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Effect of Nitrogen Application Time on Yield and Yield Components and Nitrogen Use Efficiency of Bread wheat (*Triticum aestivum* L.) Varieties in Ambo District of Western Ethiopia

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Abstract: Bread wheat (*Triticum aestivum* L.) is the most important crop in West Shoa Zone of Oromia, central Ethiopia. However, its productivity is very low as compared to the productivity of world bread wheat which is attributed due to poor agronomic management practices such as inappropriate N fertilize application time and use of local varieties. Therefore, a field experiment was conducted on farmer's field at Bilo kebele in Ambo District, in West Shoa zone during 2018/2019 cropping season. The experiment consisted of seven application time of nitrogen along with two varieties (Dendea and Wane) of bread wheat were used and laid out in randomized complete block design with factorial arrangement in three replications. Significantly higher (64.07) mean number of seeds per spike, (13131 kg ha^{-1}) dry biomass, (4989 kg ha^{-1}) grain yield, (47kg ha^{-1}) thousand seed weight, (7837kg ha^{-1}) straw yield and (42%) harvest index of bread wheat varieties was obtained with N application time. The apparent nitrogen recovery efficiency, agronomic nitrogen efficiency and nitrogen utilization efficiency were recorded from three splits N application time. In conclusion, three splits application time of N 1/3 at sowing, 1/3 at tillering and 1/3 at anthesis followed by two split nitrogen application ½ at sowing and ½ at mid-tillering gave optimum mean grain yield and nitrogen use efficiency bread wheat. Therefore, three and two split nitrogen application time alternatively recommended for sustainable bread wheat production in Ambo district and similar agroecology.

Key words: Bread Wheat · Varieties · Yield · Nitrogen Use Efficiency · Nitrogen

INTRODUCTION

Soil fertility degradation in regions is the most importance due to permanent and irreversible degradation of soil quality and productivity. Soil fertility management processes, the application time of inorganic amendments is used for increasing yield and productivity. The use of fertilizers for soil fertility amendment with improved varieties of bread wheat could sustainably increase production and productivity [1]. Bread Wheat (*Triticum aestivum* L.) is an essential crop for national and global food security [2]. It is King of the cereals and important staple food crop [3]. In Ethiopia, bread wheat made up of 15.33% (48, 380, 740.91 quintals) of the grain cereal production in the country [4]. However, the national yield of wheat is very low as compared to the global average yield. Despite the large area under wheat, the national average yield of wheat in Ethiopia is about 2.67 t ha^{-1} [5] which is below the world's average which is about 3 t ha^{-1} [5]. This might be due to depleted soil fertility, low levels of chemical fertilizer usage, limited knowledge on time and rate of fertilizer application and use inappropriate improved cultural crop management practices [6]. Improved bread wheat varieties were released and adapted to a wider range of environmental of conditions in Ethiopia [7]. Bread wheat grain yield potential has significantly increased in Ethiopia [8]. However, increasing yield requires successful adoption of improved agricultural technologies [9], which includes use of improved varieties.

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Nitrogen fertilizer application time is one of the most important aspects in cereal crops, as it interferes with grain yield and quality by physiological stimuli. Thus, early or late applications usually show low Nitrogen use efficiency due to poor utilization of plants [10]. Globally, nitrogen is considered as the first most limiting factor in the crop production and limits yield in non-fertilized agriculture [11]. Appropriate N application timing and rates are crucial for meeting crop needs and indicate considerable opportunities for improving NUE. According to Tamene *et al.* [12], optimum and efficient time of N fertilizer application can increase the recovery of applied N up to 58-70% and hence increase yield and grain quality of a crop. In Ethiopia, wheat is grown during the high rain-fall season and losses of applied N through leaching may be decreased through proper timing of N application.

Limited research has been done on time of N application effects in relation to improving grain yield and nitrogen use efficiency of bread wheat in the study area. Such studies may give a clue for enhancing grain yield of the crop through manipulating timings of N fertilizer application. Thus, appropriate nitrogen fertilizer application timing on bread wheat varieties has to be determined for optimum bread wheat production. Therefore, the objective was to determine the effect of nitrogen application time on yield and yield components and nitrogen use efficiency of bread wheat (*Triticum aestivum* L.) varieties in Ambo district of western Ethiopia

MATERIALS AND METHODS

Description of the Study Area: The experiment was conducted in 2018/2019 cropping season in Bilo kebele, Ambo District, West Showa Zone. Ambo district is located in West Showa Zone of Oromia National Regional State of Ethiopia, about 115 km away from Addis Ababa. The district has 32 peasant association and one town in the district. Bilo kebeles was one of the peasant associations and situated at altitude of 2195 meters above sea level. The amount of rainfall and temperature ranges between 800-1115 mm and 11.7 - 25.4°C, respectively. The soil of the study area was clay loam soil type. A total seasonal (June to November) rainfall of 866.8 mm was recorded in Ambo district during 2017/18 cropping season. Average minimum temperature of 11.08°C and maximum temperatures of 25.39°C with a relative humidity of 62.4% were recorded in the study district.

Experimental Materials: Two bread wheat varieties (Dendea and Wane) were obtained from Kulumsa Agricultural Research Center. The descriptions of the two varieties used in the study were indicated in (Table 1).

Treatments and Experimental Design: The time of N fertilizer application were adjusted according to Zadoks decimal growth stage for wheat [13]. at the time when moisture is available for nutrient dissolution and absorption. Seven different times of N fertilizer application including a negative control with two varieties of bread wheat were used. The nitrogen application time was T_1 = Nil application (control); T_2 = N application 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anhtesis; T_3 = N application ½ at sowing and ½ at mid-tillering; T_4 = N application ½ at mid-tillering and ½ at anthesis; T_5 = Full N application T_6 = Full N application mid-tillering, T_7 = Full N at anthesis used main factor. The two bread wheat varieties (Dendea and Wane) was used as sub factor. The design used was randomized complete block design with factorial arrangement in three replications.

