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Residual effect of bio char, crop residues and humic acid on plant micro nutrient content in black gram

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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- black gram cropping sequence.

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, Zinc and copper content in plant was recorded with the residual effect of B_4- Green leaf manure @ 6 t ha^{-1} at all the growth stages of rabi black gram, whereas, significantly higher manganese content was recorded with residual effect of B_4- Green leaf manure @ 6 t ha^{-1} and S_2 - Humic acid @ 30 kg ha^{-1} in *rabi* black gram 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 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) [6]. 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 black gram.

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, 15º 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^{-1})] 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 30, 60 days and harvest stages of black gram were washed with dilute HCl and then with double distilled water. The samples were shade dried initially and then oven dried at 65 ºC 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) [5].

Results and Discussion

Micro nutrient Content in black gram

Iron Content

Close observation of data related to iron content in black gram presented in table 1, 2, 3 and 4 and 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 black gram and year of the study, application of B_4 – Green leaf manure @ 6 t ha^{-1} recorded significantly higher iron content [(217.59 mg kg^{-1} in *rabi* 2020 and 226.15 mg kg^{-1} *rabi* 2021), (195.93 mg kg^{-1} in *rabi* 2020 and 220.45 mg kg^{-1} *rabi* 2021), (98.64 mg kg^{-1} in *rabi* 2020 and 103.41 mg kg^{-1} *rabi* 2021) and (173.66 mg kg^{-1} in *rabi* 2020 and 178.83 mg kg^{-1} *rabi* 2021)] in 30 days, 60 days and harvest (seed and haulm) stages respectively in black gram. And it was on par with the application of B_3 - Paddy straw @5t ha^{-1} [(207.77 mg kg^{-1} in *rabi* 2020 and 214.55 mg kg^{-1} *rabi* 2021), (187.50 mg kg^{-1} in *rabi* 2020 and 210.63 mg kg^{-1} *rabi* 2021), (94.24 mg kg^{-1} in *rabi* 2020 and 97.81 mg kg^{-1} *rabi* 2021) and (165.40 mg kg^{-1} in *rabi* 2020 and 169.92 mg kg^{-1} *rabi* 2021)] in 30 days, 60 days and harvest (seed and haulm) stages respectively in black gram. The iron content was increased with the addition of organic manures might be due to organic materials supply chelating agents, which help in maintaining the solubility of iron (Debiprasad *et al.*, 2010) [2].

With regard to, the individual effect of RDF and two levels of humic acid application and the interaction effects like F and B; F and S; B and S; F and B and S were found non-significant effect on iron content in 30 days, 60 days and harvest (seed and haulm) stages of *rabi* black gram.

Manganese Content

Manganese content in black gram at all growth stages (30 days, 60 days and harvest (seed and haulm)) 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 [(61.72 mg kg^{-1} in *rabi* 2020 and 64.75 mg kg^{-1} *rabi* 2021), (57.40 mg kg^{-1} in *rabi* 2020 and 63.21 mg kg^{-1} *rabi* 2021), (37.23 mg kg^{-1} in *rabi* 2020 and 46.14 mg kg^{-1} *rabi* 2021) and (48.96 mg kg^{-1} in *rabi* 2020 and 50.89 mg kg^{-1} *rabi* 2021)] in 30 days, 60 days and harvest (seed and haulm) stages respectively in black gram. Increase in manganese content with the application of organic manures might be due to addition of the water soluble plus exchangeable and easily reducible fractions of manganese to soil. Khaled *et al*. (2011) [3] and Kumar *et al*. (2012) [4] also reported increase in Mn concentration with the combined application of organics and inorganics.

Among the two levels of humic acid application, the S_2 – 30 kg ha^{-1} recorded significantly higher manganese content [(52.84 mg kg^{-1} in *rabi* 2020 and 56.23 mg kg^{-1} *rabi* 2021), (48.70 mg kg^{-1} in *rabi* 2020 and 53.83 mg kg^{-1} *rabi* 2021), (31.63 mg kg^{-1} in *rabi* 2020 and 39.86 mg kg^{-1} *rabi* 2021) and (38.98 mg kg^{-1} in *rabi* 2020 and 42.22 mg kg^{-1} *rabi* 2021)] than S_1 – 20 kg ha^{-1} humic acid application in 30 days, 60 days and harvest (seed and haulm) stages respectively in black gram.

With regard to, the individual effect of RDF and the interaction effects like F and B; F and S; B and S; F and B and S were found non-significant effect on manganese content in 30 days, 60 days and harvest (seed and haulm) stages of *rabi* black gram.

