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Effect of micronutrients in conjunction with FYM on growth, yield and yield attributes of late sown wheat

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Abstract

This study was planned and conducted to find the effect of micronutrients in conjunction with FYM on growth, yield and yield attributes of late sown wheat in Meerut (U.P.). An experiment was conducted in respective rabi seasons 2018-2019 and 2019-2020 on Crop Research Centre (CRC), Chirodi of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut-250110, Uttar Pradesh, India. Comprising of Applied doses are mentioned below. A) N:P: K was applied evenly at a rate of 80 kg:40 kg: 40 kg per hectare in all treatments. B) Zn was applied @ 5.0 kg ha⁻¹ C) Fe was applied @ 5.0 kg ha⁻¹ D) Mn was applied @ 5.0 kg ha⁻¹ E) 5 t FYM ha⁻¹ which were assigned to different respective plots replicated 3 times in randomized block design. Application of micronutrients in conjunction with FYM were equally good as they recorded higher growth and yield parameters. The findings of experiments revealed that the growth parameters like plant height, number of tillers per m², dry matter accumulation and yield attributes i.e. spike length, spikelet per spike, no. of grain per spike, 1000 grain weight and yield of grain and straw was registered maximum with application of T₇ (RDF + Zn @ 5.0 kg ha⁻¹ + 5 ton FYM ha⁻¹) followed by T₈ (RDF + Fe @ 5.0 kg ha⁻¹ + 5 ton FYM ha⁻¹) and T₉ (RDF + Mn @ 5.0 kg ha⁻¹ + 5 ton FYM ha⁻¹). Thus, balanced nutrients application through micronutrients along with organic manure and recommended dose of fertilizers is found to be better in improving every aspect of wheat cultivation including the soil fertility. Optimum level of micronutrients in conjunction with FYM for late sown wheat was assessed based on the results obtained for growth, yield as well as water use efficiency. It was recorded that T₇ (RDF + Zn @ 5.0 kg ha⁻¹ + 5 ton FYM ha⁻¹) was found best for higher grain yield of late sown wheat.

Keywords: Micronutrients, FYM, Soil Fertility, Crop Productivity, INM, SOM

1. Introduction

In India, Uttar Pradesh is leading wheat growing state with an area of 9.65 million ha (36.6%), production of 26.87 million tons (39.3%) and productivity of 2785 kg/ha-1 (Anonymous, 2019) [14]. Wheat productivity in the state is however far lower than that in Punjab (4.3t / ha⁻¹) and Haryana (4 t/ha-1) accounted to late sowing after long duration rice varieties and harvest of sugarcane, poor seed replacement rate, lack of quality seed, imbalanced fertilization, unscientific water management and poor mechanization etc. In western Uttar Pradesh wheat sowing is delayed up to end of December and sometimes even to IInd week of January leading to severe yield reduction. Delayed sowing install maturity under the influence of high temperature and by and large, farmers attempt to make amend it by excessive application of nutrients particularly nitrogen ignoring yield physiology in constrained environments. Fertilizer recommendations based on soil test values, residual effect, and yield targets have become increasingly critical and urgent in the face of rising fertilizer prices and the environmental consequences of unbalanced fertilizer use (Prasad, 2009). Low nutrient use efficiency (NUE) is a key concern while designing and evaluating various crop production systems. It can be greatly impacted by fertilizer, soil and water management to provide economically optimum nourishment to the crop for maximizing production and minimizing nutrient losses from the field (Fixen *et al.*, 2014) [14]. The widespread use of inorganic fertilizer without the addition of organic manures for the past 50 years has resulted in a large-scale deficiency of micronutrients, which play an important role in improving the quality and quantity of agricultural produce by increasing enzyme system and photosynthesis.

Zinc, iron and manganese deficiency are common micronutrient inadequacies around the world, especially in lowland rice and light textured soils, resulting in lower crop production and poor

