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Effects of Copper Nutrition on Production Potential and Nutrients Uptake by Wheat (*Triticum aestivum* L.) Crop

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ABSTRACT

This field experiment was carried out on sandy loam soil with wheat variety HD 2967 as a test crop during *Rabi* season (2019-2020) to study the effects of copper nutrition on production potential and nutrients uptake by wheat (*Triticum aestivum* L.) crop. The experiment comprised of Control (T_1), 0.5 kg Cu ha^{-1} + RDF (T_2), 1.0 kg Cu ha^{-1} + RDF (T_3) 1.5 kg Cu ha^{-1} + RDF (T_4), 2.0 kg Cu ha^{-1} + RDF (T_5) and 2.5 kg Cu ha^{-1} + RDF (T_6). Highest plant height (92.75 cm) at 120 DAS, number of tillers (441 tiller m^{-2}) at 60 DAS, number of leaves (64.53 leaves $plant^{-1}$) at 60 DAS, number of grains (42.41 grains per ear head), spike length (18.23 cm), test weight (38.67 gm), grain yield (45.98 q ha^{-1}), straw yield (76.98 q ha^{-1}), biological yield (122.96 q ha^{-1}) and harvest index (37.39%) of wheat were obtained with T_5 treatment followed by $T_5>T_6>T_4>T_3>T_2>T_1$. Among various treatments, the nutrients (NPK and Cu) uptake by wheat were recorded highest under 2.5 kg Cu ha^{-1} + RDF (T_5) treated plot and lowest under control (T_1).

***Key words*:** Wheat, Growth, Yield, Nutrient uptake

Wheat (*Triticum aestivum* L.) is the cereal crop with the most widespread cultivation around the world due to its wider adaptability to different agro-climatic and soil conditions. It is consumed in various forms by more than one thousand million human beings in the world. It is the most important staple food of about two billion people (36% of the world population). It is an important industrial crop and is a main raw material in feed mills with bread, cake, biscuits, pasta, spaghetti, Dalia, halva, sweets and the formation of a high-quality alcohol-containing reasonable amount of wheat. Worldwide, wheat provides nearly 55% of the carbohydrates and 20% of the calories consumed in the world's food supply. Wheat contributes more protein (8-15%) to the diet than any other cereal and it has a relatively high content of niacin and thiamine. Today, India ranks second in wheat production with a harvest of 102.19 million tonnes and an area is 29.14 million hectares during 2018-2019 (Directorate of Economics & Statistics). China leads the world, in terms of area under wheat cultivation, followed by India, Russia and the USA. Micronutrient deficiency has become a major constraint for crop productivity in many Indian soils. Copper is one of the essential micronutrients for plants. Cu plays an important role in regulating multiple biochemical reactions, so plant growth is highly dependent on its availability. Copper also influences on the metabolic processes of plant-like photosynthesis and reduction of respiration in pollen capability and its deficiency increases infertility of spikelet in a lot of unfilled grains [1]. Soil applied Cu significantly increases the grain yield of wheat [2]. Copper sulphate is used as an antifungal agent in many pesticides. The excess of copper affects the activity of enzymes, it impairs the DNA, the protein oxidation and the integrity of membranes which alters the photosynthesis, and it damages plasma membranes and produces functional changes and other metabolic disorders [3-4].