Zinc Content

Data pertaining to zinc content presented in tables 9, 10, 11 and 12. Perusal of the data revealed that the zinc content was significantly influenced by the individual effect of green leaf manure application. However the individual effect of RDF, two levels of humic acid and interaction effect between RDF, B_1, B_2, B_3, B_4; F and S; B and S; was found non-significant effect on zinc content in 30 days, 60 days and harvest (seed and haulm) stages respectively in black gram.

The significantly higher zinc content was recorded in that the application of B_4 – Green leaf manure @ 6 t ha^{-1} [(39.77 mg kg^{-1} in *rabi* 2020 and 45.10 mg kg^{-1} *rabi* 2021), (37.99 mg kg^{-1} in *rabi* 2020 and 39.77 mg kg^{-1} *rabi* 2021), (27.42 mg kg^{-1} in *rabi* 2020 and 31.08 mg kg^{-1} *rabi* 2021) and (22.52 mg kg^{-1} in *rabi* 2020 and 26.44 mg kg^{-1} *rabi* 2021)] in 30 days, 60 days and harvest (seed and haulm) stages respectively in black gram and it was on par with the application of B_3 - Paddy straw @ 5t ha^{-1} [(37.75 mg kg^{-1} in *rabi* 2020 and 41.52 mg kg^{-1} *rabi* 2021), (35.97 mg kg^{-1} in *rabi* 2020 and 37.75 mg kg^{-1} *rabi* 2021), (26.05 mg kg^{-1} in *rabi* 2020 and 29.16 mg kg^{-1} *rabi* 2021) and (21.36 mg kg^{-1} in *rabi* 2020 and 25.11mg kg^{-1} *rabi* 2021)] in 30 days, 60 days and harvest (seed and haulm) stages respectively in black gram. Aghili *et al.* (2014) [1] reported that the DTPA – extractable Zn was found to be increased in the treatment receiving with green leaf manures.

With regard to, the individual effect of RDF, two levels of humic acid application and the interaction effects like F and B; F and S; B and S; F and B and S were found non-significant effect on zinc content in 30 days, 60 days and harvest (seed and haulm) stages of *rabi* black gram.

Copper Content

Data pertaining to copper content presented in tables 13, 14, 15 and 16. Perusal of the data 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 30 days, 60 days and harvest (seed and haulm) stages respectively in black gram.

The significantly higher copper content was recorded in that the application of B_4 – Green leaf manure @ 6 t ha^{-1} [(15.65 mg kg^{-1} in *rabi* 2020 and 16.13 mg kg^{-1} *rabi* 2021), (12.52 mg kg^{-1} in *rabi* 2020 and 12.78 mg kg^{-1} *rabi* 2021), (11.19 mg kg^{-1} in *rabi* 2020 and 11.71 mg kg^{-1} *rabi* 2021) and (9.55 mg kg^{-1} in *rabi* 2020 and 9.82 mg kg^{-1} *rabi* 2021)] in 30 days, 60 days and harvest (seed and haulm) stages respectively in black gram and it was on par with the application of B_3 - Paddy straw @ 5t ha^{-1} [(14.85 mg kg^{-1} in *rabi* 2020 and 15.25 mg kg^{-1} *rabi* 2021), (11.39 mg kg^{-1} in *rabi* 2020 and 11.98 mg kg^{-1} *rabi* 2021), (10.65 mg kg^{-1} in *rabi* 2020 and 11.08 mg kg^{-1} *rabi* 2021) and (9.08 mg kg^{-1} in *rabi* 2020 and 9.35 mg kg^{-1} *rabi* 2021)] in 30 days, 60 days and harvest (seed and haulm) stages respectively in black gram.

Higher concentration of Cu in plant under green leaf manure applied treatments might be due to release of Cu from organic manures during decomposition and increase of native Cu availability. The increase in copper content in organic treatments might be due to better root proliferation which helped in the absorption of copper from native source under favourable reduced conditions (Debiprasad *et al.*, 2010) [2]. Copper had a strong affinity for the nitrogen atom of amino groups and it appeared quite likely that soluble nitrogen compounds like amino acids act as copper carriers in xylem and phloem.

With regard to, the individual effect of RDF, two levels of humic acid application and the interaction effects like F and B; F and S; B and S; F and B and S were found non-significant effect on copper content in 30 days, 60 days and harvest (seed and haulm) stages of *rabi* black gram.

