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Influence of Zinc, Iron and Manganese Applications on Soil Properties, Protein Content and Sedimentation Value of Wheat

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Micronutrient insufficiency in plants is becoming increasingly common, particularly in cereals crops around the world. These deficits result in a loss of yield as well as deterioration in the nutritional quality of the crops. The experiment was carried out in screen house for Rabi season of 2017-18, Soil Science Department, CCS HAU, Hisar to measure the impact of methods and dosages of zinc (Zn), iron (Fe) and manganese (Mn) application on post-harvest soil characteristics and wheat quality. The findings of this research illustrated that DTPA-extractable Zn and Mn increased significantly with the addition of Zn and Mn, respectively as compared to control. With the application of micronutrients, the sedimentation value and protein content of wheat both significantly increased in comparison to the control. Maximum increase in sedimentation value (54.0) was found when 0.5 % $ZnSO_4$ + 2.5 % urea was applied. Whereas, maximum increase in protein content (12.2%) was observed when 0.5 % $FeSO_4$ + 3 % urea was applied. Overall, quality

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of wheat improved with the application of micronutrients but there was no significant effect of these applications on soil parameters. There was no significant variation in soil pH, soil organic carbon (SOC), electrical conductivity (EC), available nitrogen (N), phosphorus (P), potassium (K) and DTPA-extractable Fe when micronutrients were applied as foliar or basal doses.

Keywords: Fe; micronutrients; Mn; wheat and Zn.

1. INTRODUTION

Wheat is a staple diet for individuals all over the globe. It is India's most vital food grain second only to rice and is grown mostly in the country's northern and northwestern territories. Wheat is raised on 29.72 million hectares in India with a normal yield of 98.61 million tones and a productivity of 33.18 q ha^{-1}. Wheat is grown on over 2.53 million hectares in Haryana, with an average productivity of 46.24 q ha^{-1} and a yield of 11.68 million tones (Anonymous, 2018). The Green Revolution assisted in increasing food production, resulting in a significant reduction in hunger, calories, and protein malnutrition. Micronutrient inadequacies, particularly Zn, Fe, and Mn are triggered by intensive cultivation of high-yielding cultivars with extensive applications of high-analysis N, P, and K supplements [1]. Micronutrient deficits in the rice-wheat cropping system are becoming more prevalent worldwide. Shukla et al. [2] analyzed soil samples to determine the status of micronutrient deficiencies in Haryana and revealed that 15.3%, 21.6%, and 6.1% of Haryana soils were deficient in Zn, Fe, and Mn, respectively. They also stated that Zn inadequacy has diminished by 10.5 percent as a result of prolonged use of zinc sulphate. However, due to very little or no application of micronutrients, Fe and Mn deficit grew significantly. These minerals present in small quantities are taken up by crop resulted into deficiency, limited crop yield and deteriorating soil health. Micronutrient content has decreased over the last decade as a result of persistent micronutrient mining and the usage of micronutrient-free fertilizers [3].

The amount of these nutrients depends on a variety of factors including the soil's ability to deliver these nutrients, the rate of absorption of nutrients to functional areas and the mobility of nutrients within the plants. The chemical form of metal, soil pH, organic matter, type of clay and its content, redox conditions, and root exudates chelators produced in the rhizosphere which facilitate uptake of immobile or relatively less dynamic metals affect the mobility and availability of micronutrients to plants in soil.

2. MATERIALS AND METHODS

2.1 Experiment Location

A pot experiment was carried out in screen house of Soil Science department, CCS HAU, Hisar to evaluate the impact of Zn, Fe, and Mn application on soil attributes and wheat quality parameters during the Rabi season 2017-18. The soil used in the experiment had a neutral reaction, was non-saline and had low organic carbon content. The soil contains 80.54, 7.20 and 174.06 kg ha^{-1} of N, P and K respectively. The DTPA-extractable Zn, Fe and Mn were found 0.49, 2.08 and 2.40 mg kg^{-1}, respectively. The soil had a sandy texture. With three replications and sixteen distinct combinations of Zn, Fe and Mn applications, the experiment was designed using a completely randomized design (CRD). Different treatments of Zn, Fe and Mn were analyzed in different pots.