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MATERIALS AND METHODS

A field experiment was conducted in Rabi season (2019-20) at the agricultural farm of U.P. Autonomous College, Varanasi developed on alluvium deposited soil. The texture of the soil at the experimental site was sandy clay loam and in response, it's slightly saline and non-alkaline. The initial physicochemical properties of experimental soil were bulk density 1.43 g cm^{-3}, particle density 2.65 g cm^{-3}, pH (1:2.5) 7.42, EC 0.35 dS m^{-1}, organic carbon 0.35%, water holding capacity 43.5%, available nitrogen 173 kg ha^{-1}, available phosphorus 13.6 kg ha^{-1}, available potassium 183.36 kg ha^{-1} and DTPA-extractable copper 3.82 kg ha^{-1}. The various treatments applied to wheat crop were Control (T_1**)**, 0.5 kg Cu ha^{-1} + RDF (T_2), 1.0 kg Cu ha^{-1} + RDF (T_3) 1.5 kg Cu ha^{-1} + RDF (T_4), 2.0 kg Cu ha^{-1} + RDF (T_5) and 2.5 kg Cu ha^{-1} + RDF (T_6). The treatments were tetra replicated in a randomized block design (RBD). The recommended dose for wheat was 120-60-40 kg N-P_2O_5-K_2O ha^{-1}. The crop received a differential dose of Cu from inorganic fertilizer as per treatments. Nitrogen from urea was given as 50% basal, 25% after 45days of sowing and 25% after

60 days. The full dose of P and K through single super phosphate and muriate of potash and copper through copper sulphate (25%) were applied at the time of sowing as basal dressing. Soil samples were taken from 0 to 15 cm depth in plastic bags from individual plots after harvest of the crop. One soil sample of each plot was air-dried, processed to pass through 2 mm round hole sieve and analyzed for oxidizable organic carbon (1N $K_2Cr_2O_7$), available N (0.32% alkaline $KMnO_4$ oxidizable), P (0.5 M $NaHCO_3$ extractable), K (1N neutral ammonium acetate extractable) and Cu (DTPA-extractable) following the methods described by Walkley and Black method [5], Subbiah and Asija [6], Olsen's *et al*. [7], Lindsay and Norvell [8], respectively. With the use of a glass electrode in a digital pH metre, soil pH was evaluated in a 2:1 soil: water suspension. A conductivity bridge was used to assess the electrical conductivity of soil in the supernatant liquid of a soil-water suspension (1:2) [9]. Bulk density in undisturbed samples collected with metal cores of 4.2 cm diameter and 5.8 cm height was measured [5]. Variety HD 2967 of wheat was selected as the test crop. Five plants are marked randomly in each replicated plot and height was measured from the base of the plant to the tip of the uppermost fully matured and stretched leaf before the emergence of the ear and from the base of the plant to the tip of the ear after its emergence for calculating mean plant height at 30 and 120 days after sowing. After harvesting and threshing, the grain weight was recorded. The straw yield was calculated by subtracting grain yield from biological yield. Plant samples (grain and leaf) drawn at harvesting were dried in the shade before being placed at 70°C for 12 hours to make them free from moisture. After there, samples were ground in the grinder and the total P, K and Cu content in plant samples were determined by digesting the samples with di–acid (HNO_3:$HClO_4$ in 10:4) mixture [9] and estimated by calorimetrically as described by Jackson [9] using flame photometer procedure [9] and atomic absorption spectrophotometer [8] while N was determined by chromic acid Method respectively. Plant uptake of NPK and Cu were computed by multiplying the yield with the respective nutrient content. The data collected from the field and laboratory were analyzed statistically using the standard procedure of randomized block design. Critical difference (C.D.) and standard error of the mean (SEm) were calculated to determine the significance among treatment means.

RESULTS AND DISCUSSION

Effect of copper nutrition on growth and yield attributes of wheat crop

Plant height

Plant height of wheat significantly increased with an increase in the application rate of Cu (Table 1). At all growth stages, the maximum plant height i.e., 28.73 cm, 53.50 cm, 92.00 cm, 92.75 cm at 30 DAS, 60 DAS, 90 DAS, 120 DAS, respectively were recorded under treatment T_5 (2.0 kg Cu ha^{-1} + RDF) and minimum plant height was observed in treatment T_1 (control). Significantly higher plant height was recorded with treatment T_5 (2.0 kg Cu ha^{-1}) over the rest of the treatments at all growth stages might be due to the role of Cu and N in plant growth metabolism and higher photosynthetic activity. Cells developed with an elevated level of nutrients and have higher meristematic activity and formation of protoplasm which increases growth. A similar response of copper application on wheat was also reported by [10-12]. Thus, the plants at low copper had decreased height which could be attributed to the loss of apical dominance of the main stem. Low Cu has been shown to produce similar effects in a variety of plants [13-15].

