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RESEARCH ARTICLE

Response of Different Micronutrients (Zn, Cu and Mn) Soil Application on Yield and Quality of Late Sown Wheat (*Triticum aestivum* L.) in Agro-Climatic Conditions of Faisalabad, Pakistan

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ABSTRACT

A field trial was conducted at agronomy farm, University of Agriculture Faisalabad, Pakistan during winter season 2018-19, to observe the response of soil-applied micronutrients (Zn, Mn and Cu) on the wheat. The experiment was executed in Randomized Complete Block Design (RCBD) with eight treatments and each treatment was replicated three times. Different micronutrients at the rate of M_0= Control, M_1= Zn (8 kg ha^{-1}), M_2= Cu (12 kg ha^{-1}) M_3= Mn (14 kg ha^{-1}), M_4=(Zn + Cu) 8kg ha^{-1}, 12 kg ha^{-1}, M_5=(Zn + Mn) 8kg ha^{-1}, 14 kg ha^{-1}, M_6=(Cu + Mn)12 kg ha^{-1}, 14 kg ha^{-1}, M_7=(Zn + Cu + Mn) 8 kg ha^{-1}, 12 kg ha^{-1}, 14 kg ha^{-1}. The sources of Zn, Cu and Mn were $ZnSO_4$, $CuSO_4$ and $MnSO_4$, respectively. The NPK fertilizers @ 120:85:60 kg.ha^{-1} were applied as a basal dose. The results indicated that micronutrients Zn, Cu and Mn positively affected the wheat crop. Plant characteristics were escalated using micronutrients as these were highly affected the plant height, spikelet $spike^{-1}$, spikes $plant^{-1}$, 1000-grain weight (g), economic yield (kg ha^{-1}), biological yield (kg ha^{-1}), harvest index (%), crude protein contents (%) and grain carbohydrate contents (%). The results revealed that the highest productive tillers, grains $spike^{-1}$, harvest index and grain yield was obtained from treatment M_6 (Cu + Mn). Moreover, Cu alone enhance plant height, Zn increase biological yield. Zn + Mn have highest protein and carbohydrate contents. However minimum value of these parameters was obtained from control. It is concluded that Cu + Mn have positive role to enhance economic yield in wheat crop.

INTRODUCTION

Wheat is the highly valuable cereal crop of Pakistan and is also staple food in the country. In Pakistan, the requirement of wheat is enhancing over time due to the expansion of population and low yield per unit area. Data indicated that Pakistan gains 2.5 times less yield as compared to the potential yield of advanced countries (Khan et al., 2000). Wheat contributes 9.1% of value-added in agriculture. It contributes about 1.7% to GDP. In Pakistan, wheat cultivation was done over an area of 8.7 thousand hectares during 2017-18. It is 2.6% less as compared to last year which is about 8972 thousand hectares. The main reasons of late sowing of the wheat crop are prolonged sugarcane crushing season, water shortage, fog, smog and late harvesting of rice (Anonymous, 2018). Protein and energy are mostly obtained from wheat for the whole population of the world. Almost all the soils in Punjab-Pakistan are calcareous and have a relatively large proportion of alkali, possess less organic matter which caused micronutrient deficiency (Rafique et al., 2006). Currently, 40% of the world population is facing micro-nutrients deficiency which is the cause of diabetic children and other health problems in people (Sanchez and Swaminathan, 2005). Shortage of different micronutrients documented in most of the Asian countries owing to soils with calcareous characteristics, higher soil pH, less organic matter, high salt concentration, low irrigation water availability for longer period, high concentration of bicarbonates content in irrigational water, and improper fertilizers use (Narimani et al., 2010). Farmers are still approaching the traditional ways of cropping in which they are continuously ignoring the usage of micronutrients. Micronutrients have prominent effects on dry matter, grain yield and straw yield in wheat (Nisar and Rashid, 2003; Saleem et al., 2020). Management of crop nutrition is important for enhanced crop production (Saleem et al., 2020). It is proved by research that micronutrients can help in the overall output enhancement (Rehm and Sims, 2006; Ahmad et al., 2018). There are different factors which cause low yield of wheat in Pakistan. Among which Micronutrients are vital for crops and helps in grain setting, but there deficiency is increasing due to fixation in calcareous soils of Pakistan which results in crop yield reduction (Saleem et al., 2020). We can enhance the wheat yield by proper crop rotation and nutrient management (macro and micro nutrients). One of the reasons for low yield in wheat crop production is the farmer's unawareness of the importance of micronutrients for crop production. Different micronutrients are necessary for crop production. Varieties that are highly susceptible to fertilizers (macro nutrients) show their maximum output potential when micronutrients are used along with macronutrients or (NPK) fertilizers (Nataraja et al., 2006).