Table 1: Residual effect of bio char, crop residues and humic acid on iron content (mg kg^{-1}) at 30 days stage of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	160.43	167.27	163.85	192.65	167.68	174.95	171.32	199.72
	B_2	177.20	180.63	178.91		185.00	187.28	186.14	
	B_3	206.91	210.15	208.53		212.46	217.10	214.78	
	B_4	216.63	222.01	219.32		224.02	229.29	226.65	
	F x S	190.29	195.01			197.29	202.16		
F_2	B_1	154.89	165.96	160.42	189.74	165.94	172.98	169.46	198.36
	B_2	172.81	178.53	175.67		181.09	186.97	184.03	
	B_3	205.96	208.06	207.01		212.00	216.63	214.31	
	B_4	213.96	217.76	215.86		223.04	228.27	225.65	
	F x S	186.91	192.58			195.52	201.21		
B x S				B Mean		B x S		B Mean	
B_1		157.66	166.61	162.14		166.81	173.97	170.39	
B_2		175.01	179.58	177.29		183.04	187.12	185.08	
B_3		206.44	209.10	207.77		212.23	216.87	214.55	
B_4		215.30	219.88	217.59		223.53	228.78	226.15	
S Mean		188.60	193.79			196.40	201.68		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		3.641	NS	9.33		3.440	NS	8.47	
B		4.699	14.48	8.51		4.445	13.70	7.74	
S		2.358	NS	7.04		2.252	NS	7.54	
F x B		6.646	NS			6.286	NS		
F x S		3.335	NS			3.184	NS		
B x S		4.716	NS			4.503	NS		

F x B x S	6.669	NS		6.369	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: Residual effect of bio char, crop residues and humic acid on iron content (mg kg^{-1}) at 60 days stage of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	141.01	149.53	145.27	172.99	163.29	170.13	166.71	195.51
	B_2	163.30	161.60	162.45		180.05	183.48	181.77	
	B_3	186.89	187.07	186.98		209.77	213.01	211.39	
	B_4	193.13	201.41	197.27		219.49	224.87	222.18	
	F x S	171.08	174.90			193.15	197.87		
F_2	B_1	138.39	147.72	143.05	170.48	157.74	168.81	163.28	192.60
	B_2	153.74	158.84	156.29		175.67	181.39	178.53	
	B_3	186.79	189.24	188.01		208.82	210.91	209.87	
	B_4	193.11	196.05	194.58		216.82	220.62	218.72	
	F x S	168.01	172.96			189.76	195.43		
B x S				B Mean		B x S		B Mean	
B_1		139.70	148.63	144.16		160.52	169.47	164.99	
B_2		158.52	160.22	159.37		177.86	182.44	180.15	
B_3		186.84	188.16	187.50		209.29	211.96	210.63	
B_4		193.12	198.73	195.93		218.15	222.74	220.45	
S Mean		169.54	173.93			191.46	196.65		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		3.805	NS	10.86		3.641	NS	9.19	
B		4.533	13.97	9.14		4.699	14.48	8.39	
S		2.336	NS	6.66		2.358	NS	5.95	
F x B		6.411	NS			6.646	NS		
F x S		3.304	NS			3.335	NS		
B x S		4.672	NS			4.716	NS		
F x B x S		6.607	NS			6.669	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}, - Humic acid @ 20 kg ha^{-1}, S_2 - Humic acid @ 30 kg ha^{-1}

