsm^{-1})	3.02	3.54	3.65
O.C (%)	25.92	23.31	20.01
O M (%)	44.7	40.2	34.5
C:N ratio	17.4:1	14.2:1	10.6:1
Nitrogen (%)	1.49	1.64	1.89
Phosphorus (%)	1.32	1.55	2.00
Potassium (%)	1.33	1.41	1.68
Calcium (%)	1.24	1.33	1.59
Magnesium (%)	1.22	1.37	1.69
Sulphate (%)	1.48	1.52	1.78
Sodium (%)	1.20	1.44	1.48
Iron (mg kg^{-1})	1250	1288	1350
Manganese (mg kg^{-1})	258	292	310
Zinc (mg kg^{-1})	79	125	189
Copper (mg kg^{-1})	52	63	76

T_1—0 t ha^{-1}, T_2—1.25 t ha^{-1}, T_3—2.50 t ha^{-1}, T_4—3.75 t ha^{-1} and T_5—5.00 t ha^{-1} of enriched pressmud compost. The rice varieties, viz., ADT 36, ADT 43 and the hybrid ADTRH 1 were used for the experiment. The experiment was laid out by raising bunds to a height of 15 cm all around with buffer channels to individual plots. The plot size adopted was 5 m × 4 m. Twenty-eight-day old seedlings were transplanted at the rate of two seedlings per hill in the case of ADT 43 and ADT 36 and one seedling per hill in the case of ADTRH 1 with the spacing of 20 cm × 10 cm. A blanket recommendation of 120 kg N, 40 kg P_2O_5 and 40 kg K_2O ha^{-1} was adopted for this investigation. The P_2O_5 and K_2O were applied in the form of single super phosphate (SSP) and muriate of potash (MOP) after the application of enriched pressmud compost but before transplanting and the N was applied as per the treatments by using both enriched pressmud compost (EPC) and urea in equi-nitrogen basis. Except control (0 t ha^{-1}), all the treatments were received an equal quantity (120 kg N ha^{-1}) of nitrogen through enriched pressmud compost and urea. The EPC was incorporated as basal and the urea was applied in three equal splits as top dressings at the time of active tillering, panicle initiation and first flowering stages. The growth and yield components of the paddy crop was evaluated by taking the biometric observations, viz., plant height, number of tillers, number of productive tillers, number of seeds per panicle, dry matter production, thousand grain weight and yields of grain and straw at appropriate stages. Available N, P and K were determined by following standard procedure given by Jackson (1973).

Computation of efficiency parameters

Various efficiency parameters of rice, viz., harvest index, agronomic efficiency and apparent N recovery were calculated by using the following formulas.

Harvest index

Harvest index represents the ratio of quantity of economic produce to total biomass.

$$\mathrm{HI} = \frac{\text{Grain yield (kg ha}^{-1})}{\text{Total biomass at harvest (kg ha}^{-1})}$$

Agronomic efficiency

The response of rice (increase in grain yield per kg of fertilizer N applied) in different treatments were calculated from the formula,

$$\text{Responese ratio} = \frac{\text{Grain yield in treated plot (kg ha}^{-1}) - \text{Grain yield in control plot (kg ha}^{-1})}{\text{Total N applied (kg ha}^{-1})}$$

Apparent N recovery

$$\text{Apparent N recovery} = \frac{\left\{\begin{array}{l}\text{N uptake in nutrient}\\ \text{applied treatment (kg ha}^{-1}\text{)}\end{array}\right\} - \left\{\begin{array}{l}\text{N uptake in}\\ \text{N control treatment (kg ha}^{-1}\text{)}\end{array}\right\}}{\text{Total N applied (kg ha}^{-1}\text{)}}$$

Statistical analysis

The various biometric observations, yield and yield parameters were subjected to statistical scrutiny. One-way ANOVA was used to analyse the differences between treatments. A Tukey's *t* test was also performed to identify the homogeneous type of the data sets. IRRISAT statistical package was used for data analysis.