Experimental Procedures: The field experiment was conducted using two improved bread wheat varieties (Dendea and Wane) which were released by Kulumsa Agricultural research centre in 2010 and 2016 respectively. Dendea variety is one of the potential bread wheat varieties for Ambo district in West Shoa Oromia. Dendea being cultivated widely and has been accepted by farmers due to its high yielding ability, consumers' preference and wider adaptation and relatively resistant to disease compared to other wheat, while the recently released improved variety (Wane) is not introduced yet in the study area. The land was prepared with oxen and big soil clods were broken down into small sizes. The field was leveled manually. Urea (46 kg N ha^{-1}) and triple super phosphate (46 kg P_2O_5 ha^{-1}) were used as sources of N and P, respectively. Triple super phosphate (46 kg $P_2O_5ha^{-1}$) was applied to all plots uniformly at sowing time, while the recommended nitrogen fertilizer (69 kg N ha^{-1}) was added in seven application times were used as per the treatment. Bread wheat varieties were sown at the recommended rate of 125 kg ha^{-1} and sown in rows. All agronomic practices were applied uniformly to all plots. Finally, bread wheat plants in the whole plot area were harvested at maturity.

Table 1: Description of bread wheat varieties used in research study

		Area of adaptation			Yield (t ha^{-1})	
Varies	Year of release	Altitude (m)	RF (mm)	Maturity day	On-station	On-farm
Dendea	2010	2000-3000	$\geq$ 600	135-150	6-7	5.5-6.5
Wane	2016	2100-2700	700-1000	125-140	5-6	4-5

Source: Kulumsa Research Center (2016)

Data Collection: Number of seeds per spike: was taken as average number of grains per part of five random plants and was expressed as average number per spike.

Dry Biomass Yield: Was taken after harvested and dried for two weeks in open air from the whole plant parts, including leaves and stems and seeds from the whole rows of plot.

Grain Yield: Was measured after harvesting and threshing, the crop from whole plot eleven rows of each plot area of 6.6 m^2. Seed moisture content was determined using seed moisture tester instrument. Then the grain yield of each treatment was adjusted to the standard moisture level by computing the conversion factor for each treatment to get the adjusted yield using the following formula [14]:

Straw Yield: Was measured by subtracting the grain yield from the total above ground biomass yield.

Harvest Index: Was calculated by dividing grain yield to the total above ground biomass yield and expressed in percentages.

Grain Quality Parameters

Thousand Seed Weight: Was counted by grain counter machine and the thousand counted grain was weighed and taken as thousand grain weight.

Grain Protein Content (GPC %): Was determined by multiplying grain N percent by 6.25, that is, Grain Protein (%) = % N in grain x 6.25 [15].

Total N Uptake: Grain nitrogen (kg ha^{-1}) uptake was computed as grain yield multiplied by percent N content of the grain for each plot. Straw nitrogen (kg ha^{-1}) uptake was calculated as straw yield multiplied by percent N content of the straw in each plot. Total nitrogen (kg ha^{-1}) uptake was obtained as the sum of grain nitrogen uptake and straw nitrogen uptake. Total N in the straw and grain samples were used to analyze the N use efficiency and its component traits according to an expanded models of Haile *et al.* [16].

Agronomic Nitrogen Efficiency (ANE): Is a measure how grain yields are affected by nutrient applications. N agronomic efficiency (NAE) was obtained by dividing the grain yield to the applied N as presented in equation [17].

Physiological Nitrogen Efficiency (PNE): Was calculated as total dry matter or grain yield produced per unit of N absorbed. N utilization efficiency was calculated as described by Ladha *et al.* [18].

Apparent Recovery Nitrogen Efficiency (ARNE): Is the amount of fertilizer N taken up by the plant per kg of N applied as fertilizer; this was calculated as described by Tufa *et al.* [19].

Nitrogen Harvest Index (NHI): Was calculated by N uptake by the grain divided to total N uptake by the grain and straw x 100 [20].

Statistical Analysis: The data was subjected to analysis of variance (ANOVA) as per the design used in the experiment using statistical analysis software version 9.1 [21]. Mean separation was conducted using the least significant difference test (LSD) to evaluate the different nitrogen time on bread wheat varieties at 5% level of significance [22]. The correlation analysis was performed to determine relations between yield and yield components as influenced by nitrogen application times.

RESULTS AND DISCUSSION

Number of Seeds per Spike: The main effect of bread wheat varieties, time of nitrogen application and their interaction showed significant (*$P<0.05$*) effect on number of seeds spike^{-1} of bread wheat (Table 2). The highest (64.07) and lowest (46.73) number of seeds spike^{-1} of bread wheat were recorded from the interaction of Wane bread wheat variety with 1/3 N application at sowing, 1/3 N at mid-tillering and 1/3 nitrogen application at anthesis and Dendea bread wheat variety at control (Table 2). The interaction of bread wheat varieties with times of nitrogen application was increased mean number of seeds spikle^{-1} by 15.28% over control. This may be due to efficient utilization and arresting volatilization or

Table 2: Interaction effect of nitrogen application time and varieties on number of seed per spike

	Time of Nitrogen Application							
Varieties	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean
Dendea	46.73^{h}	62^{ab}	53.4^{efg}	49.27^{gh}	50.7^{fgh}	58.33^{bcd}	54.73^{def}	53.36
Wane	60.07^{abc}	64.07^{a}	60.27^{abc}	59.93^{abc}	60.27^{abc}	58.3^{bcd}	55.93^{cde}	59.90
Mean	53.4	63.03	56.83	54.60	55.50	58.47	55.33	56.63
LSD ($_{5\%}$)				3.6				
CV (%)				3.44				

T_1 = Nil application (control); T_2 = N application 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anhtesis; T_3 = N application ½ at sowing and ½ at mid-tillering; T_4 = N application ½ at mid-tillering and ½ at anthesis; T_5 = Full N application T_6 = Full N application mid-tillering, T_7 = Full N at anthesis. Values with the different letter (s) in column and row are significantly different at 5% probability level

Table 3: Interaction effect of nitrogen application time and varieties on dry biomass

	Time of Nitrogen Application							
Varieties	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean
Dendea	5252^{d}	13081^{a}	10960^{ab}	9747^{bc}	11263^{ab}	13131^{a}	10152^{b}	10512
Wane	7778^{c}	11010^{ab}	12576^{a}	9899^{bc}	9394^{bc}	10859^{ab}	9394^{bc}	10130
Mean	6515	12045	11768	9823	10328	11995	9773	10321
LSD (5%)				2308.6				
CV (%)				13.3				

T_1 = Nil application (control); T_2 = N application 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis; T_3 = N application ½ at sowing and ½ at mid-tillering; T_4 = N application ½ at mid-tillering and ½ at anthesis; T_5 = Full N application T_6 = Full N application mid-tillering, T_7 = Full N at anthesis. Values with the different letter (s) in column and row are significantly different at 5% probability level.

