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Effect of bio char, crop residues and humic acid on plant micro nutrient content in direct seeded rice

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Abstract
Micronutrients help in chlorophyll formation, nucleic acid, protein synthesis and play an active role in several enzymatic activities of photosynthesis as well as respiration and influences rice and black gram yields. This study aims to examine the integrated effect of bio char, crop residues and humic acid on plant micronutrient contents in direct seeded rice.

The experiment was laid out in split – split plot design with main, sub and sub-sub plots with direct seeded rice–black gram cropping sequence. The main plot comprised of two levels of fertilizers *viz.*, F_1- 100% RDF and F_2- 75% RDF, the sub plot comprised of two doses of pigeon pea bio char *viz.*, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1} and B_4- Green leaf manure @ 6 t ha^{-1} and the sub-sub plot comprised of two levels of humic acid *viz.*, S_1 - Humic acid @ 20 kg ha^{-1} and S_2 - Humic acid @ 30 kg ha^{-1} and replicated thrice.

The results of this study showed that, significantly higher iron and manganese contents in plant was recorded with the application of B_4- Green leaf manure @ 6 t ha^{-1} and S_2 - Humic acid @ 30 kg ha^{-1} at all the growth stages of direct seeded rice, whereas, the higher zinc (except in panicle initiation stage) and copper content was significantly recorded with application of B_4- Green leaf manure @ 6 t ha^{-1} only. However, the zinc content in panicle initiation stage significantly influenced by the application of B_4- Green leaf manure @ 6 t ha^{-1} and S_2 - Humic acid @ 30 kg ha^{-1}. Significant interaction effect was observed between B_4 – Green leaf manure @ 6 t ha^{-1} and S_2 – 30 kg ha^{-1} (B_4S_2) in manganese content at active tillering and panicle initiation stages of *kharif* direct seeded rice during two years of study.

Keywords: Green leaf manure, humic acid and Micro nutrient content

Introduction
Cultivation of high yielding crop varieties and multiple cropping is depleting the fertility of soils at a rapid pace. The soils, which were, once well supplied with available nutrients, are now gradually becoming deficient. Soil organic matter encourages granulation, increases cation exchange capacity (CEC) and is responsible for adsorbing power of the soils up to 90%. Cations such as Ca^{2+}, Mg^{2+} and K^+ are produced during decomposition. Addition of organic materials like green leaf manure increases the availability of micronutrients. The increased availability was attributed to enhanced microbial activity in the soil and the consequent release of complex organic substances that could have prevented micronutrients from precipitation, fixation, oxidation and leaching and also addition of these nutrients through organic sources. The unbalanced use of N fertilizers has at times led to environmental confrontations, disturbance in soil nutrient balance and depletion of soil fertility. Even the introduction of high yielding varieties and intensive cultivation with excess and imbalanced use of chemical fertilizers and irrigation showed reduction in the soil fertility status.

Rice-pulse (Green gram/Black gram) is the predominant cropping system of major rice growing areas of Andhra Pradesh. This cropping sequence is practically feasible, viable, economical, eco-friendly, water saving technology for sustaining soil fertility and rice productivity. Thus, increasing soil fertility and long-term sustainable production of direct seeded rice – black gram cropping sequence through the integrated application of bio char, green leaf manure, paddy straw and humic acid along with inorganic fertilizers is of significant importance to mitigate the problems of fertilizer consumption, environmental contamination, and economic cost of the production of direct seeded rice – black gram cropping sequence, while maintaining the soil fertility, crop yield and soil quality.

Green leaf contains higher content of easily mineralizable nitrogen. Karanj (*Pongamia pinnata* L. Pierre) is one of the nitrogen fixing trees (NFTS) medium sized deciduous and are

commonly found in many rural areas and it is an easily available and cheapest source of nutrient which can be used as green leaf manure. Incorporation of pongamia leaves improves soil fertility and had favourable effect on growth and yield of many crops. Rice straw is the source of primary, secondary and micronutrients to the plant growth and constant source of energy for heterotrophic microorganisms which help in increasing availability of nutrients, quality and quantity of crop produce, it can be hypothesized that the use of proper combination of these locally available organic wastes which are narrow in C:N ratio and safe to apply for agricultural purposes, is as critical as that for integrated use. Humic substances are major components of organic matter, have both direct and indirect effects on plant growth (Sangeetha *et al.,* 2006) [10]. Humic acid (HA) improves the physical chemical and biological properties of the soil and influences plant growth. Because of its molecular structure, it provides numerous benefits to crop production. It helps to maintain soil structure, assisting in transferring the nutrients from the soil to the plant, enhances the water retention, increases seed germination rate, improves water availability, root penetration and stimulates development of micro flora population in the soils. Humic acid though is not a fertilizer but considered complementary to fertilizer.

Integrated application of bio char, green leaf manure, paddy straw and humic acid along with inorganic fertilizers could be one of the primary game-changer in soil fertility and long-term sustainable production of direct seeded rice – black gram cropping sequence. Therefore, we made a complete focus in our research study to compare and explore the positive effects of the integrated application of bio char, humic acid and other amendments on carbon contents, stocks and soil quality in direct seeded rice – black gram cropping sequence. As a part of our study we are presenting the one of the objective of our study *i.e:* micro nutrient contents in direct seeded rice.

Material and Methods

Experimental site description

Field experiment were carried out during *kharif* and *rabi* seasons of 2020-21 and 2021-22 at Agricultural College Farm, Bapatla, geographically located at an altitude of 5.49 m above mean sea level, 15° 54' North latitude, 80^0 30' East longitude and about 8 km away from Bay of Bengal. It is located in Krishna agro-climatic zone of Andhra Pradesh. The experimental soil was neutral in reaction, low in electrical conductivity, while all micro-nutrients [(Fe: 6.96 mg kg^{-1}), (Mn: 3.80 mg kg^{-1}), (Zn: 1.01 mg kg^{-1}) and (Cu: 2.15 mg kg^{-})] were above critical levels.

