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Effect of Rice straw compost and mineral fertilizers on yield and nutrient uptake by Indian mustard in saline soil

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Abstract

We investigated the effect of rice-straw compost (RSC) with and without mineral fertilisers on yield of Indian mustard (*Brassica juncea* L.) and chemical properties of saline soil. A field experiment was conducted for three consecutive years during 2012–15. Treatments consisted of control (cont), recommended dose of N:P:K fertilizers at 60:30:30 kg ha^{-1} (100% RDF), rice straw compost at 14 t ha^{-1} (RSC-14) and RSC@ 7 t ha^{-1} + 50% RDF (RSC+RDF) laid out in randomized block design with three replication. Integrated use of RSC+RDF produced in 13 and 16% mean of (3 year) grain and straw yield respectively, over the alone use of 100% RDF. RSC had higher grain yield of mustard as compared to 100%RDF, however, it was statistically at par with 100%RDF. Significantly higher grain (23.1 q ha^{-1}) and straw (61.2 q ha^{-1}) yield was observed with RSC+RDF than other treatments except RSC. Higher NPK uptake by mustard grain and straw was registered under 100%RDF than cont. Significant build-up of soil fertility in terms of available nitrogen (N) and potassium (K) was maintained with RSC+RDF as compared to cont. Soil treated with 100%RDF had 56 and 37% higher available N and K respectively, over cont. Soil organic carbon (SOC) was significantly influenced with integration of RSC+RDF than 100% RDF. Treatment receiving RSC-14 had 18% higher SOC than 100% RDF. The magnitude of changes in electrical conductivity (EC) was at par among the treatments, though lowest soil EC was reported with integrated use of compost and mineral fertilizers. Our results highlight that combined use of RSC (RSC-7) and mineral fertilizers (50% RDF) is beneficial option for improving mustard yield and fertility of saline soils.

Key words: *Mustard yield, mineral fertilizers, nutrient uptake, rice straw compost, salinity*

Introduction

Improving the productivity of Indian mustard [*Brassica juncea* (L.) Czern & Coss.] is a paramount importance to full fill the demands of vegetable oil and nutritional security for an ever-increasing population, which is expected to reach 1.6 billion by 2050 and vegetable oil demand will increase 17.84 Mt by 2050. Rapeseed-mustard crops have a significant role in Indian agriculture since almost each part of the plant is consumed either by human beings or animals depending upon the crop and its growth stage (Meena *et al*., 2015). Indian mustard is a vital oilseed crop of India stands second after soybean in production amongst eight annual edible oilseeds cultivated in the country. It contributes about 80% of the total rapeseed-mustard production and nearly 27% of edible oil pool in India, and accounts for >13% of the global edible oil production (Meena *et al*., 2014). The average productivity is about 1190 kg ha^{-1} (AICRPRM, 2009). Mustard requires relatively large amount of nutrients for enhancing yield potential but inadequate supply often leads to low productivity (Tripathi *et al.*, 2010).

Salinity is a major impediment to sustainable crop production in arid and semi-arid regions of the world. Soil salinity and nutrients poorness are a serious threat to global agriculture (Zhang *et al.*, 2007). About 20% of the world's cultivated area and nearly 50% of the irrigated croplands are affected by soil salinity (Zhu, 2001). In India, soils covering 6.73 Mha are salt-affected, with sodic soils comprising 3.77 M ha and saline soils 2.96 M ha (Sharma *et al.*, 2015), another 16.2 Mha of land is predicted to become salt-affected by 2050 (Central Soil Salinity Research Institute, 2014). Excess amount of salts inhibits plant growth through more negative osmotic potential of the soil solution, specific ion toxicity and ion imbalance, which further reduce nutrient uptake and also affects mustard yield and quality (Marschner, 2012; Meena *et al.*, 2016). However, inappropriate irrigation and drainage systems have resulted in rising groundwater levels, which have the potential to trigger salt accumulation in the soil profile and have a negative effect on crop production (Sharma and Minhas, 2005). It is well known that saline soil has low fertility and biological activity. Saline soils are deficient in soil organic carbon (SOC), N, P and K (Meena *et al.,* 2016).

