Effect Of Fertilizers And Humic Acids On Soil Micro Nutrients Of Foxtail Millet Crop

Abstract: Humic acids is an important soil component that can improve nutrient availability and impact on other important chemical, biological, and physical properties of soils. The ecological benefits of Humic acids are diverse and represent profitable and effective solutions for environmental problems and preservation of the environment. It can be integrated into the soils in the form of manure; it improves the physico chemical and biological properties of the soil. A field experiment was conducted at the College Farm, Agricultural College, Mahanandi, ANGRAU during kharif & rabi seasons of 2020-21 and 2021-22. The experimental soil was sandy loam in texture with a pH of 7.52, an Electrical Conductivity (EC) of 0.42 dS/m, 0.32% Organic Carbon (OC), low available nitrogen (175 kg ha-1), medium phosphorus (P) at 18.48 kg ha-1, high potassium (K) at 580 kg ha-1, and sufficient zinc (Zn) status at 0.85 ppm. The experiment was laid out in split plot design with three replications with four main plots and six sub plots total twenty four treatments. After critical observation of the study, available iron, Zinc, Copper and Manganese contents in soil revealed that there was significant difference between the subplots that received different levels of Humic acids but main plots that received different levels of inorganic fertilizers and their interaction was found to be non significant at panicle initiation and harvest stages of foxtail millet crop in two *kharif* seasons of 2020 and 2021. Similar results were recorded in soil Copper and Manganese contents during two kharif seasons of Foxtail millet crop. However, the similar trend was followed in succeeding bengalgram crop.

Key words: Foxtail millet-Bengalgram cropping system- Humic acids -In-Organic fertilizers- - Soil Micro nutrients Content.

Introduction:

"Sustenance of soil fertility is the key to crop productivity. Use of chemical fertilizers and organic manures has been found promising in arresting the decline trend in soil-health and productivity through the correction of marginal deficiencies of some secondary and micro-nutrients, micro-flora and fauna and their beneficial influence on physical and biological properties of soil. Integrated nutrient management system can bring equilibrium between degenerative and restorative activities in the soil eco-system" (Upadhyay *et al*., 2011). "Humic substances are generated through organic matter decomposition and employed as soil fertilizers in order to improve soil structure and soil microorganisms. Soil organic matter has been fractionated on the basis of solubility in dilute mineral acid and alkali in to three groups *viz*. fulvic acid, Humic acids and humin. Fulvic acids are soluble in both acid and alkali, Humic acids are soluble in alkali but insoluble in acids and humins are insoluble in both. Fulvic acids are relatively simple in composition and assimilable by plants, are labile in the soil. Humins are highly complex of the three forms and are unavailable to the plants.

Humic acids occupy an intermediate position between these three groups and persist in the soil for a prolonged period so as to be useful to the crop plants" (Ravichandran, 2011).

"Humic acids are organic compounds that play crucial roles in enhancing the qualities of soil, the growth of plants, and other agronomic factors. In recent years, products based on Humic acids have been incorporated into crop production to ensure the agricultural output's continued viability. According to the research that was conducted, HA has the potential to have a beneficial effect on the soil's physical, chemical, and biological properties. These properties include the aggregation and relative proportion of soil particles, the capacity of soil to hold water, cation exchange capacity (CEC), pH, carbon content in the soil, enzymes activity, macronutrients cycling, and availability" (Pooja Bhatt and V K Singh 2022). "Humic acids (HA) producers claim that 1 kg of HA is as much beneficial as 1 tonne of cattle manure because manure needs a lot of time for humidification, the form that can be utilized and assimilated by plants" (Satish Kumar *et al*., 2021).

"Humic acids fraction contains about 60% organic carbon (C), which plays an important role in the growth of soil microorganisms. In addition to C, Humic acids also contain nitrogen (N), oxygen (O), hydrogen (H), and sulfur (S). Humic acids play several important roles such as increase soil physical and biochemical activities by improving structure, texture, water holding capacity (WHC), and microbial population increase soil nutrients availability, especially micronutrients by chelating and co-transporting micronutrients to plants reduce the transportation of toxic heavy metals by precipitating them, thus reducing toxic heavy metals intake by plants" ((Nardi et al., 2017, 2021; Ampong *et al*.,2022).