Experimental design and treatments

The experiment was laid out in split – split plot design with main, sub and sub-sub plots with direct seeded rice–black gram cropping sequence. The main plot comprised of two levels of fertilizers *viz.,* F_1- 100% RDF and F_2- 75% RDF, the sub plot comprised of two doses of pigeon pea bio char *viz.,* B_1 - Bio char @ 5 t ha^{-1}, B_2 - Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1} and B_4- Green leaf manure @ 6 t ha^{-1} and the sub-sub plot comprised of two levels of humic acid *viz.,* S_1 - Humic acid @ 20 kg ha^{-1} and S_2 - Humic acid @ 30 kg ha^{-1} and replicated thrice. The *rabi* experiment was continued on the same site without disturbing the soil with black gram as test crop to study the residual effect of different nutrient sources applied to preceding rice crop.

Plant Analysis details

Collection and Preparation of Plant Samples

The plant samples collected (at tillering, panicle initiation and at harvest stages) in direct seeded rice and (30, 60 days and harvest stages) in black gram were washed with dilute HCl and then with double distilled water. The samples were shade dried initially and then oven dried at 65ºC temperature and powdered.

Micronutrients Fe, Mn, Cu, Zn: Zinc, copper, manganese, and iron in the diacid extract were determined using atomic absorption spectrophotometer as per the specifications mentioned by Lindsay and Norvell (1978) [6].

Results and Discussion

Micro nutrient content in direct seeded rice

Iron content

Close observation of data related to iron content in direct seeded rice presented in table 1, 2, 3 and 4, revealed that different nutrient management in sub plots viz., B_1, B_2, B_3 and B_4 had shown significant influence on iron content. Irrespective of the growth stage of direct seeded rice and year of the study, application of B_4 – Green leaf manure @ 6 t ha^{-1} recorded significantly higher iron content [(601.99 mg kg^{-1} in *Kharif* 2020 and 607.95 mg kg^{-1} *Kharif* 2021), (548.51 mg kg^{-1} in *Kharif* 2020 and 554.98 mg kg^{-1} *Kharif* 2021), (178.93 mg kg^{-1} in *Kharif* 2020 and 183.55 mg kg^{-1} *Kharif* 2021) and (411.67 mg kg^{-1} in *Kharif* 2020 and 419.53 mg kg^{-1} *Kharif* 2021)] at active tillering, panicle initiation and harvest (grain and straw) stages respectively in direct seeded rice.

The increased Fe content due to combined application of green leaf manure and inorganic sources over RDF alone might be due to the supply of chelating agents by organic materials, which help in maintaining the solubility of micronutrients including Fe. The profound influence of organic matter on the solubility of Fe was proved by Debiprasad *et al.* (2010) [4]. Irrespective of the year of the study, the Fe content in rice decreased with the growth stage from active tillering to harvest stage. Among different organic sources, green leaf manure recorded maximum Fe content at all stages over others. These results were in conformity with the findings of Shinde *et al*. (2017) [12] and Shahi *et al*. (2017) [11] who recorded increased iron content at early stages of rice crop.

Among the two levels of humic acid application, the S_2 – 30 kg ha^{-1} recorded significantly higher iron content [(495.30 mg kg^{-1} in *Kharif* 2020 and 501.19 mg kg^{-1} *Kharif* 2021), (445.85 mg kg^{-1} in *Kharif* 2020 and 451.25 mg kg^{-1} *Kharif* 2021), (162.13 mg kg^{-1} in *Kharif* 2020 and 166.23 mg kg^{-1} *Kharif* 2021) and (373.02 mg kg^{-1} in *Kharif* 2020 and 379.08 mg kg^{-1} *Kharif* 2021)] than S_1 – 20 kg ha^{-1} humic acid application in active tillering, panicle initiation and harvest (grain and straw) stages respectively in direct seeded rice. Nikbakht *et al.* (2008) [8], Celik, *et al.* (2010) [1], also recorded similar results. However the individual effect of RDF and interaction effect between RDF, B_1, B_2, B_3, B_4 and two doses of humic acid application on iron content was found non-significant.

Manganese Content

Manganese content in direct seeded rice at all growth stages [(tillering, panicle initiation and harvest (grain and straw)] was presented in the tables 5, 6, 7 and 8. Perusal of the data revealed that the application of B_4 – Green leaf manure @ 6 t

ha^{-1} recorded significantly higher manganese content [(216.31 mg kg^{-1} in *Kharif* 2020 and 220.39 mg kg^{-1} *Kharif* 2021), (198.07 mg kg^{-1} in *Kharif* 2020 and 202.00 mg kg^{-1} *Kharif* 2021), (48.63 mg kg^{-1} in *Kharif* 2020 and 55.00 mg kg^{-1} *Kharif* 2021) and (117.48 mg kg^{-1} in *Kharif* 2020 and 122.65 mg kg^{-1} *Kharif* 2021)] at active tillering, panicle initiation and harvest (grain and straw) stages respectively in direct seeded rice.

The results of the present study revealed that the combined application of organics (*viz.*, paddy straw and green leaf manure) and inorganic fertilizers recorded highest manganese content. This might be due to increased water soluble, exchangeable and easily reducible fractions of Mn in soil. Irrespective of the year of study, the Mn content in rice straw decreased with the advancement of crop growth from active tillering to harvest indicating the dilution effect (Debiprasad *et al.*, 2010) [4].