grain quality (Impa *et al.*, 2013)^[22]. Furthermore, due to genetic variability, the concentration of Zn, Fe and Mn in wheat cultivars varies greatly (Fageria, 2001)^[13]. In these nutrient-deficient soils, the cultivars' responses to Zn, Fe and Mn application may also differ. One of the most significant obstacles to increasing plant nutrient content is a lack of understanding of the various routes and gene products involved in mineral transport to the seeds. Several studies have discovered genes/proteins involved in mineral intake from the rhizosphere, some of which are responsible for translocation to vegetative tissues and eventual seed accumulation. Rice's response to Zn fertilization has been more varied than wheat's, with Zn fertilization having little influence on grain Zn concentration at times (Wissuwa *et al.*, 2008). Zinc deficiency is a well-known global micronutrient deficiency issue that affects both human populations and crop output. Plant-available zinc deficiency is estimated to be present in roughly half of all cereal-cultivated soils worldwide, resulting in lower crop productivity and lower nutritional quality of harvested grains (Graham *et al.*, 1992; Cakmak, 2008)^[17, 9]. Since cereals are naturally low in zinc, cultivating them on possibly zinc-deficient soils diminishes grain zinc and, as a result, dietary zinc intake. Cereals are an important source of daily calorie intake in many underdeveloped countries. Zinc deficiency in the diet has been linked to serious repercussions in human health, including deficits in brain function and development, immune system weakness, and physical development delays. Human zinc insufficiency is a well-known condition that affects people mostly in countries/regions where soils are low in accessible zinc and grains are a main staple meal. Many crop plants suffer from iron deficiency, which results in chlorosis, low yield, and poor nutritional quality. An important technique for reducing Fe insufficiency in humans is to increase accessible Fe levels in main staple food crops (Cakmak, 2002)^[8]. According to the World Health Organization (WHO), a shortage of essential micronutrients, such as Fe and Zn, is a severe threat to the world's population's health and development (WHO, 2007)^[40]. Fe deficiency is one of the most common micronutrient deficiencies in humans, with 0.8 million fatalities and 2 billion individuals affected each year (WHO, 2007). Despite the fact that dietary supplementation and fortification programs have been successful in some nations, their overall success in underdeveloped countries remains limited. Mn is one of the most important essential micronutrients that contributes significantly to crop yield. It's involved in a number of metabolic pathways in plants. Mn is also an important structural component and cofactor for several important enzymes in plants (Burnell, 1988)^[7]. Its insufficiency has recently become a widespread agricultural nutritional problem in several areas throughout the world, resulting in lower crop yields (Sadana *et al.*, 2005)^[32]. The reduction in crops growth resulting from manganese deficiency is possibly due to reduced photosynthesis (Nejia *et al.*, 2016). The continued use of chemical fertilizers is thought to be a major contributor to soil degradation and water contamination. A balanced use of both mineral fertilizer and organic manures is required to maintain sustainability of soil and high crop productivity. In such a situation, there is a greater urgency to find an alternative source that may augment or replace costly inputs such as chemical fertilizer while simultaneously protecting the delicate ecology. Farmyard manure is a beneficial additive that may be used instead of chemical fertilizers. It promotes plant development and may aid in the prevention of plant disease, as well as improving the quality of the produce. So, this experiment was conducted with

the objectives of finding out the effect of micronutrients in conjunction with FYM on growth, yield and yield attributes of late sown wheat.

2. Materials and Method

- Experimental site and soil:** A two-year-field experiment was conducted during *Rabi* 2019 and 2020 at Crop Research Centre Farm of Chirodi (Agronomy), Sardar Vallabhai University of Agriculture and Technology, Meerut. The experiment site was located at 29° 08' N latitude and 77° 41' E longitude, at an elevation of 237 meters above sea level. The region is located in the state of Uttar Pradesh's western region. The research field was located at Crop Research Centre (CRC), Chirodi which is about two kilometers away from 3rd milestone of Daurala to Sardhana Road, Meerut. The climate in the region is subtropical and semi-arid, with hot and dry summers (April to June), a hot and humid monsoon period (July to September), a warm winter (October to November), and a cold winter (December to February). The mean minimum temperature was 5.12 and 4.96 °C during both the years in last week of December. The mean maximum temperature 40.00 and 35.05 °C registered in the month of April during 2018-19 and 2019-20, respectively. During the months of December and January, frost does occur as rarely. The average annual rainfall was 732 mm, with the majority (approximately 80%) falling during the south-west monsoon from July to September and a few showers of cyclonic rains falling during the winter. August has the highest mean relative humidity while May has the lowest.
- Soil** was clay loam in texture, alkaline in pH (7.80+0.17) and electrical conductivity was normal (0.30substack+0.04dSm⁻¹), medium in organic carbon (4.55 +0.05%); low in available N (215.30 +5.68 kg ha⁻¹), available P O (12.50 +0.90 kg ha⁻¹), medium in available K O (230.15+6.45 kg ha⁻¹), medium in available zinc (0.80+0.52 mg kg⁻¹), low in manganese (1.50+0.52 mg kg⁻¹) and iron (9.61+0.52 mg kg⁻¹).
- Experimental design and treatments:** The present study entitled "Application effect of micronutrients in conjunction with FYM on availability of nutrients in soil and growth performance of late sown wheat" has been carried out during the *Rabi* season of 2018-19 and 2019-20 at the Crop Research Centre (CRC) of Sardar Vallabhbhai Patel University of Agriculture & Technology, Meerut-250110, Uttar Pradesh, India. Comprising of Applied doses are mentioned below. A) N:P:K was applied evenly at a rate of 80 kg:40 kg: 40 kg per hectare in all treatments. B) Zn was applied @ 5.0 kg ha⁻¹ C) Fe was applied @ 5.0 kg ha⁻¹ D) Mn was applied @ 5.0 kg ha⁻¹ E) 5 t FYM ha⁻¹ which were assigned to different respective plots replicated 3 times in randomized block design. Grains of late sown wheat var. DBW-71 was sown in lines 20 cm apart -1.
- Fertilizer application:** In experiment, recommended dose of NPK @80 kg:40 kg: 40 kg per hectare in all treatments uniformly and micronutrients fertilizer was applied through Urea, DAP, MOP, Zinc Sulphate Monohydrate, Ferrous sulphate and Manganese Sulphate. A half dose of N, a full dose of P and K and micronutrient fertilizers were administered as a base at the time of sowing. The remaining half of the N was applied in two equal split doses, the first after the first irrigation at crown root initiation and the second before the third irrigation at pre-flowering. According to the treatments, farm yard manure (FYM) was