Recycling of agricultural wastes for crop production especially rice straw is gaining significant importance as it has limited use as an animal feed because of its high silica content (Meena and Biswas, 2014a). According to FAO (2013), over the past ten years, the global paddy rice output on an average was about 664.3 million tonnes (Mt). Direct incorporation of the rice straw into the soil is also limited as it may cause certain agronomic problems such as temporary immobilization of nutrients and associated crop yield reduction (Yadvinder-Singh *et al.,* 2005). As a result, a large amount of straw is left unutilized, which is mostly burnt onfarm (Gadde *et al.,* 2009), although burning of the straw in situ is the most discouraged option as it emits air pollutions (Gadde *et al.,* 2009), and causes considerable loss of both organic C and nutrients, and there is environmental pollution from the emissions of toxic and greenhouse gases. Attempts were made to produce compost from rice straw and bioinoculant with *Trichoderma viride* which may serve as a supplement source of plant nutrients (Meena and Biswas, 2013; Meena and Biswas, 2014b). Hence, research priorities have been directed toward how to recycle the huge amount of rice straw instead of burning, the best and environmentally sustainable way is converting in to value added product through composting technology and use as organic fertilizers. The aim of this study was to investigate the effects of organic and mineral fertilizers on mustard yield and nutrient availability in saline soil.

Materials and Methods

Compost preparation

Rice straw compost (RSC) was prepared with *Trichoderma viride* inoculation. For composting, chopped rice straw (length 5–6 cm), soaked in water for 24 h, was mixed thoroughly on a polyethylene sheet. A uniform dose of urea solution at 0.25 kg N 100 kg^{-1} rice straw (air-dry weight basis, 30 ±1 ^{0}C) was added to reduce the C:N ratio. Fresh cow dung at 10 kg 100 kg^{-1} rice straw was made into slurry and added to the compost mass to acts as a natural inoculant. A uniform dose of *T. viride* at 50 g fresh mycelia 100 kg^{-1} rice straw was added to the compost mass to hasten the decomposition rate. The entire composting mass was mixed thoroughly and put in cemented pits. Manual turning was performed after 30, 60 and 90 days of composting to provide adequate aeration. Moisture was maintained at 60% of water-holding capacity throughout the composting period (120 days).

Chemical analysis of Rice straw compost (RSC)

Total N in compost was determined by digesting the sample with H_2SO_4 using a digestion mixture (K_2SO_4:$CuSO_4$::10:1) in a micro-Kjeldahl method (Bremner and Mulvaney,1982). For estimation of total P and K content, samples were digested with di-acid mixture (HNO_3:$HClO_4$::9:4).Total phosphorus contents in the acid digest were determined using spectrophotometer after developing vanadomolybdo–phosphate yellow colour complex as described by Jackson (1973) and potassium was determined by flame photometer (Jackson, 1973). Total C content was determined by ignition method (Jackson, 1973) Chemical properties of compost are shown in table 1. Nutrient contents in mustard grain and straw were analysed as per the procedure adopted in analysis of compost samples.

Table1: Characteristics of rice straw compost (RSC)

Parameters	RSC (mean±SD)
Moisture %	9.46 ± 0.24
pH_w (1:5)	8.16 ± 0.39
EC_w (dSm^{-1})	2.80 ± 0.24
CEC [cmol(p+) kg^{-1}compost]	170 ± 12
Total C (%)	32.4 ± 0.47
Total N (%)	1.15 ± 0.1
C/N	28.3 ± 0.2
Total P (%)	0.38 ± 0.05
Total K (%)	1.27 ± 0.04
Total Fe (%)	0.3 ± 0.08
Total Mn (mg kg^{-1})	170.5 ± 26.0
Total Zn (mg kg^{-1})	186.1 ± 38.2
Total Cu (mg kg^{-1})	49.1 ± 10.6