MATERIAL AND METHODS

A field experiment was conducted at the college farm, Agricultural College, Mahanandi, Andhra Pradesh during *kharif & rabi* seasons of 2020-21 and 2021-22. The experimental site was geographically situated at 15.51^0 N latitude, 78.61^0 E longitude with an altitude of 233.48 meters above the mean sea level in Scarce Rainfall Zone of Andhra Pradesh. The experimental soil was sandy loam in texture with 7.52 pH, 0.42 dsm^{-1} EC, 0.32 % OC, low available N (175 kg ha-1), medium in P (18.48 kg ha^{-1}), high in K (580 kg ha^{-1}) and sufficient in Zn status (0.85 ppm). The experiment was laid out in Split plot design with three replications with four main plots and six sub plots total twenty four treatments viz., Control (M_1), 50 % RDF (M_2) , 75 % RDF (M_3) and 100% RDF (M_4) as main plots and six Humic acids levels to foxtail millet crop comprising of No Humic acids application (S_1), 10 kg ha-1 Humic acids as soil application (S_2) , 20 kg Humic acids as soil application (S3), 0.2% of foliar application of Humic acids (S_4), 10 kg ha-1Humic acids as soil application + 0.2% foliar application of Humic acids (S_5) and 20 kg ha-1Humic acids as soil application + 0.2% foliar application of Humic acids (S6) as sub- plot treatments. These treatments were imposed to foxtail millet crop during kharifseason and bengalgram crop during rabi season.

The 100% RDF for foxtail millet crop is 40:20:0 kg N, P_2O_5 and K_2O ha^{-1}. P fertiliser was applied as basal doses and half of the N was applied as basal and other half at 30 DAS. Humic acids was applied as basal as per treatments mentioned. Available nitrogen in soil was estimated by alkaline permanganate method using macro Kjeldahl distillation unit (Subbiah and Asija, 1956). Available phosphorus in the soil was extracted with 0.5 M NaHCO3 buffered at pH 8.5 and the phosphorus in the extract was estimated by ascorbic acid method using spectrophotometer at 660 nm (Watanabe and Olsen, 1965). Available Potassium was extracted with neutral normal ammonium acetate and estimated with the help of flame photometer (Jackson, 1973). Available zinc, iron, manganese and copper in the soils were determined in DTPA extract, using atomic absorption spectrophotometer (Lindsay and Norvell, 1978).

RESULTS AND DISCUSSION

Available Micro-nutrients

1 Iron

After critical observation of the study, available iron content in soil presented in tables 1 & 2 revealed that there was significant difference between the subplots that received different levels of Humic acids but main plots that received different levels of inorganic fertilizers and their interaction was found to be non significant at panicle initiation and harvest stages of foxtail millet crop in two *kharif* seasons of 2020 and 2021. Though the main plots that receives different doses of fertilizers have not shown significant influence on soil iron content, the minimum soil iron content was recorded in control, where there is no fertilizers were applied (M1-6.24, 6.21mg kg^{-1} in 2020 and 6.22, 6.19 mg kg^{-1} in2021) at panicle initiation and harvest stages, respectively). Whereas maximum available iron content was recorded in the main plot that received 100% RDF (M_4-6.40, 6.36mg kg^{-1} in 2020 and 6.77, 6.72 mg kg^{-1} in 2021).Increase in available Fe might be due to lowering of pH as a result of decomposition of organics which was known to increase the solubility of metallic elements (Prasad *et al.*, 2010b).

Irrespective of the Humic acids treatments applications to foxtail millet crop, significantly the highest iron at panicle initiation and harvesting stages of crop was recorded in the treatment with 20 kg ha^{-1}Humic acids as soil application+ 0.2% foliar application(S_6-6.51, 6.47mg kg^{-1}in 2020 and 6.93, 6.88 mg kg^{-1} in 2021). However it was on par with the treatment20 kg ha^{-1}Humic acids as soil application (S_3). Significantly lower available iron content was recorded in control (S_1-6.15, 6.12 in 2020 and 6.11, 6.08 mg kg^{-1} in 2021) at panicle initiation and at harvest stages of *kharif* foxtail millet respectively. Humic acids has a good tendency to form chelates with metal ions and the formation of humate-metal ion complexes make them easily available to plants. The formation of humate-Fe complexes might have contributed to increased Fe availability in Humic acids applied plots. Similar results were also reported by Sharif *et al.* (2002), Kumar & Singh (2017) , Manjeera (2020) and Mankotia *et al.*2024.

2. Zinc

Data pertaining to available zinc content presented in tables 3 & 4 revealed that there was significant difference between the subplots that received different levels of Humic acids but main plots that received different levels of inorganic fertilizers and their interaction was found to be non significant at panicle initiation and harvest stages of foxtail millet crop in two *kharif* seasons of 2020 and 2021.

Among the different levels of RDF, the minimum available zinc content was recorded in control (M_1-0.89, 0.88mg kg^{-1} in 2020 and 0.86, 0.85 mg kg^{-1} in 2021) at panicle initiation and harvest stages, respectively. Whereas maximum zinc content was recorded in the main plot that received 100% RDF (M_4-1.02, 1.01mg kg^{-1} in 2020and 1.00, 1.00 mg kg^{-1}in 2021)at panicle initiation and harvest stages, respectively. The available zinc decreased with advancement of crop stage during both the years of study period. The decrease might be attributed to uptake of zinc by the growing plants. Subhalakshmi and Pratapkumarreddy (2017) also concluded that due to precipitation as in soluble sulfides and carbonates.

