

Impact of Indigenous Industrial Compost on the Growth of Coarse and Fine Rice Varieties under Saline Environment

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ABSTRACT

Pakistani rice is popular throughout the globe due to its specific aroma. Rice is categorized as salt-sensitive plant as its growth is significantly reduced under salt toxicity. The effect of exogenous application of indigenous industrial compost (IIC) on the coarse (IRRI-9) and fine (Super basmati-2000) rice varieties under salt stress was investigated in this study. IIC was applied at 0, 0.5 and 1.0% of soil weight, along with recommended chemical fertilizers in respective pots. Twenty-day old rice nursery was transplanted in glazed clay pots filled with normal ($EC_e = 1.70 \text{ dS m}^{-1}$) and saline soil ($EC_e = 8.0 \text{ dS m}^{-1}$) under flooded condition. Plants were harvested at maturity and different physiochemical parameters were recorded. Salinity stress was found to have significantly ($p < 0.05$) reduced both biological and paddy yield of rice, and the reduction was lower in coarse than fine rice. The compost application significantly improved ($p < 0.01$) dry matter four times as compared with control. In the same way, paddy yield increased three folds both under normal as well as saline growth medium. Na^+ concentration in shoots at 1% IIC in growth medium had a significant negative correlation ($r = 0.90$, $p < 0.01$) but potassium concentration proved a significant positive correlation ($r = 0.92$, $p < 0.01$) in both rice varieties. Enhanced salinity tolerance in rice by IIC application was attributed to increased K^+ uptake, thereby increasing $K^+ : Na^+$ ratio and lower Na^+ translocation towards shoot (sodium exclusion at the shoot level). It was concluded that indigenous industrial compost application improved the growth of rice plant under salt stress.

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INTRODUCTION

In spite of having potential to produce crop, the yield per hectare is very low in Pakistan with an average yield of 2347 kg ha⁻¹ (Anonymous, 2010). There are several reasons for it, and these include low organic matter, alkaline soil pH, calcareousness, mining of nutrients with extensive cropping, use of micronutrients free NPK fertilizers and less use of manures. Soils are also being depleted due to inappropriate uses of plant nutrients and cropping sequences. Among the various reasons, soil fertility is the most important. Therefore, restoration and maintenance of fertility status of soil is important, and for which, any addition of organic materials apart from other field practices is important (NFDC, 1998).

Once fertilizer requirement has been evaluated, the nutritional status of soil can be maintained by the addition of organic or inorganic fertilizer or an integrated use of both. However, continued application of inorganic fertilizers may contribute to poor organic matter level of soil and lower crop yields. Some studies have shown that continued use of inorganic fertilizers may results in diminishing soil quality and productive capacity (Doran *et al.*, 1996; Bhandari *et al.*, 2002; Manna *et al.*, 2005). Meanwhile, long-term use of inorganic nutritional sources leads to accumulation of harmful heavy metal ions, thus, polluting the soil with precipitates of hydroxides, carbonates, sulphides and sulphates. Thus, use of organic amendments is necessary for safety of soil environment and health (Choi *et al.*, 2002; Ibrahim *et al.*, 2011).

In the past, the inherited problems of low fertility, salinity and moisture shortage in semi-arid areas of Pakistan were overcome by applying organic manures like farm manure, as it enhances soil organic matter, humus contents, improve soil water holding capacity, infiltration rate, aeration, porosity, moisture conservation, cation exchange capacity, water stable aggregates, decrease bulk density (Bhagat & Verma, 1991; Sarwar *et al.*, 2008). The application of farm manure has been proven to improve crop growth by improving soil physical, chemical and biological properties (Mahmood *et al.*, 1997; Ibrahim *et al.*, 2008; Iqbal *et al.*, 2008).