SD, Standard deviation

Experimental site and soil

The present field experiment, on combined use of RSC and mineral fertilizers in mustard was conducted on ICAR-Central Soil Salinity Research Institute (CSSRI), Karnal, India research farm located at village Nain (29^{0}19$'$7.09$''$ to 29^{0}19$'$10.0$''$ N latitude and 76^{0}47$'$30.0$''$ to 76^{0}48$'$0.0$''$ E longitude) district Panipat (Haryana), India during 2012-15. The soil of experimental site is sandy loam and climate is semi-arid subtropical with hot summers (May–June) and cold winters (December–January). Initial soil samples were collected at surface soil (0-15 cm depth). The main physico-chemical and biological properties of the pre-experimental soil were: texture sandy loam with sand 56.4%, silt 25% and clay 18.6% (Bouyoucos, 1962); electrical conductivity (EC_w 1:2, soil : water) 7.2 dSm^{-1};

CEC 11.68 cmol (p^+) kg^{-1} soil (Jackson, 1973); organic C 1.9 g kg^{-1} (Walkley and Black, 1934) and available P 18.0 kg ha^{-1} (Olsen *et al.*, 1954).

Field experiment and treatments details

Performances of RSC with and without mineral fertilizers were evaluated using mustard cv. CS-54. Four treatments comprised of (1) control; without compost and mineral fertilizers (Cont); (2) 100% recommended dose of 60, 30 and 30 kg ha^{-1} N, P and K, respectively through mineral fertilizers (100%RDF); (3) rice straw compost at the rate of 14 tha^{-1} (RSC-14) and (4) RSC at the rate of 7 t ha^{-1}+50% RDF (RSC+RDF). The experiment was laid out in a randomized block design with three replications in plots of size 5.0 m × 5.0 m. The doses of compost and mineral fertilizers were based on nutrients content in compost and fertilizers as well as crop requirement. The purpose of combined use of RSC+RDF was to maintain balanced nutrient supply to mustard.

Mustard was sown in October and harvested in March during 2012-13, 2013-14 and 2014-15. The row to row spacing was 45 cm. Indian mustard variety CS-54 was salt tolerant. Ground water of experimental site was highly saline in nature (16 to 20 EC dSm^{-1}), which was not suitable for irrigation, and soil was also saline. Mustard was irrigated using rain water (EC 1-2 dSm^{-1}) harvested during rainy season (July- September) in a farm pond. Fertilizer used for supplying N, P and K were urea, diammonium phosphate (DAP) and muriate of potash (MOP), respectively. Half of the total N and full quantities of RSC, P and K were applied as basal in each year. Remaining half of N was applied at 35-40 days after sowing of mustard.

Soil analysis

Post-harvest soil samples were collected from each plot after harvest of mustard crop, air-dried, ground to pass through a 2-mm sieve by using a wooden pestle and mortar, and analysed for organic C (Walkley and Black, 1934), available N (Subbiah and Asija, 1956), available P (Olsen *et al.*, 1954) and available K (Hanway and Heidel, 1952).

Statistical analysis

Data generated from the field experiment was subjected to the statistical analyses of variance appropriate to the experimental design. Data were assessed by Duncan's multiple range tests with a probability P=0.05 (Duncan 1955). Least significant difference (LSD) between means was calculated using the SPSS program (SPSS version 16.0; SPSS Inc., Chicago).