2.2 Experiment Details

A completely randomized (CRD) design was used to examine the experimental data. Wheat variety WH 1105 was planted on November 29, 2017 and harvested on April 17, 2018. Ten seeds were placed in each pot. After three weeks the pots were thinned with just four plants permitted to grow. Irrigation was applied to the crop on a regular basis depending on its needs. Micronutrients were delivered to the pots as a basal dose (in treatments T_2 and T_{13} to T_{16}) and as a basal dose with foliar spray (T_4) at several stages of the crop, such as CRI, tillering and milking (T_3 and T_5 to T_{12}). $ZnSO_4$, $FeSO_4$ and $MnSO_4$ were used to apply zinc, iron and manganese, respectively. Soil samples were collected and analyzed for different parameters given in table below. Sedimentation value of wheat was determined by using sodium dodecyl sulphate (SDS method) medium for a standard time of settling. Wheat protein content was determined from nitrogen content by it 6.25.

I.e., protein content = nitrogen content x 6.25

Table 1. Treatment detail

Treatment	Nutrients level		
	Zn	**Fe**	**Mn**
T_1	Control	Control	Control
T_2*	2.5 mg Zn kg^{-1} through $ZnSO_4$	5 mg Fe kg^{-1} through $FeSO_4$	5 mg Mn kg^{-1} through $MnSO_4$
T_3**	0.5% $ZnSO_4$ solution	0.5% $FeSO_4$ solution	0.5% $MnSO_4$ solution
T_4	2.5 mg Zn kg^{-1} + 0.5% $ZnSO_4$	5 mg Fe kg^{-1} + 0.5% $FeSO_4$	5 mg Mn kg^{-1} + 0.5% $MnSO_4$
T_5**	0.5% $ZnSO_4$ + 0.2% Urea	0.5% $FeSO_4$ + 0.2% Urea	0.5% $MnSO_4$ + 0.2% Urea
T_6**	0.5% $ZnSO_4$ + 0.5% Urea	0.5% $FeSO_4$ + 0.5% Urea	0.5% $MnSO_4$ + 0.5% Urea
T_7**	0.5% $ZnSO_4$ + 1% Urea	0.5% $FeSO_4$ + 1% Urea	0.5% $MnSO_4$ + 1% Urea
T_8**	0.5% $ZnSO_4$ + 1.5% Urea	0.5% $FeSO_4$ + 1.5% Urea	0.5% $MnSO_4$ + 1.5% Urea
T_9**	0.5% $ZnSO_4$ + 2% Urea	0.5% $FeSO_4$ + 2% Urea	0.5% $MnSO_4$ + 2% Urea
T_{10}**	0.5% $ZnSO_4$ + 2.5% Urea	0.5% $FeSO_4$ + 2.5% Urea	0.5% $MnSO_4$ + 2.5% Urea
T_{11}**	0.5% $ZnSO_4$ + 3% Urea	0.5% $FeSO_4$ + 3 % Urea	0.5% $MnSO_4$ + 3 % Urea
T_{12}**	0.5% $ZnSO_4$ + 0.1% citric acid	0.5% $FeSO_4$ + 0.5% Citric acid	0.5% $MnSO_4$ + 0.5% Citric acid
T_{13}*	2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1}		
T_{14}*	2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1} + 30 mg N kg^{-1}		
T_{15}*	2.5mg Zn kg^{-1} + 5mg Fe kg^{-1} + 5mg Mn kg^{-1}		
T_{16}*	2.5mg Zn kg^{-1} + 5mg Fe kg^{-1} + 5mg Mn kg^{-1} + 30 mg N kg^{-1}		

**Basal application, **foliar spray at CRI, tillering and milking stage*

List 1. List of soil parameters and method used for the study

Sr. No.	Soil parameters	Method
1.	EC and pH	Soil-water suspension (1:2)
2.	Soil texture	International Pipette Method
3.	soil organic carbon	Walkley and Black method
4.	Available nitrogen	Subbiah and Asija method
5.	Available phosphorus	Olsen *et al.* 1954
6.	Available potassium	1N NH_4Oac extractable
7.	Micronutrient (Zn, Fe and Mn)	DTPA-extractable by (AAS)