Results and discussion

Plant height

Significant variations were observed in plant height between hybrid and varieties at all the stages of crop growth (Table 2). The hybrid ADTRH 1 (genetic potential: 6.5 t ha^{-1}) measured the maximum plant height of 92.2 cm than the other varieties. Among the varieties, the ruling variety ADT 43 registered higher plant height (69.7 cm) than the variety ADT 36 (64.4 cm) at maturity stage. Similar trend was also observed with earlier physiological growth stages of rice. This might be due to the genetic makeup of hybrid and varieties as well as the differential absorption of nutrients. In all stages, viz., active tillering, panicle initiation and maturity stages, the increased plant height was observed with application of 1.25 and 2.50 t ha^{-1} of enriched pressmud compost. This is expected, because the growth of the crop depends on the nutrients availability from the soil. The rapid mineralization of N from inorganic fertilizer and steady supply of nutrients from enriched pressmud compost might have met the N requirement throughout the crop growth and especially at the critical stages of crop growth, which manifested the highest plant height. This kind of results were evinced through the studies of many authors (Kumar et al. 2007; Khan et al. 2014) who experienced that the application of pressmud and other organics could be able to release and supply more N through mineralization process for favouring the height of plants in rice crop.

Number of tillers and productive tillers

The numbers of tillers were higher with ADTRH 1 and ADT 43 and lower with ADT 36 at all physiological stages of crop growth (Table 2). Among the varieties, the hybrid ADTRH 1 produced significantly the maximum number of tillers recording 628 m^{-2}, when compared to ADT 43 and ADT 36, which recorded 591 and 517 tillers m^{-2}, respectively, at maturity stage. The per cent increase in hybrid was 6.26 over ADT 43 and 21.7 over ADT 36. This variation in number of tillers at active tillering, panicle initiation and maturity stages within the varieties and hybrid were observed again due to the intrinsic character of the varieties and hybrid. In the case of different levels of enriched pressmud compost, the levels of 1.25 and 2.50 t ha^{-1} were equally influencing the production of number of tillers. However, the treatments, 3.75 and 5.00 t ha^{-1} was significantly on par in producing the number of tillers as, 583 and 582 m^{-2}, respectively, during maturity stage. The maximum number of tillers m^{-2} at active tillering as well as panicle initiation stages with 1.25 t ha^{-1} of enriched pressmud compost and at maturity stage with both 1.25 and 2.50 t ha^{-1} levels might be due to the continuous and enhanced N supply ensured by these treatments. The application of pressmud in combination with inorganic fertilizer increased the number of tillers was also reported by Omar Hattab et al. (1998).

The number of productive tillers also attributed to the inherent characteristics of the varieties and hybrid. The ADTRH 1 registered maximum number of productive tillers m^{-2} of 493 over ADT 43 (416 m^{-2}) and ADT 36 (349 m^{-2}), which was 18.5 per cent increase over ADT 43 and 41.3 per cent increase over ADT 36. The number of productive tillers m^{-2} recorded higher with application of 1.25 and 2.50 t ha^{-1} of enriched pressmud compost in all the varieties and hybrid (Table 3). Among the enriched pressmud compost levels, the application of 1.25 t ha^{-1} favoured the release of a maximum number of 454 productive tillers m^{-2}, followed by 2.50, 3.75, 5.00 t ha^{-1} and control by recording 444, 434, 425 and 339 tillers m^{-2}, respectively. All the treatments were on par in recording

Table 2 Plant height (cm) and number of tillers (m^{-2}) at different physiological stages of rice