Table 4: Interaction effect of nitrogen application time and varieties on grain yield of wheat varieties

	Time of Nitrogen Application							
Varieties	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean
Dendea	1937^{f}	4989^{a}	4090^{c}	3724^{cd}	4010^{c}	4783^{ab}	4599^{b}	4019
Wane	3055^{de}	3993^{c}	4619^{ab}	3957^{c}	3094^{e}	3867^{d}	3764^{cd}	3764
Mean	2496	4491	4355	3841	3552	4325	4182	3891.5
LSD ($_{5\%}$)				386				
CV (%)				5.9				

T_1 = Nil application (control); T_2 = N application 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis; T_3 = N application ½ at sowing and ½ at mid-tillering; T_4 = N application ½ at mid-tillering and ½ at anthesis; T_5 = Full N application T_6 = Full N application mid-tillering, T_7= Full N at anthesis. Values with the different letter (s) in column and row are significantly different at 5% probability level

Table 5: Interaction effect of nitrogen application time and varieties on thousand seed weight

	Time of Nitrogen Application							
Varieties	T_1	T_2	T_3	T_4	T_5	T_6	T_7	Mean
Dendea	42.2^{bc}	46.7^{a}	43^{bc}	42^{bcd}	43.7^{ab}	44.2^{ab}	43.2^{bc}	43.4
Wane	41.3^{bcd}	42.4^{bc}	41.3^{bcde}	40.7^{cde}	39.1^{de}	41.9^{bcd}	38.4^{e}	40.8
Mean	41.7	44.4	42.2	41.4	41.4	43.1	40.8	
LSD (5%)	4.56							
CV (%)	3.2							

T_1 = Nil application (control); T_2 = N application 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis; T_3 = N application ½ at sowing and ½ at mid-tillering; T_4 = N application ½ at mid-tillering and ½ at anthesis; T_5 = Full N application T_6 = Full N application mid-tillering, T_7= Full N at anthesis. Values with the different letter (s) in column and row are significantly different at 5% probability level

leaching down of N fertilizer. Increased number of seeds per spike due fertilization can be attributed to improved crop performance in fertilized plots [23], or higher nutrient availability as compared to control.

Dry Biomass Yield: The main effect of bread wheat varieties, time of nitrogen application and their interaction showed significant ($P<0.05$) effect on dry biomass yield of bread wheat (Table 3). Significantly higher (13131 kg ha^{-1})

was recorded from Dendea variety with full dose nitrogen application at mid-tillering, which was statistically at par with when Dandea variety with nitrogen application at the time of 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis (13081 kg ha^{-1}), ½ at sowing and ½ at mid-tillering (10960 kg ha^{-1}) and full N application (11263 kg ha^{-1}); and Wane wheat variety combined with nitrogen fertilizer at the time of 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis (11010 kg ha^{-1}), ½ at sowing and ½ at mid-tillering (12576 kg ha^{-1}) and full dose application at mid-tillering (10859 kg ha^{-1}) (Table 3).

The minimum (5252 kg ha^{-1}) dry biomass yield was obtained from control treatment. Dandea bread wheat variety with full dose of nitrogen application at anthesis was increased mean of dry biomass yield by 1.5 folds over control treatment. This in turn might be due to adequate availability of nutrient which triggered physiological growth processes and produced more yield. N fertilizer application at optimum amount and right time significantly enhanced biomass yield of bread wheat [24]. Similarly, Zemichael *et al.* [25] reported that split application of nitrogen reduces the chance of N losses due to leaching, denitrification and runoff.

Grain Yield: The mean grain yield of bread wheat was significantly ($P_{<}$ 0.001) influenced by the interaction of time of N fertilizer application and wheat varieties (Table 4). The highest (4989 kg ha^{-1} and 4619 kg ha^{-1}) mean grain yield of bread wheat was obtained from Dendea and Wane varieties with three times N application (1/3 at sowing, 1/3 at mid tillering and1/3 at anthesis) and twice application (½ at sowing and ½ at mid tillering), respectively. The minimum grain yield (1937 kg ha^{-1}) was registered from control treatment (Table 4). Higher mean grain yield of bread wheat due to efficient utilization and reducing volatilization or leaching down of N. Most of the investigations on time of N fertilizer application are geared towards split-applications to synchronize timing of fertilization according to the crop demand and increase grain yield. Similarly, Haile *et al.* [16] reported higher grain yields due to one third split applications of N at sowing, at mid tillering and at anthesis respectively, relative to applications of urea all at sowing. This N application timing might have enhanced uptake of N during these stages and there by increased crop performance and ultimately grain yield.

Thousand Seed Weight: Thousand seed weight of bread wheat was highly significantly (P <0.001) influenced by the interaction of time of N fertilizer application with bread wheat varieties (Table 5). The highest (47 g) thousand seed weight was obtained from Dendea variety with N application 1/3 at sowing, 1/3 at mid tillering and 1/3 at anthesis which was statistically at par with the combination of Dendea variety to full dose of nitrogen application at the time of sowing (44 g) and to full dose of nitrogen application at the time of mid-tillering (44 g) (Table 5). This variation might be observed by the influence of genetic potential of variety.

The minimum amount of thousand Seed weight (38g) was recorded from Wane variety with full N application fertilizer at anthesis (Table 5). Most of the investigations on time of N fertilizer application are geared towards split-applications to synchronize timing of fertilization according to the crop demand and increase thousand Seed weight. In line with this result, Abdullah [26] reported that supplying N in two or three applications are a good recommendation to increase N use efficiency in sorghum. Similarly, Shanahan *et al.* [27] reported greater synchrony between crop demand and nutrient supply is necessary to improve nutrient use efficiency and split applications of N during the growing season, rather than a single, more application, which is known to be effective in increasing N use efficiency. The optimum amount of N fertilizer within right time gave better grain weight [28].