Among the two levels of humic acid application, the S_2 – 30 kg ha^{-1} recorded significantly higher manganese content [(180.50 mg kg^{-1} in *Kharif* 2020 and 184.44 mg kg^{-1} *Kharif* 2021), (159.84 mg kg^{-1} in *Kharif* 2020 and 163.37 mg kg^{-1} *Kharif* 2021), (44.27 mg kg^{-1} in *Kharif* 2020 and 49.37 mg kg^{-1} *Kharif* 2021) and (105.11 mg kg^{-1} in *Kharif* 2020 and 109.74 mg kg^{-1} *Kharif* 2021)] than S_1 – 20 kg ha^{-1} humic acid application in active tillering, panicle initiation and harvest (grain and straw) stages respectively in direct seeded rice. Turan *et al.* (2011) [13], Asri *et al.* (2015) [1], also recorded similar results.

The significant interaction was established between B and S. The higher interaction effect was observed between B_4 – Green leaf manure @ 6 t ha^{-1} and S_2 – 30 kg ha^{-1} (B_4S_2) (220.40 and 224.62 mg kg^{-1} in *Kharif* 2020 and 2021 respectively) at active tillering stage and it was on par with the application of B_4 – Green leaf manure @ 6 t ha^{-1} and S_1 – 20 kg ha^{-1} (B_4S_1) (212.23 and 216.17 mg kg^{-1} in *Kharif* 2020 and 2021 respectively) and with the application of B_3 - Paddy straw @ 5t ha^{-1} and S_2 – 30 kg ha^{-1} (B_3S_2) (210.93 and 214.79 mg kg^{-1} in *Kharif* 2020 and 2021 respectively) at active tillering stage in direct seeded rice.

In panicle initiation stage, the same significant B and S interaction effect was found. The higher interaction effect was observed between B_4 – Green leaf manure @ 6 t ha^{-1} and S_2 – 30 kg ha^{-1} (B_4S_2) (200.51 and 203.99 mg kg^{-1} in *Kharif* 2020 and 2021 respectively) and it was on par with the application of B_4 – Green leaf manure @ 6 t ha^{-1} and S_1 – 20 kg ha^{-1} (B_4S_1) (195.63 and 200.01 mg kg^{-1} in *Kharif* 2020 and 2021 respectively) at panicle initiation stage in direct seeded rice.

However the individual effect of RDF and interaction effect between RDF, B_1, B_2, B_3, B_4; F and S interaction effect on manganese content was found non-significant at active tillering, panicle initiation and harvest (grain and straw) stages in direct seeded rice.

Zinc Content

Data pertaining to zinc content presented in tables 9, 10, 11 and 12, revealed that the zinc content was significantly influenced by the individual effect of green leaf manure and two levels of humic acid. However the individual effect of RDF and interaction effect between RDF, B_1, B_2, B_3, B_4; F and S; B and S; was found non-significant on zinc content in active tillering, panicle initiation and harvest (grain and straw) stages in direct seeded rice.

The significantly higher zinc content was recorded with the application of B_4 – Green leaf manure @ 6 t ha^{-1} [(46.76 mg kg^{-1} in *Kharif* 2020 and 52.61 mg kg^{-1} *Kharif* 2021), (41.68 mg kg^{-1} in *Kharif* 2020 and 47.40 mg kg^{-1} *Kharif* 2021), (29.00 mg kg^{-1} in *Kharif* 2020 and 34.96 mg kg^{-1} *Kharif* 2021) and (22.99 mg kg^{-1} in *Kharif* 2020 and 28.26 mg kg^{-1} *Kharif* 2021)] at active tillering, panicle initiation and harvest (grain and straw) stages respectively in direct seeded rice.

Increase in concentration of zinc with application of organics along with the inorganics was probably due to chelation of zinc with organic ligands, which might have enhanced the availability of zinc and its absorption by the plants. The result of this study was in accordance with the findings of Muthukumararaja and Sriramachandrasekharan (2014) [7]. Nitrogen enhances zinc content partly through growth promotion but mainly by increasing soil Zn solubility and root efficiency for Zn absorption as reported by Ghoneim *et al* (2016) [5]. The higher nutrient content in organics treated plot might be due to its effect on microbial activity that in turn enhanced the rate of decomposition of organic matter and solubility of nutrients.

Irrespective of the year of the study, the Zn content in rice decreased with the growth stage from active tillering to harvest stage in straw due to dilution effect and as the Zn content in grain was higher when compared to straw. The decreased zinc content with the advancement of crop growth could be due to highest utilization of zinc in the synthesis of some growth promoting hormones and in the reproductive processes of plants which are vital for grain formation. Similar results were reported by Prakash *et al.* (2019) [9].

Whereas in panicle initiation stage only, among the two levels of humic acid application, the S_2 – 30 kg ha^{-1} recorded significantly higher zinc content (35.93 mg kg^{-1} in *Kharif* 2020 and 40.59 mg kg^{-1} *Kharif* 2021) with compare to S_1 – 20 kg ha^{-1} humic acid application in direct seeded rice. However, the same humic acid application showed non-significant individual effect in other growth stages like active tillering and harvest (grain and straw) stages. Similar results were reported by Nikbakht *et al.* (2008) [8].

With regard to the other individual effect like RDF and interaction effect between RDF, B_1, B_2, B_3, B_4; F and S; on zinc content was found non-significant in active tillering, panicle initiation and harvest (grain and straw) stages in direct seeded rice.

Copper Content

Data pertaining to copper content presented in tables 13, 14, 15 and 16, revealed that the copper content was significantly influenced by the application green leaf manure. However the individual effect of RDF, two levels of humic acid application and interaction effect between RDF, B_1, B_2, B_3, B_4; F and S; B and S; was found non-significant on copper content in active tillering, panicle initiation and harvest (grain and straw) stages in direct seeded rice.