Treatments (*T*)	Tillering			Mean	Panicle initiation			Mean	Post-harvest			Mean
Pressmud compost levels ($t\ ha^{-1}$)	Varieties (*V*)				Varieties (*V*)				Varieties (*V*)			
	ADT 36	ADT 43	ADTRH 1		ADT 36	ADT 43	ADTRH 1		ADT 36	ADT 43	ADTRH 1	
	Plant height											
0.00	29.5	32.4	43.7	35.2	55.2	58.6	79.3	64.4	60.8	63.9	87.2	70.6
1.25	34.4	36.9	49.0	40.1	62.2	64.6	88.8	71.8	67.1	74.0	95.1	78.7
2.50	33.8	36.5	48.0	39.5	61.8	63.9	88.4	71.3	65.5	70.7	94.3	76.8
3.75	33.4	36.1	46.3	38.6	60.0	63.1	87.4	70.2	64.1	70.2	92.1	75.5
5.00	31.5	35.7	45.7	37.7	59.7	62.1	86.7	69.5	64.4	69.9	92.3	75.5
Mean	32.5	35.5	46.5		59.8	62.5	86.1		64.4	69.7	92.2	
Sources	*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*	
SEd	1.28	1.65	2.85		1.46	1.88	3.26		1.01	1.31	2.26	
CD (5 %)	2.62	NS	NS		2.99	3.86	NS		2.07	2.68	NS	
	Number of tillers											
0.00	187	207	240	211	403	453	433	430	450.	487	557	498
1.25	263	294	293	284	530	617	657	601	560	647	653	620
2.50	240	290	277	269	494	597	603	565	530	640	653	608
3.75	237	270	270	259	493	573	593	553	523	603	623	583
5.00	220	260	263	248	460	561	593	538	517	577	653	582
Mean	229	264	269	254	476	560	576	538	517	591	628	578
Sources	*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*	
SEd	6.32	8.15	14.1		13.5	17.4	30.2		9.30	12. 0	20.7	
CD (5 %)	12.9	16.7	NS		27.6	35.7	NS		19.0	24.5	NS	

SEd standard error of difference, *CD* critical difference

Table 3 Dry matter production at tillering and panicle initiation stage ($t\ ha^{-1}$) and number of productive tillers (m^{-2})

Treatments (*T*)	Tillering			Mean	Panicle initiation			Mean	Number of productive tillers			Mean
Pressmud compost levels ($t\ ha^{-1}$)	Varieties (*V*)				Varieties (*V*)				Varieties (*V*)			
	ADT 36	ADT 43	ADTRH 1		ADT 36	ADT 43	ADTRH 1		ADT 36	ADT 43	ADTRH 1	
0.00	1.00	1.08	1.55	1.21	3.27	3.91	6.66	4.61	277	318	422	339
1.25	1.32	1.35	1.98	1.55	5.79	5.36	8.14	6.43	380	455	528	454
2.50	1.27	1.26	1.89	1.47	5.54	5.06	7.87	6.16	368	445	518	444
3.75	1.26	1.22	1.85	1.44	5.11	5.04	7.58	5.91	362	437	503	434
5.00	1.21	1.20	1.84	1.42	4.95	4.71	7.38	5.68	357	423	508	425
Mean	1.21	1.22	1.82		4.93	4.82	7.52		349	416	493	
Sources	*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*	
SEd	0.03	0.03	0.06		0.28	0.36	0.62		11.8	15.2	26.4	
CD (5 %)	0.05	0.07	NS		0.57	0.73	NS		24.1	31.2	NS	

SEd standard error of difference, *CD* critical difference

the number of productive tillers m^{-2} except the control. This might be due to the rapid mineralization of N from these treatments. This is in consonance with the studies of Omar Hattab et al. (1998). The other treatment such as 3.75 and 5.00 $t\ ha^{-1}$ of enriched pressmud compost, which contributed organic N, has also influenced the number of productive tillers, but their effect was second in the order of merit. This could be due to the delayed mineralization of N, when compared to 1.25 and 2.50 $t\ ha^{-1}$ levels of enriched pressmud compost. The addition of more amount of pressmud compost decreased the number of productive tillers, presumably due to their poor mineralization of N at the time of requirement as well as the immobilization of soil native N. This kind of result finds support from Jeyabal et al. (1999).

Dry matter production

The significant increase in dry matter production was found with ADTRH 1 than ADT 43 and ADT 36 at active tillering and panicle initiation stages (Table 3). This might be due to the nature of hybrids to produce more dry matter than the varieties. The highest dry matter production with the application of 1.25 t ha^{-1} of enriched pressmud compost could be attributed to rapid mineralization of N from this treatment and absorption of the N by the rice crops. The application of spent slurry pressmud and spent wash slurry pressmud increased the DMP of maize was reported by Patil and Shinde (1995) in rice.