Table 1 Effect of Cu application on plant height (cm) of wheat crop

Treatment	Plant height			
	30 DAS	60 DAS	90 DAS	120 DAS
T_1	24.63	45.05	79.68	82.50
T_2	26.06	46.74	82.00	85.22
T_3	26.56	47.58	85.15	87.93
T_4	27.40	50.00	87.50	91.00
T_5	28.73	53.50	92.00	92.75
T_6	28.36	52.10	90.06	91.64
SEm ±	0.459	0.601	0.553	0.595
CD (P=0.05)	1.383	1.812	1.666	1.794

Table 2 Effect of Cu nutrition on number of tillers m^{-2} of wheat crop

Treatment	Number of tillers		
	30 DAS	60 DAS	90 DAS
T_1	212	335	304
T_2	227	359	321
T_3	239	377	343
T_4	248	399	360
T_5	270	441	397
T_6	260	419	384
SEm ±	1.387	1.610	1.417
CD (P=0.05)	4.181	4.852	4.271

Number of tillers per m^2

The number of tillers increased continuously with crop stage up to harvest under all treatments and was found in the order T_5>T_6>T_4>T_3>T_2>T_1 (Table 2). According to the data, copper was applied to wheat and had a statistically significant effect. The numbers of tillers were minimum in the control plots and increased with an increase in copper application rate to a maximum at 2.0 kg Cu ha^{-1} (T_5). At levels higher than 2.0 kg Cu ha^{-1}, the number of tiller decreased slightly in wheat plants [16]. The addition of 2.0 kg Cu ha^{-1} (T_5) shown a significant increase in number of the tiller of the wheat crop over other treatments due to increase in copper availability is attributed to the rapid conversion of carbohydrates into proteins at consequently increasing the number and size of growing cells which ultimately increased in the number of tillers [17]. The positive effect of the copper application on studied wheat growth parameters can be attributed to the important function of copper in plant metabolism since copper participates in photosynthesis and chloroplast development [18].

Number of leaves per plant

The number of leaves per plant under wheat crop significantly increased with an increase in the application rate of copper up to 2.0 kg ha^{-1}. The maximum number of leaves were found with the treatment T_5 followed by other treatments arranged in decreasing order as $T_5>T_6>T_4>T_3>T_2>T_1$ (Table 3). The observations recorded at 30 DAS of crop showed that the number of leaves varied from 14.98 to 18.87 among all the treatments. The maximum number of leaves was recorded in treatment T_5 (18.87) and the minimum was observed in treatment T_1 (14.98). At 60 DAS, the number of leaves per plant among all the treatments ranged from 60.75 to 64.53. The maximum number of leaves recorded in the case of treatment T_5 (64.53) and the minimum was recorded in treatment T_1 (60.75). The number of leaves per plant among all treatments at 90 DAS was ranged from 43.89 to 48.98. Like 30 and 60 days after sowing (DAS), the maximum number of leaves recorded in case of treatment T_5 (48.98) and minimum was noted in treatment T_1 (43.89). The maximum number of leaves at all the stages was found in the treatment T_5 due to the application of micronutrient (Cu) which involves in chlorophyll formation and could have aided cell division, meristematic activity in apical tissue, cell growth, and the production of new cell walls. A similar trend of the increased number of leaves per plant with the application of copper and other micronutrients was also reported by [19-20].