Table 3: Residual effect of bio char, crop residues and humic acid on iron content (mg kg^{-1}) in seed of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	62.33	65.06	63.70	81.98	66.33	69.74	68.04	85.73
	B_2	69.44	70.88	70.16		72.03	74.43	73.23	
	B_3	93.85	95.32	94.58		96.65	99.22	97.94	
	B_4	98.26	100.70	99.48		102.36	105.10	103.73	
	F x S	80.97	82.99			84.34	87.12		
F_2	B_1	59.32	64.34	61.83	80.57	62.87	68.03	65.45	84.80
	B_2	67.45	70.05	68.75		71.37	74.57	72.97	
	B_3	93.42	94.37	93.89		96.80	98.58	97.69	
	B_4	97.05	98.57	97.81		102.42	103.75	103.09	
	F x S	79.31	81.83			83.37	86.23		
B x S				B Mean		B x S		B Mean	
B_1		60.83	64.70	62.76		64.60	68.88	66.74	
B_2		68.45	70.46	69.46		71.70	74.50	73.10	
B_3		93.63	94.84	94.24		96.72	98.90	97.81	
B_4		97.65	99.63	98.64		102.39	104.42	103.41	
S Mean		80.14	82.41			83.85	86.68		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		1.541	NS	9.29		1.631	NS	9.37	
B		1.745	5.38	7.44		1.963	6.05	7.98	
S		0.983	NS	7.92		0.921	NS	7.29	
F x B		2.467	NS			2.776	NS		
F x S		1.390	NS			1.303	NS		
B x S		1.965	NS			1.842	NS		
F x B x S		2.780	NS			2.606	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: Residual effect of bio char, crop residues and humic acid on iron content (mg kg^{-1}) in haulm of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	123.63	129.09	126.36	151.22	128.75	133.76	131.25	155.78
	B_2	136.98	139.71	138.34		140.77	144.11	142.44	
	B_3	164.71	167.29	166.00		168.95	171.79	170.37	
	B_4	172.45	175.94	174.19		176.80	181.31	179.05	
	F x S	149.44	153.01			153.82	157.74		
F_2	B_1	119.23	128.03	123.63	149.33	123.30	132.35	127.83	153.79
	B_2	133.49	138.04	135.76		136.48	142.03	139.26	
	B_3	163.95	165.62	164.79		168.78	170.14	169.46	
	B_4	170.32	175.94	173.13		175.56	181.64	178.60	
	F x S	146.75	151.91			151.03	156.54		
B x S				B Mean		B x S		B Mean	
B_1		121.43	128.56	125.00		126.02	133.06	129.54	
B_2		135.23	138.87	137.05		138.63	143.07	140.85	
B_3		164.33	166.46	165.40		168.87	170.97	169.92	
B_4		171.39	175.94	173.66		176.18	181.47	178.83	
S Mean		148.10	152.46			152.42	157.14		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		2.937	NS	9.58		2.867	NS	9.07	
B		2.940	9.06	7.78		3.259	10.04	7.29	
S		1.576	NS	7.14		1.604	NS	7.08	
F x B		4.158	NS			4.609	NS		
F x S		2.229	NS			2.269	NS		
B x S		3.152	NS			3.209	NS		
F x B x S		4.458	NS			4.538	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: Residual effect of bio char, crop residues and humic acid on manganese content (mg kg^{-1}) at 30 days stage of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	41.96	43.96	42.96	52.32	45.60	46.96	46.28	55.78
	B_2	45.74	46.48	46.11		49.56	50.49	50.03	
	B_3	57.00	59.45	58.22		60.36	62.82	61.59	
	B_4	60.87	63.13	62.00		64.45	65.97	65.21	
	F x S	51.39	53.26			54.99	56.56		
F_2	B_1	41.16	43.07	42.12	51.75	45.27	46.93	46.10	55.11
	B_2	45.93	46.29	46.11		49.19	50.18	49.69	
	B_3	56.65	58.01	57.33		59.16	61.59	60.37	
	B_4	60.57	62.31	61.44		63.66	64.92	64.29	
	F x S	51.08	52.42			54.32	55.91		
B x S				B Mean		B x S		B Mean	
B_1		41.56	43.52	42.54		45.44	46.95	46.19	
B_2		45.83	46.39	46.11		49.38	50.34	49.86	
B_3		56.82	58.73	57.78		59.76	62.21	60.98	
B_4		60.72	62.72	61.72		64.06	65.45	64.75	
S Mean		51.23	52.84			54.66	56.23		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.767	NS	7.22		0.889	NS	7.85	
B		0.651	2.01	7.33		0.495	1.53	7.09	
S		0.401	1.20	6.78		0.358	1.07	6.16	
F x B		0.921	NS			0.700	NS		
F x S		0.567	NS			0.506	NS		
B x S		0.802	NS			0.716	NS		
F x B x S		1.134	NS			1.012	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: Residual effect of bio char, crop residues and humic acid on manganese content (mg kg^{-1}) at 60 days stage of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	37.47	39.28	38.38	48.29	41.72	43.64	42.68	53.53