Grain and straw yield of rice

The hybrid ADTRH 1 recorded significantly higher grain and straw yield than ADT 43 and ADT 36 (Table 4). This might be due to the known fact that the hybrid is able to produce higher yield than the conventional varieties due to its inherent genetic makeup and its ability to mobilize more nutrients for realizing potential yields. While studying the effect of enriched pressmud compost levels, the 1.25 t ha^{-1} level registered higher grain yield of 4.32 t ha^{-1}, which was on par with 2.50 t ha^{-1} level. The lowest grain yield of 3.42 t ha^{-1} was recorded with control (0 t ha^{-1}). The yield reduction was observed with increase in the levels of pressmud compost. Higher grain yield obtained from the above treatments might be attributed to rapid mineralization of N and sustained supply of N from pressmud, which might have met the N requirement of crop over a long period and specifically at the critical stages of crop growth. This is in accordance with the reports of Kumar et al. (2007) and Khan et al. (2014). The interaction effects did not manifest any difference in realizing grain and straw yield. However, the hybrid ADTRH 1 recorded the highest grain and straw yield of 5.24 t ha^{-1} and 8.24 with 1.25 t ha^{-1} of pressmud compost and the variety ADT 36 registered the lowest grain and straw yield of 2.76 and 4.85 t ha^{-1} with control.

Yield parameters

The number of grains per panicle was significantly varied with the different levels of enriched pressmud compost (Table 4). Among the pressmud compost levels,

Table 4 Number of grains per panicle, 1000 grain weight and grain and straw yield of rice (t ha^{-1})

Treatments (*T*) Pressmud compost levels (t ha^{-1})	Varieties (*V*)			Mean	Varieties (*V*)			Mean
	ADT 36	ADT 43	ADTRH 1		ADT 36	ADT 43	ADTRH 1	
	No. of grains per panicle				*1000 grain weight*			
0.00	93.7	92.0	95.3	93.7	17.1	19.5	22.2	19.6
1.25	99.7	99.7	101	101	18.4	20.9	23.7	21.0
2.50	97.3	97.7	101	98.9	18.2	20.9	23.2	20.8
3.75	95.7	94.3	98.0	96.0	18.2	20.8	23.1	20.7
5.00	95.3	93.7	94.3	94.4	18.2	20.6	23.1	20.6
Mean	96.3	95.5	98.7		18.0	20.5	23.1	20.5
Source	*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*	
SEd	2.21	2.86	4.94		0.50	0.65	1.12	
CD ($P = 0.05$)	NS	NS	NS		1.03	NS	NS	
	Grain yield (t ha^{-1})				*Straw yield (t ha^{-1})*			
0.00	2.76	3.29	4.22	3.42	4.85	5.74	7.08	5.89
1.25	3.34	4.38	5.24	4.32	5.35	7.27	8.24	6.95
2.50	3.32	4.22	5.19	4.24	5.34	7.17	8.22	6.91
3.75	3.12	4.15	4.86	4.04	5.28	7.07	8.20	6.85
5.00	3.06	4.03	4.58	3.89	5.17	6.77	7.68	6.54
Mean	3.12	4.01	4.82		5.20	6.80	7.88	
Source	*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*	
SEd	0.10	0.13	0.23		0.11	0.14	0.26	
CD ($P = 0.05$)	0.20	0.26	NS		0.22	0.28	NS	

SEd standard error of difference, *CD* critical difference application of 1.25 t ha^{-1} level was favoured in increasing the number of grains per panicle. This might be due to the release of nutrients from this level, which could match the N requirement by the crop. Kumar et al. (2007) also observed the increased number of grains per panicle by the application of pressmud compost. The results of thousand grain weight of the varieties and hybrid are the reflection of the intrinsic characters. As such, this parameter varies with varieties and hybrid, but not by different levels of enriched pressmud compost. All the treatments had similar influence in increasing the 1000 grain weight (Table 4). Most probably, the N mineralized from the organics with subsequent addition of inorganic N might have maintained a balanced N nutrition of rice crop leading to proper translocation of photosynthates to grain which ultimately kept 1000 grain weight constant at all levels.