Table 3 Effect of different treatments on number of leaves per plant at various stages of crop growth

Treatment	Number of leaves		
	30 DAS	60 DAS	90 DAS
T_1	14.98	60.75	43.89
T_2	15.85	61.54	44.68
T_3	16.77	62.73	45.67
T_4	17.63	63.36	46.52
T_5	18.87	64.53	48.98
T_6	18.65	64.29	48.56
SEm ±	0.268	0.510	0.364
CD (P=0.05)	0.809	1.538	1.098

Number of grains per ear head

The application of copper significantly increased the number of grains per ear head as compared to without copper. The number of grains per ear head varied from 38.11 to 42.41. Per ear head, the maximum quantity of grains was recorded with treatment T_5 followed by T_6 and T_4. Effect of various treatments of Cu was found in the order $T_5>T_6>T_4>T_3>T_2>T_1$ (Table 4) and values were ranged between 38.11 to 42.41 among treatments. The maximum number of grains per ear head was observed with 2.0 kg Cu ha^{-1} application because copper elongates the main rachis of the ear head, thereby giving more space to the spikelets for their free development and fertilization resulting in the formation of more grains [21-22].

Spike length (cm)

Results revealed that the longest spike length (18.23 cm) was achieved from treatment T_5 (2.0 kg Cu ha^{-1}) and the shortest spike length (13.65 cm) was obtained from treatment T_1 (control) which was significantly different from all other treatments (Table 4). It was also found that spike length increased with the increasing rates of Cu up to 2.0 kg ha^{-1}. Here, it can be stated that copper had a contribution for longer spike length and treatment T_5 @ 2.0 kg Cu ha^{-1} showed the best result where no application of copper (T_1) showed shorter spike length. However, the spike length was reduced by further addition of Cu at 2.5 kg ha^{-1} may be due to excess of Cu [23-24]. Combination of micronutrients (Cu + Fe + Mn + Zn) produced the highest values of spike length [25].

Test weight

Test weight of grain is an important yield contributing character. Higher 1000 grain weight indicates more healthy seeds and resulted in higher grain yield (q ha^{-1}). Effect of different levels of copper on test weight of wheat could be arranged in order $T_5>T_6>T_4>T_3>T_2>T_1$ (Table-4). The highest test weight (38.67 gm) was observed with treatment T_5 whereas the lowest (34.90 gm) was obtained from treatment T_1 (control). This may be attributed to the application of copper and the synergistic effect of nitrogen which might have increased the test weight [26-27].

Grain yield

Grain yield is the main achievement of crop production. Maximum grain yield (45.98 q ha^{-1}) was produced by employing 2.0 kg Cu ha^{-1} (T_5). However, significantly poor grain yield has been obtained with control (T_1). The effect of various treatments on grain yield was found in the order of $T_5>T_6>T_4>T_3>T_2>T_1$ (Table-5) and respective values were 45.98, 45.10, 42.54, 40.26, 35.95, 30.49 q ha^{-1}. Here, it can be stated that the application of copper @ 2.0 kg Cu ha^{-1} was more effective than other doses. The grain yield enhancement at 2.0 kg Cu ha^{-1} was mainly due to the cumulative effect of the increase in all yield attributing components such as effective tillers/m^2, number of grains per ear head, spike length, 1000 grain weight. The findings support previous observations that plants growing in Uttar Pradesh's alluvial soils respond to Cu application even when the soil is not poor in accessible Cu [28-29]. Reduced grain yield in low Cu plots is consistent with [30-31]. This is attributable to a decrease in the number of effective tillers, as well as a disruption in grain setting and the production of rudimentary and blind ears in such plants. The reduction in grain yield at 2.5 kg Cu ha^{-1} levels might be possible due to an excess of copper and its interaction with other micronutrients. like Fe and Zn [32]. Asad and Rafique [26] stated that combined application of micronutrients has a significant impact on grain yield, dry matter.

Straw yield

Effect of various treatments on straw yield of wheat was found in order $T_5>T_6>T_4>T_3>T_2>T_1$ (Table 5) and the values were 76.98, 76.22, 73.96, 71.84, 70.98, 65.78 q ha^{-1} under respective treatments. The significantly higher straw yield was recorded in the case of T_5 (2.0 kg Cu ha^{-1}) in comparison to other treatments and poor straw yield obtained with the treatment T_1 (control). The increase in straw yield was due to the cumulative effect of the increase in all the straw yield attributing indices such as plant height, dry matter accumulation and the number of tillers. The increase in straw yield might be possible due to the combined action of micronutrients (Cu and Mn) increased wheat dry matter, straw yield and grain yield significantly over control. Similar results were reported by [33]. Production of wheat dry matter enhanced with increasing Cu levels and reached the maximum at 1.5 mg kg^{-1} also responsible for higher straw yield [17].

