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

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Abstract

Globally, nitrogen is considered as the second most limiting nutrient in the crop production and limits yield in non-fertilized agriculture. A greenhouse experiment on the 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 was conducted, to determine the optimum nitrogen (N) rate and N timing of application on durum wheat plant yield components. The experimental was laid out in randomized complete block design (RCBD) with five N levels (0, 23, 46, 69, and 92 kg ha^{-1}) in factorial combination with three N timings (So = full dose at sowing, S_1 = ½ dose at sowing + ½ dose at tillering, S_2 = 1/3 dose at sowing + 1/3 dose at tillering + 1/3 dose at booting) as a treatments with three replications. Soil analysis of TN ranged from 0.19% to 0.20% rated as deficient, indicative of N fertilizer has response on production of durum wheat plant. The ANOVA results of both sole N rates and N timing had highly significant difference on durum wheat plant parameters. The highest grain nitrogen (GN) of 2.0% and 11.4% grain crude protein (GCP) with 11% higher over the control was obtained when 92 kg ha^{-1} N rate was applied. Generally; with increasing N fertilizer application rate there was increasing grain and straw crude protein with the overall mean of (13.98%). Applications of all N rates at planting and twice split application timing showed the same significance effect on grain yield (each 5.4 t ha^{-1}) with 8% higher yield over trice split N timing. the maximum grain yield of 7.3 t ha^{-1} with 152% increase; the maximum straw yield of 8 t ha^{-1} with 88% increase; TKW (59.99 gm) with 38.4% increase were obtained over the control. Similarly; double split application of 92 kg ha^{-1} N at sowing and mid tillering (S1) resulted in: longest spike length of 4.78 cm with 9% longer; the maximum biomass yield of 12.29 t ha^{-1} (16% higher over the control). As a conclusion both sole applications of 92 kg ha^{-1}N rate and 92 kg ha^{-1} N rate twice split application timing in the recommended from the current study and also further onfarm field experiments of durum wheat production at large scale are recommended.

Keywords: Straw, Grain nitrogen, Crude protein, Vertisols

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1. Introduction

Durum wheat (*Triticum turgidum Var L. Durum*) is one of the oldest and traditiionly grown wheat plant in Ethiopia. It is usually grown in the water logged Vertisol during the late rainy season; in wheat belt zones of Bale and Arsi. It is produced as input, row materials for Agro-industry for pasta and sphagati production. Durum wheat grain is also consumed traditionally in Ethiopia in the form of whole wheat, fermented and leavened local bread.

Globally, nitrogen is considered as the second most limiting factor in the crop production and limits yield in non-fertilized agriculture. Low soil fertility is one of the constraints in durum wheat production (Teklu and Teklewold, 2009). Although, nitrogen (N) is widely distributed in nature; it is an essential element for plant growth and is frequently the major limiting nutrient in most agricultural soils (Teklu and Teklewold, 2009).

Soil fertility depletion is among the major impediments to sustained agricultural productivity especially in the less developed countries because of limited application of fertilizers (Donovan and Casey, 1998; Teklu and Teklewold, 2009). Plants take up nitrogen from the time the roots begin to function until all uptake of nutrients ceases with maturity. Lack of supplying adequate N can adversely affect crop protein content which is a major component in crop protein quality grading system (Casagrande *et al*., 2009). It requires 12–18 kg ha^{-1} N to change protein by 1% where wheat was under water stress during grain fills. The TN requirement could then be computed by summing the N required for raising protein and the N removed by the crop in the year when the grain was harvested (Engel *et al*., 1999).