	B_2	41.88	42.79	42.34		46.73	47.82	47.28	
	B_3	54.44	55.29	54.87		59.83	60.87	60.35	
	B_4	57.00	58.15	57.57		62.94	64.65	63.79	
	F x S	47.70	48.88			52.80	54.25		
F_2	B_1	36.02	38.93	37.47	47.66	39.60	43.14	41.37	52.52
	B_2	40.73	42.24	41.48		45.33	47.15	46.24	
	B_3	54.19	54.74	54.47		59.53	60.20	59.86	
	B_4	56.30	58.15	57.22		62.08	63.16	62.62	
	F x S	46.81	48.51			51.64	53.41		
B x S				B Mean		B x S		B Mean	
B_1		36.75	39.10	37.92		40.66	43.39	42.03	
B_2		41.31	42.51	41.91		46.03	47.49	46.76	
B_3		54.32	55.02	54.67		59.68	60.53	60.11	
B_4		56.65	58.15	57.40		62.51	63.91	63.21	
S Mean		47.25	48.70			52.22	53.83		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.896	NS	9.15		1.146	NS	10.59	
B		0.949	2.92	8.85		1.060	3.26	8.92	
S		0.473	1.42	7.83		0.528	1.58	7.88	
F x B		1.342	NS			1.498	NS		
F x S		0.669	NS			0.746	NS		
B x S		0.946	NS			1.055	NS		
F x B x S		1.337	NS			1.493	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: Residual effect of bio char, crop residues and humic acid on manganese content (mg kg^{-1}) in seed of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	23.84	25.54	24.69	31.35	31.42	33.40	32.41	39.06
	B_2	27.83	28.71	28.27		33.98	36.06	35.02	
	B_3	34.31	35.14	34.73		41.92	43.26	42.59	
	B_4	36.80	38.60	37.70		44.91	47.53	46.22	
	F x S	30.70	32.00			38.05	40.06		
F_2	B_1	22.72	24.83	23.77	30.58	30.38	32.34	31.36	38.61
	B_2	26.71	28.17	27.44		33.50	35.85	34.67	
	B_3	34.07	34.61	34.34		41.67	43.05	42.36	
	B_4	36.12	37.43	36.77		44.77	47.36	46.06	
	F x S	29.91	31.26			37.58	39.65		
B x S				B Mean		B x S		B Mean	
B_1		23.28	25.19	24.23		30.90	32.87	31.88	
B_2		27.27	28.44	27.86		33.74	35.95	34.84	
B_3		34.19	34.87	34.53		41.80	43.16	42.48	
B_4		36.46	38.01	37.23		44.84	47.44	46.14	
S Mean		30.30	31.63			37.82	39.86		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.594	NS	9.40		0.653	NS	8.24	
B		0.794	2.45	8.88		0.888	2.73	7.92	
S		0.438	1.31	7.93		0.380	1.14	7.79	
F x B		1.123	NS			1.255	NS		
F x S		0.620	NS			0.537	NS		
B x S		0.876	NS			0.759	NS		
F x B x S		1.240	NS			1.074	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: Residual effect of bio char, crop residues and humic acid on manganese content (mg kg^{-1}) in haulm of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	30.24	32.14	31.19	38.38	31.88	33.84	32.86	41.67
	B_2	33.48	34.33	33.90		37.96	39.39	38.68	
	B_3	37.52	40.83	39.17		43.09	44.64	43.87	
	B_4	48.47	50.02	49.24		50.06	52.52	51.29	
	F x S	37.43	39.33			40.75	42.60		
F_2	B_1	29.99	31.31	30.65	37.74	31.42	32.75	32.08	41.06
	B_2	32.58	33.91	33.24		37.27	39.16	38.22	
	B_3	37.16	39.66	38.41		42.84	44.07	43.45	
	B_4	47.66	49.68	48.67		49.57	51.42	50.49	
	F x S	36.85	38.64			40.27	41.85		
B x S				B Mean		B x S		B Mean	
B_1		30.12	31.72	30.92		31.65	33.30	32.47	
B_2		33.03	34.12	33.57		37.62	39.27	38.45	
B_3		37.34	40.24	38.79		42.97	44.36	43.66	
B_4		48.06	49.85	48.96		49.82	51.97	50.89	
S Mean		37.14	38.98			40.51	42.22		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.683	NS	8.80		0.677	NS	8.01	
B		0.788	2.43	7.17		0.775	2.39	7.49	
S		0.474	1.42	7.11		0.445	1.33	7.27	
F x B		1.115	NS			1.095	NS		
F x S		0.671	NS			0.629	NS		
B x S		0.949	NS			0.890	NS		
F x B x S		1.342	NS			1.258	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: Residual effect of bio char, crop residues and humic acid on zinc content (mg kg^{-1}) at 30 days stage of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	28.13	29.53	28.83	34.70	31.31	33.79	32.55	38.83
	B_2	31.58	32.28	31.93		35.66	35.90	35.78	
	B_3	37.58	38.24	37.91		40.58	42.94	41.76	
	B_4	39.58	40.68	40.13		43.56	46.86	45.21	
	F x S	34.21	35.18			37.78	39.87		
F_2	B_1	26.99	29.26	28.12	34.10	30.23	33.59	31.91	38.35
	B_2	30.67	31.85	31.26		34.31	36.20	35.26	
	B_3	37.38	37.81	37.60		40.27	42.28	41.28	
