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Effect of Integrated Application of Vermicompost and N Fertilizers on Quality Parameters of Wheat (*Triticum aestivum* L.) Varieties in Welmera District, Central Ethiopia

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Abstract: Nitrogen source is one of the main inputs of the wheat crops (*Triticum aestivum* L.) in in the world including Ethiopia. Nitrogen efficient management is basic to optimizing its utilization while decreasing pollution. The objective of this study was to determine the effect of vermicompost and nitrogen fertilizer rate on wheat genotypes quality parameters under nitisol condition of walmera district. The majority of wheat varieties quality parameters were influenced by the main effect their interaction except thousand kernel weights. Combined application of vermicompost at 5 t ha^{-1} and mineral nitrogen fertilizer at 46 kg ha^{-1} has better improved thousand kernel weights. As the rate of vermicompost and nitrogen fertilizer most quality parameter found increased. Wheat grain moisture content, hectoliter weight (kg hl^{-1}), Vitreousness (%) and grain protein concentration were significantly influenced by the main effect of varieties and nitrogen fertilizer. However, integrated application of vermicompost and nitrogen fertilizer with two wheat varieties improved soil fertility, nitrogen uptake and wheat crop yield. Therefore, use of medium rate of vermicompost and nitrogen fertilizer could be one option to improve majority the wheat quality parameters.

Key words: Nitrogen · Vermicompost · Nitisol · Quality · Wheat Varieties

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the significant staple grains with worldwide production being 672 million tonnes in 2012 [1]. In Ethiopia also wheat is an important staple food crop. It is a staple food in the diets of several Ethiopians, providing about 15 percent of the caloric intake for the countries over 90 million populations [2], placing it second after maize and slightly ahead of teff, sorghum and enset, which contribute 10-12 percent each [3]. Wheat is also the fourth largest cereal crop produced around 5 million smallholder farmers, which makes about 35 percent of all small farmers in the country. This shows significant contribution of wheat in meeting the food requirements of the country. The demand for wheat by 2050 is expected to increase by 31% over the 683 million tons consumed in 2008 [4]. Increasing wheat productivity is a national target to fill the gap between wheat consumption and production. Therefore, this is necessary to provide a good soil conditions for better growth of wheat crops in achieving not only yield quantity but also quality issue is another factor.

Grain quality is defined by a range of physical and compositional properties where threshold requirements are set according to end-use requirements. Maintaining grain quality under stress condition is critical for human nutrition, end-use functional properties and commodity value. Increasing environmental stress on wheat production associated with climate, soil, water and management can affect both the yield and quality of wheat production. There is strong genetic control over kernel attributes such as shape, germ tissue, thickness of bran and crease characteristics. However, the post-anthesis environment such as water availability and temperatures strongly influence seed size which also influence grain quality parameters [5]. Similarly, environmental conditions, particularly atmospheric CO_2 concentration and high temperature heat shock during the grain filling phase effects protein concentration and functional properties including dough rheology and baking quality [6]. Grain protein concentration and composition is also an important quality measure which defines nutritional and end uses properties of dough mixing and rheological characteristics including dough

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strength, development time, extensibility, breakdown and loaf volume all of which effect the efficiency of the bread making process and product quality. Wheat productivity and quality is conditioned by several factors of which soil condition, genetics and management practice are the most relevant.

Organic production is an agricultural management system that preserves the soil, plants and ecosystem in their natural state. It is based on the application of non-synthetic naturally occurring pesticides and fertilizers of organic origin. Despite lower yields, especially in wheat production, the benefits from organic production are various, such as improved physical and chemical properties of soil, enhanced crop diversity and biodiversity of beneficial insects, enhanced nutrient uptake and use efficiency of the crop and reduced pollution [7] and likely positive effect on human health [8]. According to the Food and Agriculture Organization of the United Nations, there is a modest increase in area under organic crop production worldwide in the last ten years, while in the same period, in the countries of the European Union, the area under organic crop production has risen by 70%. In 2017, cereals were grown in 16% of the area under organic production in the EU, while in 2018, cereals accounted for 22% of the crops exported from the European Union. Interest in organic crop production in both Serbia and Hungary is expanding. Since 2012, the total area under organic production and specifically organic cereals in both countries have risen [9].