Straw Yield: the main effects of time of nitrogen fertilizer application were highly significantly (P<0.001) influenced straw yield but main effect of bread wheat varieties and the interaction effect of bread wheat varieties with time of nitrogen fertilizer application were non-significantly (P<0.05) influenced straw yield of bread wheat (Table 6). Significantly higher (7837 kg ha^{-1}) straw yield was obtained from full dose of nitrogen fertilizer application at the time of mid-tillering which was statistically at par with application of nitrogen fertilizer 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis (7554 kg ha^{-1}); ½ at sowing and ½ at mid-tillering (7413 kg ha^{-1}); and full dose nitrogen application at sowing (6776 kg ha^{-1}) (Table 6). While the lowest (3847 kg ha^{-1}) straw yield was obtained from control (Table 6). Application of full dose of nitrogen fertilizer at mid-tillering increased the straw yield by about 104% over control treatment. The possible reason might be that N was readily available and not retained in the soil for longer time and so translocated soon to leaves and stem yielded higher straw and also the significant increase in straw yield of wheat probably came through favorable influences of time of N application on vegetative growth in terms of plant height, higher number tillers and more dry matter accumulation. These results are in agreement

Table 6: Main effects of nitrogen application time and varieties on Straw yield and Harvest index of bread wheat in Ambo district

Treatments	Straw yield ($kgha^{-1}$)	Harvest index (%)
Varieties		
Dandea	6493	38.54
Wane	6364	37.47
Mean	6428.5	38.01
$LSD_{(5\%)}$	NS	NS
Time of Nitrogen Application		
Nil application (control)	3847^{d}	38.79^{ab}
N application 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis	7554^{ab}	42.00^{a}
N application ½ at sowing and ½ at mid-tillering;	7413^{ab}	37.12^{ab}
N application ½ at mid-tillering and ½ at anthesis	5983^{bc}	39.42^{ab}
Full N application	6776^{abc}	34.47^{b}
Full N application mid-tillering	7837^{a}	35.74^{b}
Full N at anthesis	5591^{c}	40.90^{a}
Mean	6429	38.35
LSD (5%)	1584.6	5.52
CV (%)	7.00	12.18

Values with the different letter (s) in column and row are significantly different at 5% probability level

Table 7: Effects of time of Nitrogen application on N concentration and use efficiencies of bread wheat

NAT×BWV	Total N uptake (Kg ha^{-1})	ANE (Kg kg^{-1})	NUtE (Kg ha^{-1})	PNE (Kg kg^{-1})	NUE (Kg kg^{-1})	ANRE (%)	NHI (%)	GPC (%)
T1×Dv	116	-	-	-	28.1	-	46.61	6.44
T2×Dv	375	44.2	62.2	12	72.3	376	46.69	8.38
T3×Dv	272	31.2	15	14	59.3	226	39.11	6.06
T4×Dv	260	25.9	3	12	54.0	209	47.94	8.00
T5×Dv	294	30.0	17.4	12	58.1	258	51.34	8.38
T6×Dv	332	41.2	40.7	13	69.3	313	46.64	7.38
T7×Dv	266	38.6	5.3	18	66.7	217	46.95	7.69
Mean	274	35.2	2.7	13.5	58.3	266.5	46.5	7.5
T1×Wv	197			-	44.3	-	50.20	7.94
T2×Wv	290	13.6	-58.4	10	57.9	134	48.67	8.00
T3×Wv	264	22.7	-79.9	23	66.9	97	60.95	8.00
T4×Wv	259	13.1	-74.2	14	57.3	90	49.24	8.06
T5×Wv	205	0.6	-107.6	5	44.8	101	58.26	7.94
T6×Wv	306	11.8	-43.3	7	56.0	158	46.81	8.25
T7×Wv	256	10.3	-75.9	12	54.6	86	49.82	8.50
Mean	254	12	1.0	12	54.5	111	52	9.2

Dv = Dendea variety, Wv = Wane variety, T_1 = Nil application (control); T_2 = N application 1/3 at sowing, 1/3 at tillering and 1/3 at anthesis; T_3 = N application ½ at sowing and ½ at tillering; T_4 = N application ½ at tillering and ½ at anthesis; T_5 = Full N application T_6 = Full N application tillering, T_7= Full N at anthesis, ANE = Agronomic nitrogen efficiency.NUtE = Nitrogen uptake efficiency, PNE = Physiological nitrogen efficiency, NUE = Use efficiency, ANRE =Apparent recovery efficiency, NHI = Harvest index and GPC = Grain protein concentration

with Limon-Ortega *et al.* [29] who reported maximum straw yield when N is applied in split doses at different growth stages. Similarly, Berhe *et al.* [30] reported highest straw yield of bread wheat in response to applying 69 kg N ha^{-1}.

Harvest Index: The main effect of time of nitrogen application were significantly ($P \leq 0.05$) influenced mean harvest index of bread wheat but main effect of bread wheat varieties and the interaction effect of bread wheat varieties with time of nitrogen fertilizer application were non-significantly ($P \leq 0.05$) influenced on harvest index bread wheat (Table 6). The highest (42%) harvest index was recorded on application of 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis which was statistically at par with non-nitrogen application at control treatment (38.79 %), ½ at sowing and ½ at mid-tillering (37.12 %) and nitrogen application ½ at mid-tillering and ½ at anthesis (39.42%) and full dose of nitrogen at anthesis (40.9%) (Table 6). The lowest (34.47%) harvest index was obtained from full dose of nitrogen application at the time of sowing, which was statistically at par with full dose of nitrogen fertilizer application at mid-tillering (35.74%) (Table 6). In consistent with Haile *et al.* [16] reported that greater synchrony between crop demand and nutrient supply is necessary to improve nutrient use efficiency and three split applications of N during the growing season, rather than single, more application are known to be effective in increasing N use efficiency and plants uses nutrients effectively. In general, N application of 1/3 of the dose at sowing, 1/3 at mid-tillering and the remaining 1/3 at anthesis led to the highest harvest indices.

Total Nitrogen Uptake of Bread Wheat: Total N uptake reflected the biomass yield response of varieties to the applied N fertilizer rates and time of application. Total uptake of nitrogen differed between time of N fertilizer application and variety (Table 7). The highest total nitrogen uptake (375kg ha^{-1} and 306 kg ha^{-1}) were recorded for variety Dendea and Wane at parities with split time of N applications of 1/3 at sowing, 1/3 mid tillering and 1/3 at anthesis and full dose N application at mid-tillering which had parity with full N application at mid tillering in the Dandea (332 $kgha^{-1}$) on growing season, while the lowerst total nitrogen uptake (116 Kg ha^{-1}) value was recorded from Dendea varieties with no N application or at control (Table 7).