	B_4	39.03	39.81	39.42		43.34	46.61	44.98	
	F x S	33.52	34.68			37.04	39.67		
B x S				B Mean		B x S		B Mean	
B_1		27.56	29.40	28.48		30.77	33.69	32.23	
B_2		31.13	32.07	31.60		34.99	36.05	35.52	
B_3		37.48	38.03	37.75		40.43	42.61	41.52	
B_4		39.30	40.25	39.77		43.45	46.74	45.10	
S Mean		33.87	34.93			37.41	39.77		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.728	NS	10.36		0.768	NS	9.75	
B		0.750	2.31	8.55		0.491	1.51	8.41	
S		0.615	NS	8.75		0.811	NS	8.29	
F x B		1.060	NS			0.695	NS		
F x S		0.869	NS			1.147	NS		
B x S		1.229	NS			1.622	NS		
F x B x S		1.739	NS			2.293	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: Residual effect of bio char, crop residues and humic acid on zinc content (mg kg^{-1}) at 60 days stage of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	24.35	25.75	25.05	31.92	26.13	27.53	26.83	33.70
	B_2	27.80	28.50	28.15		29.58	30.28	29.93	
	B_3	35.80	36.46	36.13		37.58	38.24	37.91	
	B_4	37.80	38.90	38.35		39.58	40.68	40.13	
	F x S	31.43	32.40			33.21	34.18		
F_2	B_1	23.21	25.48	24.34	31.32	24.99	27.26	26.12	33.10
	B_2	26.89	28.07	27.48		28.67	29.85	29.26	
	B_3	35.60	36.03	35.82		37.38	37.81	37.60	
	B_4	37.25	38.03	37.64		39.03	39.81	39.42	
	F x S	30.74	31.90			32.52	33.68		
B x S				B Mean		B x S		B Mean	
B_1		23.78	25.62	24.70		25.56	27.40	26.48	
B_2		27.35	28.29	27.82		29.13	30.07	29.60	
B_3		35.70	36.25	35.97		37.48	38.03	37.75	
B_4		37.52	38.47	37.99		39.30	40.25	39.77	
S Mean		31.09	32.15			32.87	33.93		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.620	NS	9.60		0.728	NS	10.67	
B		0.691	2.13	8.58		0.750	2.31	8.78	
S		0.617	NS	9.55		0.615	NS	9.02	
F x B		0.978	NS			1.060	NS		
F x S		0.872	NS			0.869	NS		
B x S		1.233	NS			1.229	NS		
F x B x S		1.744	NS			1.739	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: Residual effect of bio char, crop residues and humic acid on zinc content (mg kg^{-1}) in seed of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	17.23	18.18	17.70	22.83	19.76	20.53	20.15	25.85
	B_2	19.57	20.05	19.81		21.97	23.29	22.63	
	B_3	25.93	26.38	26.15		28.77	30.05	29.41	
	B_4	27.29	28.04	27.66		30.29	32.17	31.23	
	F x S	22.50	23.16			25.20	26.51		
F_2	B_1	16.45	18.00	17.22	22.42	19.01	20.34	19.67	25.40
	B_2	18.96	19.75	19.36		21.49	22.72	22.11	
	B_3	25.80	26.09	25.94		28.06	29.75	28.91	
	B_4	26.91	27.44	27.18		29.96	31.90	30.93	
	F x S	22.03	22.82			24.63	26.18		
B x S				B Mean		B x S		B Mean	
B_1		16.84	18.09	17.46		19.38	20.43	19.91	
B_2		19.26	19.90	19.58		21.73	23.00	22.37	
B_3		25.86	26.23	26.05		28.42	29.90	29.16	
B_4		27.10	27.74	27.42		30.12	32.04	31.08	
S Mean		22.27	22.99			24.91	26.34		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.516	NS	11.18		0.632	NS	10.08	
B		0.732	2.26	11.21		0.736	2.27	9.95	
S		0.463	NS	10.03		0.496	NS	9.49	
F x B		1.035	NS			1.041	NS		
F x S		0.655	NS			0.702	NS		
B x S		0.926	NS			0.992	NS		
F x B x S		1.310	NS			1.403	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: Residual effect of bio char, crop residues and humic acid on zinc content (mg kg^{-1}) in haulm of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	15.16	15.96	15.56	19.26	18.41	19.33	18.87	22.91
	B_2	17.12	17.53	17.33		20.68	21.14	20.91	
	B_3	21.26	21.64	21.45		24.99	25.43	25.21	
	B_4	22.40	23.03	22.72		26.31	27.03	26.67	
	F x S	18.99	19.54			22.60	23.23		
F_2	B_1	14.51	15.81	15.16	18.92	17.66	19.16	18.41	22.52
	B_2	16.61	17.28	16.95		20.08	20.86	20.47	
	B_3	21.15	21.40	21.28		24.86	25.15	25.00	
	B_4	22.09	22.54	22.31		25.95	26.46	26.20	
	F x S	18.59	19.26			22.14	22.90		
B x S				B Mean		B x S		B Mean	
B_1		14.83	15.88	15.36		18.03	19.24	18.64	
B_2		16.87	17.40	17.14		20.38	21.00	20.69	
B_3		21.21	21.52	21.36		24.93	25.29	25.11	
B_4		22.25	22.79	22.52		26.13	26.75	26.44	
