American Journal of Bioscience and Bioengineering
2021; 9(6): 169-178
http://www.sciencepublishinggroup.com/j/bio
doi: 10.11648/j.bio.20210906.14
ISSN: 2328-5885 (Print); ISSN: 2328-5893 (Online)

Nitrogen Uptake and Use Efficiency of Wheat (*Triticum aestivum* L.) Varieties as Influenced by Combined Application of Vermicompost and Nitrogen Fertilizer Rate

Negessa Gadisa[1, *], Tesfaye Wakgari[2]

[1]Ethiopian Institute of Agricultural Research, Holeta Agricultural Research Canter, Holeta, Ethiopia
[2]Department of Natural Resource Management, Ambo University, Ambo, Ethiopia

Email address:
nagasagadisa@gmail.com (N. Gadisa)
[*]Corresponding author

To cite this article:
Negessa Gadisa, Tesfaye Wakgari. Nitrogen Uptake and Use Efficiency of Wheat (*Triticum aestivum* L.) Varieties as Influenced by Combined Application of Vermicompost and Nitrogen Fertilizer Rate. *American Journal of Bioscience and Bioengineering.* Vol. 9, No. 6, 2021, pp. 169-178. doi: 10.11648/j.bio.20210906.14

Received: November 17, 2021; **Accepted**: December 6, 2021; **Published**: December 24, 2021

Abstract: Crop management strategies that improve nitrogen use efficiency and increase profits while reducing the detrimental effects on the environment due to loss of nitrogen fertilizer. A study was conducted in 2019 cropping season to evaluate effectiveness of vermicompost, N fertilizer and their combinations in improving nitrogen uptake and nitrogen use efficiency at Holeta Agricultural Research Center. The experiment was designed in a split- split-plot combination with wheat varieties (Wane and Danda'a) as main plots, four vermicompost rates (0, 2.5, 5 and 7.5 t ha^{-1}) as sub-plot and four N fertilizer rates (0, 23, 46 and 69 kg N ha^{-1}) as sub-sub plot with three replications. Synergistic nutrient interaction effect sourced from vermicompost and urea fertilizer brought positive influence on wheat nitrogen uptake and use efficiency. The highest (154.33 kgha^{-1}) total nitrogen uptake was obtained from combined application of Wane variety together with 5 t ha^{-1} vermicompost and 46 kgha^{-1} of nitrogen fertilizer while the lowest value (33.21kgha^{-1}) was obtained from control plot. Maximum grain nitrogen use efficiency (93.45 kg kg^{-1}) was recorded from plot that received Wane variety with 23 kg N ha^{-1} and the value decreased as vermicompost and N fertilizer level increased while the lowest (29.63 kg kg^{-1}) value was obtained when Danda'a variety used with vermicompost at 7.5t ha^{-1} and 69 kg ha^{-1}nitrogen fertilizer. Similarly, the highest nitrogen apparent recovery efficiency (111.42%) and agronomic efficiency (42.59 kg kg^{-1}) were observed in treatment that received Wane variety with combined application of vermicompost at 5 t ha^{-1} and nitrogen at 46 kg ha^{-1} while the lowest value was respectively obtained from Danda'a variety with nitrogen at 69 kg ha^{-1} and Danda'a variety with vermicompost at 2.5t ha^{-1}. The maximum (72.64%) N harvest index was recorded from variety Wane when applied with combination of vermicompost at 2.5t V ha^{-1} and nitrogen at 46kgha^{-1}, but the minimum (61.98%) value was recorded from application of vermicompost at 7.5tha^{-1}. Therefore, integrated use of variety, vermicompost and nitrogen fertilizer is found to be better in enhancing nitrogen fertilizer efficiency and reducing environment problems.

Keywords: Nitrogen, Nitrogen Uptake, Organic Source, Wheat

1. Introduction

Nitrogen (N) is required in large quantities for wheat production and is considered the most yield limiting nutrient. Usually, farmers apply either limited or excess N regardless of crop requirement and nature of crop management practices [1]. According to the Food and Agriculture Organization of the United Nations, about 85 million Mt of nitrogenous fertilizers were applied globally in 2002 [2]. Nitrogenous fertilizer consumption continued to grow worldwide to improve crop yield. Improper application of N fertilizes to fields contaminate surface and ground water. Yet, improvement of N Use efficiency (NUE) has been a primary focus of soil scientists and agronomists for a long time [3, 4]. Crop management strategies that improve NUE obviously increase farm profits while reducing the detrimental effects on the environment associated with fertilizer N loss [5].

Use of various sources of fertilizers has made a tremendous contribution in enhancing food production. It has been estimated that nutrient inputs are responsible for 30-50% of crop yield [6]. However, the issues such as low NUE and associated environmental pollution and global warming have raised serious concerns about the current nutrient management practices. The recovery efficiency of fertilizer nitrogen is about 20-40%, which is in a low range [7]. The major reasons for low and declining crop responses to fertilizer nutrients include continuous nutrient mining from the soil due to imbalanced nutrient use (7:2.8:1 NPK) leading to depletion of some of the major, secondary and micro nutrients like N, K, S, Zn, Mn, Fe etc., decreasing use of organic nutrient sources such as vermicompost or compost and integration of these sources with chemical fertilizers in cropping systems leading to serious soil fertility depletion.

Worldwide NUE for cereal production was estimated to be 33 percent [8]. This low percentage was influenced by both direct and indirect factors. Among the causes and pathways for direct N loss, application of N in amounts that exceed crop growth requirements is the major one. It has been clearly shown in the literature that applying the correct rate and source of N is considered to be the most important factor in improving nitrogen fertilizer efficiency [9]. This can be achieved by easily implementing laws governing mobile nutrients and using soil test facilities when available [10]. Proper nutrient management practice is useful to increase the performance of crop, provide economically optimum nourishment to the crop, and minimize nutrient losses from the field and supporting agricultural system sustainability. Cropping system, soil and water management, use of appropriate N fertilizer source and rate based on crop variety and soil type are among the main management options to increase N fertilizer use efficiency [11].