The significantly higher copper content was recorded in application of B_4 – Green leaf manure @ 6 t ha^{-1} [(19.33 mg kg^{-1} in *Kharif* 2020 and 25.85 mg kg^{-1} *Kharif* 2021), (16.77 mg kg^{-1} in *Kharif* 2020 and 20.09 mg kg^{-1} *Kharif* 2021), (7.36 mg kg^{-1} in *Kharif* 2020 and 10.34 mg kg^{-1} *Kharif* 2021) and (8.75 mg kg^{-1} in *Kharif* 2020 and 10.81 mg kg^{-1} *Kharif* 2021)] at active tillering, panicle initiation and harvest (grain and straw) stages respectively in direct seeded rice.

Irrespective of the year of the study, the Cu content in rice decreased with the growth stage from active tillering to

panicle initiation stage. When compared to Cu content in grain, straw at harvest was higher in all treatments. Among different organic sources, green leaf manure recorded maximum Cu content at all stages over others.

The increase in Cu content due to combined application of green leaf manure and inorganics might be due to better root proliferation which helped in the absorption of Cu from native source under favourable reduced conditions (Debiprasad *et al.*, 2010) [4]. Cu had a strong affinity for the N atom of amino groups and it appeared quite likely that soluble N compounds like amino acids act as Cu carriers in xylem and phloem Davari *et al.* (2012) [3].

With regard to the other individual effect like RDF and interaction effect between RDF, B_1, B_2, B_3, B_4; F and S; on copper content was found non-significant in active tillering, panicle initiation and harvest (grain and straw) stages in direct seeded rice.

Table 1: Effect of biochar, crop residues and humic acid on iron content (mg kg^{-1}) at active tillering stage of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	371.66	375.41	373.54	482.11	375.75	382.55	379.15	487.73
	B_2	409.05	414.17	411.61		413.20	420.24	416.72	
	B_3	507.63	572.10	539.87		511.69	577.21	544.45	
	B_4	583.18	623.70	603.44		590.86	630.30	610.58	
	F x S	467.88	496.35			472.88	502.58		
F_2	B_1	370.04	374.16	372.10	478.49	374.39	380.15	377.27	484.61
	B_2	403.68	411.60	407.64		413.51	416.93	415.22	
	B_3	498.02	569.31	533.67		506.33	574.91	540.62	
	B_4	579.10	621.97	600.53		583.43	627.20	605.32	
	F x S	462.71	494.26			469.42	499.80		
B x S				B Mean		B x S		B Mean	
B_1		370.85	374.79	372.82		375.07	381.35	378.21	
B_2		406.37	412.88	409.63		413.36	418.59	415.97	
B_3		502.83	570.71	536.77		509.01	576.06	542.54	
B_4		581.14	622.84	601.99		587.15	628.75	607.95	
S Mean		465.30	495.30			471.15	501.19		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		8.360	NS	8.53		8.228	NS	8.29	
B		11.139	34.32	8.03		10.881	33.53	7.75	
S		6.625	19.86	7.76		6.356	19.06	7.41	
F x B		15.753	NS			15.387	NS		
F x S		9.369	NS			8.989	NS		
B x S		13.250	NS			12.713	NS		
F x B x S		18.738	NS			17.979	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 2: Effect of bio char, crop residues and humic acid on iron content (mg kg^{-1}) at panicle initiation stage of direct seeded rice

RDF	Bio char, Paddy straw and Green leaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	329.84	337.08	333.46	434.05	334.10	342.00	338.05	439.10
	B_2	361.77	368.83	365.30		365.81	374.45	370.13	
	B_3	459.85	515.17	487.51		465.65	519.57	492.61	
	B_4	534.10	565.79	549.95		538.43	572.82	555.63	
	F x S	421.39	446.72			426.00	452.21		
F_2	B_1	326.35	335.47	330.91	431.41	331.01	339.80	335.41	436.91
	B_2	359.18	368.20	363.69		362.85	372.11	367.48	
	B_3	452.76	515.15	483.96		462.01	518.84	490.43	
	B_4	533.08	561.07	547.08		538.22	570.43	554.33	
	F x S	417.84	444.97			423.52	450.30		
B x S				B Mean		B x S		B Mean	
B_1		328.09	336.27	332.18		332.56	340.90	336.73	
B_2		360.47	368.52	364.49		364.33	373.28	368.80	
B_3		456.31	515.16	485.73		463.83	519.21	491.52	
B_4		533.59	563.43	548.51		538.33	571.63	554.98	
S Mean		419.62	445.85			424.76	451.25		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		6.859	NS	8.77		7.245	NS	8.10	
B		10.486	32.31	8.39		10.791	33.25	8.53	
S		6.034	18.09	7.83		5.624	16.86	7.29	