S Mean		18.79	19.40			22.37	23.07		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.367	NS	9.41		0.445	NS	9.60	
B		0.402	1.24	8.29		0.621	1.91	9.46	
S		0.314	NS	8.06		0.343	NS	7.40	
F x B		0.568	NS			0.878	NS		
F x S		0.444	NS			0.485	NS		
B x S		0.628	NS			0.686	NS		
F x B x S		0.888	NS			0.970	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: Residual effect of bio char, crop residues and humic acid on copper content (mg kg^{-1}) at 30 days stage of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	9.79	9.41	9.60	12.71	10.03	9.71	9.87	13.10
	B_2	10.54	10.62	10.58		10.96	11.07	11.01	
	B_3	14.69	15.04	14.87		15.10	15.42	15.26	
	B_4	15.56	16.05	15.81		16.07	16.49	16.28	
	F x S	12.65	12.78			13.04	13.17		
F_2	B_1	9.76	9.36	9.56	12.59	10.02	9.69	9.85	13.02
	B_2	10.51	10.43	10.47		10.94	11.04	10.99	
	B_3	14.67	15.01	14.84		15.09	15.40	15.24	
	B_4	15.32	15.67	15.49		15.86	16.11	15.99	
	F x S	12.57	12.62			12.98	13.06		
B x S				B Mean		B x S		B Mean	
B_1		9.78	9.39	9.58		10.03	9.70	9.86	
B_2		10.53	10.52	10.53		10.95	11.05	11.00	
B_3		14.68	15.02	14.85		15.09	15.41	15.25	
B_4		15.44	15.86	15.65		15.97	16.30	16.13	
S Mean		12.61	12.70			13.01	13.11		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.240	NS	9.30		0.254	NS	9.52	
B		0.295	0.91	8.08		0.347	1.07	9.22	
S		0.243	NS	9.42		0.233	NS	8.73	
F x B		0.417	NS			0.491	NS		
F x S		0.344	NS			0.329	NS		
B x S		0.486	NS			0.465	NS		
F x B x S		0.688	NS			0.658	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: Residual effect of bio char, crop residues and humic acid on copper content (mg kg^{-1}) at 60 days stage of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	7.34	7.44	7.39	10.02	8.42	8.04	8.23	10.59
	B_2	8.70	8.84	8.77		9.17	9.24	9.21	
	B_3	10.89	11.92	11.40		11.81	12.17	11.99	
	B_4	12.41	12.64	12.52		12.69	13.17	12.93	
	F x S	9.83	10.21			10.52	10.66		
F_2	B_1	7.33	7.41	7.37	10.00	8.39	7.99	8.19	10.47
	B_2	8.70	8.83	8.76		9.14	9.05	9.10	
	B_3	10.86	11.90	11.38		11.79	12.13	11.96	
	B_4	12.40	12.61	12.51		12.45	12.79	12.62	
	F x S	9.82	10.19			10.44	10.49		
B x S				B Mean		B x S		B Mean	
B_1		7.34	7.43	7.38		8.40	8.01	8.21	
B_2		8.70	8.83	8.76		9.15	9.15	9.15	
B_3		10.87	11.91	11.39		11.80	12.15	11.98	
B_4		12.40	12.63	12.52		12.57	12.98	12.78	
S Mean		9.83	10.20			10.48	10.57		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.193	NS	10.43		0.240	NS	11.17	
B		0.336	1.04	9.63		0.295	0.91	9.71	
S		0.195	NS	9.56		0.243	NS	9.32	
F x B		0.476	NS			0.417	NS		
F x S		0.276	NS			0.344	NS		
B x S		0.391	NS			0.486	NS		
F x B x S		0.553	NS			0.688	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: Residual effect of bio char, crop residues and humic acid on copper content (mg kg^{-1}) in seed of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	6.75	7.10	6.92	9.13	7.14	7.62	7.38	9.58
	B_2	7.60	7.78	7.69		7.96	8.30	8.13	
	B_3	10.60	10.77	10.69		11.07	11.14	11.10	
	B_4	11.10	11.38	11.24		11.58	11.85	11.72	
	F x S	9.01	9.26			9.44	9.73		
F_2	B_1	6.71	7.10	6.90	9.08	7.12	7.60	7.36	9.56
	B_2	7.58	7.76	7.67		7.95	8.29	8.12	
	B_3	10.55	10.66	10.61		11.00	11.12	11.06	
	B_4	11.04	11.26	11.15		11.57	11.81	11.69	
	F x S	8.97	9.19			9.41	9.71		
B x S				B Mean		B x S		B Mean	
B_1		6.73	7.10	6.91		7.13	7.61	7.37	
B_2		7.59	7.77	7.68		7.96	8.30	8.13	
B_3		10.58	10.72	10.65		11.04	11.13	11.08	
B_4		11.07	11.32	11.19		11.58	11.83	11.71	
S Mean		8.99	9.22			9.42	9.72		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.219	NS	10.75		0.206	NS	10.54	
B		0.201	0.62	8.64		0.193	0.60	8.00	
S		0.165	NS	7.88		0.167	NS	7.55	
F x B		0.284	NS			0.274	NS		
F x S		0.234	NS			0.236	NS		
B x S		0.330	NS			0.334	NS		
F x B x S		0.467	NS			0.473	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 16: Residual effect of bio char, crop residues and humic acid on copper content (mg kg^{-1}) in haulm of black gram