The effect of organic management on wheat protein content and bread making quality investigated in different studies were incongruent. Investigations on the differences in physical properties of seeds and processing quality traits between wheat species and varieties grown under organic and/or conventional management systems showed that the environment, management system and genotype had a strong significant influence on the physical properties of the grain [10]. However, some authors reported that different management systems did not affect wheat protein content and bread making quality [11, 12]. Differences of grain quality parameters between wheat genotypes under organic and chemical fertilizers are not well known. Therefore, the objective of this study was to investigate effect of different rates of vermicompost and nitrogen fertilizers on grain quality parameters of wheat varieties in Welmera District, Central High Land of Ethiopia

MATERIALS AND METHODS

Description of the Study Area: The experiment was conducted at Holeta Agricultural Research Center, which is located at a distance of 29 km from Addis Ababa and found at latitude of 9°2' 30" to 9° 3' 19.43" North and longitude of 38° 28'15" to 38° 30' 25.43" East.

Climate and Topography: The study area is characterized by mono-modal rainfall pattern. The ten year an average annual rainfall recorded was 1067 mm (834 to 1300 mm). It was high during the three summer months (June to August), which accounts for 85 percent of the annual rainfall. Average minimum and maximum temperatures are 6.2°C and 22.1°C, respectively. The mean relative humidity is 58.7% at Holeta Agricultural Research Center. Welmera district is situated at an altitude of 2, 400 m above sea level and characterized by plateau plains, which are moderately elevated and gentle sloping.

Vermicompost Preparation Procedures: Vermicompost preparation was conducted at Holeta Agricultural Research center. A vermicomposting unit dimension of 1× 1 × 1 m^3 was set up. The vermicompost was prepared from organic materials such as green plants, animal dung, pulse straw and leaves. The raw materials were put up in layers in the following sequence according to Suparno *et al.* [13]. A layer of 20 cm crop residues which accounts 60% was spread as bedding materials. A layer of 5-10 cm animal dung which accounts for 30% was scattered over the bedding materials and then a layer of 2-4 cm topsoil which was equal to 10% was spread over cattle dung. Then, species of earthworms (*Eisenia foetida)* were introduced. After inoculation of worms, well chopped castor leaf was spread over as feeding materials subsequently upon decomposition. The materials in the bin were turned every 3 days and sprinkling of water was done to maintain 60-70% moisture content until 90% bio-wastes were decomposed. Maturity of the vermicompost was judged visually by observing the formation of black-brown color and granular structure of the vermicompost at the surface of the bin. Two months later, upon decomposition, the vermicompost was harvested. The harvesting was made by manual separation of castings from worms. The vermicompost obtained was shade dried, sieved and analyzed for nutrient contents using standard procedures in the laboratory.