F x B	14.829	NS		15.260	NS	
F x S	8.533	NS		7.953	NS	
B x S	12.068	NS		11.247	NS	
F x B x S	17.066	NS		15.906	NS	

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 3: Effect of bio char, crop residues and humic acid on iron content (mg kg^{-1}) in grain of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	132.47	141.03	136.75	160.22	135.65	145.53	140.59	164.16
	B_2	153.29	158.87	156.08		157.94	162.22	160.08	
	B_3	165.40	169.52	167.46		169.39	174.08	171.73	
	B_4	177.59	183.62	180.61		181.24	187.19	184.21	
	F x S	157.19	163.26			161.05	167.26		
F_2	B_1	125.73	139.36	132.55	157.52	132.33	143.03	137.68	162.31
	B_2	152.26	156.49	154.38		156.11	160.23	158.17	
	B_3	164.31	167.54	165.92		168.96	172.05	170.50	
	B_4	173.88	180.62	177.25		180.25	185.52	182.89	
	F x S	154.04	161.00			159.41	165.21		
B x S				B Mean		B x S		B Mean	
B_1		129.10	140.20	134.65		133.99	144.28	139.14	
B_2		152.78	157.68	155.23		157.03	161.23	159.13	
B_3		164.85	168.53	166.69		169.18	173.06	171.12	
B_4		175.74	182.12	178.93		180.74	186.35	183.55	
S Mean		155.62	162.13			160.23	166.23		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		2.430	NS	8.49		2.648	NS	8.95	
B		3.826	11.79	8.34		3.668	11.30	7.79	
S		1.778	5.33	7.48		1.723	5.17	7.17	
F x B		5.411	NS			5.188	NS		
F x S		2.514	NS			2.437	NS		
B x S		3.555	NS			3.446	NS		
F x B x S		5.028	NS			4.874	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 4: Effect of bio char, crop residues and humic acid on iron content (mg kg^{-1}) in straw of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	304.77	324.47	314.62	368.63	309.32	330.09	319.71	373.45
	B_2	352.69	365.51	359.10		357.61	369.42	363.51	
	B_3	380.54	390.01	385.28		383.39	396.45	389.92	
	B_4	408.60	422.47	415.53		413.69	427.65	420.67	
	F x S	361.65	375.61			366.00	380.90		
F_2	B_1	289.26	320.64	304.95	362.42	294.94	325.61	310.27	369.08
	B_2	350.32	360.05	355.18		355.11	364.16	359.64	
	B_3	378.03	385.46	381.75		381.11	394.97	388.04	
	B_4	400.05	415.55	407.80		412.51	424.27	418.39	
	F x S	354.42	370.43			360.92	377.25		
B x S				**B Mean**		**B x S**		**B Mean**	
B_1		297.02	322.55	309.79		302.13	327.85	314.99	
B_2		351.50	362.78	357.14		356.36	366.79	361.57	
B_3		379.29	387.74	383.51		382.25	395.71	388.98	
B_4		404.32	419.01	411.67		413.10	425.96	419.53	
S Mean		358.03	373.02			363.46	379.08		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		5.590	NS	8.49		5.179	NS	8.83	
B		8.802	27.12	8.34		9.045	27.87	8.44	
S		4.090	12.26	7.48		4.046	12.13	7.34	
F x B		12.448	NS			12.792	NS		
F x S		5.784	NS			5.722	NS		
B x S		8.180	NS			8.092	NS		
F x B x S		11.568	NS			11.443	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 5: Effect of bio char, crop residues and humic acid on manganese content (mg kg^{-1}) at active tillering stage of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	137.28	139.15	138.22	176.81	141.12	142.73	141.93	180.90
	B_2	149.35	152.92	151.14		153.55	157.08	155.31	
	B_3	187.97	212.16	200.07		191.94	216.06	204.00	
	B_4	214.27	221.41	217.84		218.21	226.50	222.36	
	F x S	172.22	181.41			176.21	185.59		
F_2	B_1	136.16	138.67	137.42	174.48	139.55	142.34	140.95	178.18
	B_2	147.68	150.56	149.12		151.62	154.58	153.10	
	B_3	183.50	209.70	196.60		186.99	213.52	200.26	
	B_4	210.19	219.38	214.79		214.13	222.73	218.43	
	F x S	169.38	179.58			173.08	183.29		
B x S				**B Mean**		**B x S**		**B Mean**	
B_1		136.72	138.91	137.82		140.34	142.54	141.44	
B_2		148.52	151.74	150.13		152.59	155.83	154.21	
B_3		185.74	210.93	198.33		189.47	214.79	202.13	
B_4		212.23	220.40	216.31		216.17	224.62	220.39	
S Mean		170.80	180.50			174.64	184.44		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		3.274	NS	9.13		3.528	NS	9.63	
B		3.408	10.50	7.72		3.380	10.41	8.52	
S		1.875	5.62	7.23		1.816	5.44	7.95	
F x B		4.820	NS			4.780	NS		
F x S		2.651	NS			2.568	NS		
B x S		3.750	11.24			3.632	10.89		
F x B x S		5.303	NS			5.136	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 6: Effect of bio char, crop residues and humic acid on manganese content (mg kg^{-1}) at panicle initiation stage of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	116.61	119.52	118.07	156.45	121.60	123.84	122.72	160.39
	B_2	127.62	132.49	130.05		130.94	135.80	133.37	
	B_3	166.80	190.59	178.70		170.12	194.57	182.35	
	B_4	196.78	201.18	198.98		202.10	204.16	203.13	
	F x S	151.95	160.94			156.19	164.59		
F_2	B_1	114.58	118.45	116.52	153.97	118.15	121.43	119.79	157.48
	B_2	127.28	130.29	128.79		131.47	132.61	132.04	
	B_3	160.43	186.38	173.41		163.75	190.70	177.22	
	B_4	194.48	199.84	197.16		197.91	203.82	200.87	
	F x S	149.19	158.74			152.82	162.14		
B x S				**B Mean**		**B x S**		**B Mean**	
B_1		115.60	118.98	117.29		119.87	122.63	121.25	
B_2		127.45	131.39	129.42		131.21	134.21	132.71	
B_3		163.62	188.49	176.05		166.93	192.64	179.78	
B_4		195.63	200.51	198.07		200.01	203.99	202.00	
S Mean		150.57	159.84			154.50	163.37		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		3.122	NS	9.86		3.180	NS	9.80	
B		3.615	11.14	8.07		3.628	11.18	7.91	
S		1.695	5.08	7.35		1.676	5.02	7.17	
F x B		5.112	NS			5.131	NS		
F x S		2.397	NS			2.370	NS		
B x S		3.390	10.16			3.352	10.05		
F x B x S		4.795	NS			4.740	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 7: Effect of bio char, crop residues and humic acid on manganese content (mg kg^{-1}) in grain of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	38.33	39.33	38.83	43.96	41.64	44.30	42.97	48.88