In addition, uses of slow N releasing fertilizer source and N efficient species or genotypes are important factors to be considered to improve N use efficiency [12]. Nutrient use efficiency addresses some but not all aspects of crop performance [13]. Improved nitrogen use efficiency is important for sustainable crop production and maintaining environmental quality. Nitrogen accumulation or uptake and nitrogen harvest index are the key indicators of nitrogen fertilizer use efficiency [15]. Estimates of NUE calculated from research plots on experimental stations are generally greater than those for the same practices applied by farmers in production fields. Nitrogen uptake increases with combined use of organic substance and mineral fertilizer due to improvement in soil structure, crop root development and increases in crop yield. The most important practices that can improve fertilizer efficiency are liming acid soils, use of adequate N rates, source and timing and planting N efficient genotypes within species [16]. Therefore, the study was conducted to evaluate effect of vermicompost and nitrogen fertilizer rates on nitrogen uptake and nitrogen use efficiency of wheat varieties under Nitosols in Welmera District.

2. Materials and Methods

2.1. 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.

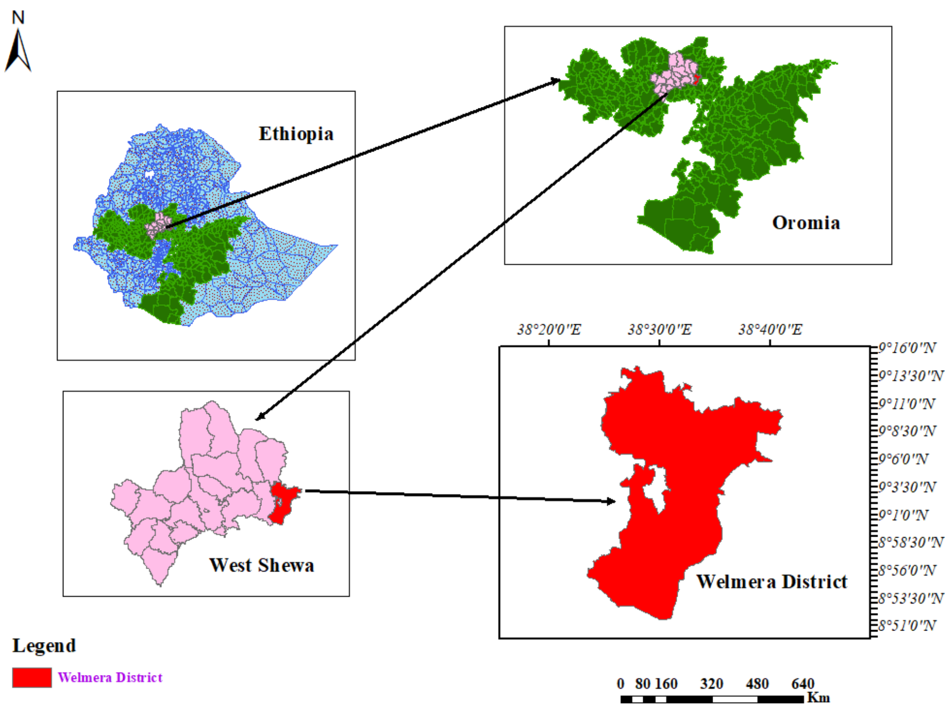

Figure 1. *Map of the Study Area.*

2.2. 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.

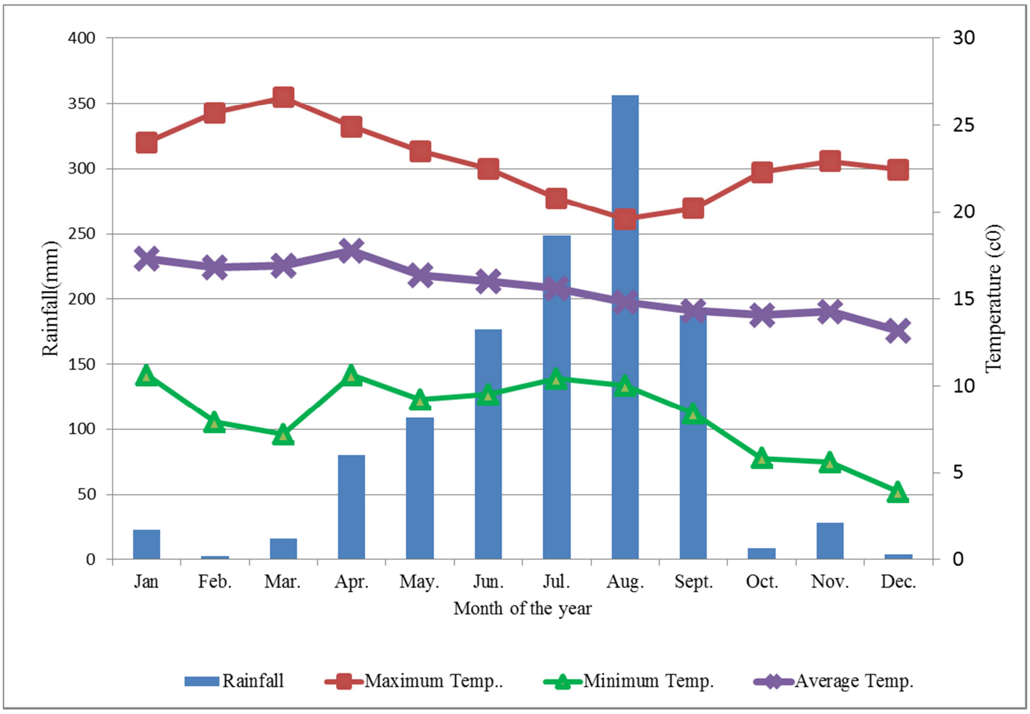

Figure 2. *Total rainfall and mean temperature of HARC center.*

2.3. 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 [16]. 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.

2.4. 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.

2.5. Soil Sampling and Analysis

Soil samples were taken both before and after planting from the experimental field. Disturbed (using auger) soil samples which were composited by thoroughly mixing and undisturbed (using core) one was also collected. Before planting, disturbed samples were randomly taken from five different spots across each block from a depth of 0-20 cm to make one composite sample. After harvesting (five months later), soil samples were collected from each plot at a depth of 0 - 20 cm. The collected soil samples were bagged, labeled and submitted to the Holeta Agricultural research laboratory. In the laboratory sufficient amount of composite soil samples were air dried and ground to pass a 2-mm sieve except for organic carbon and total N in which 0.5 mm sieve was used. Then, soil samples were analyzed for physicochemical properties following standard laboratory procedures.