With increasing levels of Humic acids, significantly the highest zinc content was recorded with treatment S_6(1.03, 1.01mg kg^{-1} in 2020 and 1.01, 1.00mg kg^{-1} in 2021)at panicle initiation and at harvest stages, respectively over control. This treatment was on par with the treatment which receives 20 kg ha^{-1}Humic acids as soil application (S_3). Lower zinc content was recorded in control (S_1-0.86, 0.86 mg kg^{-1} in 2020 and 0.84, 0.83 mg kg^{-1} in

2021) at panicle initiation and at harvest stages, respectively. Humic acids has a good tendency to form chelates with metal ions and the formation of humate-metal ion complexes make them easily available to plants. Increased zinc availability might be attributed due to prevention of formation of immobile and insoluble hydroxides of zinc by Humic acids. Similar results were also reported by Singhal *et al.* (2012), Kumar *et al.* (2012) and Ameta *et al*., (2017) & Kumar & Singh (2017), De Ávila *et al*. (2024).

Similar results were recorded in soil Copper and Manganese contents during two kharif seasons of Foxtail millet crop.

Conclusions: After critical observation of the study, available iron, Zinc, Copper and Manganese contents in soil revealed that there was significant difference between the subplots that received different levels of Humic acids but main plots that received different levels of inorganic fertilizers and their interaction was found to be non significant at panicle initiation and harvest stages of foxtail millet crop in two *kharif* seasons of 2020 and 2021. Similar results were recorded in soil Copper and Manganese contents during two kharif seasons of Foxtail millet crop.

FUTURE LINE OF WORK

Future research may be carried out to consider the potential effects of imposed treatments on Iron, Zinc fractions in soil, to test the treatments in other important cropping systems viz., rice-millet, cereal-pulse *etc.*

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Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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Table 1. Effect of inorganic fertilizers and Humic acids on available iron content (mg kg^{-1}) in soil at panicle initiation stage of Foxtail millet

Sub Plots (Humic acids)	*Kharif 2020*				Mean	*Kharif 2021*				Mean
	Main Plots (In-Organics)					Main Plots (In-Organics)				
	M_1	M_2	M_3	M_4		M_1	M_2	M_3	M_4	
S_1	6.12	6.15	6.16	6.18	**6.15**	6.08	6.11	6.12	6.14	**6.11**
S_2	6.23	6.28	6.32	6.35	**6.30**	6.20	6.86	6.89	6.94	**6.72**
S_3	6.31	6.42	6.55	6.61	**6.47**	6.32	6.98	7.13	7.19	**6.90**
S_4	6.14	6.16	6.16	6.20	**6.17**	6.10	6.12	6.12	6.16	**6.12**
S_5	6.25	6.31	6.37	6.39	**6.33**	6.26	6.89	6.96	6.98	**6.77**
S_6	6.38	6.45	6.56	6.64	**6.51**	6.39	7.00	7.14	7.21	**6.93**
Mean	**6.24**	**6.30**	**6.35**	**6.40**		**6.22**	**6.66**	**6.73**	**6.77**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	0.01		NS		6.5	0.02		NS		7.5
S	0.04		0.11		6.2	0.04		0.13		6.5
M X S	0.02		NS			0.08		NS		
S X M	0.06		NS			0.04		NS		

Main Plots	Sub Plots
M1-Control	S1-0kg/ha
M2-50%RDF	S2-10kg/ha H.A
M3-75%RDF	S3-20Kg/ha H.A
M4-100%RDF	S4-0.2% H.A
	S5-10kg/ha H.A+0.2%
	S6-20kg/ha H.A+0.2%

Table 2.Effect of inorganic fertilizers and humicacidon available iron content (mg kg^{-1}) in soil at harvesting stage of Foxtail millet

Sub Plots (Humic acids)	*Kharif 2020*				Mean	*Kharif 2021*				Mean
	Main Plots (In-Organics)					**Main Plots (In-Organics)**				
	M_1	M_2	M_3	M_4		M_1	M_2	M_3	M_4	
S_1	6.08	6.12	6.13	6.14	**6.12**	6.05	6.08	6.09	6.11	**6.08**
S_2	6.21	6.25	6.28	6.32	**6.27**	6.17	6.83	6.86	6.90	**6.69**
S_3	6.28	6.39	6.52	6.58	**6.45**	6.28	6.92	7.06	7.13	**6.85**
S_4	6.10	6.13	6.13	6.16	**6.13**	6.07	6.09	6.09	6.13	**6.09**
S_5	6.23	6.28	6.34	6.36	**6.30**	6.22	6.86	6.92	6.94	**6.74**
S_6	6.35	6.41	6.53	6.60	**6.47**	6.35	6.94	7.07	7.14	**6.88**
Mean	**6.21**	**6.27**	**6.32**	**6.36**		**6.19**	**6.62**	**6.68**	**6.72**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	0.02		NS		6.5	0.05		NS		6.0
S	0.05		0.15		6.8	0.04		0.13		6.8
M X S	0.06		NS			0.02		NS		
S X M	0.03		NS			0.01		NS		