3. RESULTS AND DISCUSSION

3.1 Effect of Zn, Fe and Mn Application on Soil Properties

Research data analysis showed that DTPA-extractable Zn increased significantly in T_2, T_4 and T_{11} -T_{16} except T_{12} over control. The DTPA-extractable Zn content was relatively higher in the treatments (T_2, T_{13}, T_{14}, T_{15} and T_{16}) where zinc was applied as basal dose as compared to those where it was applied as either alone (T_3) or in combination with urea/citric acid (T_5 to T_{12}) as a foliar spray. Along with it, DTPA-extractable Mn significantly increased under treatments T_{15} and T_{16} compared to control and it was also noticed that treatment T_4 was on par with control. The content of DTPA-extractable Mn was relatively higher in the treatments (T_2 and T_{13} to T_{16}) where manganese was applied as basal dose as compared to those where it was applied as either alone (T_3) or in combination with urea/citric acid (T_5 to T_{12}) as a foliar spray. Dube et al. [4] and Kulandaivel et al. [5] both observed that increasing Zn levels enhanced the available Zn content of soil if experimental soil was low in available Zn. Foliar applications of Zn, Fe and Mn does not have any effect on soil micronutrient content. Similar findings were noticed by Jha et al. [6] and Naga et al. [7].

The application of Zn, Fe and Mn either alone or in combination with each other however, have no significant effect on soil pH, EC, OC, available N, P, K and DTPA-extractable Fe. This might be because adding micronutrients doesn't significantly change the chemical characteristics of soil. Both Sankaranarayanan et al. [8] and Jat et al. [9] reported similar findings. The available P content decreased, but not significantly. This non-significant decrease in the amount of available phosphorus caused by the addition of micronutrients may be the result of an antagonistic interaction between P and Zn with Fe. Similar results were reported by Jat et al. [9], Naga et al. [7], Keram et al. [10], Jha et al. [6] and Kulandaivel et al. [5].

Table 2. Effect of mode and doses of Zn application on soil properties and nutrient content

Treatment	pH	EC ($dS\ m^{-1}$)	OC (%)	N	P	K	Zn	Fe	Mn
				($kg\ ha^{-1}$)			($mg\ kg^{-1}$)		
T_1 – Control	7.2	0.19	0.06	79.84	7.08	173.91	0.43	1.90	2.24
T_2* - 2.5 mg Zn kg^{-1}	7.3	0.18	0.07	78.62	7.00	173.57	0.55	1.88	2.22
T_3**- 0.5% $ZnSO_4$ solution	7.3	0.20	0.08	80.66	7.04	173.82	0.47	1.86	2.28
T_4- T_2* + T_3**	7.1	0.19	0.07	78.45	7.01	172.85	0.57	1.92	2.23
T_5** - 0.5% $ZnSO_4$+ 0.2% Urea	7.2	0.20	0.07	80.94	7.00	173.16	0.42	1.93	2.21
T_6** - 0.5% $ZnSO_4$+ 0.5% Urea	7.3	0.21	0.07	80.85	7.04	173.18	0.45	1.95	2.31
T_7**- 0.5% $ZnSO_4$+ 1% Urea	7.1	0.20	0.06	80.24	7.00	173.64	0.47	1.98	2.34
T_8** -0.5% $ZnSO_4$+ 1.5% Urea	7.3	0.20	0.06	80.28	7.02	173.10	0.46	1.96	2.26
T_9** -0.5% $ZnSO_4$+ 2% Urea	7.2	0.20	0.06	80.25	6.95	172.88	0.46	1.86	2.23
T_{10}**- 0.5% $ZnSO_4$+ 2.5% Urea	7.3	0.19	0.07	80.08	6.97	172.60	0.43	1.84	2.37
T_{11}**-0.5% $ZnSO_4$+ 3% Urea	7.2	0.19	0.06	79.20	6.97	172.30	0.48	1.94	2.21
T_{12}**- 0.5% $ZnSO_4$+ 0.1% citric acid	7.1	0.21	0.07	80.05	6.99	173.76	0.41	1.83	2.25
T_{13}*- 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1}	7.2	0.20	0.06	79.90	6.80	172.78	0.56	2.04	2.33
T_{14}*- 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1} + 30 mg N kg^{-1}	7.2	0.20	0.06	80.96	6.94	173.56	0.54	2.01	2.30
T_{15}*- 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1} + 5mg Mn kg^{-1}	7.3	0.21	0.07	79.62	6.80	173.25	0.52	2.04	2.39
T_{16}*- 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1} + 5mg Mn kg^{-1} + 30 mg N kg^{-1}	7.1	0.19	0.06	80.91	6.68	173.12	0.55	2.00	2.38
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	0.05	NS	NS