Particle size distribution was determined by the hydrometer method [17]. After determining sand, silt, and clay separates; the soil was assigned to textural classes using the USDA soil textural triangle [18]. Bulk density was determined using the core method as described by Jamison *et al*. [19]. The average soil particle density (2.65 g cm^{-3}) was used for estimating total soil porosity [20]. Soil water content was determined using gravimetric method following the procedures described by [21].

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 [22]. Organic carbon content was determined using wet digestion method [23]. Total Nitrogen content was determined by the Kjeldahl digestion [24]. Available Phosphorus was extracted using Bray-II method [25]. The P extracted with this method was measured by spectrophotometer following the procedures described by [26]. Exchangeable acidity of the soil was determined by leaching-titration with 1N KCl as described by [27]. Cation exchange capacity was determined from the extract using ammonium acetate method [28].

2.6. Vermicompost Analysis

Total Nitrogen content of vermicompost was analyzed using the Kjeldahl digestion, distillation and titration method as described by [29]. Phosphorus content of vermicompost was analyzed according to [30]. Other parameters determined following similar standard methods used for soil analysis.

2.7. Plant Tissue Sampling, Preparation and Analysis

At maturity, five non-boarder wheat plant samples were randomly collected from net plots of each plot and partitioned into grain and straw [31]. 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 to constant weight. Oven dried plant samples were ground with the help of Willy mill grinder. After grinding the sample was passed through 0.5 mm sieve. Then, the grains and straw samples were analyzed for nitrogen content following wet digestion using Kjedahl method as described by [29].

2.8. Nitrogen Uptake and Use Efficiency Indices

Total nitrogen uptake (TNU) was calculated as the sum of the respective grain nitrogen uptake (NUG) and straw nitrogen uptake (NUS) values. Then, nitrogen use efficiency parameters by the crop were determined using the formulae described by [32]

$$\text{NUG (kg ha}^{-1}) = \text{Av. Gy} * \frac{\text{NCG}}{100} \tag{1}$$

Where, NUG -nitrogen uptakes of grain, Av.GY- average grain yield (kgha^{-1}), NCG-nitrogen concentration of grain in percent.

$$\text{NUS (kg ha}^{-1}) = \text{Av. SY} * \frac{\text{NCS}}{100} \tag{2}$$

Where NUG nitrogen uptake of straw, Av.GY average grain straw, NCG nitrogen concentration of straw in percent.

$$\text{TNU(kg ha}^{-1}) = \text{NUG} + \text{NUS} \tag{3}$$

Where TNU total nitrogen uptake, NUG nitrogen uptake of grain, NUS nitrogen of straw.

Nitrogen Use Efficiency (NUE) is Weight of grain per unit of total nitrogen supplied determined as follows:

$$\text{NUE(kg/kg)} = \frac{\text{Grain yield}}{\text{Total nitrogen supply}} * 100 \tag{4}$$

Agronomic efficiency (*kg grain/ kg N*): It expressed as units increase in economic yield per unit N fertilizer applied was calculated as:

$$\text{AE(kg /kg)} = \frac{\text{GYf} - \text{GYu}}{\text{Na}} \tag{5}$$

AE stands for agronomic efficiency, Gyf and Gyu for grain yield in fertilized and unfertilized plots, respectively, and Na for quantity of fertilizer applied.

Apparent fertilizer N recovery efficiency (%): It indicates the quantity of nutrient uptake per unit of nutrient applied and was calculated as:

$$\text{ARE(\%)} = \frac{\text{Nf} - \text{Nu}}{\text{Na}} * 100 \tag{6}$$

where Nf is the total N uptake of the fertilized plot (kg), Nu is the total N uptake of unfertilized plot (kg) and Na is the quantity of N applied (kg).

Nitrogen harvest index (NHI) the ratio of nitrogen uptake by grain and nitrogen uptake by grain plus straw and determined as follows:

$$\text{NHI}\ (\%) = \frac{\text{GNU}}{\text{TNU}} * 100 \quad (7)$$

2.9. Data 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 [33]. Significance of the treatments was tested using the agricolae package of R [34]. The means were compared using the lsmean package of R [35] with Duncan Multiple Range Test (DMRT) set at a 5% level of significance.

3. Results and Discussion

3.1. Soil Physico-chemical Properties Before Planting

Selected physico-chemical properties were analysed 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 [18] 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 [36]. The mean total soil porosity of the study area was 51.7 percent while the percentage of soil moisture content in the study area was 16.25. 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 [37], 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. The average concentrations of the exchangeable bases of vermicompost were 12.34, 15.4, 8.2, and 1.32 cmol (+) kg^{-1}, for potassium, calcium, magnesium, and sodium respectively.

3.2. Effects of Vermicompost and N-fertilizer on N-uptake and Efficiency Indices

3.2.1. Nitrogen Uptake of Wheat Varieties

Analysis of variance indicated that the main effect of varieties, vermicompost and nitrogen significantly ($P < 0.05$) influenced grain nitrogen uptake of wheat. Similarly, the two-way interaction of variety x vermicompost, varieties x nitrogen, vermicompost x nitrogen and the three-way interaction of variety x vermicompost x nitrogen significantly ($P < 0.05$) affected nitrogen uptake of wheat varieties. Grain nitrogen uptake reflected grain yield response to the applied nitrogen fertilizer rate. The nitrogen uptake by the grain was significantly ($P < 0.05$) influenced by the interaction of varieties x vermicompost x nitrogen fertilizer (Table 1). The highest (110.84 kg ha^{-1}) amount of nitrogen taken up by the grain was recorded from combined application of variety Wane along with application of 7.5t ha^{-1} vermicompost and 46 kg ha^{-1} nitrogen fertilizer while the lowest (23.81 kg N ha^{-1}) nitrogen uptake by grain was recorded from Danda' a variety without fertilizer input.