	B_2	41.66	43.18	42.42		45.68	48.90	47.29	
	B_3	44.95	46.07	45.51		49.57	50.10	49.84	
	B_4	48.27	49.90	49.09		54.61	56.21	55.41	
	F x S	43.30	44.62			47.88	49.88		
F_2	B_1	38.17	38.54	38.36	43.39	41.06	42.73	41.90	47.94
	B_2	41.38	42.53	41.96		44.76	47.11	45.94	
	B_3	44.66	45.53	45.09		48.81	49.86	49.33	
	B_4	47.26	49.09	48.17		53.46	55.73	54.60	
	F x S	42.87	43.92			47.02	48.86		
B x S				**B Mean**		**B x S**		**B Mean**	
B_1		38.25	38.94	38.59		41.35	43.52	42.43	
B_2		41.52	42.85	42.19		45.22	48.01	46.61	
B_3		44.80	45.80	45.30		49.19	49.98	49.58	
B_4		47.76	49.50	48.63		54.04	55.97	55.00	
S Mean		43.08	44.27			47.45	49.37		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.688	NS	7.72		0.801	NS	8.11	
B		0.982	3.03	7.79		1.213	3.74	8.68	
S		0.381	1.14	6.27		0.489	1.47	6.95	
F x B		1.389	NS			1.716	NS		
F x S		0.538	NS			0.692	NS		
B x S		0.761	NS			0.978	NS		
F x B x S		1.077	NS			1.383	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 8: Effect of bio char, crop residues and humic acid on manganese content (mg kg^{-1}) in straw of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	91.56	92.21	91.89	104.51	95.59	96.27	95.93	109.41
	B_2	99.46	99.87	99.66		103.84	104.26	104.05	
	B_3	106.43	110.70	108.56		111.11	115.57	113.34	
	B_4	116.41	119.46	117.94		121.53	124.72	123.12	
	F x S	103.46	105.56			108.02	110.21		
F_2	B_1	90.36	91.79	91.08	103.72	94.34	95.83	95.09	108.00
	B_2	99.23	99.62	99.42		103.59	104.00	103.80	
	B_3	105.35	109.35	107.35		109.98	114.16	112.07	
	B_4	116.17	117.90	117.03		121.28	123.08	122.18	
	F x S	102.78	104.66			107.30	109.27		
B x S				**B Mean**		**B x S**		**B Mean**	
B_1		90.96	92.00	91.48		94.96	96.05	95.51	
B_2		99.34	99.74	99.54		103.72	104.13	103.92	
B_3		105.89	110.02	107.96		110.55	114.86	112.71	
B_4		116.29	118.68	117.48		121.40	123.90	122.65	
S Mean		103.12	105.11			107.66	109.74		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		1.331	NS	8.26		1.389	NS	8.26	
B		1.700	5.24	7.66		1.775	5.47	7.66	
S		0.638	1.91	6.00		0.667	2.00	6.12	
F x B		2.405	NS			2.511	NS		
F x S		0.903	NS			0.943	NS		
B x S		1.277	NS			1.333	NS		
F x B x S		1.806	NS			1.885	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 9: Effect of bio char, crop residues and humic acid on zinc content (mg kg^{-1}) at active tillering stage of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	31.53	32.42	31.98	39.36	35.55	36.46	36.00	43.75
	B_2	36.59	36.77	36.68		40.31	41.40	40.86	
	B_3	40.49	42.89	41.69		44.19	46.93	45.56	
	B_4	46.22	47.95	47.08		51.76	53.40	52.58	
	F x S	38.71	40.01			42.95	44.55		
F_2	B_1	31.62	32.82	32.22	39.02	34.75	35.87	35.31	43.24
	B_2	36.19	36.59	36.39		39.72	40.31	40.02	
	B_3	39.87	42.22	41.05		43.62	46.42	45.02	
	B_4	46.00	46.88	46.44		51.68	53.59	52.63	
	F x S	38.42	39.63			42.44	44.05		
B x S				**B Mean**		**B x S**		**B Mean**	
B_1		31.58	32.62	32.10		35.15	36.17	35.66	
B_2		36.39	36.68	36.53		40.02	40.86	40.44	
B_3		40.18	42.56	41.37		43.90	46.68	45.29	
B_4		46.11	47.41	46.76		51.72	53.49	52.61	
S Mean		38.56	39.82			42.70	44.30		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.804	NS	10.05		0.966	NS	10.88	
B		0.993	3.06	8.78		1.069	3.29	8.51	
S		0.567	NS	7.09		0.728	NS	8.20	
F x B		1.405	NS			1.512	NS		
F x S		0.803	NS			1.030	NS		
B x S		1.135	NS			1.456	NS		
F x B x S		1.605	NS			2.059	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 10: Effect of bio char, crop residues and humic acid on zinc content (mg kg^{-1}) at panicle initiation stage of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	27.80	30.70	29.25	35.30	32.18	34.73	33.45	40.00
	B_2	32.75	34.58	33.67		35.57	37.41	36.49	
	B_3	35.09	37.21	36.15		41.14	43.53	42.34	
	B_4	40.71	43.57	42.14		46.86	48.59	47.73	
	F x S	34.09	36.52			38.94	41.07		
F_2	B_1	27.67	28.99	28.33	34.50	31.26	32.80	32.03	39.29
	B_2	32.57	33.10	32.84		35.50	37.23	36.37	
	B_3	34.82	36.39	35.60		40.52	42.87	41.69	
	B_4	39.50	42.93	41.22		46.64	47.53	47.08	
	F x S	33.64	35.35			38.48	40.11		
B x S				B Mean		B x S		B Mean	
B_1		27.74	29.85	28.79		31.72	33.76	32.74	
B_2		32.66	33.84	33.25		35.53	37.32	36.43	
B_3		34.95	36.80	35.88		40.83	43.20	42.01	
B_4		40.10	43.25	41.68		46.75	48.06	47.40	
S Mean		33.86	35.93			38.71	40.59		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.609	NS	8.54		0.865	NS	10.69	
B		0.996	3.07	9.89		1.035	3.19	9.04	
S		0.625	1.87	8.77		0.603	1.81	7.46	
F x B		1.409	NS			1.463	NS		
F x S		0.883	NS			0.853	NS		
B x S		1.249	NS			1.207	NS		
F x B x S		1.767	NS			1.707	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 11: Effect of bio char, crop residues and humic acid on zinc content (mg kg^{-1}) in grain of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	21.80	22.49	22.15	25.73	25.35	27.35	26.35	30.54
	B_2	24.13	25.18	24.66		28.77	30.04	29.41	
	B_3	26.43	27.21	26.82		30.40	31.86	31.13	
	B_4	28.74	29.89	29.32		34.29	36.27	35.28	
	F x S	25.27	26.19			29.70	31.38		
F_2	B_1	26.22	21.95	24.08	25.66	25.26	26.17	25.71	29.99
	B_2	21.95	24.73	23.34		28.65	29.02	28.84	
	B_3	26.22	26.83	26.53		30.21	31.30	30.75	
	B_4	28.04	29.32	28.68		33.45	35.83	34.64	
	F x S	25.60	25.71			29.39	30.58		
B x S				B Mean		B x S		B Mean	