Varieties Dendea exhibited a strongly positive response to total N uptake with the split in N supply, where the highest values were recorded at 1/3 at sowing, 1/3 mid tillering and 1/3 at anthesis. The increase in total N uptake at the highest N frequency could be explained by the highest N within the grain of the varieties which allowed it to concentrate nitrogen as their yield increased [31]. Correspondingly, the total nitrogen uptake was superior for varieties Dendea under the different N time relative to variety in time of application. This could be explained by the stable grain nitrogen uptake of the varieties, which allowed it to concentrate nitrogen as their yield increased. The lower N uptake value of variety Dendea at control, while possessing a higher grain N concentration, could be due to the lodging of the variety in the early reproductive phase which reduced its yield. This result was in agreement with Belete *et al*. [2] who reported higher total nitrogen uptake for a relatively high-yielding variety under three N application timing.

Most of the variation in total N uptake was due to differences in growth rather than to differences in N concentration. The difference in N uptake might be due to the difference in environmental condition at N application time which reduced the incidence of water logging or increased availability of nitrogen for the wheat to grow and provide yield better [32]. The difference recorded among the two wheat varieties in relation to total N uptake was in agreement with the results reported by Bayeh [33]. Likewise, Hossain *et al.* [34] reported that increasing nitrogen rate and frequency also increases nitrogen concentration and total uptake of grain and straw. Similarly, Etwire [35] stated that grain and straw nitrogen concentration increased with the N fertilizer levels.

Agronomic Nitrogen Efficiency: Agronomic nitrogen use efficiency is the amount of additional yield obtained from each additional kg of nutrient applied [36]. There was a difference between the effect of nitrogen application time and varieties on agronomic nitrogen use efficiency (Table 7). The maximum (44.2 kg kg^{-1}) agronomic nitrogen use efficiency was recorded with the combination of 1/3 at sowing, 1/3 at mid tillering and 1/3 at anthesis with Dendea variety, whereas the minimum (0.6 kg kg^{-1}) agronomic nitrogen use efficiency of nitrogen was obtained with the combination of N fertilizer from full dose of N fertilizer application at mid tillering in Wane variety. The agronomic nitrogen use efficiency was increase with increasing frequency of nitrogen fertilizer application, which indicated efficient use of nitrogen at lower rate and different frequency of nitrogen fertilizer application. Similarly, Dargie *et al.* [36] showed that high agronomic efficiency obtained if the yield increment per unit N applied is high because of reduced losses and increased N uptake. Similarly, Kumar *et al.* [37] obtained higher fertilizer use efficiency which is always associated with low fertilizer rate; cultural practices meant for promoting integrated nutrient management will help to save the amount of fertilizer applied to the crops and to improve fertilizer use efficiency.

Different bread wheat varieties showed different agronomic use efficiency of nitrogen under the same environmental condition. This result was in agreement with Adugna [38] who reported that agronomic nitrogen use efficiency of different genotypes was different. Mean agronomic nitrogen use efficiency of all genotypes decreased with increased rates while split timing of nitrogen fertilizer is the reverse. Similarly, Gadisa [39] also asserted that high agronomic efficiency is obtained if the yield increment per unit N applied is high because of reduced losses and plants enhanced use of nutrients effectively.

Nitrogen Uptake Efficiency: Nitrogen uptake efficiency (NUpE) was affected by the time of N application and Variety (Tables 9). The values of NUpE ranged from (0.1%) for Wane with N application time full dose at sowing to (3.8%) for Dendea variety with N application time 1/3 N at sowing, 1/3 N at mid-tillering and 1/3 N at anthesis (Table 7). Comparing the NUpE of variety Danadea had higher NUpE than the Wane cultivar under all N time (Table 7). The highest NUpE (3.8%) was recorded for the variety Dendea with application of 1/3 N at sowing, 1/3 N at mid tillering and 1/3 N at anthesis application, which was in similar with NUpE of the time of N application full dose N application at mid tillering under the same variety, while the lowest (0.1%) NUpE was recorded for the variety Wane with full dose of N application at sowing. The data further revealed that both bread wheat varieties showed decline in NUpE as N level increased. The values of varieties grown on soil treated with N application time across variety Dendea was superior in NUpE at all the nitrogen application times in 1/3 N at sowing, 1/3 N at mid tillering and 1/3 N at anthesis application over both Wane and the control variety (Table 7). Similarly, Tarekegn [40] reported the variation in NUpE of wheat which was ascribed to differences in climate, cultivar, nitrogen rates and time of applications.

Physiological Nitrogen Use Efficiency: Physiological efficiency is the biological yield obtained per unit of nutrient uptake [41]. Physiological nitrogen efficiency was influenced by N application times and varieties (Table 7). The highest (23 kg kg^{-1}) physiological nitrogen efficiency was recorded from the N fertilizer application 1/2 at sowing and 1/2 at mid tillering of Wane variety, whereas the lowest (5.0 kg kg^{-1}) physiological efficiency of nitrogen obtained from full dose at sowing of Wane variety. Results indicated that physiological efficiency of varieties decreased with increasing split time of N fertilizer application. Likewise, Temteme [42] reported that the physiological nitrogen efficiency of genotypes of bread wheat was decreased significantly with increasing split time of N fertilizer application. It showed that biomass increased per kilogram nitrogen accumulated in wheat plant was decreased with increasing N fertilizer application time. The ability of the plant to transform applied nutrient acquired from sources to total yield decreased whenever nitrogen fertilizer rates rise. Genetic variability of varieties had influence on physiological nitrogen efficiency. Similarly, Daba [43] reported that varieties had significant differences on physiological nitrogen efficiency.

Nitrogen Use Efficiency: Nitrogen use efficiency expressed as grain production per unit of N applied, indicated that bread wheat had the maximum NUE (72.3 kg kg^{-1}) when the N was applied in split of 1/3 at sowing, 1/3 at mid tillering and 1/3 at anthesis while minimum NUE (28.1kg kg^{-1}) was recorded at control (Table 7). N fertilizer applications that exceed crop N requirements lead to environmental pollution including nitrate leaching and N gaseous emissions. As a result, N fertilizer application time is so essential to determine the plant response to N fertilization and its real N demand to develop rational practices for more NUE improving N application timing that may lead to achieve the highest yield with decline in environmental hazards. Several research reports noted that split applications of N one third at sowing, one third at mid tillering and the other one third at anthesis stage in terms of apparent N recovery and other N use efficiency measures [25] increased. Split N applications time might have decreased the loss of N applied at due to de nitrification, leaching and runoff and improved the agronomic NUE. Similar to this finding, numerous reports indicate increase in NUE with split N applications since leaching is one of the main challenges for N loss in especially in high rainfall areas [25].