This crop N demand increases sharply just prior to onset of the most rapid phase of crop growth that is stem elongation. Shortage of N during this period and subsequent shoot development, lead to increased shoot mortality, and smaller spike size results. The highest nitrogen rate of 120 kg ha^{-1} consistently increased grain yield, but had less effect on harvest-index. Split application of nitrogen had a favorable effect on grain yield and total biomass with 120 kg nitrogen rate per hectare (Tilahun *et al*., 1997). Wheat grain is the staple food of the Ethiopian highlanders and wheat straw represent the major dry season feed resource for Ethiopian's livestock population (Selamyihun, 1999). Thus, both human and livestock populations benefitted from an increase in dietary protein intake as well as an increase in the quantity of dietary staples (Selamyihun, 1999). Besides N-fertilizer, its application times are also considered a key to high production. The time of N-fertilizer application has been found effective in increasing crop yield and grain crude protein compared with the full application of N-fertilizer at sowing time (Tilahun *et al*. 1997, Haile *et al*. 2012).

Time of N fertilizer application depends on the soil, climate, nutrients and varieties; crops should be applied at a time that will maximize recovery by the crops and reduce the potential of environmental pollution (Tisdale *et al*., 2002). Proper timing of nitrogen fertilizer applications to high yielding varieties can be successful as one of the means in attempting to achieve high yield goal and high protein quality (Garrido-Lestachea *et al*., 2004). Application of half or one-third of total fertilizer N at stem elongation improved grain yield and grain protein content with respect to applications at sowing alone or at both sowing and tillering (Garrido-Lestachea, *et al*., 2004).

Nitrogen is important in determining the final grain yield of wheat during the rapid phase of crop development because it is required for higher rates of increasing grains (Frank and Baeur, 1982; Abdo *et al*., 2012) and for biomass formation (Peterson and Frye, 1989 and Abdo *et al*., 2012]. Nitrogen applied early may not be utilized by the plant but rather lost through leaching and or run off if there are heavy rains immediately after sowing. At present, both commercial and small-scale farmers has a high demand for durum wheat production with high grain yield and better end-use quality to supply the increasing need of durum wheat grain processors in Ethiopia (Garrido-

Lestachea *et al*., 2004). Also farmers use blanket recommendation of 100 kg DAP and 50 kg urea per hectare. The gap is lack of enough information on grain yield and yield components response to different nitrogen rates and timing for durum wheat in Ethiopia. Therefore, in the present study the optimum N fertilizer rate and time of its application for durum wheat production in the greenhouse pot experiment of SARC on Vertisols of Bale zone was evaluated.

2. Materials and Methods

2.1. Description of the study area

The research was conducted in Sinana district in a greenhouse of Sinana Agricultural Research Centre (SARC) during the 2011/12 cropping season. Sinana Agricultural Research Center (SARC), is located at 07° 07' N latitude and 40° 10' E longitude and altitude of 2400 meter above sea level (masl). The soil used for the study was Vertisols.