Efficiency parameters

The efficiency parameters, viz., the harvest index, agronomic efficiency and apparent N recovery are presented in Table 5. Harvest index was considerably more in ADTRH 1 than ADT 43 and ADT 36. The effect of treatment did not have any influence on altering this parameter. Since all the treatments had their respective influence both on the economic yield and total biomass. The proper N nutrition made through application of 1.25 and 2.50 t ha^{-1} of enriched pressmud compost was able to maintain higher agronomic efficiency, which was reflected in grain yield. The better performance of this levels of pressmud compost in higher agronomic efficiency could be attributed to their capacity to supply N associated with improved soil condition. Omar Hattab et al. (1998) found that the supply of nutrients and agronomic efficiency varied according to the nature of decomposition of the materials and their mineralization. The higher N recovery resulted through the application of 1.25 t ha^{-1} of enriched pressmud compost might be due to their capacity to supply N at appropriate time. The apparent N recovery was decreased with increasing the levels of enriched pressmud compost due to its nature of decomposition based on the quantities of its presence, which in turn would have immobilized the released native soil N (Kumar et al. 2007; Khan et al. 2014).

Effect of enriched pressmud compost on N, P and K availability

Available nitrogen

Available soil N at active tillering, panicle initiation and at post-harvest stages is furnished in Fig. 1. The available nitrogen in soil at active tillering stage was not influenced either by cultivars or by treatments and its interactions. At panicle initiation also, the available soil nitrogen was not influenced by the varieties and hybrid. Among the treatments, the control recorded significantly lower amount of available soil nitrogen of 127 kg ha^{-1}, whereas the other four treatments established more of less equal status of available soil nitrogen at panicle initiation stage. The interaction between varieties and treatments did not influence the available soil N at panicle initiation stage. At post-harvest, the varieties and hybrid did not show any effect on realizing available soil nitrogen at this stage. Among the treatments, the application of 1.25 t ha^{-1} of enriched pressmud compost favoured for higher amount of available soil nitrogen of 171 kg ha^{-1}, followed by 2.50, 3.75, 5.00 t ha^{-1} and by control at post-harvest stage. The application of 1.25 t ha^{-1} of enriched pressmud compost sustained higher N availability and it was comparable with 2.50 t ha^{-1} of enriched pressmud compost. The increase in available soil nitrogen on account of these pressmud application indicated that the nitrogen present in the pressmud was immediately available for crop nutrition. This might also be due to the congenial environment for soil organisms involved in nitrogen transformation with application of pressmud compost (Yang et al. 2013). Since

Table 5 Effect of enriched pressmud compost on harvest index, agronomic efficiency and apparent N recovery of rice

Treatments (*T*)	Harvest index (HI)			Mean	Agronomic efficiency			Mean	Apparent N recovery			Mean
Pressmud compost levels (t ha^{-1})	Varieties (*V*)				Varieties (*V*)				Varieties (*V*)			
	ADT 36	ADT 43	ADTRH 1		ADT 36	ADT 43	ADTRH 1		ADT 36	ADT 43	ADTRH 1	
0.00	0.36	0.36	0.37	0.36	0	0	0		0	0	0	
1.25	0.38	0.38	0.39	0.38	4.86	8.47	9.08	7.47	26.7	28.2	32.4	29.1
2.50	0.37	0.38	0.39	0.38	4.69	8.08	7.75	6.84	25.3	27.6	31.6	28.2
3.75	0.37	0.37	0.37	0.37	2.97	5.36	7.17	5.17	24.8	25.3	29.8	26.6
5.00	0.37	0.37	0.37	0.37	2.53	3.00	6.17	3.90	24.6	24.6	28.4	25.9
Mean	0.37	0.37	0.38		3.76	6.23	7.54		25.4	26.4	30.1	