Zinc, Boron, Iron, Manganese, Copper and Molybdenum are necessary for optimum plant growth and development (Farooqi et al., 2019, Saleem, et al., 2020; Fatima et al., 2021). The Zn, Cu and Mn play an important part in crop yield and production (Fatima et al., 2021). Mn helps in electron transport, enzyme activation and disease resistance. Mn is essential for few metabolic reactions, helps in enzyme activation, photosynthesis, electron transport, biosynthesis of chlorophyll, accelerates germination, enhances uptake of phosphorus and calcium and improves the immune system (Abbas et al., 2011; Monreal et al., 2015). Manganese increase the production of chlorophyll in plants and enhance the photosynthetic activities of plants (Card et al., 2005; Manal et al., 2010). The addition of external Mn significantly increased growth, relatively improved yield, photosynthetic activity and net assimilation (Sultana et al., 2001). Mn plays a vital part in the metabolism of carotenoids, isoprenoids, phenolics and chlorophyll. Zinc plays basic role in many membrane integrity phytochrome processes, metabolic reactions, carbohydrate production and acts as a co-factor in enzyme systems (Monreal et al., 2015). The key factors which are responsible and greatly influence the amount of Zn in the soil are pH, organic matter, soil texture, carbonate content and interaction of Zn with other micro-nutrients (Bukvic et al., 2003). Studies have shown that there presents an antagonistic relationship between Zn and Cu in the soil solution (Dangarwala, 2001). Deficiency of copper and zinc each slow down the vegetative growth and delay the crop maturity. At maturity deficiency of each can increase the straw yield and reduce the grain yield. Grotz and Guerinot (2006), reported that Zn can play a vital role as a metallic component of different enzymes or may act for the regulation and working of cofactors for several active enzymes.

In soil solution, Cu levels tend to decrease pH raises because of high adhesive forces between soil particles and Cu (Lindsay, 1972). That is why soils with high pH values may have more problems regarding Cu. The Cu is also supposed to have a great role in the physiological functions of plants and its deficiency results in increasing infertility of spikelet's which results in unfilled grains (Dobermann and Fairhurst, 2000). Cu plays significant functions in all tall trees as it regulates above 30 enzymatic activities which also include redox catalysts (Mohamed and Taha, 2003). Cu is well known and has been documented as essential for normal growth and many metabolic activities in plants (Singh et al., 2007).

The mixture of micronutrients (Cu + Zn + Mn) improved yield determining features, protein percentage in grain, harvest index and biological yield (Mer and Ama, 2014). Using a mixture of different micronutrients in wheat considerably enhanced the overall yield. The use of micronutrients at jointing, tillering, booting and earring give rise to net economic returns and maximum grain production (Khan et al., 2010).

The amount of the micronutrients used is helpful in chlorophyll synthesis and plays an important role in physiological processes i.e. photosynthesis and respiration as reported by Reddy (2004). There is a narrow range of micronutrients requirements and toxicity, a little addition above optimum level may cause toxicity in plants. (Sharma and Bapat, 2000). Keeping in view, this study was conducted to assess the potential of different micronutrients in enhancing productivity of late sown wheat.