Table 1. *Interaction of effect of variety, vermicompost and N on grain N-uptake.*

Grain N-uptake (%)					
Variety	**VC**	**N**			
		0	**23**	**46**	**69**
Danda'a	0	23.81^{o}	31.34o	47.04^{l}	58.80^{j}
	2.5	33.24^{mn}	47.52^{l}	60.16^{ij}	67.94^{gh}
	5	48.51^{kl}	68.92^{g}	94.78^{c}	89.62^{d}
	7.5	57.12j	76.34^{f}	90.88^{cd}	87.27^{d}
Wane	0	24.74^{o}	36.91^{m}	45.56^{l}	57.89^{j}
	2.5	35.85^{mn}	44.54^{l}	64.01^{hi}	74.06^{f}
	5	52.35^{l}	74.80^{f}	110.33^{ab}	103.30^{b}
	7.5	61.45^{ij}	80.92^{e}	110.84^{a}	107.72^{ab}
$CD_{(5\%)}$			4.43		
$CV_{(\%)}$			4.2		

The highest nitrogen up taken by varieties wane at the highest rate of vermicompost and nitrogen fertilizer might be due to improvement in crop yield as well as enhancement in soil physical properties that help crop root growth and distribution which reduce nitrogen loss hence, increase uptake by the crop. In general, an improvement in grain yield had resulted from increased in nitrogen uptake by the grain. Therefore, variety Wane had higher grain nitrogen uptake than Danda'a variety. The finding agreed with [38] who reported significant increase in grain nitrogen uptake of wheat varieties as a result of combined application of organic and chemical fertilizer and genetic differences in varieties.

Straw nitrogen uptake was significantly ($p < 0.05$) affected by the main effect of varieties, vermicompost and nitrogen rates. Similarly, the two-way interaction effect of varieties x vemicompost, varieties x nitrogen, vermicompost x nitrogen and the three-way interaction of varieties x vermicompost x nitrogen were significantly ($p<0.05$) influenced straw and total nitrogen uptake of both varieties.

Table 2. *Interaction of variety, vermicompost and N on straw N-uptake.*

Straw N-uptake (%)					
Variety	**VC**	**N-level**			
		0	**23**	**46**	**69**
Danda'a	0	9.40^{l}	16.00^{kl}	22.31^{h-k}	25.48^{g-j}
	2.5	15.75^{kl}	18.79^{jk}	24.93^{g-j}	26.61^{g-i}
	5	26.29^{g-i}	30.51^{e-g}	41.77^{a-c}	43.09^{ab}
	7.5	35.19^{c-e}	33.96^{d-f}	38.60^{b-d}	41.61^{a-c}
Wane	0	10.82^{l}	16.39^{kl}	22.64^{h-k}	27.50^{f-i}
	2.5	20.52^{i-k}	27.36^{f-i}	24.19^{g-j}	29.45^{e-h}
	5	25.80^{g-j}	36.16^{c-e}	43.33^{ab}	46.52^{a}
	7.5	32.05^{e-g}	35.36^{e-g}	43.69^{ab}	46.91^{ab}
$CD_{(5\%)}$			6.41		
$CV_{(\%)}$			7.5		

Straw nitrogen uptake was consistently increased with increasing the levels of vermicompost and nitrogen fertilizer rates (Table 2). The highest straw N contents (46.91kgN ha^{-1}) was observed in the plot that received variety wane with vermicompost (7.5t ha^{-1}) and nitrogen fertilizer (69kgha^{-1}) while the lowest uptake (9.40 kg N ha^{-1}) was recorded from plot that received Danda' a variety without fertilizer (Table 2). Similar finding was reported by [39, 40] who indicated combined application of organic and chemical fertilizers enhanced nutrient uptakes and yields of crop. Total nitrogen uptake of was also significantly ($p<0.05$) affected by the main effect of variety, vermicompost and nitrogen rates.

Likewise, the two-way interaction effect of variety x vermicompost, variety x nitrogen, vermicompost x nitrogen and the three-way interaction of variety x vermicompost x nitrogen significantly ($p<0.05$) influenced total nitrogen uptake of wheat varieties (Table 3). The total N uptake reflected the biomass yield response of varieties to the applied N fertilizer rates. Accordingly, the highest total nitrogen uptake was recorded from variety Wane when treated with vermicompost at 5t ha^{-1} and nitrogen fertilizer at the rate of 46kgha^{-1} while the lowest value was obtained from variety Danda'a without any fertilizer application.

Total N taken up by both varieties increased with increasing rate of vermicompost application. It could be due to positive impact of vermicompost in improving soil bulk density and root exploration of nitrogen so that the varieties taken up more nitrogen in biomass. Higher accumulation of N in grain than straw help improvement in wheat yield and consequently leads to higher use efficiency of the nutrients. According to [41, 42], plants having vigorous and extensive root systems can explore large soil volumes and absorb more water and nutrients under nutrient stress conditions and can increase crop yield and nutrient use efficiency.

Table 3. *Interaction of variety, vermicompost and N on total N-uptake.*

Total N-uptake (%)					
Variety	**VC**	**N**			
		0	**23**	**46**	**69**
Danda'a	0	33.21^{o}	47.35^{n}	69.35^{kl}	84.28^{i}
	2.5	48.99^{n}	66.31^{l}	85.09^{i}	94.55^{fg}
	5	74.81^{jk}	99.42^{ef}	136.55^{b}	132.71^{bc}
	7.5	92.31^{gh}	110.30^{d}	129.48^{c}	128.88^{c}
Wane	0	35.56^{o}	53.29^{mn}	68.19^{l}	85.40^{i}
	2.5	56.36^{m}	71.91^{kl}	88.20^{hi}	103.51^{e}
	5	78.14^{j}	110.96^{d}	154.33^{a}	149.82^{a}
	7.5	93.50^{f-h}	116.28^{d}	153.53^{a}	149.96^{a}
CD $_{(5\%)}$			5.7		
CV $_{(\%)}$			3.71		

This result was in agreement with Dobocha *et al*. [43] who reported that N uptake of wheat increased with increasing addition of organic source and nitrogen fertilizer rates. Similarly, Sofonyas [44] and Singh *et al*. [45] suggested that integrated application of organic source with chemical fertilizers as well as increased in N rates resulted in the increase in N uptake with split dose of urea fertilizer application.

