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Jay Nath Patel
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Mukesh Kumar
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Vivek
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Adesh Singh
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

PK Singh
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Yogesh Kumar
Department of Soil Science and Agril. Chemistry, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Corresponding Author
Jay Nath Patel
Department of Agronomy, Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut, Uttar Pradesh, India

Application of micronutrients and their methods of delivery on the physical characteristics of the soil and the availability of nutrients after harvest of wheat crop

Jay Nath Patel, Mukesh Kumar, Vivek, Adesh Singh, PK Singh and Yogesh Kumar

Abstract
A field experiment was conducted during the *Rabi* seasons of 2020-21 and 2021-22, to evaluate the effect of micronutrients and their application modes on soil physical property and availability of different nutrients after harvest of wheat crop [*Triticum aestivum* (L.)] at the Crop Research Centre of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut (U.P.). The experiment was laid out in factorial RBD design, where four methods of micronutrients application were assigned *viz*; soil application, seed priming, foliar application and seed priming+ foliar application with three micronutrients namely-zinc, manganese and boron and was replicated thrice. After two year of experiment results showed no significant impact on value of available nitrogen, phosphorus, potash and sulphur, while significantly higher availability of zinc was found in zinc treated plots, manganese founds in manganese treated plots and boron in boron treated plots with soil application. The scrutiny of data showed that the different micronutrients and their application modes had no significant impact on pH, EC and organic carbon of soil. This study demonstrated the importance of application of micronutrients in maintaining micronutrients availability in soil for sustainable crop production of wheat crop.

Keywords: Soil application, seed priming, foliar application, zinc, manganese, boron, wheat

Introduction

Wheat (*Triticum aestivum* L.) is a major food crop in the world, which plays an important role in ensuring food security. In the year of 2021-22, globally wheat was grown in an area of about 222.62 million hectares, producing 779 million metric tons and productivity of 3.49 Metric tons per hectare (Anonymous 2021-22) [2]. It is now understood that when crops are cultivated in succession, the overall fertiliser requirements of the cropping sequence take precedence over those of the individual crops. The majority of the time, farmers must have prior knowledge of the soil fertility condition and the nutrient needs of a certain crop in order to apply fertilisers. Micronutrients are essential for the sustainable cultivation of crops in India. According to numerous studies, micronutrients plays a significant impact in increasing the effectiveness of NPK use even if they are only required in trace levels (Shukla *et al*., 2009) [21]. In wheat, micronutrients significantly affect dry matter, grain yield and straw yield (Asad and Rafique, 2000) [4]. Even a single key micronutrient deficiency has the potential to disrupt plant growth processes and significantly lower crop production (Tripathi *et al*., 2015) [27]. Application of zinc, boron, and manganese has been reported to boost cereals growth and yield (Ullah *et al*., 2018) [28].

Micronutrients are as important to plant nutrition as primary and secondary nutrients, though plants do not require as much of them. They play major role in plant growth like protein synthesis, improving seed quality, cell division and pollen tube growth. Deficiency of micronutrients during the last three decades has grown in both, magnitude and extent because of increased use of high analysis fertilizers, use of high yielding crop varieties and increase in cropping intensity. The deficiency of Zn, B and Fe are 49%, 33% and 12%, respectively in Indian soils (Singh *et al*., 2006) [23]. The soil's capacity to provide vital nutrients to developing plants is a key factor in determining its long-term productivity. Nutrient deficiencies are now a significant barrier to soil stability, production, and sustainability. The kind of mineral present and the degree of weathering processes affect the micronutrient levels of a soil and the availability of those nutrients to plants. Recent years have seen an increase in the unbalanced use of chemical fertilizers, which has led to multiple nutritional shortages, especially in micronutrients, declining soil fertility, and unsustainable agricultural yields. Due to the increased productivity of the crops, the native soils have begun depleting their nutrient reserves and the crops started responding to application of micronutrient fertilizers (Sidhu and Sharma, 2010) [22].