5.2.1.1. Map of the study area

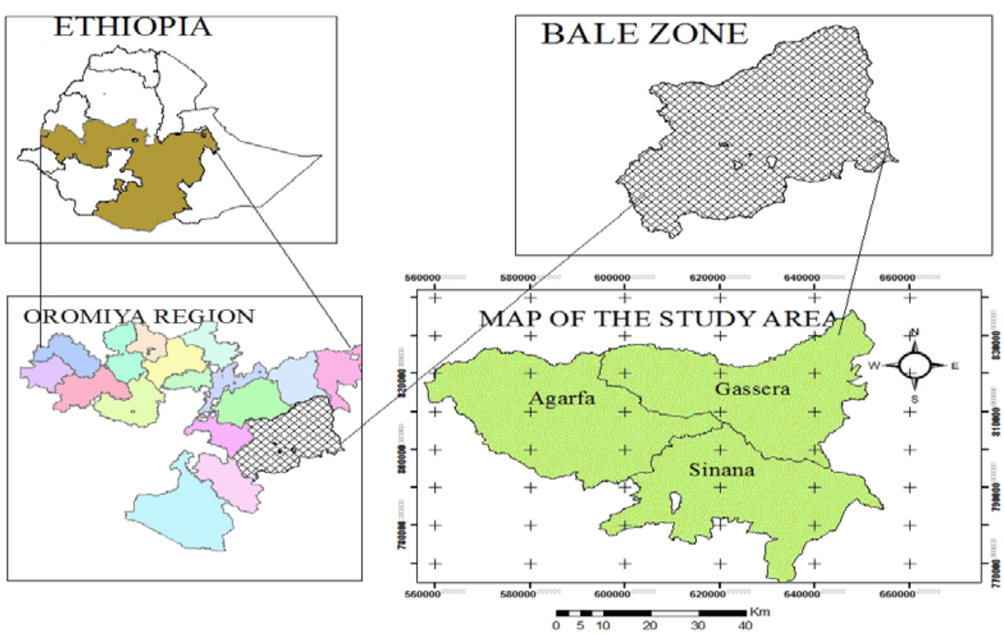

Figure 5.1. Potting soil sample collection sites for the greenhouse experiment; Geographical positioning system coordinate and map.

2.2. Climate characteristics

The highlands of Bale in the southeastern Ethiopia are known for intensive agricultural production with vast potential area, characterized by bimodal rainfall and having two distinct growing season *viz., 'Belg or Ganna'* (March-July) and *'Meher or Bona'* (August-December). The average annual rainfall, minimum and maximum temperatures during the experimental year was 1174.5 mm; 9.5^{0}C and 21^{0}C, respectively at SARC metrological station.

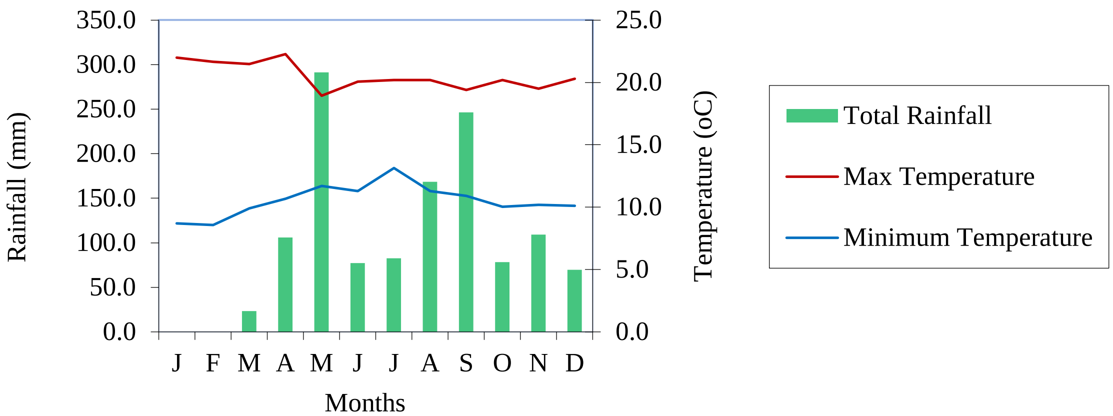

Figure 5.2. (X,Y) Mean monthly rainfall (mm), minimum and maximum temperature of SARC metrological station for 1990-2011 cropping seasons.

2.3. Methods of Durum wheat planting

The experiment was conducted using durum wheat variety *("Ejersa")* as a test crop in a greenhouse of SARC Bale Zone during 2011/2012 cropping season.