3.2.2. Nitrogen Use Efficiency (NUE)

Grain nitrogen use efficiency was significantly ($P<0.05$) affected by the main effect of varieties, vermicompost and nitrogen rates. Likewise, the two-way interaction effect of vermicompost x nitrogen rate as well as the three-way interaction of varieties x vermicompost x nitrogen also significantly ($p < 0.05$) affected nitrogen use efficiency (Table 4). However, the interaction effect of varieties x vermicompost and variety x nitrogen didn't significantly affect NUE of the varieties.

In the present study, nitrogen use efficiency was calculated based on the yield response relative to applied N and residual N in the soil. N use efficiency of wheat grain yield in response to the interaction effect of treatments ranged from 29.63 kg kg^{-1} to 93.45 kg kg^{-1} N. The highest grain nitrogen use efficiency (93.45 kg kg^{-1}) was obtained from plot that received variety Wane with 23 kg N ha^{-1} and the value decreased as vermicompost and N fertilizer level increased. The lowest value (29.63 kg kg^{-1}) was obtained when variety Danda'a used with 7.5t VC ha^{-1} and 69 kg N ha^{-1}. This might be resulted from the capacity of varieties to absorb nitrogen at higher rate from low rhizosphere nitrogen concentration which responsible for efficient nitrogen use by plant.

Table 4. *Interaction of variety, vermicompost and N on grain nitrogen use efficiency.*

NUE (%)					
Variety	**VC**	**N**			
		0	**23**	**46**	**69**
Danda'a	0	-	79.19^{b}	58.49^{d}	48.44^{ef}
	2.5	63.72^{c}	51.08^{e}	45.15^{f-h}	38.98^{ij}
	5	45.17^{f-h}	45.70^{f-h}	48.86^{d}	37.96^{ij}
	7.5	34.95^{j}	36.65^{j}	36.13^{j}	29.63^{k}
Wane	0	-	93.45^{a}	58.06^{d}	48.40^{ef}
	2.5	76.32^{b}	48.96^{e}	48.28^{ef}	42.35^{g-i}
	5	47.32^{e-g}	49.15^{ef}	56.48^{d}	42.82^{g-i}
	7.5	36.70^{j}	37.43^{j}	42.23^{hi}	34.86^{j}
CD $_{(5\%)}$			4.42		
CV $_{(\%)}$			5.9		

This confirms the finding of Fageria *et al*.[46] who reported that NUE was influenced by the levels of nitrogen concentration in the growth medium of plant which also influenced the rate at which varieties absorb nitrogen around the root zone. For both varieties, the result generally indicated a decreased in efficiency of N use by grain as vermicompost and nitrogen fertilizer rate increased. There was strong relationship between fertilizer rate and nitrogen use efficiency. Nitrogen use efficiency of wheat grain decreased with increasing in N-fertilizer application rate. Similarly, Bhatt *et al*. [47] reported that nitrogen use efficiency was found to be greater at low nitrogen dose and decreased with increased in application rate. Improvement in NUE is important in order to minimize both N- fertilizer losses and the direct production costs of the crop. Moreover, Freeman *et al*. [48] suggested that N use efficiency of wheat decreased significantly in responses to increasing N fertilizer rates. This finding indicated that the use of wheat varieties with higher NUE can contributed to decreasing in the amount of N to be applied without decreasing grain yield and quality.

3.2.3. Agronomic Nitrogen Use Efficiency (AE)

The main effect of variety ($P< 0.05$), vermicompost and nitrogen significantly ($P< 0.05$) affected nitrogen agronomic efficiency. Similarly, the two-way interaction of vermicompost x nitrogen as well as the three-way interaction of varieties x vermicompost x nitrogen significantly affected ($P< 0.05$) nitrogen agronomic efficiency of wheat. However, the interaction of variety x vermicompost and varieties x nitrogen didn't significantly influence nitrogen agronomic efficiency. The result showed that increasing application rates of nitrogen fertilizer decreased agronomic nitrogen use efficiency (Table 5). Nitrogen agronomic efficiency indicated that the capability of yield increases per kilogram of N applied declined. Thus, the highest (42.59 kg kg^{-1}) agronomic nitrogen efficiency was obtained from Wane variety with application of 5 t VC ha^{-1} and 46 N $kgha^{-1}$ while the lowest (17.98kg kg^{-1}) agronomic efficiency was obtained from Danda'a variety with application of vermicompost (2.5t ha^{-1}) alone. Common agronomic nitrogen efficiency value ranges from 10 to 30 and values higher than 30 indicates efficiently managed farm lands.

Thus, the agronomic N efficiency obtained at the medium rates of combined application of vermicompost and nitrogen fertilizers in this experiment was high. Similarly, Dorsey [49] and Ramesh [42] concluded that combined application of vermicompost with urea fertilizer produced higher grain yield and agronomic efficiency; indicating a best way for sustainable wheat cultivation. Integrated application of vermicompost and mineral N fertilizer not only increased growth and yield of wheat crop but also enhanced N agronomic efficiency. This confirms findings by others who suggested high agronomic efficiency obtained when yield per unit of nitrogen applied is increased because N uptake increased while at the losses decreased [50, 51].