It was reported by several researchers that an integrated use of organic nutritional sources (farm and green manure), along with inorganic nutritional sources (25:75), produced more yields as compared to inorganic nutritional sources alone in the rice-wheat system (Yadav *et al.*, 1996; Ibrahim *et al.*, 2010). In Pakistan, several organic nutritional sources like farm and green manures, straws and crop residues are available. However, the shortage of these products and the use of straw as animal feed and burning of crop residues limit the scope for their uses as organic supplement to increase soil organic matter for sustaining crop yield (Korboulewsky *et al.*, 2002). Thus, the objective of present study was to evaluate the efficiency of indigenous industrial compost (IIC) to enhance the salinity tolerance in rice crop.

MATERIAL AND METHODS

Soil Characteristics and Growth Conditions

A bulk surface (0-15 cm) sample of a sandy clay loam, hyperthermic Ustalfic Haplargids (Gee & Bauder, 1986) was collected from the University College of Agriculture, Sargodha experimental farms. The samples were dried, ground, and passed through a 2 mm sieve. The prepared soil samples were analyzed for various physicochemical properties, as shown in Table 1). Soil pH was measured in a saturated soil paste by calomel glass electrode assembly using a Beckman pH meter. Soluble salt (EC_e) in the saturated extracts was measured by WTW-Cond 3I 5i EC meter. The $CaCO_3$ in the samples was analyzed by using the acid dissolution method, while the organic matter content was estimated by using the Walkley-Balack method (Nelson & Sommers, 1982). Soil was filled at 10 kg in 36 glazed

clay pots. In half of the pots, salinity was artificially induced using sodium chloride salt to maintain soil EC_e level 8 dS m^{-1} and the rest of the pots were kept as control having original soil EC_e of 1.70 dS m^{-1} . This level of EC_e (8 dS m^{-1}) was selected because various earlier researchers have reported a 65% yield reduction in rice at this EC. A basal dose of N at 100 mg kg^{-1} as urea, P at 90 mg kg^{-1} as single super phosphate and K at 120 mg kg^{-1} as potassium sulphate were added prior to transplanting. Indigenous industrial compost (IIC) was applied at 0, 0.5, and 1.0% of soil weight as ICC (Organo-power™). The compost was thoroughly mixed with soil and irrigated using distilled water to field capacity (70%). The average temperature in the greenhouse varied between 35 and 45°C during the night and day, respectively. Meanwhile, the relative humidity in the greenhouse ranged from 27 % to 30% during the day and night, respectively. Light intensity varied between

TABLE 1
Selected physico-chemical properties of the soil used in this experiment

Property	Unit	Values	
Sand	%	55.16	
Silt	%	24.19	
Clay	%	20.65	
Textural class	Sandy clay loam		Hydrometer method
pH of soil paste		7.68	Saturated water extract
EC_e	dS m^{-1}	1.12	Saturated water extract
Organic matter	%	0.78	Walkley and black method
Calcium Carbonate	%	2.01	Extracted with NaHCO_3
NaHCO_3^{-1} extractable P	mg kg^{-1} soil	6.05	CaCO_3 equivalent by acid dissolution
Available K	mg kg^{-1} soil	220	Extracted with 1N HN_4OAC
Available Si	mg kg^{-1} soil	31	Extracted with CaCl_2
Total Si	mg kg^{-1} soil	225	Extracted with sodium acetate buffer

600 and 1600 $\mu\text{mol photon m}^{-2}\text{S}^{-1}$, depending upon day and cloud conditions during the growth period.

Indigenously Industrial Compost (ICC)

The ICC was in the shape of small excluder and the basic raw material of ICC was sugar industry waste, filter cake pressmud, molasses, vegetable market waste, rock phosphate and windrow technique was employed for its preparation. The ICC contained organic matter (35.5%), C:N ratio (20:1), nitrogen (1%), P_2O_5 (2%), sulphur (4%), potassium (1%) and calcium (1%).