Numerous researches revealed that despite balanced fertilization with nitrogen (N), phosphorus (P), and potassium (K), the factor productivity of different crops decreased. The quantity and quality of crops can be significantly impacted by the soil's micronutrient content. The key factor influencing changes in the status of accessible micronutrients in soil is changes in basic soil properties including pH, electrical conductivity (EC), and soil organic carbon (SOC) concentration under various nutrient management strategies. In addition to soil qualities like pH, calcium carbonates (CaCO3), organic matter, and CEC, it has been found that the soil microenvironment has a significant impact on the availability of soil micronutrients (Wei *et al.*, 2006) [29]. Zinc (Zn), iron (Fe), and manganese (Mn) are all readily available in soil due to soil organic matter, but copper (Cu) is not as readily available due to soil organic matter (Aulakh and Mahi, 2005; Chaudhary and Narwal, 2005; Li *et al.*, 2007) [5, 6, 15]. The availability of micronutrients and their uptake by crops are also impacted by the interactions between other macronutrients and micronutrients in soil. Application of N, P, and K fertilizers at the proper rates can improve the availability of Cu, Zn, and Mn in the soil as well as the concentrations of Cu, Zn, Fe, and Mn in wheat (Li *et al.*, 2007) [15].

In order to provide readily available micronutrients for crop productivity, maintaining or increasing SOM is crucial. Micronutrient supplementation is necessary due to the fact that depletions in available micronutrient status under unfertilized as well as NPK treated plots suggested that these nutrients were used from the soil to meet the requirements of crops. The impact of soil fertility on the uptake of micronutrients from soil and their transfer from tissues to grains is not well documented, and little attention has been dedicated to micronutrients in response to various fertilizations strategies. Zinc is essential for the growth and operation of chloroplasts. Zinc deficiency in plants reduces growth, stress tolerance and chlorophyll synthesis (Kawachi *et al.*, 2009; Lee *et al.*, 2010) [12, 14]. It has been proposed that adding manganese fertilizers to the soil can be a useful strategy for addressing manganese deficiency, but only if the pH of the soil is also adjusted (White and Greenwood, 2013) [30]. Therefore, it can be claimed that the ideal quantity of micronutrients is required to prevent their toxicity for wheat crop. The micronutrients required only in very small quantity and are essential as in low level for completion of plants life cycle, while when it's got excess or high amount it becomes the toxic for plant growth and development.

Soil fertility is the primary limiting factor which influences production under intensive crop cultivation. Introduction of exhaustive high yielding varieties and hybrids in many crops increasing the use of high analysis chemical fertilizers devoid of micronutrients and inadequate application of organic manures due to scarcity has resulted in wide spread micronutrient deficiency and nutrient imbalance which adversely affected yield of many crops. Therefore, it is essential to supply macro and micro nutrients in a balanced ratio in required quantity for obtaining higher yield. These micronutrients can be added to crop through soil fertilization, foliar sprays and seed treatment. Each method has the potential to affect plant micronutrient nutrition both in the treated plant directly and in the progeny plants through enrichment of the seeds by micronutrient treatment of the parent. Foliar applications of micronutrient sprays prove to be best to achieve both Savithri *et al.*, 1999 [20]. Foliar application has been proved to avoid the problem of leaching out in soils and prompts a quick reaction in the plant. Foliar application of Zn and Fe brings the greatest benefit in comparison with addition to soil where they become less available Odell 2004 [18].

Materials and Methods

Site and soil

Table 1: Physicochemical properties of the experimental soil before commencing the study

