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Effect of Nitrogen Application Time on Phenology, Growth, Yield and Economic Feasibility of Bread wheat (*Triticum aestivum* L.) Varieties in Ambo District of Western Ethiopia

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Abstract: Bread wheat (*Ttriticum aestivum* L.) is one of the most important crops in West Shoa Zone of Ethiopia but its productivity is very low due to poor agronomic practices like improper time of nitrogen fertilizer application and use of different bread wheat varieties. This in view, a field experiment was conducted on farmer's field at Bilo kebele in Ambo District, in West Shoa zone, during 2018/2019 cropping season with the objective to determine the effect of nitrogen application time on phenology, growth, yield and economic feasibility of bread wheat varieties. The experiment consisted of seven application time of nitrogen along with two varieties of bread wheat (Dendea and Wane) were used. The experiment was laid out in randomized complete block design with factorial arrangement in three replications. The mean days to 50% emergence, days to physiological 90% maturity, plant height (96.28 cm), spike length (7.34 cm) and grain yield of bread wheat were significantly ($P<0.05$) affected by the main effect of nitrogen application time and varieties. Higher net benefit ETB 51439.7 ha^{-1} with marginal rate of return of 526% and value to cost ratio of ETB 46.55 per unit of investment of bread wheat varieties was obtained from three times of 1/3 at sowing, 1/3 at tillering and 1/3 at anthesis of N application followed by net benefit ETB 50012.5 ha^{-1} with marginal rate of return of 3668% and value to cost ratio of ETB 84.77 per unit of investment from full N application tillering for bread wheat varieties. Thus, the use of full N application at tillering and three times of 1/3 at sowing, 1/3 at tillering and 1/3 at anthesis of N application gave higher grain yield and net benefit of bread wheat which confirm the national recommendation. Therefore, full N application at tillering and three times of 1/3 at sowing, 1/3 at tillering and 1/3 at anthesis of N application was alternatively recommended for bread wheat production in Ambo district and similar agro ecologies.

Key words: Bread Wheat · N Application Time · Varieties · Yield

INTRODUCTION

Bread wheat (*Triticum aestivum* L.) is the one of global leading cereal grain where more than one-third of the population of the world uses as a staple food [1]. It ranks first in the world cereal production and is a staple food of about one third of the world's population [2]. Bread wheat is one of the most staple food crops in the world and in similar manner the most important cereals cultivated in Ethiopia [3]. The national average yield of wheat in Ethiopia is about 2.76 t ha^{-1} [4] as compared to the world's average about 3 t ha^{-1} [5]. This is because of depleted soil fertility, low levels of chemical fertilizer usage, limited knowledge on time and rate of fertilizer application and the unavailability of other modern crop management inputs [6]. 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 [7].

Appropriate timing of N fertilizer application and rates are crucial for meeting crop needs and indicate considerable opportunities for improving NUE. According

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to Abdulkadir *et al.* [8] 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. Growth stage of plants at the time of application determines nitrogen use efficiency. In Ethiopia, wheat is grown during the high rain-fall season and losses of applied N through leaching may be decreased through improper timing of N application. Limited research has been done on time of N application effects in relation to growth, 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. Hence, this study was initiated to study the different N time of applications on the growth, yield and yield components of wheat and nitrogen use efficiency. At Ambo District little effort was made to determine agronomic requirement of bread wheat crop. Agronomic practices like low fertilizer level, poor management practices and use of low yielding varieties are the most yield limiting factors in bread wheat production in the study area. However, there were little scientific findings on the effect of nitrogen fertilizer timing on the productivity of different varieties for the study area. Particularly farmers of the study area have little idea on appropriate time of N fertilizer application. Thus, the objective was to determine appropriate nitrogen fertilizer timing on phenology, growth, yield and economic feasibility of bread wheat 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.

Treatments and Experimental Design: The time of N fertilizer application were adjusted according to Zadoks decimal growth stage for wheat [9] at the time when moisture is available for nutrient dissolution and absorption. Accordingly, treatments were comprised of seven different times of N fertilizer application including a negative control with two varieties of bread wheat. The design used was randomized complete block design with factorial arrangement in three replications with a plot size of 3 m x 3 m (9 m^2).

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 (Table 1). 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 wheats, 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 ha^{-1} N) and triple super phosphate (46 kg ha^{-1} P_2O_5) were used as sources of N and P, respectively. Triple super phosphate (46 kg ha^{-1} P_2O_5) 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.