On farm soil samples under Vertisol were collected for the greenhouse experiment under conventional tillage practices from surface 0-30 cm soil depth. The experimental design was laid out in randomized complete block design (RCBD) with five nitrogen levels (0, 23, 46, 69, and 92 kg N ha^{-1}) in factorial combination with three nitrogen timings (So = full dose at sowing, S_1 = ½ dose at sowing + ½ dose at tillering, S_2 = 1/3 dose at sowing + 1/3 dose at tillering + 1/3 dose at booting) with three replications. All methods of treatment applications were made by row placement at planting time and broadcasted at tillering and booting. A basal dose of 20 kg ha^{-1} phosphorus fertilizer was applied to all plots at planting time. The choice of the fertilizers treatment application rates was based on choosing equal levels bellow and above blanket recommendation 100 kg DAP and 50 kg urea (41/46 kg ha^{-1} N /P_2O_5), which was used nationally for long time. The durum wheat has been grown by irrigating tap water once every third days in the greenhouse at 60% of field capacity so as to avoid leaching of nutrients from the root zone. The field capacity was determined by taking the difference in the moisture contents of 3 kg of soils at full saturation of pot soil and that it was kept for three days after saturation of dry state potting soil. A total of thirteen wheat plant seeds were sown in each plot (Rowell, 1994). The experiment was conducted using durum wheat variety (*Ejersa*) at 150 kg ha^{-1} as a test crop. The durum wheat plant was sown in the green house on 5th of September, 2011 and was harvested on 5th of January, 2012. Out of thirteen total wheat plants per pot, eight of them were selected per pot. Then durum wheat plant were harvested and placed in small bag, tied and threshed by placing on clean canvas mat for biomass yield, grain yield and TKW determination. TKW, biomass and grain yield were measured by counting the number of grains per pots using seed counter machine and sensitive balance. Before harvesting of durum wheat plant, randomly three durum wheat plants were selected to measure above ground plant heights, number of tillers per plants, number of seeds per spike and spike length (cm) and average were taken for the statistical analyses. Soil samples were also collected after harvest of durum wheat by completely mixing soils in the pot. Then the soil samples per pot were prepared by drying, grinding and sieving in a sieve with diameter less than 2 mm. Finally the soil samples were analyzed for OC, TN, and pH.

2.4. Methods of soil sample analyses

Soil particle size distribution was determined by the Bouycouos hydrometer methods (Bouyoucos.1962). Soil pH was measured potentiometrically using a glass-calomel combination electrode by a pH meter in 1:2.5 soils to water and in 1:2.5 soil to potassium chloride (1M KCl) suspension (Sahlemedhin and Taye (eds.), 2000). Organic carbon (OC) was determined by wet digestion method according to (Walkley and Black, 1934). Total N of soil, straw and grain N of durum wheat samples; were also determined using the standard Kjeldahl methods compiled by (Sahlemedhin and Taye (eds.), 2000).

3. Statistical Analysis

The data collected for each parameter were subjected to analysis of variance (ANOVA) using general linear model (GLM) procedures SAS version 9.1.3 (SAS, 2004). Treatment means were also compared using Fisher's protected least significant difference test at $P \leq 0.05$.

4. Results and Discussions

The results of the greenhouse pot experiment undertaken at SARC during 2011/2012 cropping season revealed that the sole applications of N rates had highly significant effect (P<0.01) on most of the yield and yield components of durum wheat plant considered (Table 5.1 and 5.2) on Vertisols. Nitrogen fertilizer application time data showed (Table 5.1) significant difference only to spike length (cm), number of seeds per spike, biomass, grain and straw yield at $p \leq 0.05$ or $P \leq 0.01$ significance level. The interaction of N rate by N Timing showed significant difference only to biomass and straw yield.

Table 5.1. ANOVA results of the effect of nitrogen rate and application time on grain yield and yield components of durum wheat at greenhouse experiments

Treatment	Plant height (cm)	Number Tillers per plant	Spike length (cm)	Nos of seeds per spike	Biomass Yield (tha^{-1})	Grain Yield (tha^{-1})	Straw Yield (tha^{-1})	TKW (g)
Model	**	**	**	**	**	**	**	*
NR	**	**	**	**	**	**	**	*
NT	NS	**	**	NS	**	*	*	NS
NR*NT	NS	NS	NS	NS	**	NS	*	NS
Mean	62.28	24.170	4.53	1.21	11.26	5.30	5.95	52.02
CV(%)	3.17	11.77	6.74	21.51	7.61	7.43	13.91	9.77
R2	0.90	0.86	0.93	0.95	0.97	0.97	0.92	0.82

NR=N rate, NT= N timings, TKW =Thousand kernel weight

4. 1 Main effect of nitrogen rates on the yield and yield components of durum wheat