B_1		24.01	22.22	23.11		25.30	26.76	26.03	
B_2		23.04	24.96	24.00		28.71	29.53	29.12	
B_3		26.01	27.02	26.51		30.30	31.58	30.94	
B_4		28.39	29.60	29.00		33.87	36.05	34.96	
S Mean		25.36	25.95			29.55	30.98		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.591	NS	10.27		0.590	NS	10.55	
B		0.758	2.34	10.22		0.625	1.92	8.15	
S		0.409	NS	7.80		0.521	NS	8.43	
F x B		1.072	NS			0.883	NS		
F x S		0.579	NS			0.737	NS		
B x S		0.818	NS			1.042	NS		
F x B x S		1.157	NS			1.473	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 12: Effect of bio char, crop residues and humic acid on zinc content (mg kg^{-1}) in straw of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	**S_2**	**F x B**	**F Mean**	**S_1**	**S_2**	**F x B**	**F Mean**
F_1	B_1	17.20	17.54	17.37	20.18	20.14	19.61	19.88	23.68
	B_2	19.12	19.19	19.16		21.56	21.42	21.49	
	B_3	20.61	21.52	21.06		23.34	26.32	24.83	
	B_4	22.78	23.44	23.11		27.70	29.36	28.53	
	F x S	19.93	20.42			23.19	24.18		
F_2	B_1	17.24	17.69	17.46	20.05	19.90	19.36	19.63	23.48
	B_2	18.97	19.12	19.05		21.43	21.35	21.39	
	B_3	20.37	21.27	20.82		23.05	26.82	24.93	
	B_4	22.70	23.04	22.87		27.33	28.64	27.98	
	F x S	19.82	20.28			22.93	24.04		
B x S				**B Mean**		**B x S**		**B Mean**	
B_1		17.22	17.62	17.42		20.02	19.49	19.75	
B_2		19.05	19.16	19.10		21.50	21.38	21.44	
B_3		20.49	21.39	20.94		23.20	26.57	24.88	
B_4		22.74	23.24	22.99		27.52	29.00	28.26	
S Mean		19.87	20.35			23.06	24.11		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.394	NS	9.59		0.405	NS	9.42	
B		0.414	1.28	7.13		0.353	1.09	8.18	
S		0.303	NS	7.38		0.437	NS	8.07	
F x B		0.586	NS			0.499	NS		
F x S		0.429	NS			0.618	NS		
B x S		0.606	NS			0.873	NS		
F x B x S		0.857	NS			1.235	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 13: Effect of bio char, crop residues and humic acid on copper content (mg kg^{-1}) at active tillering stage of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	14.86	15.12	14.99	17.16	19.87	20.21	20.04	22.94
	B_2	16.34	16.40	16.37		21.85	21.92	21.89	
	B_3	17.49	18.19	17.84		23.39	24.33	23.86	
	B_4	19.17	19.68	19.43		25.64	26.32	25.98	
	F x S	16.97	17.35			22.69	23.20		
F_2	B_1	14.88	14.90	14.89	17.02	19.90	19.93	19.91	22.76
	B_2	16.23	16.34	16.28		21.70	21.85	21.78	
	B_3	17.31	18.00	17.65		23.14	24.07	23.61	
	B_4	19.11	19.37	19.24		25.55	25.90	25.73	
	F x S	16.88	17.15			22.57	22.94		
B x S				**B Mean**		**B x S**		**B Mean**	
B_1		14.87	15.01	14.94		19.88	20.07	19.98	
B_2		16.28	16.37	16.33		21.78	21.89	21.83	
B_3		17.40	18.10	17.75		23.27	24.20	23.73	
B_4		19.14	19.53	19.33		25.59	26.11	25.85	
S Mean		16.92	17.25			22.63	23.07		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.299	NS	8.56		0.376	NS	8.06	
B		0.422	1.30	8.55		0.548	1.69	8.30	
S		0.195	NS	7.59		0.257	NS	7.51	
F x B		0.597	NS			0.774	NS		
F x S		0.276	NS			0.364	NS		
B x S		0.390	NS			0.514	NS		
F x B x S		0.552	NS			0.727	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 14: Effect of bio char, crop residues and humic acid on copper content (mg kg^{-1}) at panicle initiation stage of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	12.59	12.71	12.65	14.59	15.44	15.71	15.57	17.83
	B_2	13.62	13.50	13.56		16.98	17.04	17.01	
	B_3	14.73	15.16	14.95		18.18	18.91	18.54	
	B_4	16.90	17.52	17.21		19.92	20.45	20.19	
	F x S	14.46	14.72			17.63	18.03		
F_2	B_1	11.60	12.21	11.91	13.92	15.32	15.48	15.40	17.67
	B_2	12.55	13.28	12.92		16.86	16.98	16.92	
	B_3	14.47	14.60	14.53		17.99	18.70	18.35	
	B_4	16.12	16.55	16.34		19.86	20.13	19.99	
	F x S	13.69	14.16			17.51	17.83		
B x S				**B Mean**		**B x S**		**B Mean**	
B_1		12.10	12.46	12.28		15.38	15.60	15.49	
B_2		13.08	13.39	13.24		16.92	17.01	16.97	
B_3		14.60	14.88	14.74		18.08	18.81	18.44	
B_4		16.51	17.03	16.77		19.89	20.29	20.09	
S Mean		14.07	14.44			17.57	17.93		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.370	NS	10.72		0.395	NS	10.89	
B		0.396	1.22	9.63		0.439	1.35	8.57	
S		0.238	NS	8.19		0.216	NS	8.95	
F x B		0.560	NS			0.621	NS		
F x S		0.337	NS			0.305	NS		
B x S		0.476	NS			0.431	NS		
F x B x S		0.674	NS			0.610	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 15: Effect of bio char, crop residues and humic acid on copper content (mg kg^{-1}) in grain of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	5.59	5.96	5.78	6.55	7.52	7.79	7.65	9.04
	B_2	6.22	6.46	6.34		9.00	8.59	8.80	
	B_3	6.52	6.79	6.66		8.90	9.53	9.22	
	B_4	7.24	7.61	7.42		10.16	10.85	10.50	
	F x S	6.39	6.70			8.90	9.19		
F_2	B_1	5.58	5.74	5.66	6.45	7.27	7.46	7.37	8.71
	B_2	6.20	6.27	6.23		8.29	8.16	8.23	
	B_3	6.49	6.69	6.59		8.70	9.42	9.06	
	B_4	7.09	7.52	7.30		10.00	10.36	10.18	
	F x S	6.34	6.56			8.57	8.85		
B x S				**B Mean**		**B x S**		**B Mean**	
B_1		5.58	5.85	5.72		7.39	7.63	7.51	
B_2		6.21	6.36	6.29		8.65	8.38	8.51	
B_3		6.50	6.74	6.62		8.80	9.48	9.14	
B_4		7.16	7.56	7.36		10.08	10.61	10.34	
S Mean		6.37	6.63			8.73	9.02		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.116	NS	8.71		0.188	NS	9.35	
B		0.149	0.46	7.95		0.233	0.72	8.08	
S		0.090	NS	7.80		0.140	NS	7.71	
F x B		0.211	NS			0.329	NS		
F x S		0.127	NS			0.197	NS		
B x S		0.180	NS			0.279	NS		
F x B x S		0.255	NS			0.395	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 16: Effect of bio char, crop residues and humic acid on copper content (mg kg^{-1}) in straw of direct seeded rice