**Basal application, **foliar spray at CRI, tillering and milking stage*

Table 3. Effect of mode and doses of Fe application on soil properties and nutrient content

Treatments	pH	EC ($dS\ m^{-1}$)	OC (%)	N	P	K	Zn	Fe	Mn
				($kg\ ha^{-1}$)			($mg\ kg^{-1}$)		
T_1 – Control	7.1	0.18	0.06	80.02	7.18	173.40	0.46	1.98	2.27
T_2* - 5 mg Fe kg^{-1}	7.1	0.20	0.08	80.12	6.80	173.27	0.47	1.88	2.26
T_3**- 0.5% $FeSO_4$ solution	7.1	0.20	0.07	78.46	6.89	172.42	0.45	1.90	2.30
T_4 – T_2* + T_3**	7.2	0.19	0.07	79.90	7.10	173.53	0.46	1.86	2.34
T_5** - 0.5% $FeSO_4$+ 0.2% Urea	7.2	0.19	0.06	80.15	6.86	172.92	0.45	1.84	2.31
T_6** - 0.5% $FeSO_4$+ 0.5% Urea	7.1	0.21	0.08	80.42	6.96	172.32	0.43	1.85	2.26
T_7** - 0.5% $FeSO_4$+ 1% Urea	7.1	0.21	0.07	80.16	7.94	172.58	0.48	1.92	2.29
T_8** - 0.5% $FeSO_4$+ 1.5% Urea	7.2	0.19	0.07	80.11	6.99	173.20	0.44	1.95	2.35
T_9** - 0.5% $FeSO_4$+ 2% Urea	7.1	0.19	0.06	82.70	6.93	173.92	0.47	1.94	2.37
T_{10}** - 0.5% $FeSO_4$+ 2.5% Urea	7.1	0.19	0.06	81.85	7.06	172.98	0.45	1.97	2.31
T_{11}** - 0.5% $FeSO_4$+ 3 % Urea	7.3	0.20	0.07	81.95	7.04	172.29	0.46	1.93	2.35
T_{12}** - 0.5% $FeSO_4$+ 0.5% Citric acid	7.1	0.19	0.07	79.25	6.98	173.21	0.46	1.99	2.32
T_{13}* - 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1}	7.2	0.20	0.07	79.16	7.00	172.34	0.48	2.03	2.28
T_{14} *- 2.5 mg Zn kg^{-1}+ 5 mg Fe kg^{-1} + 30 mg N kg^{-1}	7.2	0.20	0.06	80.76	7.81	173.60	0.47	2.01	2.31
T_{15}* - 2.5mg Zn kg^{-1} + 5mg Fe kg^{-1} + 5mg Mn kg^{-1}	7.1	0.21	0.07	79.56	6.83	173.94	0.46	2.01	2.35
T_{16}* - 2.5mg Zn kg^{-1} + 5mg Fe kg^{-1} + 5mg Mn kg^{-1} + 30 mg N kg^{-1}	7.3	0.20	0.07	80.93	6.85	172.75	0.49	2.00	2.37
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS

**Basal application, **foliar spray at CRI, tillering and milking stage*

3.2 Sedimentation Value and Protein Content as Affected by Application of Zn, Fe and Mn

With combined or sole application of Zn, Fe and Mn significant increase in protein content and sedimentation value was observed as compared to control. Protein content varied from 8 to 12.2% with different treatments. A minimum of protein content was observed when Mn was applied as 0.5% $MnSO_4$ + 0.5% Citric acid and its maximum was observed when 0.5% $FeSO_4$ + 3 % Urea were applied. Micronutrients play a significant role in increasing a plant's metabolic and physiological activity because they influence the activities of carbonic anhydrase and dehydrogenase, stabilize ribosomal fractions, produce cytochrome and may have contributed to a greater uptake of nitrogen by the plant and its distribution to various plant parts, including grains. Increased nitrogen content resulted in higher protein content since nitrogen is a crucial component of protein. These findings and those of Pingoliya et al. [11] are highly congruent. Similar observations were also been reported by Paramesh et al. [12], Malakouti [13], Wang et al. [14] and Bameri et al. [15], Zeidan et al. [16] Potarzycki and Grzebisz [17] and Zhang et al. [18].