4.1.1 Plant height (cm)

The ANOVA results (Table 5.2) showed that there was high significant difference ($p<0.01$) between plant height with the application of different rates of nitrogen fertilizer levels to durum wheat plant ("*Ejersa*"). Only the sole application of N rate significantly affected durum wheat plant height at $P\leq0.01$ significance level. Plant height showed increasing tendency with increasing nitrogen application rates from 0 to 92 kg N ha^{-1}. Consequently, the maximum plant height (65.46 cm) was obtained when 92 kg ha^{-1} of N rates were applied to the soil in the pot followed by application of 69 kg ha^{-1} N (64.59 cm), which was 15% higher over control with the mean of 62.28 cm in agreement with the findings of (Selamyihun *et al.*, 1999; Abdo *et al*., 2012; Haile *et al.*, 2012;; Girma *et al*., 2012; Gerba *et al.*, 2013) increasing N rate increased plant height.

Table 5.2. Results of the effect of N rates and application time on yield components of durum wheat a greenhouse experiment

N Rate (kg ha^{-1})	Plant height (cm)	Nos Tillers plant^{-1}	Spike length (cm)	Number seeds plant^{-1}	Biomass Yield (t ha^{-1})	Grain Yield (t ha^{-1})	Straw yield (t ha^{-1})	TKW (g)
0	56.93d	0.11c	3.64c	17.85d	7.16e	2.9e	4.3c	43.33d
23	62.11c	1.15b	4.31b	22.93c	9.59d	4.6d	5.0c	47.89dc
46	62.13bc	1.20b	4.55b	25.92bc	12.26c	5.6c	6.7b	52.76bc
69	64.59ba	1.67a	4.98a	26.4ba	12.9b	6.3b	6.7b	56.00ba
92	65.46a	1.97a	5.28a	28.39a	15.3a	7.3a	8.0a	59.99a
Mean	62.28	1.21	4.53	24.17	11.23	5.30	5.9	52.02
CV(%)	3.165	6.74	21.51	11.77	7.61	7.43	13.91	9.77
Lsd(5%)	1.970	0.26	0.31	2.84	0.856	0.39	0.83	5.10
S0	61.46a	0.98c	4.38b	24.9a	11.4b	5.4a	5.8b	51.0a
S1	62.47a	1.44a	4.78a	23.6a	12.29a	5.4a	6.45a	51.3a
S2	62.80a	1.20b	4.49b	24.0a	10.68b	5.0b	5.60b	53.6a
Mean	62.28	1.21	4.5	24.2	11.26	5.3	5.95	52.02
CV(%)	3.165	11.7	21.5	6.74	7.61	7.43	13.91	9.77
LSD(5%)	1.5261	0.201	0.24	2.20	0.66	0.31	0.64	3.93

NB: Means with the same letter are not significantly different at $P<0.05$ significance level
So = All Nitrogen rate applied at planting, S_1 = N Rate double split (1/2 at planting and 1/2 at mid tillering) & S_2 = N Rate Trice Split (1/3 at planting 1/3 mid tillering and1/3 at booting).

4.1.2. Number of tillers per plant

Durum wheat plant with higher number of effective tillers could have higher grain yield, straw yield and biomass yield. The number of effective tillers were influenced highly significantly ($P < 0.01$) by both sole N rate and sole N Timing but not by their interaction (Table 5.1). Thus, there is increased number of tillers in response to increasing rate of nitrogen and its timing (Table 5.2). As a result of sole N applications rates the maximum number of tillers of 1.97 when 92 kg ha^{-1} N was applied; which is 180% over the control, followed by 69 kg ha^{-1} N (1.67); with the overall mean value of 1.21 tillers per durum wheat plants. Generally there was increasing trends of tiller number with increasing N rates. Similar work also confirmed with increasing nitrogen rate there is increasing number of tillers (Abdo *et al*., 2012; Girma *et al*., 2012; Haile *et al*; 2012; Gerb *et al.*, 2013).