Results and Discussion

Grain and straw yield of mustard

Three year mean data on grain and straw yield of mustard was significantly (P<0.05) increased with integrated use of RSC+ RDF (23.1 and 62.2 q ha^{-1} soil) respectively, relative to 100%RDF (Fig. 1). Soil treated with RSC 14 tha^{-1} had 15% higher grain yield than control (cont). However, alone use of RSC did not significantly differ with 100%RDF. Application of 100%RDF produced 11 and 17% additional grain and straw yield respectively, than cont. The higher yield of mustard with organic amendments plus 50% RDF was possibly due to beneficial effects on physical properties of saline soil and better supply of balanced plant nutrients, which are not supplied by inorganic fertilisers alone (Yadav *et al.*, 2000; Meena *et al.*, 2016). Our results demonstrated that highest grain and straw yield of mustard crop occurred with integrated use of organic amendments with mineral fertilisers. This was attributed due to integration of organic and inorganic source of nutrients.

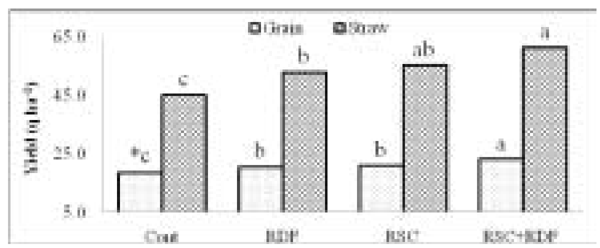

Fig.1. Three year mean mustard grain and straw yield as influenced by RSC and mineral

Cont: without compost and mineral fertilizers; 100% RDF (Recommended dose of NPK fertilizers were 60:30:30 kg ha^{-1}, respectively.); RSCC-14 t ha^{-1} and RSC-7+50%RDF

*For each parameter, different letters within the same column indicate that treatment means are significantly different at P < 0.05 according to Duncan's Multiple Range Test for separation of means.

Nutrient uptake by grain and straw

Three year mean N, P and K uptake by grain and straw of mustard was significantly higher with RSC as compared to cont, however it was statistically at par with RDF-100% (Fig. 2) Significantly higher NPK uptake by grain and straw was observed under RSC+RDF relative to 100% RDF. Treatments receiving 100% RDF had 98 and 53% higher N uptake by grain and straw of mustard respectively, as compared to cont. This might be due to mineral fertilizers had more water soluble nutrients which was easily available to plants (Meena *et al.*, 2016). Similar results of improved soil physical condition due to addition of organic amendments resulting in better crop performance were also reported by Hati *et al.* (2006) and Gopinath *et al.* (2008). Integration of organic amendment plus mineral fertilizers probably attributed to better synchrony of balanced nutrients supply which was not by mineral fertilizers alone (Yadav *et al.,* 2000).

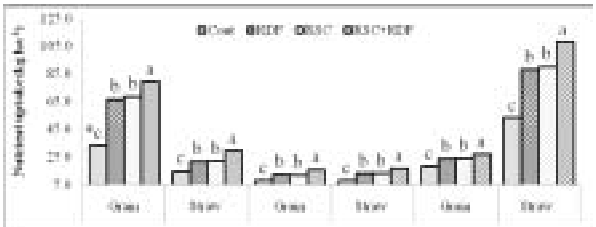

Fig.2. Effects of rice straw compost (RSC) and mineral fertilizers on nutrients uptake by mustard fertilizers on nutrients uptake by mustard

Cont: without compost and mineral fertilizers; 100% RDF (Recommended dose of NPK fertilizers were 60:30:30 kg ha^{-1}, respectively.); RSC-14 t ha^{-1} and RSC-7+50%RDF
*For each parameter, different letters within the same column indicate that treatment means are significantly different at $P < 0.05$ according to Duncan's Multiple Range Test for separation of means.