Apparent Recovery Nitrogen Efficiency of Bread Wheat: Apparent recovery nitrogen efficiency was a measure of the ability of the crop to remove N fertilizer from the soil [44]. Result of N fertilizer application time and varieties on apparent recovery nitrogen efficiency of bread wheat was presented in (Table 7). The highest apparent recovery nitrogen efficiency (376%) was recorded with combination of the three split application N fertilizer with Dendea variety while the same time of N application there were a difference between Wane and Dendea varieties.

The apparent recovery nitrogen efficiency under different of application time was varied for Dendea and Wane varieties. Data in this study indicated that apparent recovery nitrogen efficiency of bread wheat was increased with increasing nitrogen application time. Because, at high rates of nitrogen fertilizer applied the plant did not take up nitrogen. Likewise, Shara *et al.* [45] that recovery of N applied, which is determined based on measurements of N uptake in the aerial plant biomass, is highly affected by timing of N application. Supporting the results of this study, Tilahun [46] stated that about 50% of applied N remains unavailable to a crop due to a combination of leaching, fixation and volatilization. Similarly, Terefe *et al.* [47] mentioned that the apparent recovery nitrogen efficiency of bread wheat varieties decreased whenever nitrogen fertilizer application time decreased. There were differences among wheat varieties on apparent recovery nitrogen efficiency. Likewise, Wei *et al*. [48] found that genotypes differ in apparent recovery efficiency of nitrogen.

Nitrogen Harvest Index of Bread Wheat: Nitrogen harvest index was influenced by the effects of N application time and varieties (Table 7). The highest nitrogen harvest index (60.9%) was recorded in Wane variety from ½ N at mid tillering and ½ at anthesis

Table 8: Pearson correlation coefficient between yield and yield component of bread wheat at Ambo district

	NSPS	DBMH	GY	STY	TSW	HI
NSPS						
DBMH	0.17					
GY	0.30*	0.78**				
STY	0.09	0.96**	0.59**			
TSW	0.002	0.2	0.31*	0.12		
HI	0.16	-0.42**	0.33*	-0.65**	0.15	

NSPS=number of seed per spike, DBMH =Dry biomass yield, GY= Grain yield, SRY=Straw yield TSW=Thousand kernel weight and HI= Harvest index

treatments, while the lowest nitrogen harvest index (39.11%) was obtained in Dendea variety from ½ N at sowing and ½ N at mid tillering. This could be due to partitioning of the total nitrogen content more to the vegetative part of the crop than to the grain and increased the total aboveground biomass yield. In other words, the N ratio in straw enhanced with increasing N application and it has led to wheat plant uptake of N fertilizer excessively. Nitrogen harvest index was decreased with decreasing N time of application [43] mentioned that, nitrogen harvest index of wheat was decreased with increasing N application timing. In contrary, Kakabouki *et al*. [49] reported that nitrogen harvest index increased with the increasing nitrogen levels. Fageria [44] reported that significant varieties differences on nitrogen harvest index. This might be due to genetic variation of bread wheat varieties plus levels and time of nitrogen fertilizers application.

Grain Protein Content: The grain protein content in the bread wheat was dependent on genotype but it was also clearly influenced by environmental variables such as nitrogen application timing, water access and temperature during growth especially through the grain filling period [50]. The data revealed different effects of N timings on grain protein content in different growth stages (Table 7). The maximum amounts of grain protein (8.50%) were obtained from full dose fertilizing of N at anthesis time in Wane variety. This study showed that, delayed fertilizer N application increased grain protein. This is consistent with Malik [16] who reported the importance of higher proportion of N application at mid-tillering and additional lower proportions at anthesis for enhanced efficiency of N use from applied N for protein synthesis. The lowest grain protein concentration (6.06%) obtained with application of N in two split doses 1/2 at sowing and 1/2 at tillering in Dendea variety. This was in accordance with the findings of Zemichael *et al.* [25] who reported early N application at planting and tillering resulted in lower grain protein concentration compared to full or split N application up to anthesis. The same result was observed in other researches [50].

Pearson Correlation of Yield and Yield Component of Wheat Due to Time of Nutrient Application: The correlations of bread wheat agronomic parameters were observed for some of wheat yield components (Table 8). Grain yield of bread wheat showed positive and significant correlation with its components such as nitrogen difference number of seed per spike (0.30), dry biomass yield (0.78), straw yield (0.59), thousand seed per spike (0.31) and Harvest index (0.33). This means with increasing value of these parameters; and grain yield also increases as well and vice versa. According to Tolesa *et al.* [51] reported significant and positive correlation between Harvest index with grain yield, grain yield with biological yield and thousand seed weight with grain yield. Whereas, there were lower correlations indicated among days to 90% maturity (0.12) and spike length (0.22) with grain yield. Likewise, Mekonen [52] reported that there was a positive and significant correlation between grain yield and yield components parameter of bread wheat.

CONCLUSION

Bread wheat production is heavily dependent on available nutrient in the soil and other environmental conditions for plant growth. Information on bread wheat response to N fertilizer application time and improved variety is key to come up with profitable and sustainable bread wheat production. For bread wheat production in the mid-high land part of Ethiopia, increasing bread wheat yield with acceptable quality from different combined treatments with good agronomic practices is crucial in the future. This study provides basic information for additional research and development efforts for scientific recommendation of N application time with varieties from sustainable bread wheat production and economic benefit point of view. Therefore, economically, the combine application time of 1/3 N at sowing, 1/3 N at mid-tillering and 1/3 N at anthesis was maximum (56921 ETB ha^{-1}) net benefit with acceptable marginal rate of return (284%) which is economically feasible for the study area. Hence it can be recommended for wider use at Ambo area.

The definite recommendation may not be drawn from this research result, as the present result came from single experiment involving one location. So that further studies at different locations for more than one cropping season should be conducted and economically feasible N application time and varieties should be considered to give a reliable recommendation for sustainable bread wheat production.

