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Studies on the rhizosphere, yield attributes and yield of wheat (*Triticum aestivum* L.) influenced by micronutrients, FYM and biofertilizers

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Abstract
The experiments were conducted during the *Rabi* seasons of 2014-15 and 2015-16 at Students' Instructional Farm of C.S. Azad University of Agriculture and Technology, Kanpur with the objective to assess the effect of micronutrients, FYM and biofertilizers to improve root vigour, yield attributes and yield of wheat under irrigated conditions. The treatments consisted of superimposed dose of sulphur (25.0 kg.ha^{-1}), zinc (5.0 kg ha^{-1}), boron (1.0 kgha^{-1}), Iron (5.0 kg ha^{-1}), FYM (10 t ha^{-1}), *Azotobacter* and PSB (200g 10 kg^{-1} of seed) as individually and in combination along with NPK doses compared with only NPK doses (control treatment), were laid out in Randomized Block Design and replicated three times. The response of above nutrient levels was analyzed on growth parameters, yield attributes and yield as well as economics of normal sown wheat variety Mahi (K-402). The superimposition of micro nutrients and microbial inoculants over NPK doses in different treatments exhibited significant response in terms of increasing root length (25% to 40%), root fresh weight (21% to 34%), effective tillers (25% to 38%), ear length (9% to 20%), grains ear^{-1} (15% to 36%) grain yield (26% to 34%) compared to control treatment. The combined doses of NPK+FYM+S+Zn+B+Fe recorded highest grain yield (47.50q ha^{-1} and 53.05 q ha^{-1}), gross income (Rs. 90325 ha^{-1} and Rs. 103734 ha^{-1}) and net income (Rs. 46866 ha^{-1} and Rs. 58088 ha^{-1}) during 2014-15 and 2015-16, respectively.

Keywords: Sulphur, zinc, boron, iron, biofertilizers and wheat

Introduction
Wheat (*Triticum aestivum* L.) is considered as king of cereal in the world and is grown on the largest area. Wheat contains more nutritive value than other cereals specially high content of niacin and thiamine. Based on the rate of population growth of 1.5 per cent and percapita consumption of 180g of wheat per day, in India, the demand of wheat is expected to be around 109 million tons by 2020. Wheat area has risen from 12.8 million hectare in 1966-67 to 29.25 million hectare in 2015-16. Wheat production in 2015-16 was around 88.94 million tonnes and the productivity of wheat in India was 3119 kg/ha (Anonymous 2017) [3]. The major challenge for the next two to three decades of 21st century is going to be food and nutritional security for all and specially for families living below poverty line. Worldwide, there is a growing interest in the role of micronutrients in optimizing health and in prevention or treatment of diseases. Micronutrients play a crucial role in humen nutrition including the prevention and treatment of various diseases and conditions, as well as the optimization of physical and mental functioning. Globally in Asia, Africa and Latin American countries deficiency of micronutrients such as iron, zinc, folic acid and beta carotene is the most prevalent. (Antench *et al.* 2016) [4]. Selective application of particular fertilizer for increased crop productivity and restoration of heavily degrades soils could limit bio availability of certain micronutrients. Under such a situation, use of only one or two primary nutrients will not be sufficient for maintaining long term sustainability of crop production. Organic and mineral fertilizers are complimentary in nature and often the best yields are achieved when applied together. The micronutrients along with major nutrients play an important role in improvement in root biomass, yield and quality of wheat. Rhizosphere is the new area of research for agronomist concern. Thus keeping all above points in view, the present investigation was conducted during 2014-15 and 2015-16, with the objectives to assess root vigour, yield potential and economics of wheat.