Table 4. Effect of mode and doses of Mn application on soil properties and nutrient content

Treatments	pH	EC (dS m^{-1})	OC (%)	N	P	K	Zn	Fe	Mn
				(kg ha^{-1})			(mg kg^{-1})		
T_1 – Control	7.3	0.19	0.07	79.63	7.13	173.56	0.45	1.93	2.26
T_2* - 5 mg Mn kg^{-1}	7.2	0.20	0.07	80.14	6.98	172.35	0.46	1.96	2.31
T_3** - 0.5% $MnSO_4$ solution	7.2	0.19	0.06	79.91	6.94	172.61	0.48	1.88	2.29
T_4 – T_2* + T_3**	7.2	0.20	0.07	78.30	7.03	172.25	0.43	1.90	2.37
T_5** - 0.5% $MnSO_4$ + 0.2% Urea	7.1	0.19	0.06	78.49	7.10	173.76	0.44	1.91	2.32
T_6** - 0.5% $MnSO_4$ + 0.5% Urea	7.1	0.19	0.07	79.47	6.86	173.60	0.47	1.95	2.33
T_7** - 0.5% $MnSO_4$+ 1% Urea	7.1	0.20	0.07	78.13	6.99	172.53	0.43	1.87	2.29
T_8** - 0.5% $MnSO_4$+ 1.5% Urea	7.1	0.19	0.07	79.39	6.93	173.34	0.45	1.92	2.34
T_9** - 0.5% $MnSO_4$ + 2% Urea	7.2	0.20	0.07	80.24	7.93	172.95	0.47	1.91	2.28
T_{10}** - 0.5% $MnSO_4$ + 2.5% Urea	7.1	0.20	0.06	80.59	7.08	172.46	0.44	1.96	2.36
T_{11}** - 0.5% $MnSO_4$ + 3 % Urea	7.1	0.21	0.06	79.61	6.92	172.71	0.46	1.85	2.33
T_{12}** - 0.5% $MnSO_4$ + 0.5% Citric acid	7.2	0.20	0.07	79.46	7.10	173.30	0.47	1.90	2.31
T_{13}* - 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1}	7.1	0.20	0.07	80.22	6.77	172.23	0.49	2.03	2.30
T_{14}* - 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1} + 30 mg N kg^{-1}	7.1	0.21	0.06	80.45	6.71	173.26	0.48	2.01	2.35
T_{15}* - 2.5mg Zn kg^{-1} + 5mg Fe kg^{-1} + 5mg Mn kg^{-1}	7.2	0.20	0.07	79.46	7.83	173.61	0.47	2.05	2.48
T_{16}* - 2.5mg Zn kg^{-1} + 5mg Fe kg^{-1} + 5mg Mn kg^{-1} + 30 mg N kg^{-1}	7.3	0.21	0.06	80.68	6.77	172.94	0.49	2.04	2.46
CD (p = 0.05)	NS	NS	NS	NS	NS	NS	NS	NS	0.11

**Basal application, **foliar spray at CRI, tillering and milking stage*

Table 5. Effect of mode and doses of Zn application on sedimentation value and protein content (%) in wheat

Treatment	Sedimentation value	Protein Content
T_1 – Control	37.2	8.7
T_2* - 2.5 mg Zn kg^{-1}	41.7	8.9
T_3**- 0.5% $ZnSO_4$ solution	45.1	9.1
T_4 - T_2* + T_3**	42.5	9.2
T_5** - 0.5% $ZnSO_4$ + 0.2% Urea	40.0	9.7
T_6** - 0.5% $ZnSO_4$ + 0.5% Urea	47.8	10.0
T_7**- 0.5% $ZnSO_4$ + 1% Urea	49.0	10.8
T_8** -0.5% $ZnSO_4$ + 1.5% Urea	43.3	11.1
T_9** -0.5% $ZnSO_4$ + 2% Urea	50.1	11.3
T_{10}**- 0.5% $ZnSO_4$ + 2.5% Urea	54.0	11.8
T_{11}**-0.5% $ZnSO_4$ + 3% Urea	52.7	12.1
T_{12}**- 0.5% $ZnSO_4$ + 0.1% citric acid	50.2	8.1
T_{13}*- 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1}	51.3	9.0
T_{14}*- 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1} + 30 mg N kg^{-1}	48.2	9.1
T_{15}*- 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1} + 5 mg Mn kg^{-1}	46.6	8.9
T_{16}*- 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1} + 5 mg Mn kg^{-1} + 30 mg N kg^{-1}	49.1	9.3
CD (p = 0.05)	4.7	1.0