applied before 15 days of sowing.

- **Observations recorded:** Different growth, yield and yield parameters like Plant height(cm), Number of tillers meter⁻², Dry matter accumulation (g m⁻²), Spike length (cm), Spikelet's per spike, Number of grains per spike, Test weight (g), Biological yield (q/ha-1), Grain yield (q/ha-1), Straw yield (q/ha-1), Biological yield (q/ha-1) and Harvest index (%) were recorded and statistically analyzed for Analysis of Variance (ANOVA).
- **Statistical analysis:** The analysis of variance (ANOVA) was used to statistically analyses all of the experimental data for various growth characteristics, yield, yield attributes, chemical studies, and soil moisture studies. The significance of treatment effects were computed with the help of 'F' (Variation ratio) test and to judge the significance of difference between means of two treatments, critical difference (CD) was worked out as described by Gomez and Gomez (1984) [18].

3. Result & Discussion

Different treatments had a considerable impact on plant height. The maximum value of plant height at 30, 60, 90 DAS and at harvest was found with application of RDF + Zn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ followed by RDF + Fe @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹, RDF + Mn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ and RDF + 5 t FYM ha⁻¹. Plant height decline after 90 days due to some shrinkage in plant cell. The addition of any micronutrient's integration with FYM exhibited an improvement in plant height to some extent. Tiller density differs significantly under the influence of various treatments. The maximum number of tillers per metre⁻² obtained with the application of RDF + Zn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ was at par to RDF + Fe @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ and RDF + Mn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹. The number of tillers per metre⁻² decreased at 90 DAS and thereafter. All the treatments where any micronutrient applied with FYM showed an increment in number of tillers per metre⁻² at all growth stages as compared to micronutrients applied with RDF. Dry matter accumulation was affected significantly by different treatments during both years. The application of RDF + Zn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ was registered highest dry matter accumulation at all growth stages during both years. The implementation of iron and manganese along with FYM and RDF also recorded highest dry matter accumulation but remained on par with treatment where zinc was applied with