Main Plots	**Sub Plots**
M1-Control	S1-0kg/ha
M2-50%RDF	S2-10kg/ha H.A
M3-75%RDF	S3-20Kg/ha H.A
M4-100%RDF	S4-0.2% H.A
	S5-10kg/ha H.A+0.2%
	S6-20kg/ha H.A+0.2%

Table 3. Effect of inorganic fertilizers and Humic acids on available zinc content (mg kg^{-1}) in soil at panicle initiation stage of Foxtail millet

Sub Plots (Humic acids)	*Kharif 2020* Main Plots (In-Organics)				Mean	*Kharif 2021* Main Plots (In-Organics)				Mean
	M_1	**M_2**	**M_3**	**M_4**		**M_1**	**M_2**	**M_3**	**M_4**	
S_1	0.85	0.85	0.87	0.87	**0.86**	0.83	0.83	0.85	0.84	**0.84**
S_2	0.86	0.89	0.94	1.05	**0.94**	0.85	0.88	0.93	1.04	**0.93**
S_3	0.88	0.98	1.05	1.11	**1.01**	0.87	0.97	1.04	1.10	**1.00**
S_4	0.87	0.87	0.88	0.88	**0.88**	0.83	0.83	0.84	0.84	**0.84**
S_5	0.91	0.90	0.97	1.09	**0.97**	0.90	0.89	0.96	1.08	**0.96**
S_6	0.94	0.98	1.08	1.12	**1.03**	0.90	0.97	1.07	1.11	**1.01**
Mean	**0.89**	**0.91**	**0.97**	**1.02**		**0.86**	**0.90**	**0.95**	**1.00**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	0.01		NS		7.8	0.01		NS		6.5
S	0.01		0.03		6.4	0.01		0.04		6.2
M X S	0.02		NS			0.01		NS		
S X M	0.03		NS			0.02		NS		

Main Plots	Sub Plots
M1-Control	S1-0kg/ha
M2-50%RDF	S2-10kg/ha H.A
M3-75%RDF	S3-20Kg/ha H.A
M4-100%RDF	S4-0.2% H.A
	S5-10kg/ha H.A+0.2%
	S6-20kg/ha H.A+0.2%

Table 4.Effect of inorganic fertilizers and Humic acids on available zinc content (mg kg^{-1}) in soil at harvest of Foxtail millet crop.

Sub Plots (Humic acids)	*Kharif 2020* Main Plots (In-Organics)				Mean	*Kharif 2021* Main Plots (In-Organics)				Mean
	M_1	M_2	M_3	M_4		M_1	M_2	M_3	M_4	
S_1	0.84	0.85	0.86	0.87	**0.86**	0.82	0.83	0.84	0.83	**0.83**
S_2	0.85	0.88	0.93	1.04	**0.93**	0.85	0.88	0.93	1.04	**0.92**
S_3	0.87	0.97	1.04	1.10	**1.00**	0.87	0.97	1.04	1.10	**0.99**
S_4	0.86	0.87	0.88	0.88	**0.87**	0.83	0.83	0.84	0.84	**0.84**
S_5	0.90	0.89	0.96	1.08	**0.96**	0.90	0.89	0.96	1.08	**0.95**
S_6	0.93	0.97	1.07	1.11	**1.02**	0.89	0.97	1.07	1.11	**1.01**
Mean	**0.88**	**0.91**	**0.96**	**1.01**		**0.86**	**0.89**	**0.95**	**1.00**	
	SEm ±		**CD (p=0.05)**		**CV (%)**	**SEm ±**		**CD (p=0.05)**		**CV (%)**
M	0.03		NS		7.2	0.01		NS		6.8
S	0.02		0.05		6.1	0.02		0.05		6.4
M X S	0.01		NS			0.01		NS		
S X M	0.02		NS			0.02		NS		

Main Plots	**Sub Plots**
M1-Control	S1-0kg/ha
M2-50%RDF	S2-10kg/ha H.A
M3-75%RDF	S3-20Kg/ha H.A
M4-100%RDF	S4-0.2% H.A
	S5-10kg/ha H.A+0.2%
	S6-20kg/ha H.A+0.2%