Plant Material

The seeds of the two rice varieties used in this study were obtained from Kalashah Kako Rice Research Station, Lahore, Pakistan. IRRI-9 is medium duration, salt-tolerant, short-statured, coarse variety with Philippines origin and Super basmati-2000 is fine with specific aroma, salt-sensitive, and the origin is from Pakistan. For pre-germination, seeds of fine (Super basmati-2000) and coarse (IRRI-9) rice varieties were soaked in petri-dishes for 48 hours using double distilled water. The pre-germinated rice seedlings were sown in pre-washed river bed sand taken in polyethylene lined iron trays. Sand in the trays was kept moistened with distilled water for germination. The seedlings were grown on river bed sand for 21 days before transplanting. Four rice seedlings were sown in each plot under flooded conditions. Plants were grown till maturity and harvested at maturity (116 days in case of IRRI-9 and

130 in case of Super basmati-2000) and grains were separated from the shoots by hands. The samples were then dried in a forced air oven at 65°C for 48 hours. The dried samples were ground in a mechanical mill fitted with stainless steel blades to pass through a 1 mm sieve. For the determination of Na^+ and K^+ , fine ground shoot samples were digested in di-acid mixture of nitric and per-chloric acids (3:1) at 60°C for 2 hours and K^+ and Na^+ was determined using a flame-photometer (Jenway PFP-7).

Statistical Analysis

The salinity and compost treatments were arranged in two-factorial, completely randomized design with three replicates. The data were statistically analyzed using PC-based programme MStat-C. Treatment means were calculated and compared by DMR test at 5% probability (Steel *et al.*, 1997).

RESULTS

Plant Growth

The shoot dry matter (SDM) of the plants of both the varieties were shown to be significantly lower ($p < 0.01$) when grown in saline soil ($\text{EC} = 8 \text{ dS m}^{-1}$) than those grown in the normal soil. However, reduction in SDM was lower in IRRI-9 than in Super basmati-2000. Salinity stress reduced the shoot dry matter yield of both coarse and fine rice varieties. Meanwhile, the addition of IIC in the root environment significantly ($p < 0.01$) increased SDM up to 53% and 48%, respectively, at the medium level of

IIC 0.5% of the soil weight and noted 140% and 170% increases at the high level of IIC 1% of soil weight respectively in the coarse and fine rice varieties grown in the saline soil condition. Increase in SDM due to IIC application was shown to be more in Super basmati-2000 when grown in the normal soil (Table 2) but the reverse was true when plants were grown in saline soil.

The salinity stress significantly reduced the paddy yields of both the rice varieties. The application of IIC in the growth medium significantly ($p < 0.01$) enhanced the paddy yield of rice varieties both under the normal and saline soil conditions. Both the varieties differed significantly for the paddy yields as IRRI-9 produced more paddy yields (2.11 and 6.33 g pot⁻¹) under saline and normal soil conditions, respectively.

The IIC amendments enhanced the paddy yield significantly ($p < 0.01$) at the medium salinity level (4.22 g pot⁻¹) and at the high level of ICC application, the increase was found to be 7.16 g pot⁻¹ in the

case of the coarse rice variety. The paddy yield of fine rice variety on the relative basis increased at the medium and high levels of IIC application under saline environment.

Mineral Content

The application of IIC in the root environment significantly changed the ionic composition of straw under salt stress. The maximum Na⁺ concentration (1.98%) was recorded in fine rice at high salinity level under IIC free root environment. On the contrary, the minimum Na⁺ concentration (0.37%) was observed in coarse rice under salt free condition, with high level of IIC (Table 3). Similarly, the maximum K⁺ (1.75%) concentration was observed in coarse rice shoot in the IIC amended salt free soil condition but the minimum K⁺ concentration (0.35%) was recorded in the saline environment without any IIC application in the growth medium. The shoot concentration also changed with the change of IIC levels in the root environment. The fine rice variety showed

TABLE 2

The effects of indigenous industrial compost application on the straw and paddy yields of the rice genotypes grown in the normal and saline soils