FYM and RDF. Spike length differs significantly under the influence of various treatments on pooled basis it varied from minimum spike length 4.39 to maximum 10.65 cm under various variables. The application of RDF + Zn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹, RDF + Fe @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ and RDF + Mn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ were superior over control and application of zinc, iron and manganese alone with RDF. A clear reflection of different treatment combination was observed for another important yield attribute, the spikelet per spike on pooled data basis. The spikelet per spike ranged from 7.49 to 17.60 under different treatments. The maximum spikelet per spike 17.60 was found with RDF + Zn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ was at par to RDF + Fe @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ and RDF + Mn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹. The application of any macronutrient's integration with FYM and RDF achieved a higher value of spikelet per spike over application of micronutrients with RDF only. Number of grains per spike were affected significantly by the application of micronutrients and FYM and ranged from 26.30 to 46.37 on pooled basis data. The maximum number of grains per spike obtained with RDF + Zn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ while minimum in control plot. The highest value of growth characters was observed with application of RDF + Zn @ 5 kg ha⁻¹ + FYM 5 t ha⁻¹ (T₇) which recorded maximum plant height, number of tillers/ meter and dry matter production (g m⁻²), and was significantly superior over T₁ (control) and on par to treatments T₆ (RDF + FYM 5 t ha⁻¹), T₈ (RDF + Fe @ 5 kg ha⁻¹ + FYM 5 t ha⁻¹) and T₉ (RDF + Mn @ 5 kg ha⁻¹ + FYM 5 t ha⁻¹) during both the years of experimentation. These findings are in agreement with Hussain and Yosin (2004) [21] who found that applying 5 kg Zn / ha⁻¹ increased wheat yield by 12% over control. Sharma *et al.* (2004) [36] also stated that, the application of farm yard manure (FYM) @ 10 t/ha⁻¹ and mineral nutrients (S + Zn + Fe + Cu + Mn) individually or in combination improved the physio-chemical properties of saline soil and produced higher yields of wheat grain and straw. This might be due to improved physical properties of the soil, which favors better environment for plant growth along with balanced nutrition leading to improvement in the efficiency of chemical fertilizers. Data showed that with increasing levels of zinc (2.5 to 5 kg /ha⁻¹) plant growth increased, because of its critical role in important enzyme systems including carbonic anhydrase which plays vital role in transport of CO₂ in photosynthesis (Srivastava and Gupta, 1996) [38]. Similar results were also reported by Parihar *et al.* (2005) [27].

Table 3.1: Effect of micronutrients in conjunction with FYM on plant height (cm) at various growth intervals

Treatments	30 DAS			60 DAS			90 DAS			At Harvest		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
T ₁	15.75	16.10	15.93	38.12	40.20	39.16	77.05	79.12	78.09	77.00	78.76	77.88
T ₂	19.25	19.84	19.55	43.75	45.52	44.64	83.10	84.87	83.99	82.56	83.50	83.03
T ₃	20.32	20.65	20.49	48.95	50.36	49.66	88.36	89.55	88.96	87.45	87.25	87.35
T ₄	19.64	20.05	19.85	46.82	48.25	47.54	85.85	86.50	86.18	84.24	85.35	84.80
T ₅	20.02	20.62	20.32	48.35	50.02	49.19	87.24	89.20	88.22	86.52	87.00	86.76
T ₆	20.55	20.92	20.74	51.06	53.85	52.46	90.37	91.80	91.09	89.45	90.58	90.02
T ₇	22.10	23.45	22.78	58.55	61.05	59.80	96.22	99.02	97.62	95.75	98.14	96.95
T ₈	21.06	21.53	21.30	55.14	57.22	56.18	93.22	94.45	93.84	92.04	93.35	92.70
T ₉	21.15	21.80	21.48	56.32	58.42	57.37	95.62	96.62	96.12	94.10	95.24	94.67
SEm±	0.67	0.69	0.68	1.69	1.75	1.72	2.98	3.03	3.01	2.95	2.99	2.97
CD at 5%	2.03	2.08	2.06	5.09	5.28	5.19	8.99	9.13	9.06	8.88	9.00	8.94

Because of the low soil zinc and organic matter in the experimental field and the relevance of zinc for normal healthy plant growth and reproduction, the beneficial effect of 5 kg

Zn/ha-1 through inclusion of RDF+5kgZn+5tFYM / ha⁻¹ (T₇) was superior. Crop yield is diminished when plant accessible zinc is insufficient due to poor development and reproduction.

Aggrawal *et al.* (2004) also observed that applying 25 kg ZnSO₄ / ha⁻¹ promotes wheat and rice yield by 500 to 1000 kg/ha-1. Application of FYM was found to help in improvement of physiochemical properties of soil (structure, texture, aeration and CEC of soil) to give better growth and development (Sharma *et al.* 2004) ^[36].

A balance of addition and breakdown rates is required to maintain soil organic matter content. Considering soil organic matter (SOM) serves as a reservoir for various nutrients necessary for normal healthy growth, appropriate management of SOM is necessary for sustaining soil productivity, providing food security, and protecting marginal lands (Scherr, 1999) ^[34]. The bioavailability of zinc is also influenced by the amount of organic matter in the soil (Shuman, 1975; Bar *et al.* 1988; Del Castilho *et al.* 1993) ^[6, 10]. In the organic fraction, between 2% and 6% of total soil zinc was observed (Pampura *et al.* 1993) ^[28]. Randhava and Takkar (1975) ^[30] found that applying FYM at a rate of 15 tons per hectare for three years boosted zinc levels from 0.48 to 0.87 %. While zinc forms a complex with OM easily, it does not complete the sites for other cations (Fotovat *et al.* 1997) ^[16].