Data Collection:

- Days to 50% seedling emergence: was determined by counting the number of seedlings from sowing to the time when 50% of the seedlings started to emerge the tip of shoot seen through visual observation.
- Days to 90 % physiological maturity: was calculated as a number of days from sowing to the date on which 90 % of the plants in a plot reached the respective maturity stage.
- Spike length: Five spikes were randomly selected from each unit area in each plot and were measured from the base to the top of the spike excluding awns.

Table 1: Adaptation characteristic of bread wheat varieties

		Area of adaptation			Yield (kg ha^{-1})	
Varies	Year of release	Altitude (m)	RF (mm)	Maturity day	On-Research field	On-farm field
Dendea	2010	2000-3000	≥ 600	135-150	6000-7000	5500-6500
Wane	2016	2100-2700	700-1000	125-140	5000-6000	4000-5000

Source: Kulumsa Research Center (2016)

- Total number of tillers per plant : It was taken as average number of tillers per spike of five random plants and was expressed as average number per plant
- Plant height: average height was measured from the base to the tip of the plant excluding the awns at maturity for 10 randomly selected plants in the plot.
- Grain yield: the weight of the grain was taken after threshing for each net plot area and adjusted at 12.5% moisture level.

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 [10] and interpretation were made following the procedure of Gomez and Gomez [11]. 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 [12]. The correlation analysis was performed to determine relations between phonological, growth parameter and yield and yield components as influenced by nitrogen application times.

Economic Analysis: Partial Budget analysis was used to undertake economic analysis based on the procedure recommended by Melese *et al.* [13]. The field price of 1 kg of bread wheat that farmers receive from sale for the crop was taken as 13 EB based on the market price of bread wheat at Ambo. Seed cost of improved bread wheat variety was 25 EB for 1 kg. Costs of fertilizer (Urea) were 13 EB per 1 kg and laborer expenses were 50 EB/man/day. Wheat yields were adjusted downwards by 10% to more closely approximate yields under farmer condition.

RESULTS AND DISCUSIONS

Number of Days to 50% Seedling Emergence: The main effect of bread wheat varieties and the interaction of bread wheat varieties with time of nitrogen application didn't significantly (P<0.05) influenced on number of days to 50% emergence. The main effect of time of nitrogen fertilizer application showed that significantly (P<0.05) effected on days to 50% emergence (Table 2). The maximum (6.33 days) days to 50% emergence was recorded on 1/3 N at sowing, 1/3 N at mid-tillering and 1/3 N at anthesis treatment (Table 2). The lowest (5.33 days plant^{-1}) days to 50% emergence was obtained from N application ½ at mid-tillering and ½ at anthesis, which was statistically at par with full N application at sowing (5.5 days plant^{-1}) (Table 2). It might be due to the fact that N is becoming the most important requirement for cereals during reproductive as well as at vegetative stage. Similarly, increasing the rate and single application time of nitrogen at sowing significantly prolonged the days to 50% emergence of the wheat across all application times. In contrarily, Nawaz *et al.* [14] stated that split doses of N application at various growth stages enhanced good plant germination. Single or splits application of N at early growth and development stage of the crop might unable to express their effect on days to emergence [15].

Number of Days to 90 % Physiological Maturity: The main effect of bread wheat varieties was significantly (P<0.05) affected days to 90% physiological maturity but main effect of time of nitrogen application and the interaction of bread wheat varieties with time of nitrogen application non-significantly influenced on number of days to 90% physiological maturity(Table 2). The longest (140 days) number of days to 90% physiological maturity of bread wheat was recorded from Dendea variety, while the shortest (136 days) number of days to 90% physiological maturity was obtained from Wane bread wheat variety (Table 2). Varieties were differing in days to physiological maturity. This variation was due to genetic difference of bread wheat varieties. Similarly, Mulatu [16] reported that genotypes could be differing in days to physiological maturity.

Plant Height: The main effects of bread wheat varieties and time of nitrogen fertilizer application had highly significantly (P<0.01) influenced mean plant height bread wheat but the interaction effect of bread wheat varieties with time of nitrogen application had non-significant effects on plant height (Table 2). The tallest (96.28 cm)

Table 2: Main effect of nitrogen application time and varieties on number of days to 50% emergence and days to 90% maturity, plant height, spike length and number of tillers per plant of bread wheat