Particulars	Values		Method adopted
	2020-21	2021-22	
Sand (%)	62.14	61.92	Hydrometer Method
Silt (%)	20.69	20.59	
Clay (%)	18.45	18.37	
Textural class	Sandy loam	Sandy loam	Triangular basis
Soil pH (1:2.5 soil water)	7.61	7.63	pH meter (Jackson, 1973) [33]
Organic carbon (g kg^{-1})	4.53	4.57	Walkley and Black (1934) method
EC (dS/m at 25^0C) (1:2.5 soil: water)	0.32	0.33	EC meter
Available nitrogen (kg ha^{-1})	217.89	218.23	Alkaline potassium permanganate method
Available phosphorus (kg ha^{-1})	12.49	12.54	Olsen's method
Available potassium (kg ha^{-1})	223.45	224.73	1 N NH_4 OAC Extraction Method
Available sulphur (kg ha^{-1})	13.39	13.75	$CaCl_2$ extractable turbidimetric determination of available sulphur
Available zinc (mg kg^{-1})	0.87	0.89	DTPA extractant and estimated on AAS
Available manganese (mg kg^{-1})	1.53	1.55	
Available boron (mg kg^{-1})	0.69	0.70	Extracted by hot water and boron in the extract was determined by Azomethine-H colour method

The present field experiment on application of micronutrients and their method of delivery on the physical characteristics of the soil and the availability of nutrients of wheat crop was conducted at CRC farm of Sardar Vallabhbhai Patel

University of Agriculture and Technology, Meerut during *rabi* season of year 2020-21 and 2021-22. Geographically, experimental site (Modipuram, Meerut) is located at $29^{0}06'$ North latitude and $77^{0}70'$ East longitude and altitude of about 228 meters (748.03 feet) above from mean sea level in Indo-gangetic regions of Uttar Pradesh. The subtropical, semi-arid climate of this area is marked by hot summers and bitterly frigid winters. The average amount of annual precipitation in Meerut is 745 mm. The region's average maximum temperature ranges from 43^{0} to 45^{0} Celsius during the summer, while very cold temperatures and frost are possible from 15 December to 15 February. Minimum temperature 4.9 °C was recorded in 52nd week in December month during 2020 (1st year crop) and 4.7 °C in 3rd week in January month during 2022 (2nd year crop) whereas, the Maximum temperature 38.26 ^{0}C was recorded in 15th week in April month during 2020 (1st year crop) and 41.2 ^{0}C in 16th week in April month during 2022 (2nd year crop), respectively. The maximum relative humidity was 94.86% in 2nd week in January month during 2021 (1st year crop) and 92.6% in 3rd week in January month of 2022 (2nd year crop), respectively. The initial soil samples from surface (0–15 cm) and sub-surface (15-30 cm) were analyzed for mechanical composition (Sand, slit and clay), pH, electric conductivity (EC), organic carbon (OC) and available micronutrients following standard procedures. The physicochemical properties of the initial soil under study are presented in Table 1.

Experimental design and treatments

Field experiment was conducted during the Rabi seasons of 2020-21 and 2021-22, to investigate the effect of micronutrients and their application modes on soil physical property and availability of nutrient in wheat [*Triticum aestivum* (L.)]. The treatments selected for this study consisted of Four methods of micronutrient application were assign under main plots *viz*; Soil application, Seed priming, Foliar application and Seed priming+ foliar application, and micronutrient application were used: Zinc, Manganese and Boron were assigned to subplots and replicated thrice in factorial RBD design. Every plot of the experimental crop was treated with equal amount of nutrients, at the rate 150, 60, and 60 kg of N, P, and K per hectare. The treatments details are as following:-

Table 2: Details of treatments

S.N.	Factor A (Application modes)	S.N.	Factor B (Micronutrients)
1.	Soil application	1.	Zinc
2.	Seed priming	2.	Manganese
3.	Foliar application	3.	Boron
4.	Seed priming + foliar application		

Treatment combinations

T_1 = Soil application of zinc @ 5 kg ha^{-1} by $ZnSO_4$
T_2 = Soil application of manganese @ 3 kg ha^{-1} by $MnSO_4$
T_3 = Soil application of boron @ 1 kg ha^{-1} by Borax
T_4 = Seed priming with 0.5 M zinc solution of $ZnSO_4$
T_5 = Seed priming with 0.1 M manganese solution of $MnSO_4$
T_6 = Seed priming with 0.01 M boron solution of Borax
T_7 = Foliar application of zinc by $ZnSO_4$ @ 0.5% at booting and anthesis stage
T_8 = Foliar application of manganese by $MnSO_4$ @ 0.5% at booting and anthesis stage
T_9 = Foliar application of boron by Borax @ 0.2% at booting and anthesis stage
T_{10} = Seed priming with 0.5 M zinc solution of $ZnSO_4$ + foliar application of zinc by $ZnSO_4$ @ 0.5% at anthesis stage
T_{11} = Seed priming with 0.1 M manganese solution of $MnSO_4$ + foliar application of manganese by $MnSO_4$ @ 0.5% at anthesis stage
T_{12} = Seed priming with 0.01 M boron solution of Borax + foliar application of boron by Borax @ 0.2% at anthesis stage