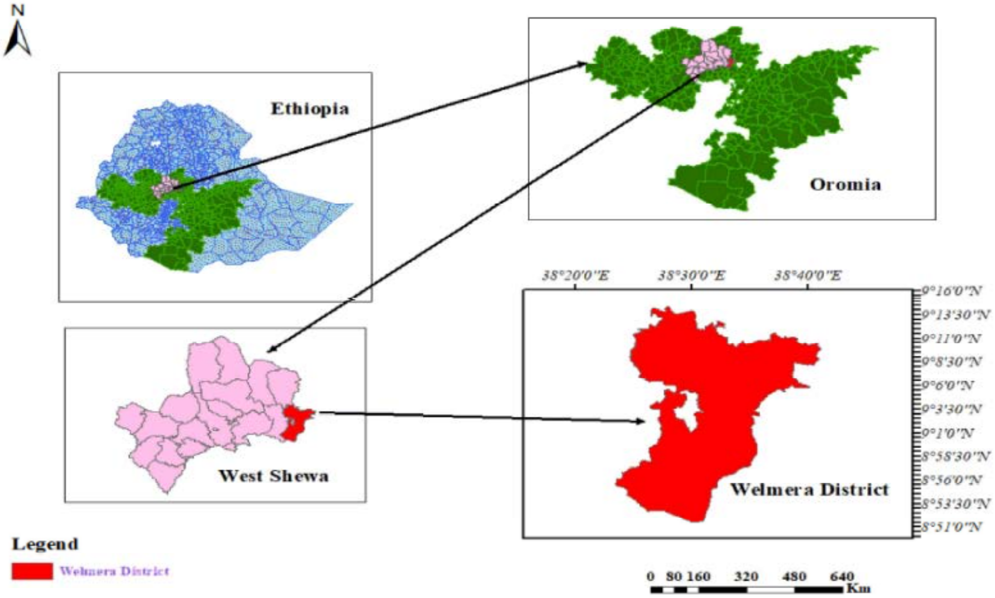

Fig. 1: Map of the Study Area

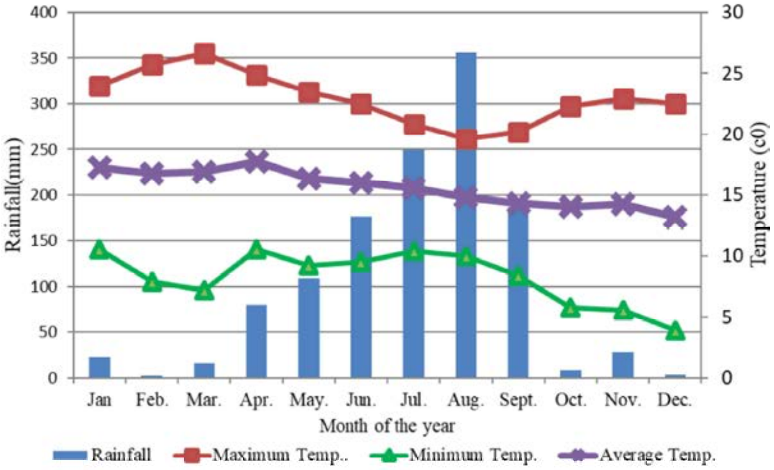

Fig. 2: Total rainfall and mean temperature of HARC center

Treatments and Experimental Design: The experiment was arranged in a factorial split- split-plot design with three replications. Two wheat varieties (Wane and Danda'a) as main plots, four vermicompost amendment levels (0, 2.5, 5 and 7.5 t. ha^{-1}) as sub-plot and four N fertilizers (0, 23, 46 and 69 kg N ha^{-1}) as sub-sub-plots were used. Treatments were randomized in every block. The experiment had total treatment combination of 2 x 4 x 4 = 32 treatments. The experimental site was prepared for sowing using standard land preparation practices of the center; Tractor-mounted disk plowing and disk harrowing was carried out in May 2019. The area of main plot was 9.5 m x 11.5 m, the area of the sub-plot and sub-sub plot was 9.5 m x 2.5 m and 2 m x 2.5 m respectively. The total area of trial site was 771.75 m^2 and the net plot size of the sub-sub plot was 1.8 m * 2.3 m (4.14 m^2). Sowing was taken place at the end of June. At the time of sowing, the experimental plots were finely delineated manually using rakes and fork diggers and the planting rows were made using iron row markers adjusted in 20 cm row spacing. Then, the Main plots were sown with two bread wheat varieties (Wane and Danda'a*)* at the rate of 150 kg ha^{-1}.

The vermicompost were applied manually and evenly to sub-plots during sowing and thoroughly mixed in the upper 15 cm of soil. The recommended nitrogen (urea) fertilizer application rate for bread wheat production is 60 kg N ha^{-1}. To minimize losses and increase efficiency, all the levels of N were applied in the row as urea in two applications; half at planting and the other half at mid-tillering during light rainfall to minimize loss of N. The recommended phosphorus fertilizer (69 kg P ha^{-1}) was uniformly applied as triple super phosphate (TSP) to all plots at sowing in a band to the rows. Other relevant field trial management practices such as weeding and crop protection were uniformly applied with close supervision during the crop growth period.

Soil and Vermicompost Analysis: The pH of the soil was measured from suspension of 1:2.5 (weight/ volume) soil to water ratio using a glass electrode attached to digital pH meter [14]. Organic carbon content was determined using wet digestion method [15]. Total Nitrogen content was determined by the Kjeldahl digestion [16]. Available Phosphorus was extracted using Bray-II method [17]. The P extracted with this method was measured by spectrophotometer following the procedures described by Murphy and Riley [18]. Exchangeable acidity of the soil was determined by leaching-titration with 1N KCl as described by Van Reeuwijk [19]. Cation exchange capacity and exchangeable bases were extracted by saturating the sample with 1N NH_4OAc. Cation exchange capacity was determined from the extract using ammonium acetate method [20]. Calcium and magnesium were determined from the extract by using atomic absorption spectrophotometer method, while exchangeable potassium and sodium was determined using flame photometer as described by Rowell [21]. The vermicompost nutrient content was determined following methods used for soil analysis.