ICC per soil volume (%)	IRRI-9		Super basmati 2000	
	Normal Soil (1.70 dS m ⁻¹)		Saline Soil (8 dS m ⁻¹)	
	Straw yield (g pot ⁻¹)			
0.0	21.35±2.97 c	16.65±2.67 cd	8.14±0.99 e	6.87±0.65 ef
0.5	28.49±3.77 b	23.41±3.53 b	12.49±1.71 d	10.21±1.12 d
1.0	37.43±4.87 a	32.16±4.78 ab	20.03±2.92 c	18.58±2.54 c
Paddy yield (g pot ⁻¹)				
0.0	6.33±1.76 c	5.06±1.54 cd	2.11±0.19 d	1.93±0.13 d
0.5	9.63±2.21 bc	8.10±1.54 cd	4.22±0.88 c	4.10±0.80 cd
1.0	12.30±2.13 a	11.13±2.33 b	7.16±1.97 c	6.98±1.88 c

ICC = indigenous industrial compost; Means sharing the same letter(s) are similar at $P < 0.05$.

TABLE 3

The effects of ICC application on the ionic composition of rice straw grown under the normal and saline soils

ICC per soil volume (%)	IRRI-9	Super basmati 2000	IRRI-9	Super basmati 2000
	Normal Soil (1.70 dS m ⁻¹)		Saline Soil (8 dS m ⁻¹)	
	Na ⁺ Concentration (%)			
0.0	0.45±0.06 d	0.48±0.06 d	1.72±0.16 a	1.98±0.19 a
0.5	0.40±0.06 d	0.44±0.06 d	1.13±0.10 b	1.23±0.11 b
1.0	0.37±0.06 d	0.38±0.06 d	0.64±0.08 c	0.68±0.08 c
	K ⁺ Concentration (%)			
0.0	1.49±0.16 a	1.53±0.17 a	0.36±0.05 d	0.35±0.05 d
0.5	1.63±0.17 a	1.67±0.17 a	0.52±0.07 c	0.56±0.07 c
1.0	1.75±0.18 a	1.72±0.18 a	1.17±0.10 b	1.28±0.11 b
	K ⁺ :Na ⁺ Ratio			
0.0	3.31±0.16 b	3.15±0.17 c	0.21±0.03 f	0.18±0.03 f
0.5	4.08±0.37 b	3.97±0.33 b	0.46±0.06 e	0.46±0.06 e
1.0	4.72±0.51 a	4.52±0.41 a	1.80±0.17 d	1.88±0.18 d

ICC = indigenous industrial compost; Means sharing the same letter(s) are similar at $P < 0.05$.

more response to applied IIC as compared with coarse rice. The application of IIC was also found to improve the K⁺: Na⁺ ratio in the saline, as well as normal field conditions. The maximum K⁺: Na⁺ ratio was achieved in the plants which were grown with a high level of IIC application, both under normal as well as in saline soil conditions. This finding indicates a possible mechanism of IIC mediated tolerance of salinity in rice plant.

DISCUSSION

Rice is recognized as a salt-sensitive plant; this means salinity affects almost every physiology and biochemical aspect of rice plant and significantly reduces vegetative and reproductive growth of salt-stressed plants (Mass & Hoffman, 1977). The use of organic soil amendments,

such as heterogeneous composted organic material, is an important component in sustainable agricultural production under saline environment (Motavalli *et al.*, 1994). A number of possible mechanisms have been proposed, whereby IIC can increase resistance of plants against salinity stress, which is a major yield limiting factor in arid and semi-arid areas. The present experiment was an attempt to monitor the beneficial effects under salt stress among two rice genotypes. The application of IIC to growth medium significantly increased dry matter production and gave higher yield in both cultivars when grown under normal as well as in saline environments (Sarwar *et al.*, 2010; Sarwar *et al.*, 2011). Meanwhile, the increase in dry matter was more pronounced in the saline environments, and this highlighted the beneficial effects of

IIC application in alleviating salinity stress (Sarwar *et al.*, 2011). The rice production in the saline environments was very less when compared with non-saline environment. Among major possible mechanism of induced salinity tolerance in rice is increased K^+ uptake (Sarwar *et al.*, 2009). The results of the present study also revealed a significant increase in the K^+ uptake in both the genotypes when ICC was added under saline conditions. However, salinity caused a significant decreased in the K^+ concentration when IIC was not applied to the root environment (Ibrahim *et al.*, 2007).