**Basal application, **foliar spray at CRI, tillering and milking stage*

Table 6. Effect of mode and doses of Fe application on sedimentation value and protein content (%) in wheat

Treatments	Sedimentation value	Protein Content
T_1 – Control	37.9	8.9
T_2* - 5 mg Fe kg^{-1} through $FeSO_4$	40.5	8.9
T_3**- 0.5% $FeSO_4$ solution	45.1	9.0
T_4 – T_2* + T_3**	42.6	9.1
T_5** - 0.5% $FeSO_4$ + 0.2% Urea	39.8	9.6
T_6** - 0.5% $FeSO_4$ + 0.5% Urea	46.3	9.9
T_7** - 0.5% $FeSO_4$ + 1% Urea	45.7	10.5
T_8** - 0.5% $FeSO_4$ + 1.5% Urea	49.1	10.7
T_9** - 0.5% $FeSO_4$ + 2% Urea	48.0	11.3
T_{10}** - 0.5% $FeSO_4$ + 2.5% Urea	53.0	11.7
T_{11}** - 0.5% $FeSO_4$ + 3 % Urea	52.3	12.2
T_{12}** - 0.5% $FeSO_4$ + 0.5% Citric acid	44.8	8.3
T_{13}* - 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1}	51.1	9.1
T_{14} *- 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1} + 30 mg N kg^{-1}	48.0	9.3
T_{15}* - 2.5mg Zn kg^{-1} + 5mg Fe kg^{-1} + 5mg Mn kg^{-1}	50.4	9.0
T_{16}* - 2.5mg Zn kg^{-1} + 5mg Fe kg^{-1} + 5mg Mn kg^{-1}+ 30 mg N kg^{-1}	47.9	9.3
CD (p = 0.05)	4.7	1.0

**Basal application, **foliar spray at CRI, tillering and milking stage*

Table 7. Effect of mode and doses of Mn application on sedimentation value and protein content (%) in wheat

Treatments	Sedimentation value	Protein Content
T_1 – Control	38.6	8.8
T_2* - 5 mg Mn kg^{-1}	42.9	8.8
T_3** - 0.5%$MnSO_4$ solution	45.4	8.9
T_4 – T_2* + T_3**	41.3	9.3
T_5** - 0.5% $MnSO_4$ + 0.2% Urea	40.8	9.8
T_6** - 0.5% $MnSO_4$ + 0.5% Urea	39.7	10.1
T_7** - 0.5% $MnSO_4$ + 1% Urea	45.1	10.6
T_8** - 0.5% $MnSO_4$ + 1.5% Urea	44.3	10.9
T_9** - 0.5% $MnSO_4$ + 2% Urea	47.2	11.4
T_{10}** - 0.5% $MnSO_4$ + 2.5% Urea	52.6	11.6
T_{11}** - 0.5% $MnSO_4$ + 3 % Urea	51.2	11.9
T_{12}** - 0.5% $MnSO_4$ + 0.5% Citric acid	50.3	8.0
T_{13}* - 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1}	46.7	8.9
T_{14}* - 2.5 mg Zn kg^{-1} + 5 mg Fe kg^{-1} + 30 mg N kg^{-1}	50.8	9.3
T_{15}* - 2.5mg Zn kg^{-1} + 5mg Fe kg^{-1} + 5mg Mn kg^{-1}	51.3	8.8
T_{16}* - 2.5mg Zn kg^{-1} + 5mg Fe kg^{-1} + 5mg Mn kg^{-1} + 30 mg N kg^{-1}	49.0	9.2
CD (p = 0.05)	4.7	1.0

**Basal application, **foliar spray at CRI, tillering and milking stage*

Sedimentation value varied from 37.2 to 54.0 with different treatments. The sedimentation value was lowest in control and was at its highest when 0.5% $ZnSO_4$ + 2.5% Urea were applied. A similar set of findings was also published by Hansch and Mendel [19], Zhang et al. [20], Shewry et al. [21] and Warechowska et al. [22,23-26].

4. CONCLUSION

This study concluded that micronutrient applications had no significant effect on soil properties like soil pH, EC, OC, available N, P and K. By applying Zn, Fe and Mn separately or in combination, grain protein content and sedimentation value both significantly increased when compared to control. The content of Zn and Mn in soil also rose significantly with their respective treatments as compared to the control.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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