MATERIALS AND METHODS

The trial was conducted at the University of Agriculture, Faisalabad with eight treatments which were repeated three times during 2018-19. Geographically, it is located at 31°30'N, 73°05' E and 214 meters above mean sea level. Climatic data of the experimental site is presented in Table 1. The trial site was sandy loam and falls in the soil series "Lyallpur", an Arid soil, a fine silty and mixed. The soil property of the experimental site is discussed in Table 2. Various doses of Zn, Cu and Mn were applied to the soil at the time of sowing. These micronutrients were used as $ZnSO_4$, $CuSO_4$ and $MnSO_4$. A basal dose NPK fertilizers at 120:85:60 kg ha^{-1} were applied. Sources of fertilizers are Urea, DAP and MOP. Full dose of DAP and MOP was applied at the time of sowing.

Table 1: Metrological condition of experimental site

Month (2018-2019)	Temperature ^0C Max.	Temperature ^0C Min.	Relative Humidity %	Rainfall (mm)	ET_0 (mm)
November	27.0	12.4	74.6	0.6	01.4
December	21.7	6.5	81.5	0.7	00.9
January	19.2	7.0	80.7	18.0	00.8
February	20.3	09.1	79.0	64.2	01.1
March	26.0	13.8	68.5	55.7	02.1
April	35.0	20.6	42.5	31.2	03.8

Table 2: Soil analysis result for physical and chemical characteristics (Normal soil)

Physiochemical characteristics	Values
Texture	Loamy soil
pH	7.87
Electrical Conductivity	2.14 d S m^{-1}
Sodium Absorption Ratio	1.6 (mmol L^{-1})
Organic matter	0.71%
Phosphorus	4.03 ppm
Potassium	281 ppm
Test element (Zn) DTPA (0.02 M)	0.2 mg kg^{-1} Soil

Half dose of urea was applied at sowing time and a half with 1st irrigation. Sowing was done with the row to row distance of 22.5cm. A wheat variety "UJALA-2016" was sown in the experiment. The net plot size was 5 m x 1.80 m. Seed rate at 100 kg ha^{-1} was used. At 17-18 days after pre-soaking irrigation land was prepared by rotavator and two to three cultivations by cultivator followed by planking to prepare the fine seedbed for proper wheat germination. All cultural practices were kept constant. The detail of all treatments are given as M_0 = control, M_1 = Zn 8 kg ha^{-1}, M_2 = Cu 12 kg ha^{-1}, M_3 = Mn 14 kg ha^{-1}, M_4 = Zn 8 kg ha^{-1} + Cu 12 kg ha^{-1}, M_5 = Zn 8 kg ha^{-1} + Mn 14 kg ha^{-1}, M_6 = Cu 12 kg ha^{-1} + Mn 14 kg ha^{-1}, M_7= Zn 8 kg ha^{-1} + Cu 12 kg ha^{-1} Mn 14 kg ha^{-1}. At maturity, equal-sized area from each treatment was harvested for the calculation of different parameters regarding yield and quality. The sample which was collected for experimental observations was evaluated from that sample by using LSD test at 5% probability level (Steel et al., 1997).

RESULTS AND DISCUSSION

Plant Height (cm)

Data showed that plant height is highly affected by different micronutrients i.e., zinc, copper and manganese individually and in combined form is shown in (Table 3).

Escalated plant height (110.54 cm) was noticed with the application of Cu alone in M_2. Whereas, the least plant height was found from control (Table 3) which is 98.9 cm. The micronutrients especially Zn, Cu, Fe and Mn possess a significant structural role which increased plant height by chlorophyll syntheses and increase grain yield. Similarly, Nadim et al. (2011), has reported increased plant height with Cu application. Cu is considered an important nutrient as it plays role in chlorophyll generation and development. Cu plays significant functions in all tall trees as it regulates above 30 enzymatic activities which also include redox catalysts (Mohamed and Taha, 2003). Malakouti (2008), stated that applying different micronutrients to plants with different methods (foliar application, soil application and side dressing) has beneficial impacts on wheat.