Materials and methods

Field experiments were conducted at Students' Instructional Farm of C.S. Azad University of Agriculture and Technology, Kanpur (Uttar Pradesh), during two consecutive *Rabi* seasons of2014-15 and 2015-16 to assess the effect of Sulphur, Zinc, Boron and Iron along with FYM, Biofertilizers superimposed over NPK doses in wheat (*Triticum aestivum* L.) variety Mahi (K-402) under irrigated situation. There were ten treatments viz. NPK (150:60:40 kg/ha) only, NPK + S (25 kg ha^{-1}), NPK + Zn (5kgha^{-1}), NPK + Bo (1.0 kg ha^{-1}), NPK + Fe (5 kg ha^{-1}), NPK + FYM (10 t ha^{-1}), NPK + Azotobacter + PSB (200 g/10 kg of seed), NPK + FYM + Azotobacter + PSB, NPK + S + Zn + Bo+Fe and NPK + FYM + S + Zn + Bo + Fe. The experiment was laid out in Randomized Block Design with a plot size of 4.0×5.0m and replicated thrice. The soil of field was alluvial in nature having low in available nitrogen (125 kg ha^{-1}), medium in available phosphorus (22.48 kg ha^{-1}) and potash (170 kg ha^{-1}). The status of available S (15.25 ppm), Zn (1.13 ppm), Fe (19.89 ppm), and Boron (1.31 ppm) in soil. The pH of the soil was neutral in reaction (pH 7.69) having EC of 0.54 dS m with low organic carbon (0.41%) content. The plant nutrients were supplied in the form of Urea, DAP, MOP, Zinc sulphate fertilizers and iron and boron in elemental form. The growth and yield observations were recorded from randomly selected plants from each plot/treatment. The cost of cultivation and gross returns were worked out based on the prevailing market rates of all inputs, labour and for final produce and B:C ratio was worked out by dividing gross returns by the total cost of cultivation.

Results and discussion

Growth of crop

Results (Table-1) revealed that plant height shown significant difference over to control. The minimum plant height (105.63 cm and 113.70 cm during 2014-15 and 2015-16, respectively) recorded under NPK only treatment, while, maximum plant height (114.27 cm and 117.81 cm during 2014-15 and 2015-16, respectively) recorded under NPK + FYM + S + Zn+ Bo+Fe treatment. The effect of different micronutrients applied either individually or in combination with or without FYM and NPK with Azotobactor and PSB with or without FYM exhibited significant effect on root biomass during both seasons over control. The maximum fresh weight of root (4.78 g and 4.82g), dry weight of root (2.45g and 2.55g) and root length (26.43 cm and 27.01 cm) recorded during 2014-15 and 2015-16, respectively, under NPK + FYM + S + Zn + Bo + Fe treatment which are found significantly superior over control. Similarly effective tiller m^{2-1} was recorded maximum (526.76 and 593.58 m^{2-1} during 2015-16, respectively) under NPK+FYM+S+Zn+Bo+Fe treatment. Other treatments found significantly at par. The findings clearly indicated that micronutrients plays important role in enhancing photosynthesis which leads accumulation of more food material in sink. Zinc and iron plays important role in nitrogen metabolism of plant body. Zinc promote growth promoting substances like auxin. The cumulative effect of micronutrients might improve the growth of crop plants. Similar findings were reported by Fageria (2002) [6] and Nadim *et al.* (2011) [11] and Gul *et al.* (2011) [7].

Table 1: Effect of treatments on root and shoot growth characters of wheat:

Treatment	Plant height (cm) at harvest			Root fresh weight plant^{-1} (g) at harvest			Root dry weight plant^{-1} (g) at harvest			Root length at harvest (cm)			Effective tillers m^{2-1} at harvest		
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
NPK(150:60:40)	105.63	113.70	109.67	3.56	3.98	3.77	1.75	2.28	2.02	18.76	21.44	20.10	418.28	427.35	422.82
NPK+S(25Kg/ha)	108.13	114.24	111.19	4.13	4.37	4.25	2.10	2.30	2.20	21.26	22.34	21.80	445.36	466.21	455.79
NPK+Zn(5 Kg/ha)	109.43	114.37	111.90	4.26	4.39	4.33	2.16	2.33	2.255	22.34	23.04	22.69	456.34	472.22	464.28
NPK+Bo(1Kg/ha)	110.04	114.46	112.25	4.21	4.39	4.30	2.26	2.38	2.32	21.78	23.77	22.78	475.98	509.47	492.73
NPK+Fe(5Kg/ha)	110.97	114.79	112.88	4.35	4.54	4.45	2.29	2.39	2.34	22.95	24.46	23.71	498.76	527.09	512.93
NPK+FYM(10 t/ha)	109.61	115.19	112.40	4.18	4.64	4.41	2.21	2.42	2.32	23.06	25.27	24.17	485.10	535.91	510.51
NPK+Azoto.+PSB)	107.88	115.40	111.64	4.13	4.75	4.44	2.19	2.43	2.31	21.67	25.58	23.63	465.16	541.91	503.54
NPK+FYM+Azoto.+PSB	109.95	116.11	113.03	4.27	4.77	4.52	2.31	2.43	2.37	24.56	26.27	25.42	478.35	564.74	521.55
NPK+S+Zn+Bo+Fe	112.03	116.32	114.18	4.65	4.81	4.73	2.36	2.48	2.42	25.35	26.92	26.14	510.23	579.16	544.70
NPK+FYM+S+Zn+Bo+Fe	114.27	117.81	116.04	4.78	4.82	4.80	2.45	2.55	2.50	26.43	27.01	26.72	526.76	593.58	560.17
SE (d) ±	1.67	1.75		0.29	0.32		0.19	0.20		1.34	1.32		39.10	38.08	
CD (P=0.05)	3.51	3.68		0.61	0.67		0.39	0.42		2.81	2.78		82.11	80.00	