Plant Tissue Sampling, Preparation and Analysis: At maturity, five non-boarder wheat plant samples were randomly collected from net plot of each plot and partitioned into grain and straw [22]. The straw samples were washed with distilled water to clean the samples from contaminants such as dust. The grain and straw samples were oven dried at 70°C for 24 hours and then the dry weight was measured using an electronic balance. The samples were ground by a rotor mill and allowed to pass through 0.5 mm sieve to prepare a sample. Then, the grains were analyzed for total nitrogen content following wet digestion using Kjedahl method as described by Nelson and Sommers [23].

Grain Quality Parameter

Thousand Kernels Weight (G): Thousand kernels weight was determined based on the weight of 1000 kernels sampled from the grain yield of each net plot by counting using electronic seed counter and weighed with electronic sensitive balance. Then the weight was adjusted to 12.5% moisture content. Hectoliter weight ($kghl^{-1}$): Hectoliter weight was determined on dockage free samples using a standard laboratory hectoliter weight apparatus. The percentage of grain moisture contents were measured by apparatus, grain analysis computer as described in the AACC (2000) method no 55-10 [24]. Virtuousness percentage was estimated according to ICC standard number 129 (ICC, 2000). The total number of vitreous kernels was recorded from a partial sample of 50g taken from cleaned and sieved 250g average samples and was observed under a transmitted light. The percent vitreousness was calculated by the following formula:

$$Vitreousness\ (\%) = \frac{F1}{F2+F3}*100$$

where, F1 was weight of fully vitreous kernels (g), F2 was weight of kernels which were not fully vitreous (g) and F3 was the weight of kernels which were not vitreous including the damaged ones (g).

Grain protein (%) Grain protein content was determined by NIR (Near-infrared reflectance) as stated in AACC (2000) method for whole grain wheat. This method determines the protein content in whole-grain wheat (constant moisture basis) based on transmittance or reflectance of near-infrared (850-2, 500 nm) energy. It is applicable to wheat after calibrating the equipment for bread wheat, cleaned and prepared sample of 300 g seeds were added to the equipment and waited for one minute and protein (%) reading was taken. Protein content was calculated after multiplying Kijeldhal nitrogen determinations by 5.7.

Statistical Analysis and Interpretation: All data were subjected to statistical analysis of variance using a generalized linear model (GLM) in R statistical software version 3.5.3 [25]. Significance of the treatments was tested using the agricolae package of R [26]. The means were compared using the lsmean package of R [27] with Duncan Multiple Range Test (DMRT) set at a 5% level of significance.

RESULTS AND DISCUSSIONS

Soil Physico-Chemical Properties Before Planting: Selected physico-chemical properties were analyzed for composite surface soil (0-20cm) samples collected from each replication before planting. The results indicated that the soil has 68 % clay followed by 20.75 silt and 11.25% sand and could be categorized as clay textural class on the basis of USDA Soil Survey Staff [28] soil textural triangle. The measured bulk density (1.29 g cm^{-3}) at the study site was close to the critical value density for plant growth at which root penetration is likely to be severely restricted for clay soil as described by Hazelton and Murphy [29]. The mean soil reaction of the experimental site was 4.74 which is strongly acidic. Soil organic matter, total nitrogen and available phosphorus content of the study area were 2.09 %, 0.11% and 6.32 ppm, respectively. According to the classification of soil total nitrogen, organic carbon and available P suggested by Tekalign [30] the soils of study area were found in low range. The pH of vermicompost was 7.6 which, moderately alkaline. Moreover, the results of the analysis showed the mean organic carbon and total nitrogen contents of vermicompost were 9% and 1.12%, respectively. Similarly; available phosphorus of vermicompost was 16.22 ppm.