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REFERENCES

1. Ali, K., M. Arif, M.T. Jan, T. Yaseen, M. Waqas and F. Munsif, 2015. Biochar: a novel tool to enhance wheat productivity and soil fertility on sustainable basis under wheatmaize-wheat cropping pattern. Pak. J. Bot., 47: 123-131. 11.
2. Belete, F., N. Dechassa, A. Molla and T. Tana, 2018. Effect of split application of different N rates on productivity and nitrogen use efficiency of bread wheat (*Triticum aestivum* L.). Agriculture & Food Security, 7: 1-10. 9.
3. Ashmawy, M., W. El-Orabey, A.E.A. Abu Aly and A. Shahin, 2014. Losses in grain yield of some wheat cultivars infected with powdery mildew. Egyptian Journal of Phytopathology, 42: 71-82. 23.
4. Gizaw, W. and D. Assegid, 2021. Trend of cereal crops production area and productivity, in Ethiopia. Journal of Cereals and Oilseeds, 12: 9-17.
5. Kebede, D., M. Ketema, N. Dechassa and F. Hundessa, 2017. Determinants of adoption of wheat production technology package by smallholder farmers: Evidences from eastern Ethiopia. Turkish Journal of Agriculture-Food Science and Technology, 5: 267-274.
6. Zerfu, D. and D.F. Larson, 2010. Incomplete markets and fertilizer use: evidence from Ethiopia. World Bank Policy Research Working Paper.
7. Mehari, M., M. Tesfay, H. Yirga, A. Mesele, T. Abebe, A. Workineh and B. Amare, 2015. GGE biplot analysis of genotype-by-environment interaction and grain yield stability of bread wheat genotypes in South Tigray, Ethiopia. Communications in Biometry and Crop Science, 10: 17-26.
8. Haileselassie, B., D. Habte, M. Haileselassie and G. Gebremeskel, 2014. Effects of mineral nitrogen and phosphorus fertilizers on yield and nutrient utilization of bread wheat (*Tritcum aestivum*) on the sandy soils of Hawzen District, Northern Ethiopia. Agriculture, Forestry and Fisheries, 3: 189-198.
9. Alemu, T., 2015. Socio-economic and Institutional Factors Limiting Adoption of Wheat Row Planting in Selected Districts of Arsi Zone. Science, Technology and Arts Research Journal, 4: 229-233.
10. Tamm, C.O., 2012. Nitrogen in terrestrial ecosystems: questions of productivity, vegetational changes and ecosystem stability. Springer Science & Business Media.
11. Tilahun Chibsa, B., H. Gebrekidan, T. Kibebew Kibret and D. Tolessa Debele, 2017. Effect of rate and time of nitrogen fertilizer application on durum wheat (*Triticum turgidum* Var L. Durum) grown on Vertisols of Bale highlands, southeastern Ethiopia. American Journal of Research Communication, 5: 39-56.
12. Tamene, L., T. Amede, J. Kihara, D. Tibebe and S. Schulz, 2017. A review of soil fertility management and crop response to fertilizer application in Ethiopia: towards development of site-and context-specific fertilizer recommendation. CIAT Publication.
13. Zadoks, J.C., T.T. Chang and C.F. Konzak, 1974. A decimal code for the growth stages of cereals. Weed Research, 14: 415-421.
14. Giday, O., 2019. Effect of type and rate of urea fertilizers on nitrogen use efficiencies and yield of wheat (*Triticum aestivum*) in Northern Ethiopia. Cogent Environmental Science, 5: 1655980.
15. Malik, A.H., 2012. Governing grain protein concentration and composition in wheat and barley.
16. Haile, D., D. Nigussie and A. Ayana, 2012. Nitrogen use efficiency of bread wheat: Effects of nitrogen rate and time of application. Journal of Soil Science and Plant Nutrition, 12: 389-410.
17. Hundessa, M., 2019. Soil Characterization and Evaluation of Nitrogen Fertilizer Sources on Nitrogen use Efficiency and Maize (*Zea maize* L.) Yield in Meki and Adamitulu, Central Rift Valley of Ethiopia.

18. Ladha, J.K., M.L. Jat, C.M. Stirling, D. Chakraborty, P. Pradhan, T.J. Krupnik, T.B. Sapkota, H. Pathak, D.S. Rana and K. Tesfaye, 2020. Achieving the sustainable development goals in agriculture: The crucial role of nitrogen in cereal-based systems. Advances in Agronomy, 163: 39-116.
19. Tufa, T., T. Abera, T. Midega, A. Adugna, H. Legesse and B. Tola, 2020. Nitrogen Use Efficiency and Performance of Wheat Crop Through Application of Urea Stable and Conventional Urea in Vertisols of Ambo District. Plant, 8: 72.
20. Liu, J., A. Zhan, H. Chen, S. Luo, L. Bu, X. Chen and S. Li, 2015. Response of nitrogen use efficiency and soil nitrate dynamics to soil mulching in dryland maize (*Zea mays* L.) fields. Nutrient Cycling in Agroecosystems, 101: 271-283.
21. SAS, 2012. SAS/STAT Software Syntax, Version 9.4. SAS Institute, Cary, NC. USA.
22. Steel, R.G.D., J.H. Torrie and D.A. Dicky, 1997. Principles and Procedures of Statistics, A Biometrical Approach. 3rd Edition, McGraw Hill, Inc. Book Co., New York, pp: 352-358.
23. Hulumtaye, Z., 2021. Growth, Yield And Yield Components Of Bread Wheat (*Triticum aestivum* L.) As Influenced By Farm Yard Manure And Nitrogen Fertilizer Rates In Moretna Jiru Woreda, North Central Highlands of Ethiopia.
24. Desta, B.T. and Y. Almayehu, 2020. Optimizing blended (NPSB) and N fertilizer rates for the productivity of Durum wheat (*Triticum turgidum* L. var. durum) in Central Highlands of Ethiopia. Cogent Food & Agriculture, 6: 1766733.
25. Zemichael, B., N. Dechassa and F. Abay, 2017. Yield and Nutrient Use Efficiency of Bread Wheat (*Triticum aestivum* L.) as Influenced by Time and Rate of Nitrogen Application in Enderta, Tigray, Northern Ethiopia. Open Agriculture, 2(1): 611-624.
26. Abdullah Faraj, B., 2013. Evaluation of nitrogen use efficiency (NUE) in wheat.
27. Shanahan, J.F., N.R. Kitchen, W.R. Raun and J.S. Schepers, 2008. Responsive in-season nitrogen management for cereals. Computers and Electronics in Agriculture, 61: 51-62.
28. Abebe, B. and A. Abebe, 2016. Effect of the time and rate of N-Fertilizer application on growth and yield of wheat (*Triticum aestivum* L.) at Gamo-gofa Zone, Southern Ethiopia. Journal of Natural Sciences Research, 6: 111-122.
29. Limon-Ortega, A., B. Govaerts and K.D. Sayre, 2008. Straw management, crop rotation and nitrogen source effect on wheat grain yield and nitrogen use efficiency. European Journal of Agronomy, 29: 21-28.
30. Berhe, T., G. Girmay and A. Kidanemariam, 2020. Validation of blended NPSB fertilizer rates on yield, yield components of Teff [Eragrostis tef (Zuccagni) Trotter] at vertisols of Hatsebo, Central Tigray, Ethiopia. Journal of Soil Science and Environmental Management, 11: 75-86.
31. Giuliani, M.M., L. Giuzio, A. De Caro and Z. Flagella, 2011. Relationships between Nitrogen Utilization and Grain Technological Quality in Durum Wheat: II. Grain Yield and Qualities. Agronomy Journal, 103: 1668-1675.
32. Mahmood, A. and R. Kataoka, 2018. Potential of biopriming in enhancing crop productivity and stress tolerance, pp: 127-145 in Advances in Seed Priming Springer.
33. Bayeh, B., 2010. Assessment of bread wheat production, marketing and selection of N-efficient bread wheat (*Tritium aestivum* L.) varieties for higher grain yield and quality in North Western Ethiopia.
34. Hossain, A., M. Skalicky, M. Brestic, S. Maitra, M. Ashraful Alam, M. A. Syed, J. Hossain, S. Sarkar, S. Saha and P. Bhadra, 2021. Consequences and Mitigation Strategies of Abiotic Stresses in Wheat (*Triticum aestivum* L.) under the Changing Climate. Agronomy, 11: 241.
35. Etwire, P.M., 2018. The Economic Impact of Climate Change on Farm Decisions and Food Consumption in Ghana.
36. Dargie, S., L. Wogi and S. Kidanu, 2020. Nitrogen use efficiency, yield and yield traits of wheat response to slow-releasing N fertilizer under balanced fertilization in Vertisols and Cambisols of Tigray, Ethiopia. Cogent Environmental Science, 6: 1778996.
37. Kumar, V., R.K. Naresh, S. Kumar, S. Kumar, A. Kumar, R.K. Gupta, R.S. Rathore, S.P. Singh, A. Dwivedi and S. Tyagi, 2018. Efficient nutrient management practices for sustaining soil health and improving rice-wheat productivity: A Review.
38. Adugna, B., 2018. Effect of untreated and urea molasses treated finger millet straw and lowland bamboo leaf as basal diet on nutrient utilization, growth and carcass characteristics of local sheep in benishangul gumuz regional state, Ethiopia.