The study also showed increasing tendency of number of tillers per plant with increasing N timing. The maximum number of tillers were recorded by twice N Split (1/2 application rate at planting and the remaining 1/2 at tillering) (1.44) which was 47% over application of all rates at sowing time; followed by trice N Split application rate (1/3 at planting, 1/3 at tillering and 1/3 at booting) (1.20) which had 22% advantage over application of all rate at planting. Therefore; application of N at different stage of wheat growth may help to retain N for plant growth and reduce N from leaching loss, which were contributing to eutrification of water bodies and environmental pollution. Results are in agreement with the findings (Tilahun *et al*., 996; Abdo *et al*., 2012; Haile *et al*.2012).

4.1.3. Spike length (cm)

The highest spike length (5.28 cm) was obtained by the application of 92 kg ha^{-1} N; which was 45% increase over the control. All the treatment showed increasing tendency of spike length with increasing nitrogen fertilizer rates. Results are in agreement with (Tilahun 1996; Abdo *et al*., 2012 and Gerba *et al.*, 2013).

Moreover; N timing also showed significance difference on spike length ($P<0.01$). The longest spike length (4.78 cm) was obtained by double split nitrogen fertilizer application at sowing and tillering when compared with the application of all N doses (So) (4.38 cm) at the time of planting. When N was trice split applied gave the next higher spike length followed by application of N at sowing and mid tillering. The mean spike length due to timing of nitrogen fertilizer was 4.53 cm for all the treatments. Application of fertilizer has positive effect on spike length (Tilahun *et al*., 1995; Abdo *et al*., 2012; Haile *et al*.; 2012; Gerba, 2013; Girma *et al*., 2012).

4.4. Number of Seeds per plant

The ANOVA results showed that only sole N rate had significant effect on the number of seeds per plant (Table 5.1). Number of seeds per spike (Table 5.1 and Table 5.2) was significantly affected only by N fertilizer rates. The highest number of seeds spike^{-1} of 28.4 cm was obtained by application of 92 kg N ha^{-1}. The number of seeds increment was 59% over the control (17.85); when 92 kg N ha^{-1} was applied as treatment. On average 24.2 seeds are present per plant with increasing tendency of number of seeds per plant with increasing N rates. However, nitrogen timing and their interaction with N rates of application had shown no significant effect on the number of seeds per spike (Table 5.1) Results are also in agreement with the findings of several researchers (Tilahun *et al*., 1995; Teklu Erkossa and Teklewold Hailemariam. 2009; Abdo *et al*., 2012; Girma *et al*., 2012; Haile *et al*.; 2012; Gerba *et al.*, 2013).

4.5. Biomass Yield (t ha^{-1})

Biomass yield is one of the yield components of durum wheat plant, the result of ANOVA indicated that N rate, N timing and their interaction showed highly significant biomass yield differences ($P<0.01$) to wheat plant (Table 5.1) There was increasing trends of total above ground dry biomass of durum wheat plant with increasing application levels of nitrogen (0 - 92 kg ha^{-1}). The maximum biomass yield of 15.3 t ha^{-1} was obtained when durum wheat plant was fertilized with 92 kg ha^{-1}; which was 113.7% higher over the control. The mean biomass yields were found to be 11.23 t ha^{-1} (Table 5.2).

Similarly; the best N timing of double split application at sowing and mid tillering resulted in the maximum biomass yield of 12.29 t ha^{-1}as compared to application of all N and trice N split applications on durum wheat plant. The reason for this may be shortage of rain fall at trice split application time and loss of nitrogen might have occurred by leaching and volatilization as it was applied on the surface. The interaction also showed significant biomass yield difference at $p<0.01$ level. The extent of yield components response to nitrogen fertilizer depends on the amount or quantity of the nutrient supplied (Teklu and Teklewold, 2009; Abdo *et al*., 2012; Tolera *et al*., 2012, Girma *et al*., 2012; Haile *et al*., 2012; and Gerba *et al*., 2013).

4.1.6. Grain yield (t ha^{-1})

Grain yield is an important yield component that contributes to overall yield of durum wheat. Results of ANOVA (Table 5.1) of the effect of nitrogen rate and time of application on durum wheat plant showed significant difference on grain yield only with sole N application rates (P<0.01) and N Timing (P<0.05).