Treatments	Days to 50% emergence	Days to 90% maturity	Plant height (cm)	Spike length (cm)	Number of tiller plant^{-1}
Varieties					
Dandea	5.730	140^{a}	96.28^{a}	7.34^{a}	5.69
Wane	5.93	136^{b}	87.65^{b}	6.47^{b}	5.65
LSD (5%)	6.62	138	91.97	6.91	5.67
Time of Nitrogen Application					
T1	5.67^{abc}	138.2		6.83^{ab}	4.83^{b}
T2	6.33^{a}	138.5	85.32^{c}	7.14^{a}	5.47^{ab}
T3	5.83^{abc}	139.2	94.64^{a}	7.21^{a}	5.77^{ab}
T4	5.33^{c}	138.5	95.51^{a}	6.9^{ab}	5.87^{ab}
T5	5.5^{bc}	137.5	89.88^{bc}	6.89^{ab}	5.87^{ab}
T6	6.17^{a}	137.3	94.82^{a}	6.84^{ab}	6.37^{a}
T7	5.83^{abc}	137	93.61^{ab}	6.54^{b}	5.5^{ab}
LSD $_{(5\%)}$	0.04	NS	89.97^{b}	0.42	1.24
CV (%)	10.7	2.79	4.6	5.15	18.49

where, 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 at 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.

and shortest (87.65 cm) plant height were obtained from Dendea and Wane bread wheat varieties, respectively (Table 2). The difference in plant height of the varieties could be attributed to the difference in their genetic makeup. In agreement with this, Assefa *et al.* [17] reported that height of the crop is mainly controlled by the genetic makeup of a genotype and it can also be affected by the environmental factors.

The tallest (95.51 cm) plant height was recorded from application of ½ doses N at sowing and ½ at mid-tillering (Table 2). While the shortest (85.32 cm) plant height was noticed in control (Table 2). This difference may be to the fact that only one-time application of full dose of nitrogen at sowing or any other stage of growth may not lead to efficient recovery of the nutrient by roots and enhanced plant growth. This could be attributed to that application of full dose of nitrogen at one time to crops may lead to loss due to leaching as nitrate ion ($NO3^{-1}$) as stated by Gebremeskel *et al.* [18]. This result is major indicator for the height of wheat mainly affected by the time of fertilizer application. Mean while the combined effect of optimum fertilizer application at right time had significant effect on height of wheat [19]. Likewise, Khan *et al.* [20] reported that the increase in plant height might be attributed to continuous supply of N during the later stages of crop growth and due to its favorable effects on plant metabolism and probably due to increase in cell size and higher merstamatic activity. The application of N with full dose at CRI (crown root initiation) or at first node stage resulted in significantly lower plant height as compared to split application of N and full dose at sowing.

Spike Length: The main effects of bread wheat varieties and time of nitrogen application were significantly ($P < 0.05$) influenced spike length of bread wheat but the interaction of bread wheat varieties with time of nitrogen application was non-significant (Table 2). The tallest (7.34 cm) and shortest (6.47 cm) spike length were obtained from Dandea and Wane bread wheat varieties, respectively (Table 2). This variation might be observed by the influence of genetic difference. Similarly Russell *et al.* [21] reported that individual genotypes responded differently to spike length for varying time of N application in bread wheat.

The tallest (7.21 cm) spike length was recorded from ½ N applications at sowing and ½ N application at mid-tillering time. Except full N application at anthesis treatment, all treatments of time of nitrogen application were statistically at par of each other and none significantly influenced on spike length plant^{-1}. Moreover, appropriate N supply at right time facilitated sufficient nitrogen partitioning towards spike length and grain [21]. The increment of spike length development of bread wheat receiving split applications might have been due to harmonization (managements) of N supply and demand which resulted in high uptake of N, resulting in cells expansion, enlargement and over and above the grain filling. Several reports indicated application of fertilizer in proper time has positive effect on spike length [21].

Number of Tillers per Plant: Time of nitrogen application was significantly ($P \leq 0.05$) influenced number of tiller plant^{-1} but main effects of bread wheat varieties and interaction effect of bread wheat varieties with time of nitrogen application were non-significantly ($P \leq 0.05$) influenced number of tillers plant^{-1}. However, (Table 2). Except control treatment, all treatments of time of nitrogen application were statistically at par of each other and significantly influenced on number of tiller plant^{-1}

(Table 2). The reason of increased number of tillers in plots receiving application of N may be similar due to sufficient availability of N during tillering stage. In addition, the effect of N application in promoting and flourishing green vegetative growth and number of tillers. Sufficient N fertilizer application during early vegetative growth stages significantly increased tiller formation in wheat crop [20]. The greater number of tillers production in fertilized plots can be attributed to the adequate N availability [22] which resulted in increased photosynthetic activities. Abayu [23] reported that, application of nitrogen resulting in vigorous growth due to its immediate availability to the plant roots [24], ultimately increased the total number tillers.