39. Gadisa, N., 2021. Effect of integrated application of vermicompost and nitrogen fertilizer on physicochemical properties of soil and performance of wheat (*Triticum aestivum* L.) varieties in welmera district, central Ethiopia.
40. Tarekegn, Y., 2019. Response Of Teff [Eragrostis Tef (Zucc.)] And Nutrient Use Efficiencies To Nitrogen And Phosphorus Application Rates On Vertisols of Laelay Maichew District, Central Zone Of Tigray, Ethiopia.
41. Sigaye, M.H., 2020. Nutrient Uptake and Use Efficiency of Food Barley (*Hordeum vulgare* L.) as Influenced by NPS and NPSB Blended Fertilizers.
42. Temteme, S., A. Argaw and T. Balemi, 2018. The response of hybrid maize (*Zea mays*) to N and P fertilizers on nitisols of Yeki District, Sheka Zone. Ethiopian Journal of Agricultural Sciences, 28: 53-64.
43. Daba, N.A., 2017. Influence of nitrogen fertilizer application on grain yield, nitrogen uptake efficiency and nitrogen use efficiency of bread wheat (*Triticum aestivum* L.) cultivars in Eastern Ethiopia. J. Agric. Sci, 9: 202-217.
44. Fageria, N.K., 2010. Optimal nitrogen fertilization timing for upland rice. In: World Congress Of Soil Science, 19., 2010, Brisbane, Australia. Soil-áGÇª.
45. Shara, S., R. Swennen, J. Deckers, F. Weldesenbet, L. Vercammen, F. Eshetu, F. Woldeyes, G. Blomme, R. Merckx and K. Vancampenhout, 2019. The soil fertility and leaf nutrient status in enset gardens in different altitude zones of the Gamo highlands, Ethiopia and inferences for Xanthomonas wilt prevalence. SOIL Discussions: 1-30.
46. Tilahun, A.L., 2015. Effects Of Combined Rates of Nitrogen And Phosphorus On Yield, Yield.
47. Terefe, D., T. Desalegn and H. Ashagre, 2018. Effect of Nitrogen Fertilizer Levels on Grain Yield, N Uptake and N Use Efficiency of Malt Barley (*Hordeum vulgare* L.) Varieties at Wolmera District, Central Highland of Ethiopia. International Journal of Research Studies in Agricultural Sciences, 4: 9-21.
48. Wei, H., L. Hu, Y. Zhu, D. Xu, L. Zheng, Z. Chen, Y. Hu, P. Cui, B. Guo and Q. Dai, 2018. Different characteristics of nutrient absorption and utilization between inbred japonica super rice and inter-sub-specific hybrid super rice. Field Crops Research, 218: 88-96.
49. Kakabouki, I., A. Folina, S. Karydogianni and C.Z. Panagiota, 2021. Evaluation of the effect of N-fertilization levels on teff (*Eragrostis tef*) yields expressed with nitrogen indices. Bulgarian Journal of Agricultural Science, 27: 736-743.
50. Abedi, T., A. Alemzadeh and S. A. Kazemeini, 2011. Wheat yield and grain protein response to nitrogen amount and timing. Australian Journal of Crop Science, 5: 330-336.
51. Tolesa, T., H. Ashagre and T. Abera, 2019. Agronomic Performance of Food Barley (*Hordeum vulgare* L.) Varieties and Their Response to Seed Rate at Elfeta District, West Showa Zone, Oromia National Regional State. Journal of Science and Sustainable Development (JSSD), 7: 20-31.
52. Mekonen, A., 2017. Effects of seeding rate and row spacing on yield and yield components of bread wheat (*Triticum aestivum* L.) in Gozamin District, East Gojam Zone, Ethiopia. J. Biol. Agric. Healthc, 7: 19-37.