Table 4 Effect of Cu addition on number of grains per ear head, spike length, test weight of grain of wheat

Treatment	Number of grains per ear head	Spike length (cm)	Test weight (g)
T_1	38.11	13.65	34.90
T_2	39.00	15.56	35.49
T_3	39.63	16.00	36.87
T_4	40.89	16.75	37.92
T_5	42.41	18.23	38.67
T_6	42.10	17.45	38.45
SEm ±	0.309	0.345	0.418
CD (P=0.05)	0.930	1.040	1.260

Table 5 Effect of Cu on grain yield, straw yield (q ha^{-1}) and harvest index (%) of wheat crop

Treatment	Grain yield	Straw Yield	Harvest Index
T_1	30.49	65.78	31.67
T_2	35.95	70.98	33.62
T_3	40.26	71.84	35.91
T_4	42.54	73.96	36.51
T_5	45.98	76.98	37.39
T_6	45.10	76.22	37.17
SEm ±	0.374	0.659	0.382
CD (P=0.05)	1.126	1.986	1.151

Harvest index (%)

The harvest index is an important parameter indicating the efficiency in the partitioning of dry matter to the economic part of the crop. Higher harvest index, higher is the economic return of the crop. From the result, it is evident that the application of Cu significantly increased the harvest index. The harvest index varied from 31.67 to 37.39. The maximum harvest index was found with the treatment T_5 followed by other treatments in order $T_5>T_6>T_4>T_3>T_2>T_1$ (Table 5). Maximum harvest index was observed in T_5 i.e., application of 2.0 kg Cu ha^{-1}. This might be due to favourable effects of increased availability of copper and nitrogen on growth and yield attributing characters which helped in the translocation of photosynthates into the grain and increased the grain yield [33].

Table 6 Nutrient uptake by wheat crop as influenced by various doses of copper addition

Treatment	Nutrient uptake (kg ha^{-1})			
	N	P	K	Cu
T_1	125.10	12.90	134.40	63.00
T_2	130.30	13.50	138.00	70.80
T_3	131.70	14.00	140.90	75.30
T_4	133.10	14.80	144.50	81.00
T_5	137.00	15.80	149.80	89.60
T_6	136.00	15.40	148.40	90.80
SEm ±	0.755	0.218	0.998	0.453
CD (P=0.05)	2.276	0.658	3.007	1.365

Influence of copper application on nutrients uptake by wheat crop

Nitrogen uptake

Nitrogen uptake by wheat was increased significantly by the application of Cu over control. The effect of various treatments on nitrogen uptake was found in the order of $T_5>T_6>T_4>T_3>T_2>T_1$ (Table 6). Among various treatments, the uptake of N varied from 125.1 to 137.0 kg ha^{-1}. Application of 2.0 kg Cu ha^{-1} recorded significantly higher nitrogen content over all other treatments. The synergistic effect of the copper application on N nutrition was brought out in the present investigation recording a significantly higher value for uptake of N by the plant [34].

Phosphorus uptake

It is evident from the table that the application of Cu under different treatments proved a significant increase in phosphorus uptake by grain and straw as compared to T_1 (control). The effect of various treatments on phosphorus uptake could be arranged in the order of $T_5>T_6>T_4>T_3>T_2>T_1$ (Table 6). The effect of T_5 was found to be significantly superior over other treatments. The uptake of P ranged from 12.9 to 15.8 kg ha^{-1} [35-37].