Grain Yield: The mean grain yield of bread wheat was significantly ($P<0.01$)) influenced by the interaction of time of N fertilizer application and bread wheat varieties (Table 3). The maximum (4989 and 4619 kg ha^{-1}) grain yield of bread wheat were obtained from Dendea and Wane varietiesy with three times N application (1/3 at sowing, 1/3 at mid tillering and 1/3 at anthesis) and twice application (½ at sowing and ½ at mid tillering), respectively. Similarly, Dendea gave maximum (4783 kg ha^{-1}) grain yield with full N at mid tillering which is statistically similar (Table 3). The minimum (1937 kg ha^{-1}) grain yield was obtained from control (Table 3). The mean grain yield of bread wheat was increased about 1.6 folds by interaction effect of Dandea variety plus application of nitrogen fertilizer at the time of 1/3 at sowing, 1/3 at mid-tillering and 1/3 at anthesis as compared to control. The higher grain yield of bread wheat due to efficient utilization and arresting 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, higher grain yield of wheat was reported when N was applied in three splits (at planting, tillering and post-anthesis) compared with two splits (at planting and tillering) and one-time application (at sowing). Belete *et al*. [3] 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.

Pearson Correlation Between Phenology, Growth and Yield Parameters of Bread Wheat Due to Seed Rates, Sowing Methods and Varieties: The correlation between phenology, growth, yield and yield components of bread

Table 3: 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				

where, 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 4: Pearson correlation coefficient between yield and yield component of bread wheat at Ambo district

	DTE	DM	NDVIR	PH	SL	TP	GY
DTE							
DM	-0.16						
NDVIR	0.09	0.30*					
PH	-0.16	0.46**	0.61**				
SL	-0.21	0.05	0.11	0.31**			
TP	-0.025	0.04	0.22	0.28*	-0.03		
NSPS	0.13	-0.07	0.27*	-0.2	-0.32*	-0.01	
DBMH	0.14	0.17	0.65**	0.53**	0.21	0.42**	
GY	0.96**	0.12^{NS}	0.49**	0.53**	0.22^{NS}	0.32*	

DTE= Date to 50% emergency, DM= Date to 90% maturity, PH =Plant height, SL= Spike length, TP=Total Number tillers.

Table 5: Partial budget analysis of nitrogen application time and varieties of bread wheat in Ambo

Time of nitrogen application	Grain yield (Kg ha^{-1})	Adjusted Grain yield (Kg ha^{-1})	Gross field benefit (EB ha^{-1})	TCV (EB ha^{-1})	Net benefit (EB ha^{-1})	Value to cost ratio	MRR (%)
T1	2496	2246	29203.2	0	29203.2		
T5	3552	3197	41558.4	350	41208.4	117.74	3430
T6	4325	3893	50602.5	590	50012.5	84.77	3668
T7	4181.5	3763	48923.55	600	48323.55D	80.54	
T3	4354.5	3919	50947.65	850	50097.65	58.94	33
T4	3840.5	3456	44933.85	1100	43833.85D	39.85	
T2	4491	4042	52544.7	1105	51439.7	46.55	526

T_1 = Nil application; 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 and T_7= Full N at anthesis, D=dominated

wheat is indicated in (Table 4). Grain yield of bread wheat showed positive and significant correlation with its components such as nitrogen difference days to 50% emergence (96), plant height (0.53) and number of tillers (0.32). This means with increasing value of these parameters; and grain yield also increases as well and vice versa. According to Bayeh [25] reported significant and positive correlation between days to 50% emergence and plant height with grain yield. Whereas, there were lower correlations indicated among days to 90% maturity (0.12) and spike length (0.22) with grain yield [26].

Effects of Nitrogen Application Time on Economic Feasibility of Bread Wheat Production: The partial budget analysis was indicated in (Table 4). The highest net benefit of ETB 51439.7 ha^{-1} with marginal rate of return of 526% and value to cost ratio of ETB 46.55 per unit of investment of bread wheat varieties was obtained from three times of 1/3 at sowing, 1/3 at tillering and 1/3 at anthesis of N application followed by net benefit ETB 50012.5 ha^{-1} with marginal rate of return of 3668% and value to cost ratio of ETB 84.77 per unit of investment from full N application tillering for bread wheat varieties. Therefore, full N application tillering and three times of 1/3 at sowing, 1/3 at tillering and 1/3 at anthesis of N application were alternatively used for bread wheat production.

CONCLUSION

Bread wheat production is heavily dependent on available nutrient in the soil and other environmental conditions for plant growth. The main effects of N application time and bread wheat varieties were significantly improved phenology, growth and grain yield of bread wheat. Therefore, full dose N application at tillering and three times of 1/3 at sowing, 1/3 at tillering and 1/3 at anthesis of N application were alternatively used for bread wheat production.. 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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