Soil analysis

The pH was determined with the help of glass electrode of a pH meter in 1:2.5 soils: water suspension Method No. 21(b), USDA Hand Book No. The EC was determined with the help of glass electrode of an EC meter in 1:2.5 soils: water suspension Method No.4, USDA Hand Book No. 60. Organic carbon in soil was determined by Walkely and Black's rapid titration method described by Jackson (1973) [33] expressed in (per cent).

Calculation of Available NPK

(a) Available Nitrogen

Available nitrogen was estimated by alkaline permanganate ($KMnO_4$) method where the organic matter in soil is oxidized with hot alkaline $KMnO_4$ Solution. The ammonia evolved during oxidation is distilled and trapped in boric acid mixed indicator solution. The amount of NH3 trapped is estimated by titrating with standard acid.

(b) Available phosphorus

The available phosphorus content of soil was determined by the method described by Olsen method, 2.5 gm. of dried soil sample containing pinch of Draco G-60 was extracted with 50ml of 0.5 M $NaHCO_3$ (PH 8.5) for 30 minutes. 5 ml of filtrate was taken in 25 ml volumetric flask; 2-3 drops of p-nitro phenol indicator added which develop yellow color. After that 5 N H2SO4 drop by drop was added until yellow color disappear to acidify up to 5 pH. 4 ml of ascorbic acid solution was added to the flask and volume was made.

Available phosphorus (kg ha^{-1}) = ppm of P calculated from standard curve x dilution factor x 2.24.

(c) Available potassium

The neutral normal ammonium acetate was determined using flame photometer. 5 gm of processed soil was taken in a 150 ml conical flask and extracted with 25 ml of neutral normal ammonium acetate solution.

Available potassium (kg ha^{-1}) = ppm K x dilution factor x 2.24.

(d) Available zinc and manganese

Available zinc and manganese was estimated by DTPA as an extranet and their concentration was read on Atomic Absorption Spectrophotometer (GBC-Avanta PM Model).

(e) Available Boron

Available boron was estimated in the soil by boiling with water directly on a hot plate. Use of azomethine–H in place of carmine or curcumin has further simplified the determination of hot-water soluble boron.

Statistical Analysis

Data for each parameter over two year period was subjected to analysis of variance using a factorial RBD design with arrangement according to OPSTAT. Treatment means were compared using least significant difference test at $p \leq 0.05$.

Results and Discussion

Changes in soil properties

pH, EC and Organic carbon

The scrutiny of data showed that the different treatment had no significant impact on pH, EC and organic carbon of soil. Among the methods of micronutrient application, micronutrient applied through soil application recorded slightly higher organic carbon and lower pH and EC of soil followed by foliar application, seed priming and seed priming + foliar application. But the differences between highest and lowest value were not beyond the significant limit. Micronutrient applied through seed priming obtained the highest pH in both years of experiment which were followed by seed priming+ foliar application> foliar application> soil application. In case of EC measurement seed priming+ foliar application has the highest value among the other treatments. However, the impact of different modes of micronutrient application was found non-significant during the years of inquiry.