Changes in soil properties
Available NPK

Available N, P and K improved significantly (P<0.05) in all plots receiving mineral fertiliser alone or in combination organic amendments than cont (Table 2). However, alone use of RSC and RDF was statistically at par in terms of available NPK, but significant over the cont. Soil treated with 100% RDF had 56%, 162% and 37% more available N, P and K, respectively than that of cont. Integration of RSC plus RDF maintained 8, 10 and 8% higher N, P and K, respectively relative to 100% RDF. Therefore our results highlighted that combined use of organic amendments along with mineral fertilizers performed better than alone use of RSC and RDF. This was attributed that organic and inorganic sources of nutrients, in saline soil enrich rhizosphere with micro- and macronutrient elements, counteracting nutrient depletion (Lakhdar *et al.,* 2008; Meena *et al.*, 2016). Muhammad *et al.* (2007) also noticed that increase in available P in saline soil due to application of 1% compost. Under saline soil, mineralisation of compost increases the plant-available K fraction through increases in CEC (Walker and Bernal, 2008).

Table 2: Three year mean of available N, P and K as influenced by rice straw compost and mineral fertilizers

Treatments	Available Nutrients		
	N kg ha^{-1}	P kg ha^{-1}	K kg ha^{-1}
Cont	90^{c*}	12^{c}	182^{b}
RDF	140^{b}	31^{ab}	248^{a}
RSC	136^{b}	30^{b}	253^{a}
RSC+RDF	150^{a}	34^{a}	267^{a}
LSD (p<0.05)	8.1	3.6	27.6

Cont: without compost and mineral fertilizers; 100% RDF (Recommended dose of NPK fertilizers were 60:30:30 kg ha^{-1}, respectively.); RSC-14 t ha^{-1} and RSC-7+50% RDF
*For each parameter, different letters within the same column indicate that treatment means are significantly different at $P < 0.05$ according to Duncan's Multiple Range Test for separation of means.

Soil organic carbon (SOC)

Data emanated from the present study clearly indicated that addition of RSC either alone or in combination with mineral fertilizers significantly (P<0.05) increased SOC content than 100% RDF (Fig. 3). SOC in RSC had 18% higher than 100% RDF. There was no significant variations were detected among RSC and 100% RDF. As such we observed that highest amount of SOC (4.5 g kg^{-1}) was reported under combined use of RSC and RDF than all treatments. It is well known that organic matter plays a key role in the soil system and is an important regulator of numerous environmental constraints especially, soil salinity (Tejada *et al.,* 2006). Combined use of RDF and RSC increased SOC content instead of alone use of RDF and RSC, it was obviously due to greater biomass incorporated through compost (Meena *et al.,* 2016; Meena and Biswas, 2014b; Moharana *et al.,* 2012).

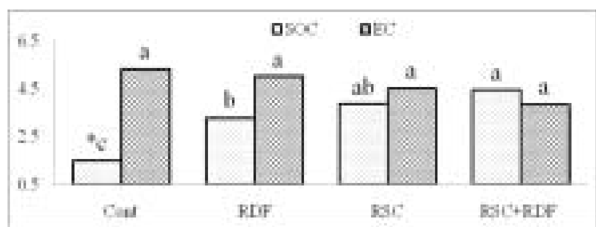

Fig.3. Effects of rice straw compost (RSC) and mineral fertilizers on soil EC (dSm^{-1}) and soil organic carbon (g kg^{-1})
Cont: without compost and mineral fertilizers; 100% RDF (Recommended dose of NPK fertilizers were 60:30:30 kg ha^{-1}, respectively.); RSC-14 t ha^{-1} and RSC-7+50%RDF
*For each parameter, different letters within the same column indicate that treatment means are significantly different at $P < 0.05$ according to Duncan's Multiple Range Test for separation of means.

Soil electrical conductivity (EC, 1:2)

Three year mean data of soil EC was more influenced with organic treatments rather than mineral fertilizers (Fig. 3). There was no significant differences were observed among the treatments, however treatment receiving RSC along with RDF had lowest value of soil EC (3.8 dSm^{-1}) and highest being with cont (5.3 dSm^{-1}). RSC and 100% RDF had 18 and 6% lower EC, respectively over cont. Soil treated with combined use of RSC and RDF was maintained lowest EC than other treatments. This was mainly due to organic amendment decreased bulk density, and enhanced soil porosity and aeration, as a result, an improvement in salt leaching (Khaleel *et al.*, 1981). Our results indicate that adverse effects of salinity could be alleviated by repeated use of organic amendments and mineral fertilizers consistently increased soil organic carbon content in comparison to control (Walker and Bernal, 2008).