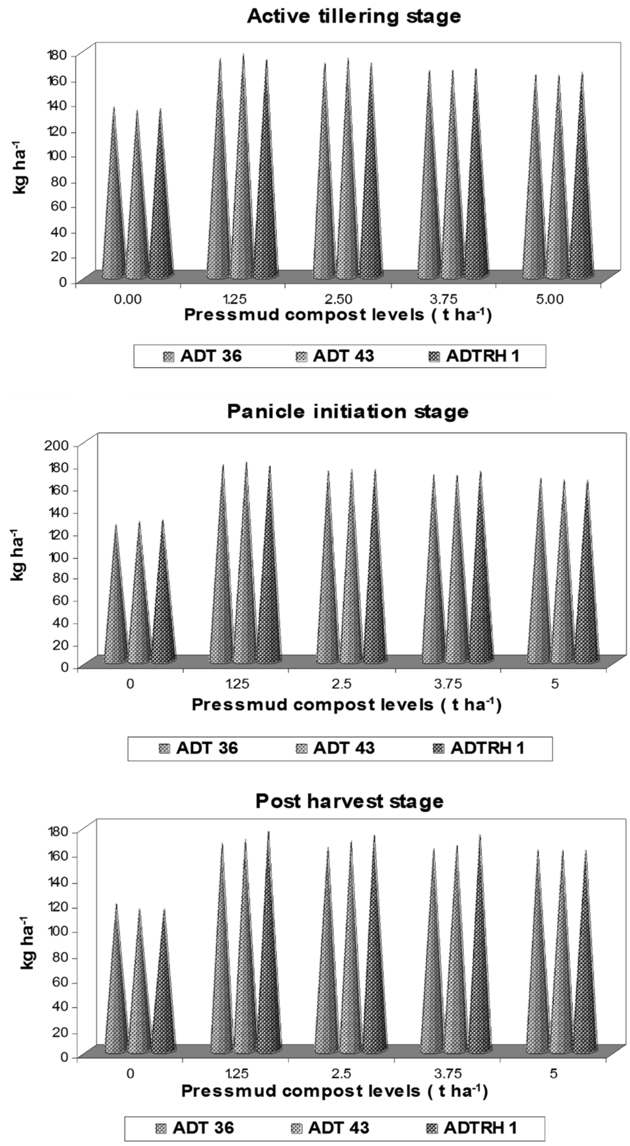

Fig. 1 Available soil nitrogen at different physiological stages (kg ha^{-1})

the C/N ratio of the material was narrow and the nitrogen present would be immediately available for plant use. Similar results were obtained by many authors (Kumar et al. 2007; Sultana et al. 2015). They have also confirmed the results of the present investigation.

Available phosphorus

The available soil phosphorus at active tillering, panicle initiation and at post-harvest stages is presented in the Table 6. At active tillering stage, the varieties and treatments did not bring any marked variation regarding the available soil phosphorus. Among the treatments, the soil available phosphorus was higher (19.5 kg ha^{-1}) at 1.25 t ha^{-1} of enriched pressmud compost. The lowest soil available phosphorus of 15.2 kg ha^{-1} was recorded at control. The two-way interactions could not show any significant variation. At panicle initiation stage also, similar trend was observed regarding the available soil phosphorus except the various levels of enriched pressmud compost. At post-harvest, the available soil phosphorus status recorded by hybrid and varieties and their interaction with treatments did not show any marked influence. The trend of results at active tillering and panicle initiation stage reflected at this stage also regarding the treatments. The level of 1.25 t ha^{-1} recorded the higher available soil P of 19.6 kg ha^{-1} and the lower value of 13.4 kg ha $^{-1}$ at control. The increment in levels of enriched pressmud compost declined the status of available soil P was observed at this stage. The available phosphorus status of the soil at different physiological stages was higher with the application of 1.25 and 2.50 t ha^{-1} of enriched pressmud compost. The decomposition processes of easily degradable organics might have reduced the binding energy and P sorption capacity of flooded rice soil which favoured the higher P availability. The increase in available P content of the soil with pressmud compost application was due to the phosphorus content of the material and probably due to the solubilization of insoluble forms of phosphate by organic acids produced during the decomposition of organic matter present in pressmud. This has confirmation with the results of many authors (Dotaniya and Datta 2014; Dotaniya et al. 2015).