Table 3: Effects of micronutrients and their application modes on physio-chemical properties of soil after harvest of wheat crop

Treatments	pH		E.C. (dSm^{-1})		Organic carbon ($g\ kg^{-1}$)	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Application modes						
Soil Application	7.63	7.64	0.34	0.36	4.50	4.52
Seed Priming	7.68	7.67	0.35	0.37	4.36	4.38
Foliar Application	7.67	7.65	0.35	0.35	4.42	4.43
Seed Priming + Foliar Application	7.67	7.66	0.37	0.38	4.39	4.39
SEm±	0.16	0.16	0.01	0.01	0.09	0.09
CD (P= 0.05)	NS	NS	NS	NS	NS	NS
Micronutrients						
Zinc	7.66	7.65	0.35	0.37	4.45	4.44
Manganese	7.66	7.66	0.36	0.36	4.42	4.44
Boron	7.67	7.63	0.34	0.36	4.39	4.41
SEm±	0.14	0.14	0.01	0.01	0.08	0.08
CD (P= 0.05)	NS	NS	NS	NS	NS	NS

In case of micro nutrient application, the pH, electrical conductivity and organic carbon in soil after harvest of wheat were not differed statistically due to various treatments. However, it seems from the data that highest pH was found in boron application and lowest values in manganese application. The organic carbon was little higher in zinc application and lowest in boron during both the year of investigation. The electrical conductivity was higher in Zinc application followed by manganese and boron application during both the years of experiment. No interactions effect was found in case of soil pH, EC and organic carbon after harvest of wheat crop during both the years. Keram and Singh (2014) [13] found that the there is no appraisal change in soil pH, EC, organic carbon and $CaCO_3$ due to rational Zn fertilization combined with recommended NPK. Choudhary and Shukla (2003) [7] evaluated different fractions of boron and correlated with soil characteristics in five soil profiles and reported that the available B was positively and significantly correlated with electrical conductivity (EC) of soil. Mathur *et al*. (2011) [17] investigated the distribution of soil boron and its relationship with some soil properties and a significant correlation was found among available boron content and EC, pH and organic carbon.

Changes in available nutrients

A rigorous inspection of the data given in Table 4 reviled that different methods of micronutrient application had no marketable impact on available N, P, K and S in soil during both the year of study. Micronutrient application provides non-significantly availability of N, P, K and S in the soil after harvest of crop. The maximum available N, P, K and S in soil after wheat harvest was noted in soil application. The lowest available N, P, K and S in soil were found in seed priming based micronutrient application followed by seed priming+ foliar application during both the years of investigation. Abbas *et al.* (2009) [32] investigated the uptake of N, P, K and Mn was significantly increased with application of $MnSO_4$. Jat *et al*. (2013) [11] found that the maximum uptake of N, K, S and Zn in wheat was recorded at 9 kg Zn ha^{-1}, Uptake of N, S, K and Zn in wheat grain was 49.3, 50, 51.4 and 53.7% higher and in straw was 44.08, 30, 41.8 and 48.2% higher under 9 kg Zn ha^{-1} over control, respectively.

Table 4: Effects of micronutrients and their application modes on different macro-nutrients (kg ha^{-1}) available in soil after harvest of wheat crop

Treatments	Available N (kg ha^{-1})		Available P (kg ha^{-1})		Available K (kg ha^{-1})		Available S (kg ha^{-1})	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Application modes								
Soil Application	214.59	216.16	12.31	12.38	221.77	223.91	13.28	13.68
Seed Priming	209.73	210.83	11.33	11.43	213.07	214.78	12.57	12.89
Foliar Application	211.76	213.07	11.55	11.66	216.73	218.76	13.24	13.60
Seed Priming + Foliar Application	210.61	211.94	11.49	11.62	215.01	216.16	12.94	13.26
SEm±	4.48	4.51	0.25	0.25	5.11	5.14	0.29	0.29
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS
Micronutrients								
Zinc	213.58	214.91	11.78	11.83	219.24	220.70	13.12	13.47
Manganese	210.64	212.24	11.66	11.78	216.32	218.03	12.98	13.33
Boron	209.30	210.35	11.58	11.64	214.38	216.47	12.92	13.27
SEm±	3.88	3.90	0.22	0.22	4.42	4.45	0.25	0.25
CD (P= 0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Application of micronutrient to the soil did not have any significant effect on the availability of N, P, K and S in the soil. However, among micronutrients application, boron application recorded higher available N, P, K and S in soil after harvest of wheat followed by Zinc and manganese. Even so, the differences unable to touch the significance level during both the years of evaluation. Rana *et al.* (2017) [19] reported that the application of boron @ 1 kg ha^{-1} significantly increased N, P, K, Zn and B concentrations at tillering of wheat. Singh *et al.* (2018) [24] reported that the highest pooled total S uptake (47.1 kg ha^{-1}) and Zn uptake (193 g ha^{-1}) by wheat was recorded with soil test based N, P and K fertilizers along with 20 kg S ha^{-1} and 5.0 kg Zn ha^{-1} over the recommended dose of N. P and K fertilizers. Similar result was found by Soni *et al.* (2000) [25] and Yang *et al.* (2011) [31].