The maximum grain yield of 7.3 t $ha^{-1}$was obtained when N was applied at 92 kg ha^{-1} with 152% increase over the control (Table 5.2). The other entire treatments showed increasing trend of grain yield with increasing application rate of N with overall average grain yield of 5.3 t ha^{-1}. Data further revealed that grain yield was significantly (P < 0.01) affected by different nitrogen levels the in agreement with (Teklu and Teklewold, 2009; Abdo *et al*., 2012; Tolera *et al*., 2012, Girma *et al*., 2012; Haile *et al*., 2012; and Gerba *et al.*, 2013) .

N timing had also shown statistically significant difference (P<0.05) on the grain yield of durum wheat. Accordingly applications of all N rate at planting and twice split (half at planting and half at tillering) had the same significance effect on grain yield (each 5.4 t ha^{-1} at 92 kg ha^{-1} rate) of durum wheat plant. Trice split N application had resulted in the lowest grain yield (5.0 t ha^{-1}). Interaction among fertilizer levels and N timing had no significant difference on the grain yield of durum wheat plant. There was significant differences in grain yield of durum wheat plant with N rate treatments (Table 5.2). The rates of nitrogen application also significantly affected grain yield. Grain yield increased as amount of nitrogen was increased from the control level to 92 kg ha^{-1}. The results agree with the findings of Teklu and Teklewold, 2009; Abdo *et al*., 2012; Tolera *et al*., 2012, Girma *et al*., 2012; Haile *et al*., 2012; and Gerba *et al.*, 2013. The highest grain yield of any crop is the result of positive relationships of most yield components due to nitrogen fertilizer application (Teklu and Teklewold, 2009; Abdo *et al*., 2012; Tolera *et al*., 2012, Girma *et al*., 2012; Haile *et al*., 2012; and Gerba *et al.*, 2013).

4.1.7. Straw Yield (t ha^{-1})

Biological yield is an important factor because farmers are also interested in straw in addition to grain. Straw of durum wheat plant is important in nutrient cycling and live stock feed for the highland farmers. Like biomass yield; straw yield was affected highly significant (P < 0.05) by the sole and interactions of applied N rate and timing (Table 5.1 and 5.2). The maximum straw yield of 8 t $ha^{-1}$was obtained when durum wheat plant was treated with 92 kg ha^{-1} with 88% increase over the control (similar trained was observed by (Teklu and Teklewold. 2009; Abdo *et al*., 2012; Girma *et al*., 2012; Haile *et al*; 2012; Tolera *et al*. 2012) ,Gerba *et al.*, 2013). The average durum wheat plant straw yield amounts to 5.9 t $ha^{-1}$with the application of the five N levels. Twice split N application rate gave the maximum straw yield (6.4 t ha^{-1}) and the minimum straw yield was obtained by trice split N application timing (5.6 t ha^{-1}). Study indicated due to applied fertilizer N the yields and N contents of the grain and straw of wheat was increased, resulting in significant increase in the total N uptake (Teklu and Teklewold, 2009; Abdo *et al*., 2012; Tolera *et al*., 2012, Girma *et al*., 2012; Haile *et al*., 2012; and Gerba *et al.*, 2013).

4.1.8. Thousand Kernel weight (TKW)

The result of ANOVA indicated that only sole N application rate had significant effect on TKW ($P<0.05$) (Table 5. 1 and 5.2). The highest TKW of 59.99 gm was recorded by 92 kg ha^{-1} N treatment with 38.4% increase over the control. The split application timing of fertilizer at different growth stages did not affect TKW. The average TKW due to application of N doses was 52.02 g. These results agree with the findings of (Teklu and Teklewold, 2009; Abdo *et al*., 2012; Tolera *et al*., 2012, Girma *et al*., 2012; Haile *et al*., 2012; and Gerba *et al.*, 2013)who reported that 1000-grain weight of wheat was significantly affected by different nitrogen levels.