Available potassium

The data on available soil potassium at active tillering, panicle initiation and post-harvest stages is given in Table 6. The independent effects of varieties and hybrids and their interaction effects did not show any marked variation regarding the available soil potassium in all three physiological stages of rice. While seeing the effect of treatments, the levels of 1.25 and 2.50 t ha^{-1} of enriched pressmud compost had equal status in establishing the available soil potassium and significantly superior over other levels in all the stages. The lowest available potassium was recorded at control in all the physiological stages. The positiveness of individual application of 1.25 and 2.50 t ha^{-1} of enriched pressmud compost on K availability was established in all stages irrespective of varieties and hybrid. This effect could be attributed to the highly reduced condition created by the easily degradable organics associated with the release of nutrient cations particularly K^{+} at higher proportions in soil solution. These kinds of results were also evinced from the reports of many authors (Kumar et al. 2007; Sultana et al. 2015).

Table 6 Available soil phosphorus and potassium (kg ha^{-1}) at different physiological stages of crop growth

Treatments (*T*)	Tillering			Mean	Panicle initiation			Mean	Post harvest			Mean
Pressmud compost levels (t ha^{-1})	Varieties (*V*)				Varieties (*V*)				Varieties (*V*)			
	ADT 36	ADT 43	ADTRH 1		ADT 36	ADT 43	ADTRH 1		ADT 36	ADT 43	ADTRH 1	
	Available phosphorus											
0.00	15.5	14.9	15.1	15.2	14.3	13.9	13.9	14.1	13.8	12.8	13.5	13.4
1.25	19.2	19.3	19.9	19.5	19.3	19.6	20.8	19.9	19.0	19.3	20.6	19.6
2.50	18.8	19.1	19.8	19.2	19.2	19.2	20.1	19.5	18.7	19.1	19.5	19.1
3.75	18.5	18.8	19.0	18.8	19.7	18.7	19.7	19.0	18.6	18.6	18.8	18.7
5.00	18.2	18.7	18.4	18.4	18.5	18.9	19.0	18.8	18.0	18.2	18.7	18.3
Mean	18.0	18.2	18.4		18.0	18.1	18.7		17.6	17.6	18.2	
Sources	*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*	
SEd	0.47	0.61	1.06		0.60	0.78	1.34		0.39	0.50	0.87	
CD (5 %)	NS	1.25	NS		NS	1.59	NS		NS	1.03	NS	
	Available potassium											
0.00	210	207	217	212	201	202	210	204	193	194	213	200
1.25	254	254	260	256	264	266	267	266	257	260	263	260
2.50	254	241	250	248	260	254	259	258	254	253	257	255
3.75	248	235	238	240	257	253	247	253	251	249	246	249
5.00	240	230	234	235	254	250	246	250	240	247	240	242
Mean	241	233	240		247	245	246		239	241	244	
Sources	*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*		*V*	*T*	*V* × *T*	
SEd	6.34	8.18	14.2		7.68	9.91	17.2		5.05	6.52	11.3	
CD (5 %)	NS	16.8	NS		NS	20.3	NS		NS	13.4	NS	

SEd standard error of difference, *CD* critical difference

Conclusion

The outcome of the present investigation revealed that the highest straw and grain yield was obtained at 1.25 t ha^{-1} of enriched pressmud compost along with inorganic fertilizers for the varieties and hybrid. Yield parameters, viz., number of grains per panicle and 1000 grain weight and efficiency parameters, viz., agronomic efficiency and apparent N recovery were at higher levels and comparable with application of 1.25 and 2.50 t ha^{-1} of enriched pressmud compost, whereas it was lower with control. Application of 1.25 and 2.50 t ha^{-1} of enriched pressmud compost were at par with respect to registering maximum plant height, number of tillers, number of productive tillers and dry matter production. The N, P and K availability in soil was at higher levels and comparable with application of 1.25 and 2.50 t ha^{-1} of enriched pressmud compost, whereas it was lower with control. The result of present study revealed that 20 % chemical fertilizers requirement could also be saved by the application of enriched pressmud compost at 1.25 t ha^{-1}, without affecting yield of rice besides improving the soil fertility. Hence, the incorporation of 1.25 t ha^{-1} enriched pressmud compost as basal along with required remaining nitrogen through inorganic fertilizer as top dressing in three splits may be recommended for rice crop to realize maximum yield in kuruvai (kharif) season.

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