Yield component

Yield components include productive tillers, grain/spike, 1000 grain weight and grain yield etc. The result indicated that using various microelements Zn, Cu and Mn separately or in combination significantly increase different yield components which include number of grain/spike, spike/plant and 1000 grain weight as compared to the control which contributes the lowest yield than all other treatments (Table.3). While M_6 (Cu + Mn) gave maximum grain yield as compared to control M_0 which gave the lowest yield. The wheat plants treated with M_3 (Mn alone) have the highest tillers as compare to control (Table 3) this result is supported with previous research that (Manal et al., 2010) reported a higher number of tillers using Mn alone.

Plants treated with M_6 (Cu + Mn) gave the highest number of productive tillers (303.22) as compared to other treatments. The lowest number of productive tillers was recorded (217.56) from M_0 (control) M_1, M_5 and M_2 respectively. This result was supported by research Kumar et al. (2009) obtained highest number of productive tillers with the use of Cu while Manal et al. (2010) get more tillers with the use of Mn at sowing.

The influence of different treatments on the grains/spike is almost like the trend which are obtained with the productive tiller. The highest grains per spike 44.78 was obtained from M_6 (Cu + Mn) as compare to control M_0 (control) which is about 35.02.

Grain Yield (kg ha^{-1})

Different microelements i.e., Zn, Cu and Mn each alone and their combination highly affected the yield of grains in the wheat crop as showed in (Table.3). The highest economic yield was obtained from M_6 which is treated with (Cu + Mn) which is (4963.6 kg ha^{-1}) followed by M_7 (Zn, Cu and Mn) which is 4790.3 kg ha^{-1} which are shown in table 3. The lowest economic yield was obtained when the crop grown without application of any micronutrients. The yield obtained from M_0 (control) is 4116 kg ha^{-1}. Current findings are compared with the previous research which showed that Kumar et al. (2009), recorded 69% yield increase over control with the application of Cu. Mn not only resists the plants against various soil-borne diseases but also fungal leaf diseases such as a tan spot in wheat, powdery mildew in grape and black leaf mold in tomato and increase plants yield (Heine et al., 2011). Since the wax layer is responsible for limiting non-stomatal water loss and reducing the heat load on leaves (Hebbern et al., 2009).

Table 3: Response of Different Micronutrients Soil Application on Yield and Quality of Late Sown Wheat (*Triticum aestivum* L.) under Faisalabad Conditions.

Treatments	Plant height (cm)	Total No. of tiller (m^{-2})	No. of productive tillers (m^{-2})	No. of spikelet's $spike^{-1}$	No. of grains $spike^{-1}$	1000-grain weight (g)	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Harvest index (%)	Grain protein contents %	Grain carbohydrate %
M_0(Control (NPK)	98.89 f	230.79 d	217.56 d	16.32 e	35.02 e	47.35 b	4116.9 e	12331 c	33.38 b	10.80 e	66.30 f
M_1(Zn) 8 kg ha^{-1}	108.91 a	240.40 d	226.77 d	16.98 cde	35.93 de	47.38 b	4714.0 b	13974 a	34.03 b	11.90 c	68.10 cd
M_2(Cu) 12 kg ha^{-1}	110.53 a	272.94 bc	255.33 bc	17.49 cd	37.55 cde	47.64 b	4413.8 d	12524 c	35.24 b	11.40 d	67.80 de
M_3(Mn) 14 kg ha^{-1}	108.23 ab	325.73 a	300.22 a	16.63 de	38.74 cd	47.38 b	4197.3 e	12354 c	33.97 b	11.50 cd	67.80 de
M_4(Zn + Cu) 8kg ha^{-1}, 12 kg ha^{-1}	106.06 bc	284.88 b	267.09 b	17.57 bc	40.38 bc	47.54 b	4593.6 c	12737 bc	36.07 b	12.90 ab	69.13 b
M_5(Zn + Mn) 8kg ha^{-1}, 14 kg ha^{-1}	103.30 de	260.26 c	244.71 c	17.34 cd	37.39 de	47.45 b	4373.8 d	12491 c	35.01 b	13.30 a	69.80 a
M_6(Cu + Mn)12 kg ha^{-1}, 14 kg ha^{-1}	104.65 cd	314.06 a	303.22 a	18.49 ab	44.78 a	48.70 a	4963.6 a	12467 c	39.81 a	11.40 d	67.30 e
M_7(Zn + Cu + Mn) 8 kg ha^{-1}, 12 kg ha^{-1}, 14 kg ha^{-1}	101.14 ef	313.30 a	299.00 a	19.15a	42.18 ab	49.10 a	4790.3 b	13834 ab	34.91 b	12.50 b	68.40 c
LSD0.05	2.4050	16.578	13.675	0.9423	2.8461	0.7938	102.93	1224.7	3.0543	0.4153	0.5182