Potassium uptake

Potassium uptake by wheat was increased significantly by the addition of Cu over control. The effect of various treatments on potassium uptake by wheat was found in the order of $T_5>T_6>T_4>T_3>T_2>T_1$ (Table 6). Among various treatments, the uptake of K varied from 134.4 to 149.8 kg ha^{-1}. The highest uptake potassium by wheat cultivars was recorded for the treatment giving higher grain and straw yields [38]. The increase in macronutrient content could be attributed to Cu which plays a major role in photosynthesis, synthesis of ATP and ADP, chlorophyll and other pigments, sugar, DNA, RNA, etc. [39-42]. These results are in agreement with those of El-Magid *et al.* (2000), Moussa (2000), Shaaban (2000), Abdel-

Maguid *et al.* (2004). Cu treatment in wheat plants increased macronutrient content in wheat shoots [43].

Copper uptake

Cu uptake by wheat was increased significantly by the addition of Cu over control. The effect of various treatments on copper uptake was found in the order of $T_6>T_5>T_4>T_3>T_2>T_1$ (Table-6). Among various treatments, the uptake of Cu varied from 63.0 to 90.8 kg ha^{-1}. The effect of T_6 was found to be significantly superior over all the treatments. Copper application increased Cu uptake in maize shoots significantly compared with the control, indicating that Cu must have been one of the limiting nutrients in the soil and it was also in this treatment level where significantly higher yield was obtained. The results indicate that the uptake of copper by grain and straw of wheat cultivars increased with Cu application at different levels over control due to an increase in grain and straw yields and concentration in plants [44-45]. The higher uptake of Cu at higher levels of Cu application as a consequence of more competition results in more exploitation of fertilizer copper for absorption. The Cu concentrations in grain and straw increased significantly with an increase in the level of applied Cu and were maximum at 2.5 kg ha^{-1} [46].

CONCLUSION

From the present study, it is concluded that the application of Cu improved Plant height, grain per spike, 1000-grain weight, biological yield, harvest index, straw yield, grain yield, and wheat crop nutrient uptake. Application of Cu in excess amount may adversely affect the growth and yield. Hence, a judicious and adequate amount of Cu can contribute to a great deal in enhancing the yield of wheat. Application of 2.0 kg Cu ha^{-1} + RDF significantly enhanced growth, yield and nutrient uptake by wheat crop. Therefore, the incorporation of copper contributes to improving crop productivity.