Yield attributes

The yield attributes viz ear length, ears $plant^{-1}$, grains weight ear^{-1} shown significant improvement with combined doses of organic manure, micronutrients, along with NPK doses compared to control treatment. The maximum ear length (9.38 cm and 9.69 cm), ears $plant^{-1}$ (7.23 and 5.83), grains ear^{-1} (52.86 and 54.94) and grain weight ear^{-1} (2.31g and 2.78g) during 2014-15 and 2015-16, respectively recorded under NPK + FYM + S + Zn + Bo + Fe treatment and minimum ear length (7.78 cm, and 8.82 cm), ears $plant^{-1}$ (5.33 and 4.34) number of grain ear^{-1} (38.66 and 47.51)and grain weight ear^{-1} (1.63g and 2.10 g) during 2014-15 and 2015-16, respectively, recorded under control treatment (NPK only). The application of zinc promotes ear length, grain size and shining of grain. Iron is necessary for the synthesis and maintenance of chlorophyll in plants and plays an important role in nuclic acid synthesis. Boron plays important role in synthesis of cell wall and its structure as well as pollen germination and the growth of pollen tube in plants. The increment in yield attributes might be due to better growth characters and application of micronutrients. Similar findings reported by Takkar and Datta (2006) [12].

Yield

The results (Table-2) depicted that grain yield and straw yield of wheat shown positive response with different treatments. The grain yield recorded minimum (37.67 q ha^{-1} and 39.55 q ha^{-1}) under NPK only treatment, while, maximum grain yield (47.50 q ha^{-1} and 53.05 q ha^{-1}) recorded under NPK + FYM + S + Zn + Bo + Fe treatment during 2014-15 and 2015-16, respectively. The increment in grain yield (26.09% and 34.13%) and straw yield (26.24% and 10.67%) recorded during 2014-15 and 2015-16, respectively over control treatment. Among individual application of different micro nutrients along with NPK doses, the use of Fe (5 kg ha^{-1}) recorded maximum mean grain yield (45.72 q ha^{-1}) and straw

yield (72.23 q ha^{-1}). The addition of all the micronutrients with NPK doses with or without FYM were found significantly at par. The addition of biofertilizer only along with NPK doses was found non-significant. Zinc is known to decrease the carbohydrate content of leaves and stem during spike formation, which apparently facilitates the flow of carbohydrates to reproductive organs and contributed to improve grain yield (Hemantaranjan and Garg 1998) [8]. Iron as a constituents of electron transport enzymes which are actively involved in photosynthesis and mitochondrial respiration resulted in higher dry matter accumulation and bolder grains. The above findings are supported by the reports of Aatif *et. al* (2017) [1]. Armin *et al.* (2014) [5] and Ali *et. al* (2009) [2].