Sodium concentration in plants is also a good indicator of salinity tolerance, whereby a lower Na^+ concentration in plants indicates a lower Na^+ uptake as in IRRI-9, suggesting that the variety is

relatively salt tolerant. Sodium in higher amounts in plants causes a reduction in shoot dry matter, which is evident from the significant negative correlation between Na^+ concentrations and shoot dry matter in both the genotypes of rice (Fig.1). The findings of the present study also clearly exhibited a reduced uptake of Na^+ in plants when grown with IIC application in soil. The percentage of increase in the Na^+ uptake by salinity treatment was significantly reduced in the plants grown with IIC application (Schlegel *et al.*, 1992).

Super basmati-2000 performed better in growth and grain yield under normal conditions; however, under saline conditions, IRRI-9 was found to perform better in terms of growth and K^+ concentration. Potassium is an important nutrient required for normal

Correlation between Na^+ , K^+ concentration and straw yield of rice

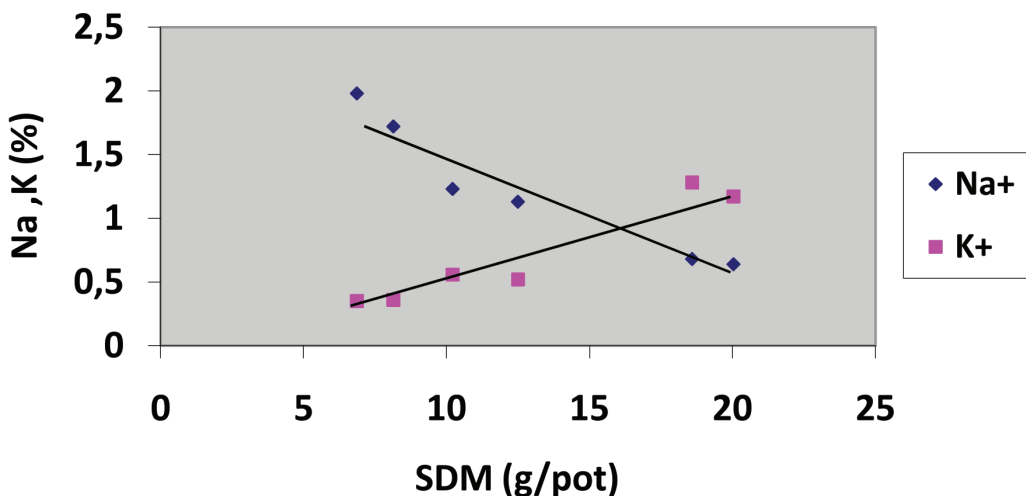


Fig.1: Correlation between Na^+ and K^+ concentrations and straw yield of rice under saline soil root environment

water uptake and transpiration flow. Low potassium uptake under saline and sodic condition further hampers crop production on these soils. In particular, potassium has a significant role in improving plant water status and mitigating the toxic effects of Na^+ . The ratio of $\text{K}^+:\text{Na}^+$ became significantly low under salt stress when IIC was not applied, and this significantly increased when IIC was added to the root environment. This is an indication of enhanced K^+/Na^+ ratio in rice shoot, which further improved dry matter and paddy yields of both rice genotypes. Increased K^+ uptake resulted in lesser Na^+ uptake by the addition of IIC in rice, which is a major mechanism responsible for better growth of plants under saline soil environment.

CONCLUSION

Rice is an important cash crop of Pakistan and it is also a food source of millions of people around the globe. The indigenous compost application improved straw and paddy yield of both the rice varieties under normal and saline conditions. IIC increased salinity tolerance in rice by reducing Na^+ uptake and its onward translocation to shoots by increasing K^+ uptake and K^+/Na^+ ratio in rice shoot. It may be concluded that the variety of waste materials be used for the production of compost to be used by resource poor farmers for sustainable agricultural production. Hence, the results of the current study have provided an avenue for the studies under field conditions.

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