LITERATURE CITED

1. Dobermann A, Fairhurst T. 2000. Rice: Nutrient disorders and nutrient management. *Potash and Phosphate Institute of Canada*. pp 192.
2. Karamanos RE, Omarenski Q, Goh TB, Flore NA. 2004. The effect of foliar copper application on grain yield and quality of wheat. *Canada Journal of Plant Science* 84: 47-56.
3. Azooz MM, Abou-Elhamd MF, Al-Fredan MA. 2012. Biphasic effect of copper on growth, proline, lipid peroxidation and antioxidant enzyme activities of wheat (*Triticum aestivum* cv. Hasaawi) at early growing stage. *Australian Journal of Crop Science* 6(3): 688-694.
4. Xue Y, Yue S, Xhang W, Liu D, Cui Z, Chen X, Ye Y, Zou C. 2014. Zinc, iron, manganese and copper uptake requirement in response to nitrogen supply and the increased grain yield of summer maize. *Plos One* 9: e93895.
5. Walkley A, Black CA.1934. An examination of digestion method for determining soil organic matter and a proposed modification of the chromic acid titration method. *Soil Science* 37: 29-37.
6. Subbais BV, Asija GL.1956. A rapid procedure for determination of available nitrogen in soil. *Current Science* 60: 1-7.
7. Olsen SR, Cole CV, Watanable FS, Dean LA. 1994. Estimation of available phosphorus in soil by extraction with sodium bicarbonate. *Department of Agriculture Circular*. pp 939.
8. Lindsay WL, Norvell WA. 1978. Development of a DTPA Soil test for zinc, copper, iron and manganese. *Soil Science Society of America* 42: 421-428.
9. Jackson ML.1973. *Soil Chemical Analysis*. Prentice Hall of India Private Limited, New Delhi.
10. Nadim MA, Awan I, Baloch MS, Khan EA, Naveed K, Khan MA, Zubair M, Hussain N. 2011. Effect of micronutrients on growth and yield of wheat. *Pakistan Jr. Agric. Sci*. 48(3): 191-196.
11. Narimani H, Rahimi MM, Khan A, Vaezi B. 2010. Study on the effects of foliar spray of micronutrient on yield and yield components of durum wheat. *Arch. Appl. Sci. Resh*. 2: 168-176.
12. Calderini DF, Dreccer MF, Slafer GA. 1995. Genetic improvement in wheat yield and associated traits. A re-examination of previous results and latest trends. *Plant Breeding* 114: 108-112.
13. Agarwala SC, Sharma CP.1976. Plant nutrients – their functions and uptake. *Soil Fertility – Theory and Practice. I.C.A.R.*, New Delhi. pp 7-64.
14. Kumar R, Mehrotra NK, Nautiyal BD, Kumar P, Singh PK. 2009. Effect of copper on growth, yield and concentration of Fe, Mn, Zn and Cu in wheat plants (*Triticum aestivum* L.). *Journal of Environmental Biology* 30: 485-488.
15. Marschner H.1995. *Mineral Nutrition of Higher Plants*. 2nd Edition. New York: Academic Press, Harcourt Brace Jovanovich. pp 674.
16. Kumar V, Yadav DV. Yadav DS.1990. Effect of nitrogen sources and copper levels on yield, nitrogen and copper contents of wheat. *Plant Soil* 126: 79-83.
17. Singh, Aggarwal SK. 2003. Growth and yield of wheat (*Triticum aestivum* L.) as influenced by levels of farmyard manure and nitrogen. *Indian Jr. Agronomy* 46: 462-467.
18. Amberger A. 1974. Micronutrients, dynamics in the soil and function in plant metabolism. *IV Copper. Proc. Egypt Botany Society, Workshop 1, Cairo*. pp 113-120.
19. Patil VK, Yadlod TB, Narsude PB. 2009. Effect of foliar application of micronutrients on flowering and fruit set of tomato (*Lycopersicon esculentum Mill*.) cv. Phule raja. *International Journal of Agricultural Sciences* 6: 164-166.
20. Gamelli H, El-Hadi. 2000. The effect of some foliar fertilizer's application on growth, bulb yield, quality and storage ability of Giza 20 onion cultivar (*Allium cepa* L.). *Annual Agricultural Science, Moshtohor* 38(3): 1727-1737.
21. Reddy, Bhardwaj RBL. 1989. Effect of nitrogen and phosphorus on growth and yield of wheat under limited and adequate irrigation. *Indian Jr. Agronomy* 29: 505-509.
22. Reddy SR. 2004. Agronomy of Field Crops. Kalyani Publishers, New Delhi.
23. Mekkei MER, El-Haggan Eman AMA. 2014. Effect of foliar application of Cu, Fe, Mn, Zn on productivity and quality of some wheat cultivars (*Triticum aestivum* L.). *Jr. Agric. Food App. Sciences* 2: 283-291.
24. Stępień A, Wojtkowiak K. 2016. Effect of foliar application of Cu, Zn, and Mn on yield and quality indicators of winter wheat grain. *Chilean Journal of Agricultural Research* 76(2): 219-226.