RDF	Bio char, Paddy straw and Greenleaf manure	*Kharif* - 2020				*Kharif* - 2021			
		Humic Acid				Humic Acid			
		S_1	S_2	F x B	F Mean	S_1	S_2	F x B	F Mean
F_1	B_1	6.69	6.78	6.74	7.75	8.27	8.38	8.32	9.58
	B_2	7.40	7.42	7.41		9.14	9.17	9.15	
	B_3	7.92	8.24	8.08		9.78	10.18	9.98	
	B_4	8.68	8.91	8.79		10.72	11.01	10.87	
	F x S	7.67	7.84			9.48	9.68		
F_2	B_1	6.60	6.75	6.67	7.63	8.16	8.33	8.25	9.42
	B_2	6.87	7.40	7.13		8.49	9.14	8.82	
	B_3	7.84	8.15	7.99		9.68	10.07	9.87	
	B_4	8.65	8.77	8.71		10.69	10.83	10.76	
	F x S	7.49	7.76			9.25	9.59		
B x S				**B Mean**		**B x S**		**B Mean**	
B_1		6.65	6.76	6.71		8.21	8.36	8.28	
B_2		7.13	7.41	7.27		8.82	9.15	8.99	
B_3		7.88	8.19	8.03		9.73	10.12	9.93	
B_4		8.66	8.84	8.75		10.71	10.92	10.81	
S Mean		7.58	7.80			9.37	9.64		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.114	NS	7.27		0.141	NS	7.81	
B		0.168	0.52	7.56		0.207	0.64	7.73	
S		0.079	NS	7.02		0.097	NS	7.21	
F x B		0.237	NS			0.293	NS		
F x S		0.111	NS			0.138	NS		
B x S		0.158	NS			0.195	NS		
F x B x S		0.223	NS			0.275	NS		

F_1: 100% RDF, F_2: 75% RDF, B_1 – Bio char @ 5 t ha^{-1}, B_2 – Bio char @ 7.5 t ha^{-1}, B_3 - Paddy straw @ 5 t ha^{-1}, B_4 - Green leaf manure @ 6 t ha^{-1}, S_1 - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Conclusion

Significantly higher iron and manganese contents in plant was recorded with the application of B_4- Green leaf manure @ 6 t ha^{-1} and S_2 - Humic acid @ 30 kg ha^{-1} at all the growth stages of direct seeded rice, whereas, the higher zinc (except in panicle initiation stage) and copper content was significantly recorded with application of B_4- Green leaf manure @ 6 t ha^{-1} only. However, the zinc content in panicle initiation stage

significantly influenced by the application of B_4- Green leaf manure @ 6 t ha^{-1} and S_2 - Humic acid @ 30 kg ha^{-1}.

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