Table 5. *Interaction of variety, vermicompost and N on agronomic efficiency.*

AE ($kgkg^{-1}$)					
Variety	**VC**	**N**			
		0	**23**	**46**	**69**
Danda'a	0	--	19.52^{kl}	28.65^{c-f}	27.88^{c-g}
	2.5	17.98^{l}	25.18^{e-i}	27.09^{d-g}	25.12^{e-i}
	5	22.30^{h-k}	29.16^{c-e}	35.92^{b}	27.32^{c-g}
	7.5	19.70^{kj}	24.50^{f-j}	26.03^{d-h}	21.00^{j-l}
Wane	0	--	29.59^{cd}	25.38^{e-h}	27.39^{c-g}
	2.5	21.24^{i-l}	21.18^{i-l}	28.90^{c-e}	27.48^{c-g}
	5	22.78^{h-k}	31.41^{c}	42.59^{a}	31.40^{c}
	7.5	19.67^{kl}	24.40^{g-j}	31.40^{c}	25.60^{d-h}
$CD_{(5\%)}$			3.49		
$CV_{(\%)}$			8.7		

3.2.4. Apparent Nitrogen Recovery Efficiency (ARE)

Analysis of data showed that the main effect of varieties ($P< 0.05$), vermicompost and nitrogen significantly ($P< 0.05$) affected apparent nitrogen recovery efficiency. Similarly, the two-way interaction of vermicompost x nitrogen as well as the three-way interaction of varieties x vermicompost x nitrogen significantly ($P< 0.05$) affected apparent nitrogen recovery efficiency of wheat varieties (Table 6). However, the interaction of varieties x vermicompost and varieties x nitrogen didn't significantly influence apparent nitrogen recovery efficiency. Nitrogen apparent recovery efficiency indicates amount of N recovered within the entire soil-crop root system and depends on the congruence between plant N-demand and the quantity of N released from applied N. I n this study, maximum ARE of 111.42% was recorded from variety Wane at combined application of 5t. ha^{-1} of vermicompost and 46 kg ha^{-1} nitrogen while the lowest recovery efficiency 60.17% was recorded from variety Danda, a at 2.5 t. ha^{-1} of vermicompost application.

Table 6. *Interaction of variety, Vermicompost and N on apparent recovery efficiency.*

ARE (%)					
Variety	**VC**	**N**			
		0	**23**	**46**	**69**
Danda'a	0	--	67.54^{j-l}	63.12^{l-n}	60.17^{mn}
	2.5	62.63^{l-n}	68.13^{j-m}	72.22^{g-j}	65.00^{k-m}
	5	74.35^{f-i}	83.40^{de}	100.33^{b}	79.23^{d-f}
	7.5	69.01^{i-l}	70.89^{h-k}	73.00^{f-j}	62.56^{l-n}
Wane	0	--	67.17^{k-m}	64.94^{h-k}	63.23^{g-j}
	2.5	65.34^{k-m}	69.58^{j-l}	72.27^{h-l}	68.63^{h-l}
	5	70.97^{h-k}	90.84^{c}	111.42^{a}	88.57^{cd}
	7.5	64.38 l^{-n}	71.44^{g-j}	87.48^{cd}	74.89^{e-g}
$CD_{(5\%)}$			7.12		
$CV_{(\%)}$			4.5		

The apparent recovery exhibited an increasing trend with the increased level of combined application of vermicompost and nitrogen fertilizer up to the upper medium dose of both vermicompost and nitrogen and then decreased with continuous addition of vermicompost and N-fertilizer rate. Accordingly, the highest apparent nitrogen recovery (111.42%) was observed in treatment that received variety wane with combined application of 5 t VC ha^{-1} and 46 kg N kg^{-1} while the lowest value was obtained from plot that received Danda'a variety with 69 kg ha^{-1} of N fertilizer. The increased in apparent nitrogen recovery efficiency of wheat variety was the expression of nitrogen uptake by the fertilized plants rather than the amount of nitrogen applied. Application of organic manures not only used as source of nitrogen but also influenced their availability and accessibility for crop. Improvement in apparent nitrogen recovery in the presence of vermicompost may be due to better nutritional environment in the crop root zone that might have enhanced the availability of nitrogen to the plant and converted the applied nitrogen in to yield more efficiently. The finding in agreement with Chatterjee *et al.* [52] and Faraj [53] who confirmed improvement in N recovery efficiency under combined use of organic and chemical fertilizer with varieties tested.

3.2.5. Nitrogen Harvest Index (NHI)

Nitrogen harvest index (NHI) is the amount of N accumulated in grain divided by the amount of N accumulated in grain plus straw. Nitrogen harvest index indicates the level of efficiency of plants to use acquired nitrogen for grain formation. A high NHI indicates efficient utilization of nitrogen. NHI was significantly influenced by the main effect of N rate, the interaction of vermicompost x N rate as well as the factor interaction of variety x vermicompost x nitrogen. However, the main effect of varieties and vermicompost did not significantly affect NHI. Similarly, the two way interaction of variety x vermicompost and variety x nitrogen did not significantly NHI. The maximum N harvest index (72.64%) was recorded from variety Wane when applied with combination of 2.5t VC ha^{-1} and nitrogen fertilizer 46kgNha^{-1} treatments while the minimum value (61.98%) was recorded from application of vermicompost at 7.5t ha^{-1} without nitrogen input (Table 7).

Table 7. *Interaction of variety, vermicompost and N-fertilizer on NHI.*

NHI (%)					
Variety	**VC**	**N**			
		0	**23**	**46**	**69**
Danda'a	0	71.77^{ab}	66.15^{c-g}	67.84^{a-e}	69.67^{a-d}
	2.5	67.79^{a-e}	71.67^{ab}	70.70^{a-c}	71.84^{ab}
	5	64.81^{d-g}	69.24^{a-d}	69.43^{a-d}	67.53^{b-e}
	7.5	61.98^{g}	69.20^{a-d}	70.23^{a-c}	67.74^{a-e}
Wane	0	68.03^{a-e}	69.25^{a-d}	67.30^{b-e}	67.76^{a-e}
	2.5	63.51^{e-g}	62.44^{fg}	72.64^{a}	71.69^{ab}
	5	66.97^{b-f}	67.49^{b-e}	71.80^{ab}	68.95^{a-d}
	7.5	65.72^{c-g}	69.69^{a-d}	71.78^{ab}	69.74^{a-d}
LSD $_{(5\%)}$			4.11		
CV $_{(\%)}$			3.7		

This improvement in NHI could be due to partitioning of the total nitrogen content more to the vegetative part of the variety than to the grain and increased the total aboveground biomass yield. The present result is consistent with the study by Sinebo *et al*. [54] who reported nitrogen harvest index in durum wheat of 65%-82%, with an average value of 73% depending on N rate and timing of application. Similarly, Fageria and Baligar [55] reported differences on nitrogen harvest index of varieties.