In our study a positive effect of micronutrients application along with FYM and primary nutrients (NPK) on plant height at all growth stages had been noticed during the both experiments. The tallest plant recorded in T₇ (RDF + Zn @ 5 kg ha⁻¹ + FYM 5 t ha⁻¹) at all stages (30, 60, 90 and at harvest) might be due to combined effect of these micronutrient application along with FYM and NPK. Our findings are in accordance with that of Rehman *et al.* (2010) ^[31] who found that organic manure is a supplemental dose that causes plant cell division to accelerate, resulting in taller plants. Zinc fertilizers stimulate both vegetative and reproductive growth (Cakmak, 2008) ^[9]. The lowest plant height found under T₁ is obvious due to absence of micronutrients which are growth promoting factors. The maximum growth was observed between 30 and 90 days after sowing indicating as “grand growth period” of crop. This was possible because of better root activity for absorption of nutrients and water, increased the rate of light absorption and high photo synthetic activities. The application of micronutrients either along with FYM or without FYM over control increase the plant height justifying the importance of micronutrients in crop nutrition. Plant nutrient sources, both organic and inorganic, have a tremendous impact on growth indices and yield characteristics. With (120: 60: 40: 25 NPK Zn kg ha⁻¹, 10 t ha⁻¹ FYM), the maximum plant height and number of tillers per plant were 86.43 cm and 7.33, respectively (Sangma *et al.* 2017) ^[33].

The number of tillers per meter-2 increased successively as the growth progressed up to 60 DAS and declined thereafter. The maximum number of tillers per metre-2 was recorded in T₇ (RDF + Zn @ 5 kg ha⁻¹ + FYM 5 t ha⁻¹) which remained at par to T₈ and T₉ respectively during both the years. The present results are in accordance with the finding of Pandey *et al.* (2009) ^[29] and Natraja *et al.* (2006), Agrawal *et al.* (2003) ^[1] and Nehara *et al.* (2001). The excellent impact of implementing greater organic manure or FYM encouraged not only better availability of plant nutrients (N and P), but also their consistent

delivery, which is important for growth and development. Combined application of Zn and FYM causes increase in tiller production due to balanced nutrition. Application of 10tFYM / ha⁻¹ added to inorganic nitrogen, enhanced nitrogen availability at earlier stage and increased production of tiller. This way increased supply of nitrogen at earlier stage caused less loss of nitrogen by leaching and become economical along with increased nitrogen use efficiency and better soil environment for root growth. The higher effectiveness of organic matter could be attributable to the fact that organic manures, particularly FYM, would have delivered optimal levels of micronutrients such as Zn, Cu, Fe, Mn, and Mg. According to Sangma *et al.* (2017) ^[33] organic and inorganic plant nutrient sources have a significant impact on growth parameters and yield attributes. The maximum plant height and number of tillers per plant were 86.43 cm and 7.33, respectively, with (120: 60: 40: 25 NPK Zn kg ha⁻¹, 10 t ha⁻¹ FYM). The dry matter accumulation was affected significantly by different treatments. According to the pooled data the final dry matter accumulation which contributes to biological yield ranged from 782.80 to 1261.60 gm⁻². The maximum dry matter accumulation at 30, 60, 90 DAS and at harvest was found in T₇ while minimum in T₁ during both experiments. There was progressive increment in dry matter. The rate of dry matter accumulation was more between 60 and 90 DAS which is obvious since during this stage flag leaves emerged and that contribute significantly in photosynthesis. The increase in dry matter accumulation under combined application of micronutrients (Zn, Mn and Mn) along with FYM and NPK was probably due to better plant growth as evidenced by more tillering and plant height with macro and micro nutrient application. The higher amount of dry matter accumulation as a result of application of RFD + FYM + Zn may be due to higher number of leaves and leaf area per meter row length which were associated with photosynthetic efficiency of wheat plants, leading to enhanced dry matter accumulation and their translocation. Application of NPK inorganic fertilizer combined with FYM enabled continued supply of required nutrients in balanced amount in addition to the enhancement of micronutrient content of soil throughout crop growth, this might be due to decomposition of FYM and production of organic acids responsible for forming micronutrient-complex (Randhava and Takkar., 1975, Stevenson, 1976, Baker and Senft, 1995) ^[30]. The vegetative growth is directly related to the yield attributes and these contribute ultimately to yield of crop. Yield attributes of wheat crop like spike length, spikelet/spike, no. of grains/spike and test weight are taken into account of assessing the crop yield and these all are closely interrelated. The maximum yield contributing traits viz., spike length, spikelet per spike, no. of grains per spike and test weight were observed under T₇: (RDF+Zn @: 5: kg: ha⁻¹+FYM: 5 tha⁻¹) while minimum in T₁ (control). The increase in yield attributes under T₇ may be due to significant increase in growth characters viz. plant height, number of tillers, number of green leaves, dry matter production, which is resulted due to increase in photosynthetic activity of leaves. The current findings are consistent with Dikshit *et al.* (2001) ^[11].