Changes in available micronutrients

Available Zn, Mn & B concentrations varied greatly amongst the different treatments. Application of micronutrient through soil application significantly increased available micronutrient concentration during both the years. During both research years, the changes in micronutrient (Zn, Mn & B) availability brought on by the impacts of different treatments were statistically significant. Ghasal *et al*. (2017) [9] found that the highest uptake of Zn was registered with application of 1.25 kg Zn ha^{-1} through Zn-EDTA as soil application + 0.5% foliar spray at maximum tillering and booting stages which was 21.78% higher over control. Liu *et al*. (2019) [16] reported that the Zn accumulation in grain resulted from pre anthesis remobilization *vs*. post-anthesis shoot uptake depended on Zn availability in soil. Soni *et al.* (2000) [25] found that increasing levels of P increased its concentration in the crop but decreased the concentration of Mn at each levels of Mn application. Similar result was found by Stepien and Wojtkowiak (2016) [26] and Fakir *et al*. (2018) [8].

Table 5: Effects of micronutrients and their application modes on different micro-nutrients (mg kg^{-1}) available in soil after harvest of wheat crop

Treatments	Available Zn (mg kg^{-1})		Available Mn (mg kg^{-1})		Available B (mg kg^{-1})	
	2020-21	2021-22	2020-21	2021-22	2020-21	2021-22
Application modes						
Soil Application	0.93	0.95	1.61	1.64	0.73	0.75
Seed Priming	0.74	0.77	1.42	1.44	0.56	0.58
Foliar Application	0.86	0.87	1.51	1.54	0.67	0.69
Seed Priming + Foliar Application	0.78	0.81	1.47	1.50	0.63	0.63
SEm±	0.02	0.02	0.03	0.03	0.01	0.01
CD (P= 0.05)	0.05	0.05	0.09	0.09	0.04	0.04
Micronutrients						
Zinc	0.88	0.90	1.48	1.50	0.64	0.65
Manganese	0.83	0.84	1.57	1.60	0.61	0.63
Boron	0.79	0.81	1.47	1.50	0.69	0.70
SEm±	0.02	0.02	0.03	0.03	0.01	0.01
CD (P= 0.05)	0.04	0.05	0.08	0.08	0.03	0.04

Significant increase in available Zn in soil was maintained in plots receiving zinc application over manganese and boron treated plots (Table 5). However, increases in available Mn in soil were observed only under plots receiving manganese application over zinc and boron treated plots. Among the treatment with the application of boron in the soil increase the availability of boron application enhance the availability boron in the soil. Table 4.5 shows that during the experiment, differences in the amount of manganese, zinc and boron that were available in the soil as a result of micronutrient application were statistically significant. Jan *et al.* (2018) [10] reported that the higher B content in wheat leaves (1.44 kg ha^{-1}) was recorded in leaves collected from the plots treated with combined application of S + Zn + B while control plots resulted in lower leaf boron content (0.38 kg ha^{-1}). Ali *et al.* (2013) [3] proved that foliar fertilization with boron and zinc increases the content of both components in the flag leaf and wheat grain.

Conclusion

The study highlights the importance of micronutrient supplementation to soil for improving the availability of micronutrient in the soil. The result concluded that zinc, manganese and boron micronutrients through soil application enhanced the availability of micronutrients in soil.

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