25. Zeidan MS, Nofal OA. 2003. Effect of urea on the efficiency of spraying iron, copper, manganese and zinc on wheat. *Egyptian Jr. of Agronomy* 24: 121-131.
26. Asad A, Rafique R. 2000. Effect of copper, zinc, iron, manganese and boron on the yield and yield components of wheat crop in Tehsil Peshawar. *Pak. Jr. Bio. Sciences* 3(10): 1615-1620.
27. Malakouti MJ, Tehrani MM, Ziaeyan A, Majidi A. 2005. Effect of balanced fertilization on the weight of thousands seeds for different wheat cultivars in the calcareous soil of Iran. *XV International Plant Nutrition Colloquium, Beijing, China*. pp 253.
28. Mehrotra NK. 1993. Productivity constraints of U.P. soils: Nutritional aspects – an overview. *Proc. Seminar, Lucknow chapter, Indian Society of Soil Science*. pp 9-19.
29. Tiwari KN, Tiwari S.1993. Management of mineral stress in soils of Uttar Pradesh. *Proc. Seminar, Lucknow chapter, Indian Society of Soil Science*. pp 84-93.
30. Nambiar EKS. 1976. Genetic differences in the copper nutrition of cereals. Differential responses of genotypes to copper. *Aust. Jr. Agric. Research* 27: 453-463.
31. Agarwala SC, Sharma, CP. 1979. Recognizing micronutrient disorders of crop plants on the basis of visible symptoms and plant analysis. *Botany Department, Lucknow University*, Lucknow.
32. Dangarwala RT. 2001. Need for sustaining balanced supply of micronutrients in soil rather than their correction. *Jr. Ind. Soc. Soil Science* 49: 647-652.
33. Arif M, Chohan MA, Ali S, Gul R, Khan, S. 2006. Response of wheat to foliar application of nutrients. *Jr. Agric. Bio. Sciences* 1(4): 30-34.
34. Sheudjhen AH, Stutz ER, Doseeva OA.1993. Effect of trace element fertilizers on the content and ratios of mineral elements of rice plans. *Agrokhimiya* 11: 34-42.
35. Badhe NN, Mundwaik SP.1982. Effect of phosphorus on iron, zinc, copper and manganese utilization by sorghum and wheat. *Jr. Maharashtra Agric. University* 7: 148-150.
36. Gill MA, Salim RM, Zia MS. 1992. Maize growth and uptake of phosphate and copper at different ambient phosphate concentrations. *Soil Science Plant Nutrition* 38: 631-636.
37. Liang J, Karamanos RE. 1993. DTPA-extractable Fe, Mn, Cu and Zn. *Canadian Society of Soil Science, Lewis Publishers, Ann Arbor, MI*. pp 87-90.
38. Hulagur BF, Dangarwala RT, Mehta BV.1975. Effect of zinc, copper and phosphorus on the yield and composition of hybrid maize grown in loamy sand. *Jr. Indian Society Soil Science* 23(1): 83-90.
39. El-Magid AAA, Knany RE, El-Fotoh HGA.2000. Effect of foliar application of some micronutrients on wheat yield and quality. *Annals of Agricultural Science Cairo* 1: 301-313.
40. Moussa BIM. 2000. Response of wheat plants grown in sandy soils to K and some micronutrients fertilization. *Egyptian Jr. of Soil Science* 40: 481-493.
41. Shaaban MM. 2002. Effect of trace-nutrient foliar fertilizer on nutrient balance, growth, yield and yield components of two cereal crops. *Pakistan Journal of Biological Sciences* 7: 770-774.
42. Abdel-Maguid AA, El-Fouly MM, El-Nour EAA. 2004. Copper as a yield limiting nutrient for wheat. *Bulletin of Fac. of Agric., Cairo University* 55(3): 385-400.
43. Korzeniowska J. 2008. Winter wheat response to copper application under different cultivation technologies and nitrogen fertilization. *Ecological Chemistry and Engineering* 15(1/2): 81-88.
44. Chandel SRS. 2004. *A Hand Book of Agriculture Statistics*. Achal Prakashan Mandir 117/574, Pandu Nagar Kanpur. pp 17-35.
45. Barik KC, Chandel AS. 2001. Effect of copper fertilization on plant growth seed yield, copper and phosphorus uptake in soybean (*Glycine max*) and their residual availability in Mollisol. *Indian Jr. Agronomy* 46(2): 319-326.
46. Loneragan JF, Snowball K, Robson AD. 1980. Copper supply in relation to content and redistribution of copper among organs of the wheat plant. *Annuals of Botany* 45: 621-632.