Table 3.2: Effect of micronutrients in conjunction with FYM on number of tillers meter-2 at various growth intervals

Treatment ts	30 DAS			60 DAS			90 DAS			At Harvest		
	2018- 19	2019- 20	Pooled	2018- 19	2019- 20	Pooled	2018- 19	2019- 20	Pooled	2018- 19	2019- 20	Pooled
T ₁	96.48	98.32	97.40	207.46	209.75	208.61	199.85	202.35	201.10	185.56	188.45	187.01
T ₂	108.25	108.30	108.28	230.90	233.05	231.98	218.40	221.40	219.90	213.85	216.12	214.99
T ₃	121.30	122.75	122.03	270.65	273.10	271.88	258.22	259.65	258.94	240.10	243.92	242.01
T ₄	115.62	117.10	116.36	248.68	250.46	249.57	232.30	234.15	233.23	220.55	222.48	221.52
T ₅	118.40	119.64	119.02	259.12	261.85	260.49	245.75	246.54	246.15	227.48	230.15	228.82
T ₆	126.85	128.05	127.45	292.42	300.35	296.39	275.46	277.66	276.56	256.20	258.35	257.28
T ₇	146.20	148.85	147.53	338.52	341.20	339.86	317.25	319.50	318.38	295.10	298.47	296.79
T ₈	134.10	135.25	134.68	312.55	314.25	313.40	292.45	293.85	293.15	270.48	272.86	271.67
T ₉	138.45	139.65	139.05	322.20	324.50	323.35	303.10	305.32	304.21	281.25	283.65	282.45
SEm±	4.17	4.22	4.20	9.42	9.50	9.46	8.86	8.93	8.90	8.29	8.37	8.33
CD at 5%	12.58	12.72	12.65	28.36	28.61	28.48	26.69	26.89	26.79	24.96	25.21	25.09

It is true that test weight cannot be increased at any desired level but it always higher in balanced fertilization plots than unbalanced fertilization. The minimum test weight 31.70 g was found under control plot and hence it clearly indicates that micronutrients importance. The maximum test weight 41.51 g achieved with a balance incorporation of organic and inorganic inputs *i.e.* RDF + Zn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ was at par to RDF + Fe @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹, RDF + Mn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ and RDF + 5 t FYM ha⁻¹ and considerably higher than rest of the treatments. The grain yield is the ultimate result of all growth and yield attributes. The grain yield differs from 25.75 to 44.50 q/ha⁻¹ under the influence of various treatments on pooled basis. The maximum grain yield 44.50 q/ha⁻¹ was registered with RDF + Zn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ was at par to RDF + Fe @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ and RDF + Mn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ and significantly higher than rest of the treatments. Even a single micronutrient fertilizer along with RDF can be increased the grain yield. The straw yield differs significantly under the influence of various treatments and ranged from 37.62 to 64.02 q/ha⁻¹. In comparison

to using inorganic fertilizers separately, combining organic and inorganic fertilizers boosted straw yield. The maximum straw yield 64.02 q/ha⁻¹ was found with RDF + Zn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ and minimum 37.62 q/ha⁻¹ under control. Biological yield is the combination of grain and straw yield and a significant difference was observed with application of various variables. The maximum biological yield 108.52 q/ha⁻¹ and minimum 63.37 q/ha⁻¹ was found with RDF + Zn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ and control, respectively. The HI increased with addition of micronutrient fertilizer along with organic manure (FYM) and RDF. The maximum harvest index 41.0 was found with application of zinc in combination with FYM and RDF (T₇) followed by RDF + Fe @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ and RDF + Mn @ 5.0 kg ha⁻¹ + 5 t FYM ha⁻¹ while minimum 40.21 with RDF + Fe @ 5.0 kg ha⁻¹ and RDF + Mn @ 5.0 kg ha⁻¹. The higher productivity and production are the aim of nutrient application and different management practices. A short discussion is made here under for justification of research findings.