Biological yield (kg ha^{-1})

Results indicated that there are significant differences between micronutrients for evaluated traits shown in (Table.3). The above result showed that the highest biological yield was obtained in M_1 (Zn alone) when plants were treated with zinc alone. 13.32% increase in biological yield was get with the use of M_1 (Zn alone) in comparison to control treatment. The lowest biological yield was obtained from control, followed by M_4 (Mn alone) showed in (Table 3). These present results were supported by previous research. Zinc has been stated as the most beneficial and effective nutrient in enhancing the dry matter in wheat (Ozkutlu et al., 2006). This rise in biological yield might be due to Zn application as it plays a significant role in plant growth and is involved in photosynthesis, many physiochemical processes and respiration is significant in attaining higher returns (Zeidan et al., 2010). Similarly, Kaya et al. (2000) and Cakmak, (2008), have also advocated that Zinc beneficial in producing higher biomass in plants.

Harvest index (%)

Above data showed that the application of various micronutrients individually or in different combination is highly imperative on HI of wheat crop. Using microelements M_6 (Cu + Mn) increase the harvest index as compared to all other treatments. Highest grain yield in M_6 can increase the harvest index. The harvest index of M_6 (Cu + Mn) is 39.8 as compared to M_0 (control) 33.38. different micronutrients can enhance the photosynthetic activity of plants which increased grain yield and enhance harvest index.

Crude protein contents (%)

The crude protein contents are illustrated in (Table.3). The treatment M_5 (Zn + Mn) has high percentage which is 13.30% and less than all other treatments. The minimum protein percentage was recorded under control condition where we don't apply any nutrients as shown in (Table 3). Micronutrients can play a massive role to contribute to the different physiological process in plants like activation of different enzymes, amino acid syntheses, enhance photosynthetic activity which resulted in more production and enhance the protein contents of grain (Rasul et al., 2015; Khan et al., 2010). The result is supported with previous research according to Hansch and Mendel (2009), Manganese, along with Zn, influences protein biosynthesis by adjusting the activity of peptidases and controlling protein metabolism. The protein contents of grain were enhanced by the application of different micronutrients (Rasheed et al., 2004).

Grain Carbohydrates Contents (%)

The data present in (Table 3) indicate that the micronutrients application has a significant effect on carbohydrate contents in grains of cereal crops. The present data showed that maximum carbohydrate concentration was found in M_5 (Zn + Mn) 69.80 fallowed by M_4 (Zn + Cu) 69.13. The lowest carbohydrate concentration was recorded in M_0 (control) followed by M_6 (Cu + Mn).

Conclusion

In conclusion, the application of different micronutrients especially Zn, Cu and Mn have a positive effect on grain yield and yield components. The lowest values for yield and yield components were obtained from M_0 (control) from where we have not applied any nutrients. The highest yield and components of yield were obtained from M_6 (Cu + Mn) followed by M_7 (Zn + Cu + Mn) and M_5 (Zn + Cu).

Authors' contributions

All authors have equally contributed to conduct this trial.

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