4. Conclusion and Recommendations

Low available soil N and reduced plant NUE are some of the major constraints limiting wheat yield 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 and NUE of wheat varieties. Efficient and inexpensive methods of organic and inorganic fertilizer application are important for farmers in the study area. The present finding demonstrated combined application of vermicompost and fertilizer is necessary to provide economically optimum wheat yields. Specifically, the use of wane variety together with vermicompost at 5t ha^{-1} and N fertilizer at 46 kg N ha^{-1} greatly enhanced the NUE, AE, ARE and NHI at Welmera district. The use of vermicompost with nitrogen fertilizer is therefore the best alternative for reducing chemical N fertilizer use. Generally, integrated use of organic and inorganic fertilizers has environmental benefits, as it reduces both chemical fertilizer usage and N losses, and allows for sustainable crop production. Further evaluation of the different available manures and their interactions with inorganic fertilizers, together with the development of new varieties, will lead to continued improvements in wheat production throughout the world.

References

[1] Torbert, H. A., K. N. Potter, and J. E. Morrison, Jr. 2001. Tillage system, fertilizer nitrogen rate and timing effect on corn yields in the Texas backland prairie. *Agron. J.* 93: 1119-1124.

[2] Food and Agriculture Organization of the United Nations (FAO). 2004. FAOSTATA database Agriculture data base: Fertilizer, FAO, Rome, Italy.

[3] Raun, W. R., J. B. Solie, G. V. Johnson, M. L. Stone, R. W. Mullen, K. Freeman, W. E. Thomason, and E. V. Lukina. 2002. Improving nitrogen use efficiency in cereal grain production with optical sensing and variable rate application. *Journal of Agronomy* 94: 815-820.

[4] Khosla, R., K. Fleming, J. A. Delgado, T. Shaver, and D. G. Westfall. 2002. Use of site-specific management zones to improve nitrogen management for precision agriculture. *Journal of Soil and Water Conservation.* 57: 515-518.

[5] Grant, C. A., G. A. Peterson, and C. A. Campbell. 2002. Nutrient considerations for diversified cropping systems in the Northern Great Plains. *Journal of Agronomy,* 94: 186-198.

[6] Stewart WM. 2002. *News and Views–A regional Newsletter*. Canada, USA: Potash and Phosphate Institute (PPI) and the Potash and Phosphate Institute of Canada (PPIC). 2p.

[7] Rao KV. Research Themes-*Site–Specific Integrated Nutrient Management for Sustainable Rice Production and Growth*. Rajendranagar, Hyderabad, India: Rice Knowledge Management Portal (RKMP), Directorate of Rice Research; 2014.

[8] Raun, W. R., and G. V. Johnson. 1999. Improving nitrogen use efficiency for cereal production. *Journal of Agronomy,* 91: 357-363.

[9] Magdoff, F. R. 1991. Managing nitrogen for sustainable corn systems: Problems and possibilities. *American Journal of alternative Agriculture.* 6: 3-8.

[10] Bray, R. H. 1954. A nutrient mobility concept of soil-plant relationships. *Soil Science,* 104: 9-22.

[11] United States Department of Agriculture (USDA).2011. National agronomy manual. 190-V- NAM, 4th Ed. 59 p.

[12] Fageria, N. K .2009. The use of nutrients in crop plants. Taylor and Francis Group, LLC: CRC Press.

[13] Mikkelsen R, Tom LJ, Cliff S, Tom WB .2012. Chapter 9. Nutrient management planning and accountability. In 4R plant nutrition: A manual for improving the management of plant nutrition (T. W. Bruulsema, P. E. Fixen, G. D. Sulewski, eds.), International plant nutrition institute, Norcross, GA, USA.

[14] Huggins, D. R., Pan, W. L .2003. Key indicators for assessing nitrogen use efficiency in cereal-based agro ecosystems. *Special edition of Journal of Crop Production,* 8: 157-186.

[15] Fageria, N. K .2014. Nitrogen harvest index and its association with crop yields. *Journal of Plant Nutrition*, 37: 795-810.

[16] Suparno, Budi, P., Abu, T. and Soemarno. 2013. The study of vermicomposting Optimization of organic Waste.

[17] Day, P. R .1965. Hydrometer method of particle size analysis. In: CA Black (edn.). Methods of soil analysis. Agronomy Part I, No. 9. *American Society of Agronomy*. Madison, Wisconsin, USA pp. 562-563.

[18] Soil Survey Staff, Natural Resources Conservation Service. 1999. Soil Taxonomy. United States Department of Agriculture. Washington, D.C.: U.S. Government Printing Office.

[19] Jamison, V. C, Weaver, H. H, Reed, I. F. 1950. A hammer-driven soil core sampler. Soil Science, 69: 487-496.

[20] Rowell, D. L., 1994. Soil Science: Methods application. Addison Wesley Longman, Limited, England.

[21] Reynolds, S. G. 1970. The gravimetric method of soil moisture determination Part IA study of equipment, and methodological problems. *Journal of Hydrology*, 11: 258-273.

[22] McLean, E. O. 1982. Soil pH and lime requirement. *In* "Methods of soil analysis. Chemical and microbiological properties. Part 2. Agron. series no. 9" (A. L. Page, ed.), pp. 199-234. ASA, SSSA, Madison, USA.

[23] Walkley, A., and Black, I. A. 1934. An examination of method of determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Science, 37*: 29-38.

[24] Bremner, J. M., and Mulvaney, C. S. 1982. Nitrogen total 1. Methods of soil analysis. *Part 2. Chemical and microbiological properties*, (methods of soil an2) 595-624.

[25] Bray, R. H., and Kurtz, L. 1945. Determination of total, organic, and available forms of phosphorus in soils. *Journal of Soil Science,* 59: 39-46.

[26] Murphy, J., and Riley. P. 1962. A modified single solution method for determination of phosphate in natural waters. Anal. Chem. *Acta*, 42: 31-36.

[27] Van Reeuwijk, L. P. 1992. “Procedures for Soil Analysis,” 3rd Edition, International Soil Reference and Information Centre (ISRIC), Wageningen, 1992.