Effects of Vermicompost and N-Fertilizer on Qualities of Wheat Varieties Thousand Grain Weights (g): Thousand kernel weight is a function of kernel size or kernel density which is an important yield contributing parameter and quality parameter which indicate the superior in predicting the milling quality of grains as compared to test weight. The analysis of variance indicated that the main effects of vermicompost, N fertilizer level as well as their interaction effect had significant ($P< 0.01$) affected thousand kernel weight of wheat varieties (Table 1). But the main effect of wheat varieties and the three-way interaction of variety x vermicompost x nitrogen did not significantly ($P \geq 0.05$) affect thousand kernel weights of wheat.

Increment in the dose of vermicompost and nitrogen fertilizer also increased thousand kernel weight of wheat varieties along all the increasing rates of fertilizers. Accordingly, the highest (43.67) thousand kernel weight was obtained at the combined application of 5 t VC ha^{-1} and 46 kg N ha^{-1} but statistically par with 7.5t VC ha^{-1} + 46 kg N ha^{-1} and 7.5t VC ha^{-1} + 69kg N ha^{-1}. On the other hand, the minimum (38.93) thousand kernel weight was recorded from control plot (Table 1). The increment in thousand kernel weights in response to increased rates of fertilizers may be due to the availability of optimum amount of nitrogen fertilizer and other nutrients as a result of vermicompost application which had led to high mean thousand kernel weight via improving leaf area and photosynthetic activities, thus improving seed organ development. The finding was in agreement with Edom *et al*. [31] and Rut-Duga [32] who observed thousand kernel weight was significantly improved due to combined application of mineral and organic fertilizers. Similarly, Wassie [33] also reported that combined application of organic and inorganic fertilizers significantly increased thousand kernel weight of wheat crop.

Grain Moisture Content (%) and Hectoliter Weight (kghl^{-1}): Moisture content is one of the most important parameters in judging the quality of wheat while hectoliter weight provides a rough estimate of flour yield potential in wheat (Bayeh, 2010); and, it is important to millers just as grain yield is important to wheat producers. The analysis of variance showed that the main effects of Varieties, vermicompost and nitrogen fertilizer had significantly ($p<0.01$) influenced moisture content and hectoliter weight of bread wheat varieties, however their interaction did not significantly ($p<0.05$) affect moisture content and hectoliter of bread wheat varieties (Table 2). The result exhibited that Danda'a Variety had higher moisture content (11.54%) than Wane Variety which contain (10.75 %) moisture. This variation in moisture content is due to the genetic make-up of the varieties. The result of this finding was in line with the result of Dobocha *et al*. [34] who reported that Hectoliter weight of bread wheat was significantly different with varieties. Moisture content is usually the principal factor governing the keeping quality of wheat. As standard the moisture content of the bread grain ranges between 8-13 percent depending upon the climatic conditions, generally, both the tested bread wheat varieties were in the ranges of standard.

Increment in the levels of vermicompost increased the moisture contents and hectoliter weight of wheat varieties. Accordingly, the highest moisture content (11.62 %) and hectoliter weight (82.17 kghl^{-1} were obtained application of 7.5 t ha^{-1} of vermicompost respectively. The result of this study was in conformity with Frehiwot [35] who reported that hectoliter weight was affected by the N, P and Vermicompost's. Similarly, Dinkinesh [36] reported that hectoliter weight was affected by different levels of blended fertilizer. Different rate of N-fertilizer significantly affected moisture content and hectoliter weight of bread wheat varieties. Thus, application of 69 kg ha^{-1} N fertilizer level scored the highest Hectoliter weight (82.84) which was statistically at par with 46 kg ha^{-1} N and exceeded by 6.9 % as compared

Table 1: Interaction effect of vermicompost and N-fertilizer on thousand kernel weights

	Thousand kernel weights (g)			
	Nitrogen rate (kgha^{-1})			
Vermicompost (t ha^{-1})	0	23	46	69
0	38.93^{g}	39.53^{fg}	40.17^{d-f}	41.33^{c-e}
2.5	40.33^{d-f}	40.47^{d-f}	40.40^{d-f}	40.33^{d-g}
5	39.80^{ef}	41.67^{bc}	43.67^{a}	42.43^{bc}
7.5	41.02^{c-e}	41.03^{c-e}	42.65^{ab}	43.02^{ab}
CD $_{0.05}$			1.13	
CV $_{(\%)}$			4.40	

Means followed by the same letter are not significantly different ($P \leq 0.05$) according to Duncan's Multiple Range Test, CD = Critical Difference