Correlation matrix

Data on Pearson's correlation matrix (Table 3) revealed that grain yield of mustard was significantly and positively correlated (P<0.01) with N uptake (r = 0.954), P uptake (r = 0.908), and K uptake (r = 0.938). Significant and positive correlation (P< 0.01) was also observed between straw yield and SOC (r=0.910), available P (r = 0.988) and available K (r=0.908). There was negative correlation between EC and available NPK, yield, nutrient uptake. This can be explained that higher soil EC negative impact on soil parameters as well as mustard yield in saline soil due to higher concentration of soluble salts. Significant correlation (P<0.01) between yield and nutrients uptake by mustard with soil properties indicate a beneficial effect of balanced and integrated use of mineral fertilizers and rice straw compost under saline condition (Meena and Biswas, 2014a). Similarly, Ladd *et al.* (1994) noticed that benefits of balanced fertilization use crop residues, organic manure and green manuring in maintaining soil organic matter levels.

Conclusions

Combined use of organic amendments (RSC) along with mineral fertilizers significantly improved grain and straw yield of mustard. RSC had higher NPK uptake by straw and grain of mustard than alone use of 100% RDF in saline condition. Application of 100% RDF had significantly build-up in available NPK over the control. Significant improvement in available N was reported with RSC+RDF relative to 100% RDF. SOC was significantly influenced with organic amendment than control. There was no significant deference as far as soil EC is concerned among the treatments, however lowest EC was observed under RSC+RDF. Our findings demonstrate that integration of organic amendment and mineral fertilisers maintained higher yield, SOC, available NPK and lower soil salinity. Organic amendments do not completely

Table 3: Pearson's correlations matrix between available nutrient, EC, SOC yield and nutrient uptake by mustard (n = 12)

Parameters	Avail N	Avail P	Avail K	EC	SOC	Grain Yield	Straw Yield	Grain N uptake	Grain P uptake	Grain K uptake	Straw N uptake	Straw P uptake	Straw K uptake
Aval. N	1	0.988**	0.908**	-0.461	0.910**	0.832**	0.808**	0.954**	0.908**	0.938**	0.836**	0.920**	0.906**
Aval. P		1	0.934**	-0.367	0.878**	0.805**	0.814**	0.945**	0.881**	0.930**	0.844**	0.919**	0.907**
Aval. K			1	-0.203	0.839**	0.833**	0.811**	0.941**	0.821**	0.908**	0.846**	0.891**	0.852**
EC				1	-0.676*	-0.559	-0.377	-0.487	-0.539	-0.494	-0.277	-0.404	-0.383
SOC					1	0.897**	0.811**	0.949**	0.899**	0.908**	0.791**	0.871**	0.862**
Grain Yield						1	0.900**	0.903**	0.901**	0.945**	0.827**	0.914**	0.858**
Straw Yield							1	0.865**	0.850**	0.917**	0.926**	0.951**	0.943**
Grain N uptake								1	0.903**	0.963**	0.861**	0.937**	0.900**
Grain P uptake									1	0.923**	0.892**	0.952**	0.931**
Grain K uptake										1	0.885**	0.970**	0.922**
Straw N uptake											1	0.960**	0.938**
Straw P uptake												1	0.970**
Straw K uptake													1

**Correlation is significant at the 0.01 level (2 tailed)
*Correlation is significant at the 0.05 level (2 tailed)

overcome the adverse effects of salinity. However, continuous use of composts improves chemical and physical properties of saline soil. Therefore, compost can provide better soil conditioning for mustard production in saline soils.

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