Table 3.3: Effect of micronutrients in conjunction with FYM on dry matter accumulation (g m⁻²) at various growth intervals

Treatments	30 DAS			60 DAS			90 DAS			At Harvest		
	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled	2018-19	2019-20	Pooled
T ₁	12.50	13.10	12.80	282.95	280.55	281.75	593.28	608.22	600.75	745.96	819.63	782.80
T ₂	15.90	16.65	16.28	301.05	306.84	303.95	695.12	701.45	698.29	975.42	1050.32	1012.87
T ₃	16.30	16.82	16.56	320.45	324.15	322.30	732.15	736.54	729.40	1070.25	1111.24	1090.75
T ₄	16.08	16.90	16.49	310.35	314.75	312.55	711.65	714.58	709.04	1020.48	1075.48	1047.98
T ₅	16.15	20.57	18.36	316.48	320.65	318.57	722.40	724.62	718.60	1048.52	1098.65	1073.59
T ₆	16.80	17.45	17.13	331.4	337.26	334.33	742.45	751.62	743.52	1098.42	1120.52	1109.47
T ₇	18.65	20.35	19.50	350.45	361.50	355.98	781.52	789.2	785.36	1272.25	1250.95	1261.60
T ₈	17.20	18.46	17.83	339.65	346.86	343.26	763.78	770.65	764.65	1186.75	1171.27	1179.01
T ₉	18.15	20.01	19.08	345.25	352.42	348.84	772.25	779.14	774.82	1225.85	1215.91	1220.88
SEm±	0.55	0.59	0.57	10.84	11.03	10.94	24.28	24.65	24.46	36.65	37.50	37.04
CD at 5%	1.67	1.80	1.73	32.65	33.21	32.93	73.10	74.21	73.66	110.34	112.9	111.50

A clear reflection of organic and inorganic sources importance was reflected from resultant maximum grain, straw and biological yield was calculated with RDF + Zn @ 5 kg ha⁻¹ + FYM 5 t ha⁻¹ which was at par to RDF + Fe @ 5 kg ha⁻¹ + FYM 5 t ha⁻¹ and RDF + Mn @ 5 kg ha⁻¹ + FYM 5 t ha⁻¹. This impact could be due to the synergistic effect of applying zinc, iron, and manganese in conjunction with organic manure (FYM). Because of the availability of nutrients from inorganic sources, especially during the early phases of crop growth, and the subsequent gradual and steady supply of nutrients by organic matter, the combination of organic and inorganic sources produces a better result. Organic matter also enhances the physical condition of the soil, increasing the efficiency in which native as well as applied nutrients are utilized. Ali *et al.* (2007) [3] concluded that integration of FYM with NPK and Zn significantly increased the grain yield of wheat over farmer's

practice and recommended dose of Fertilizer. Zinc also plays important role in grain yield and application of 5 kg Zn /ha with or without organic matter (FYM) proved better result over 2.5 kg Zn /ha⁻¹. Similar findings have also been reported by Gupta and Handore, 2009; Sharma and Katyal, 1986; Dikshit *et al.* 2001. The reason for this could be owing to zinc's stimulating effect on vegetative growth, as well as its possible effect on reproductive parts, which could explain its effect on yield components. The profound influence of combined application of both macro and micro essential nutrients led to achievement of higher biological yield. Biological yield is a combined representation of vegetative and reproductive growth of the crop, as well as an indication of both grain and straw yield by Kumar and Pannu (2012) [20, 37, 23]. Higher harvest index indicates more translocation of photosynthesis from straw and grain.

Table 3.4: Effect of micronutrients in conjunction with FYM on yield attributes of wheat crop

Treatments	Spike length (cm)			Spikelet/spike			No. of grains/spike			1000-grain weight (g)		
	2018-19	2019-20	Poole d	2018-19	2019-20	Poole d	2018-19	2019-20	Poole d	2018-19	2019-20	Poole d
T ₁	4.04	4.74	4.39	7.20	7.77	7.49	26.03	26.57	26.30	31.41	31.98	31.70
T ₂	7.08	7.77	7.43	11.20	11.57	11.38	36.10	36.53	36.32	34.01	34.60	34.31
T ₃	8.53	9.14	8.83	14.10	14.67	14.38	40.50	40.97	40.73	36.71	37.10	36.91
T ₄	7.77	8.47	8.12	13.23	13.67	13.45	38.07	38.60	38.33	35.47	35.98	35.73
T ₅	8.07	8.70	8.39	13.37	14.20	13.78	39.23	39.63	39.43	36.04	36.50	36.27
T ₆	9.60	10.31	9.96	15.50	15.97	15.73	42.10	42.57	42.33	38.10	38.60	38.35
T ₇	12.12	12.88	12.50	17.37	17.83	17.60	46.10	46.63	46.37	41.29	41.74	41.51
T ₈	10.79	11.54	11.17	16.23	16.77	16.50	43.93	44.27	44.10	39.30	39.80	39.55
T ₉	11.43	11.93	11.68	16.40	16.90	16.65	44.90	45.37	45.13	40.18	40.68	40.43
SEm±	0.66	0.46	0.46	0.79	0.70	0.73	1.17	1.14	1.15	0.84	0.86	0.82
CD at 5%	2.01	1.41	1.40	2.38	2.13	2.20	3.52	3.44	3.46	2.54	2.61	2.49