[28] Chapman, H. D .1965. Cation exchange capacity by ammonium saturation. In: C. A. Black (ed.). Methods of Soil Analysis. Agronomy Part II, No. 9. *American Society of Agronomy*. Madison, Wisconsin, USA. pp. 891-901.

[29] Nelson, D. W. and Sommers, L. E. 1973. Determination of Total Nitrogen in Plant Material. *Agronomy Journal*, 65: 109-112.

[30] Jackson, M. L. 1973. Soil Chemical Analysis, Prentice Hall India Pvt Ltd, New Delhi, India, 498-516.

[31] Ofonyas, D, Lemma, W. and Selamyihun, K. 2018. Response of Bread Wheat (Triticum aestivumL.) to Application of Slow Releasing Nitrogen Fertilizer in Tigray. *Ethiopian Journal of Agricultural Science*, 28: 111-126.

[32] Fageria, N. K., and M. P. Barbosa Filho. 2007. Dry-matter and grain yield, nutrient uptake, and phosphorus use efficiency of lowland rice as influenced by phosphorus fertilization. *Communications in Soil Science and Plant Analysis,* 38: 1289-1297.

[33] R Core Team. 2018. "R: a language and environment for statistical computing [URL: http://www. R-project.org]. Version 3.5. 1. Vienna, Austria." *R Foundation for Statistical Computing.*

[34] de Mendiburu, F. 2016. agricolae: Statistical procedures for agricultural research. In "R package version 1.2-4".

[35] Lenth, R. V. 2016. Least-Squares Means: The R package lsmean. *Journal of statistical software,* 69, 1-33.

[36] Hazelton, P., and Murphy, B. 2007. ‘Interpreting soil test results: What do all the numbers mean?’ (G. E. Rayment and F. R. Higginson, eds.). pp. 60. CSIRO Publishing, Collinwood, Melbourne.

[37] Tekalign, T. 1991. Soil, plant, water, fertilizer, animal manure and compost analysis. Working Document No. 13. International Livestock Research Center for Africa, Addis Ababa.

[38] Joachim, T. M., Kone, B., Jean-claude, N. K., Firmin, K. K., N, K. R., Florent, Z., Emanuel, D., and Albert, Y. 2017. Response Durum Wheat to Fertility Levels under Tropical Semiarid Climatic Conditions of Southern Côte d ’ Ivoire, 4,: 1-13.

[39] Molla, H., Gashaw, M., and Wassie, H. 2018. Response of bread wheat to integrated application of vermicompost and NPK fertilizers, 13: 14-20.

[40] Ramesh, S. 2018. Grain yield, nutrient uptake and nitrogen use efficiency as influenced by different sources of vermicompost and fertilizer nitrogen in rice, 7: 52 - 55.

[41] Fageria, N. K. and Baligar V. C. 2006a. Enhancing nitrogen use efficiency in crop plants.

[42] Merrill, S. D., D. L. Tanaka, and J. D. Hanson. 2002. Root length growth of eight crop species in Haplustoll soils. *Soil Science Society of America Journal,* 66: 913-923.

[43] Dobocha, D., Abera, G., and Worku, W. 2019. Grain quality and nitrogen use efficiency of bread wheat (Triticum aestivum L .) varieties in response to nitrogen fertilizer in Arsi highlands, southeastern Ethiopia 14, 1544-1552.

[44] Sofonyas, D. 2016. Response of Bread Wheat (Triticum aestivum L.) to Application of Slow Releasing Nitrogen Fertilizer in Tigray, Northern Ethiopia. MSc. *Thesis.* Haramaya University.

[45] Singh, H., Ingle, S. R., Pratap, T., Raizada, S., Singh, K., Singh, R., and Parihar, A. K. S. 2020. Effect of integrated nutrient management on nitogen content, uptake and quality of wheat (Triticum aestivum L .) under partially reclaimed sodic soil . *Cogent Environmental Science*, 9: 299-301.

[46] Fageria, N. K., Baligar, V. C. and Li, Y. C. 2008 'The Role of Nutrient Efficient Plants in Improving Crop Yields in the Twenty First Century', Journal of Plant Nutrition 31, 1121-1157.

[47] Bhatt, M. K., Labanya, R., & Joshi, H. C. 2019. Influence of Long-term Chemical fertilizers and Organic Manures on Soil Fertility - *A Review 7*, 177-188.

[48] Freeman, K. W., Girma, Kefyalew, Teal, R. K., Arnall, D. B., Tubana, B., Holtz, S., Mosali, J. and Raun, W. R. 2008. Long-Term Effects of Nitrogen Management Practices on Grain Yield, Nitrogen Uptake, and Efficiency in Irrigated Corn', Journal of Plant Nutrition 30, 2021 - 2036.

[49] Dorsey, D. N. 2011. Nitrogen use efficiency and nitrogen response of wheat varieties commonly grown.

[50] Yousefi, A. and Sadeghi, M. 2014. Effect of vermicompost and urea chemical fertilizers on yield and yield components of wheat (Triticum aestivum) in the field condition. *International Journal of Agriculture and Crop Sciences,* 7: 1227-1230.

[51] Klikocka, H., Cybulska, M and Nowak, A. 2017. Efficiency of fertilization and utilization of nitrogen and Sulphur by spring wheat. *Polish Journal of Environmental Studies*, 26: 2029-2036.

[52] Chatterjee, R., Bandyopadhyay, S., Chandra, J. J. 2014. Impact of Organic Amendments and Inorganic Fertilizers on Production Potential, Nitrogen Use Efficiency and Nitrogen Balance in Tomato (Lycopersicon esculentum Mill.). *International Journal of Scientific Research in Knowledge* 2, 233-240.

[53] Faraj, B. A. 2011. Evaluation of Nitrogen Use Efficiency (NUE) in Wheat. *Msc thesis* . University of Adelaide 1-105.

[54] Sinebo, W., Gretzmacher, R., Edelbauer, A. 2004. Genotypic variation for nitrogen use efficiency in Ethiopian barley. *Field Crops Res* 85: 43-60.

[55] Fageria, N. K. and Baligar, V. C. 2005. Methodology for evaluation of lowland rice genotypes for nitrogen use efficiency. *Journal of Plant Nutrition*, 26: 1315-1333.