Table 2: Effect of treatments on yield attributes of wheat

Treatment	Ear length (cm)			Ears plant^{-1}			Grains ear^{-1}			Grain weight ear^{-1} (g)			Grain yield (q ha^{-1})			Straw yield (q ha^{-1})		
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
NPK(150:60:40)	7.78	8.82	8.30	5.33	4.34	4.84	38.66	47.51	43.09	1.63	2.10	1.87	37.67	39.55	38.61	56.50	68.77	62.64
NPK+S(25Kg/ha)	8.35	8.90	8.63	6.73	4.52	5.63	39.50	48.49	44.00	1.64	2.06	1.85	43.00	42.50	42.75	67.00	72.97	69.99
NPK+Zn(5 Kg/ha)	8.45	8.91	8.68	6.83	4.65	5.74	39.93	48.96	44.45	1.68	2.24	1.96	40.33	43.74	42.04	60.33	79.86	70.09
NPK+Bo(1Kg/ha)	8.78	9.01	8.90	5.50	4.80	5.15	50.00	49.17	49.59	2.05	2.29	2.17	42.17	45.83	44.00	63.67	79.16	71.42
NPK+Fe(5Kg/ha)8.93	8.93	9.02	8.98	6.16	4.94	5.55	43.80	50.73	47.27	1.72	2.29	2.01	44.33	47.10	45.72	65.17	79.28	72.23
NPK+FYM(10 t/ha)	8.54	9.14	8.84	5.46	5.00	5.23	39.30	51.67	45.49	1.64	2.42	2.03	43.67	47.80	45.74	65.33	76.47	70.90
NPK+Azoto.+PSB)	8.48	9.15	8.82	5.26	5.27	5.27	39.63	51.96	45.80	1.75	2.49	2.12	37.83	41.88	39.86	56.50	73.00	64.75
NPK+FYM+Azoto.+PSB	8.92	9.22	9.07	5.73	5.27	5.50	40.90	52.84	46.87	1.70	2.58	2.14	45.67	44.36	45.02	62.89	80.08	71.49
NPK+S+Zn+Bo+Fe	9.21	9.32	9.27	7.13	5.35	6.24	51.30	52.95	52.13	1.82	2.62	2.22	47.00	51.49	49.25	70.33	76.28	73.31
NPK+FYM+S+Zn+Bo+Fe	9.38	9.69	9.54	7.23	5.83	6.53	52.86	54.94	53.90	2.31	2.78	2.55	47.50	53.05	50.28	71.33	76.11	73.72
SE (d)	0.36	0.40		0.37	0.56		0.78	1.12		0.18	0.32		1.37	1.02		1.67	1.79	
CD (P=0.05)	0.75	0.84		0.77	1.18		1.68	2.71		0.37	0.68		2.87	2.13		3.51	3.77	

Economics

The data summarised in table-3 revealed that minimum gross return (Rs. 71566 ha^{-1} and Rs. 80944 ha^{-1}), net income (Rs. 38855 ha^{-1} and 41274 ha^{-1}) recorded under NPK only (control) treatment, while maximum gross return (Rs. 90325 ha^{-1} and Rs. 103734 ha^{-1}, net income Rs. 46866 ha^{-1} and Rs. 58087 ha^{-1}) recorded under NPK + FYM + S + Zn + Bo+Fe treatment during 2014-15 and 2015-16, respectively. The gross income increased 26.22% and 28.15% and net income increased 20.61% and 40.73% during 2014-15 and 2015-16, respectively, compared to control treatment. The maximum B:C ratio (2.43 and 2.34) evaluated during 2014-15 and 2015-16, respectively, under NPK + Bo treatment due to involvement of less cost compared to other treatments. Similar findings were reported by Mali *et al.* (2015) [10] and Khan *et al.* (2009) [9].

Table 3: Effect of treatments on yield attributes of wheat

Treatment	Gross income (Rs. ha^{-1})			Net income (Rs. ha^{-1})			B:C ratio		
	2015	2016	Mean	2015	2016	Mean	2015	2016	Mean
NPK(150:60:40)	71566	80944	76255	38855	41274	40064	2.19	2.04	2.12
NPK+S(25Kg/ha)	82450	86398	84424	46559	43608	45083	2.29	2.01	2.15
NPK+Zn(5 Kg/ha)	76581	90661	83621	42704	50679	46691	2.26	2.26	2.26
NPK+Bo(1Kg/ha)	80238	93638	86938	47220	53636	50428	2.43	2.34	2.39
NPK+Fe(5Kg/ha)8.93	83835	95611	89723	50329	55369	52849	2.50	2.37	2.44
NPK+FYM(10 t/ha)	82914	95836	89375	44903	50966	47934	2.19	2.13	2.16
NPK+Azoto.+PSB)	71803	85767	78785	38245	46013	42129	2.13	2.15	2.14
NPK+FYM+Azoto.+PSB	82079	91673	86876	43220	51919	47569	2.11	2.30	2.21
NPK+S+Zn+Bo+Fe	89249	101406	95327	51090	57399	54244	2.33	2.30	2.32
NPK+FYM+S+Zn+Bo+Fe	90325	103734	97029	46866	58087	52476	2.07	2.27	2.17

Conclusion

Based on results it can be concluded that super imposition of micronutrients (S, Zn, Bo and Fe), organic manure (FYM), and microbial inoculants (*Azotobacter* and *PSB*) along with NPK doses in wheat improved rhizosphere characteristics, yield attributes, yield and economics during both years of study.

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