Table 2: Main effect of variety, vermicompost and N fertilizer on grain moisture content and hectoliter weight

Varieties	Moisture content (%)	Hectoliter weight (kg hl^{-1})
Danda, a	11.14^{a}	77.50^{b}
Wane	10.35^{b}	78.64^{a}
CD$_{0.05}$	0.72	1.12
CV (%)	4.5	3.6
Vermicompost (t ha^{-1})		
0	10.04^{c}	75.17^{c}
2.5	10.39^{b}	79.70^{b}
5	11.32^{a}	80.11^{b}
7.5	11.62^{a}	82.17^{a}
CD$_{0.05}$	0.35	1.78
CV (%)	3.15	3.02
N rate (kgha^{-1})		
0	10.94	77.14^{c}
23	10.99	79.70^{b}
46	11.15	81.61^{a}
69	11.09	82.84^{a}
CD $_{0.05}$	2.85	2.21
CV$_{(\%)}$	4.2	3.5

Means in a column followed by the same letter(s) are not significantly different at 5% probability level, CR= Critical range.

Table 3: Main effect of variety, vermicompost and N fertilizer on vitreousness and grain protein content

Varieties	Vitreousness (%)	Grain protein content (%)
Danda'a	84.64^{b}	11.06^{b}
Wane	86.76^{a}	12.36^{a}
CD$_{0.05}$	2.12	1.21
CV $_{(\%)}$	4.5	3
Vermicompost (t ha^{-1})		
0	85.4	11.41
2.5	87.71	12.01
5	88.51	12.13
7.5	90.03	12.36
CD$_{0.05}$	NS	NS
CV $_{(\%)}$	1.8	1.9
N (Kg ha^{-1})		
0	84.4^{d}	11.41^{d}
23	86.71^{c}	12.01^{c}
45	90.51^{ab}	12.13^{bc}
69	92.53^{a}	12.36^{b}
CD$_{0.05}$	4.52	0.32
CV $_{(\%)}$	6.11	3.2

Means followed by the same letter are not significantly different ($P \geq 0.05$) according to Duncan's Multiple Range Test, CD = Critical differences = non-Significant

with control N (77.14). This could be due to the great contribution of N fertilizer to quality parameter of bread wheat varieties. The result of this study was in conformity with the result of Dinkinesh [37] who reported that height hectoliter weight with high level of blended fertilizer.

Virtuousness and Grain Protein Content (%): Virtuousness is an important factor in the determination of the quality of the wheat type because it reflects the texture of the endosperm and consequently the end use of quality of wheat. In this study, the main effects of varieties and N fertilizer level significantly ($P< 0.01$) affect Vitreousness and protein concentration of bread wheat varieties, however, the main effect of vermicompost and their interaction didn't have significant effect on vitreousness and protein content. The vitreousness percentage (86.76 %) of Wane variety greater than Danda'a Variety (84.64%) as indicated in Table 3. Arega *et al*. [38] reported that significant variations in the degree of vitreousness were observed among genotypes. As the rates of nitrogen fertilizer increases the protein contents of gradually increased. Thus, the highest (12.36%) protein concentration was obtained from maximum dose of nitrogen fertilizer (69 kg ha^{-1}). The grain protein content of wheat was also varied with the N fertilizer rate.

CONCLUSION AND RECOMMENDATIONS

Low source and soil available nitrogen are one of the major constraints limiting wheat productivity and quality content in Ethiopia. Ensuring a well-balanced supply of N to the crop through integrated use of organic and inorganic fertilizer may result in higher N uptake, yield and quality of wheat varieties. Efficient and inexpensive methods of organic and inorganic fertilizer application are important for enhancing these targets. The present finding has demonstrated the impact of combined and sole application of vermicompost and fertilizer in improving the quality parameters of wheat genotypes. Wheat thousand kernel weight more influenced by interaction effect of vermicompost and nitrogen fertilizer than the main effect of both components. One the way grain hectoliter weight, moisture content, vitreousness and grain protein content are significantly influenced by the main effect of varieties, vermicompost and nitrogen fertilizer than their interaction. Therefore, integrated use of variety, vermicompost and nitrogen fertilizer is found to be better in enhancing wheat uptake and quality parameters.

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