RDF	Bio char, Paddy straw and Greenleaf manure	*Rabi* - 2020				*Rabi* - 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	5.36	5.66	5.51	7.58	5.64	5.97	5.81	7.86
	B_2	6.09	6.24	6.17		6.36	6.54	6.45	
	B_3	9.02	9.16	9.09		9.27	9.44	9.35	
	B_4	9.44	9.68	9.56		9.68	9.97	9.83	
	F x S	7.48	7.69			7.74	7.98		
F_2	B_1	5.33	5.64	5.48	7.56	5.63	5.91	5.77	7.83
	B_2	6.07	6.22	6.14		6.32	6.51	6.42	
	B_3	9.01	9.14	9.08		9.25	9.43	9.34	
	B_4	9.43	9.66	9.54		9.67	9.96	9.81	
	F x S	7.46	7.66			7.72	7.95		
B x S				B Mean		B x S		B Mean	
B_1		5.35	5.65	5.50		5.64	5.94	5.79	
B_2		6.08	6.23	6.16		6.34	6.53	6.43	
B_3		9.01	9.15	9.08		9.26	9.43	9.35	
B_4		9.43	9.67	9.55		9.68	9.96	9.82	
S Mean		7.47	7.67			7.73	7.96		
Factor		SEm±	CD (p = 0.05)	CV (%)		SEm±	CD (p = 0.05)	CV (%)	
F		0.181	NS	11.73		0.186	NS	11.59	
B		0.264	0.81	11.10		0.257	0.79	11.36	
S		0.111	NS	8.20		0.104	NS	8.51	
F x B		0.374	NS			0.364	NS		
F x S		0.157	NS			0.147	NS		
B x S		0.222	NS			0.208	NS		
F x B x S		0.315	NS			0.295	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, zinc and copper content in plant was recorded with the residual effect of B_4- Green leaf manure @ 6 t ha^{-1} at all the growth stages of *rabi* black gram, whereas, significantly higher manganese content was recorded with residual effect of B_4- Green leaf manure @ 6 t ha^{-1} and S_2 - Humic acid @ 30 kg ha^{-1} in *rabi* black gram during two years of study.

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