Shah *et al.* (2013) [35] discovered that combining FYM at 6t / ha⁻¹ with mineral fertilizers increased wheat grain yield by 13% over using only inorganic fertilizer and 9% over using sesbania and mineral fertilizers. They revealed that combining inorganic fertilizers with FYM not just to increased wheat grain yields, but also improved N and P uptakes and recoveries as compared to mineral fertilizer alone. They also claimed that the increase in wheat production was attributable to inorganic fertilizer's faster release of nutrients and FYM's extra supply of NH₄ – N,

P, and micronutrients. In wheat, Essam and Lattief (2014) [12] found that combining 50 % NPK via chemical fertilizer with 6tFYM / ha⁻¹ resulted in significantly greater grain production (4.75t / ha⁻¹) and straw yield (7.51t / ha⁻¹) . According to Gora *et al.* (2017) [19] higher grain and straw yields of wheat were attributable to a balanced nutrient supply to the crop, which boosted soil fertility and generated more tillers, higher dry matter accumulation, and ultimately improved grain and straw yields of wheat.

Table 3.5: Effect of micronutrients in conjunction with FYM on biological, grain, straw yield (q / ha⁻¹) and harvest index (%) of wheat crop.

Treatments	Grain yield			Straw yield			Biological yield			Harvest index		
	2018-19	2019-20	Poole d	2018-19	2019-20	Poole d	2018-19	2019-20	Poole d	2018-19	2019-20	Poole d
T ₁	25.15	26.35	25.75	36.72	38.52	37.62	61.87	64.87	63.37	40.65	40.62	40.63
T ₂	34.50	36.50	35.50	50.75	53.75	52.25	85.25	90.25	87.75	40.47	40.44	40.46
T ₃	37.78	39.16	38.47	55.67	57.74	56.71	93.45	96.90	95.18	40.43	40.41	40.42
T ₄	36.14	37.62	36.88	54.21	55.43	54.82	90.35	93.05	91.70	40.00	40.43	40.21
T ₅	36.95	38.20	37.58	55.42	56.30	55.86	92.37	94.50	93.44	40.00	40.42	40.21
T ₆	38.58	40.25	39.42	56.87	58.37	57.62	95.45	98.62	97.04	40.42	40.81	40.62
T ₇	43.20	45.80	44.50	62.80	65.24	64.02	106.00	111.04	108.52	40.75	41.25	41.00
T ₈	40.45	42.54	41.50	59.67	60.81	60.24	100.12	103.35	101.74	40.40	41.16	40.78
T ₉	41.67	43.90	42.79	61.50	63.20	62.35	103.17	107.10	105.14	40.39	40.99	40.69
SEm±	1.26	1.33	1.29	1.87	1.93	1.90	3.14	3.26	3.20	-	-	-
CD at 5%	3.82	4.00	3.91	5.64	5.81	5.73	9.46	9.82	9.64	-	-	-

4. Conclusion

The study clearly demonstrated that the combined application of micronutrients with FYM significantly enhanced the growth and yield performance of late-sown wheat. Among all treatments, T₇ (RDF + Zn @ 5 kg ha⁻¹ + FYM @ 5 t ha⁻¹) proved superior, resulting in the highest plant height, tiller production, dry matter accumulation, yield attributes, and grain yield. Although the applications of Fe and Mn with FYM also improved crop performance, their effects remained slightly below that of T₇. The outstanding performance of T₇ can be attributed to improved nutrient availability and enhanced soil conditions brought about by the synergistic action of zinc and FYM.

Therefore, RDF + Zn @ 5 kg ha⁻¹ + FYM @ 5 t ha⁻¹ is recommended as the most effective nutrient management strategy for maximizing the productivity of late-sown wheat.

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