4.1.9. Straw and grain nitrogen and their crude protein content of durum wheat plant

Straw and grain are the most important components of food and feed to people and livestock's. The end of durum wheat plant management is to improve the quantity and quality of straw and grain. Organic carbon, pH (H_2O), pH (KCl) and soil total nitrogen contents showed no significant effect to application of sole nitrogen fertilizer rate, timing of nitrogen fertilizers and their interactions (Table 5.3).

Table 5.3. ANOVA results of effect of nitrogen rate and application time on grain yield and yield components of durum wheat a greenhouse experiment at SARC in 2011/2012

Treatments	OC (%)	PH(1:2.5 soi:H2O)	PH(1:2.5 soil:KCl)	SoiN (%)	STN (%)	ST CP (%)	GN (%)	GCP (%)	GST N (%)	GST CP(%)
Model	NS	NS	NS	NS	*	*	**	**	**	**
N rate	NS	NS	NS	NS	NS	NS	**	**	**	**
N timings	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
N rate *N Timings	NS	NS	NS	NS	NS	NS	*	*	*	*
Mean	1.06	6.42	5.00	0.20	0.55	3.21	1.87	10.77	2.43	13.98
CV(%)	3.35	1.06	1.54	5.59	27.8	27.80	9.45	9.45	7.948	7.95
R2	0.76	0.65	0.69	0.75	0.80	0.80	0.92	0.91	0.94	0.942

NB: Means with the same letter are not significantly different. OC= organic carbon, Soil N= soil nitrogen; STN= nitrogen of straw, CPST = crude protein of straw; GN= grain nitrogen of durum wheat; GCP = grain crude protein; GSTN = grain straw nitrogen, GSTCP= grain and straw crude protein content, S0= All N rate applied at planting; S1 = N Rate Twice split applied 1/2at planting and ½ at tillering; S2 = N Rate Trice split (1/3 applied at planting, 1/3 at tillering and 1/3 at heading).

However; the organic carbon of a soil had a mean of 1.06% which indicates a low level of soil organic matter; the pH in 1:2.5 soil to H_2O ratio from 6.41 to 6.43 slightly acidic pH range; soil pKCl indicated potential acidity ranges from lowest treatment to highest as 4.97 (by 23 kg ha^{-1}) to 5.05 (by 92 kg ha^{-1}) treatments with a mean of 5.00. On the other hand; soil total nitrogen were not significantly differed from one another due to application of the different doses of nitrogen fertilizer. TN ranges from 0.19% to 0.20%), indicating the low level of total N and application of N fertilizer may improve the productivity of durum wheat plant. Only the sole nitrogen rate and sole nitrogen timings had significant difference at $P \leq 0.05$ on durum wheat N plant parameters. Whereas, interaction effects of nitrogen rate by timings of application were not significantly differed on the straw nitrogen and crude protein contents of durum wheat (Table 5.4).

Grain nitrogen of durum wheat plant showed significant difference due to the application of different rates of nitrogen fertilizers at $P \leq 0.05$ significance level. The highest GN of 2.0% was obtained which was not significantly differing from application of 69 kg ha^{-1} (1.98%) was obtained by application of the highest N rate (92 kg ha^{-1}). The highest GN was 11% higher over the control, no N fertilizer treatment. The overall mean of the GN for the applied treatments was 1.87%.

Similarly; the highest GCP was obtained when nitrogen 92 kg ha^{-1} was applied, which is 11.4% higher over the control treatments. GSTN also showed highly significant difference at P≤0.05 significance level. The highest GSTN (2.61) was obtained with the application of 69 kg ha^{-1} N. The results agree with [(Teklu and Teklewold, 2009; Abdo *et al*., 2012; Tolera *et al*., 2012, Girma *et al*., 2012; Haile *et al*., 2012; and Gerba *et al*., 2013) The GSTN was 8% higher over the control. The overall mean of GSTN for the applied N treatments was 2.43%. This value is considered as the total nitrogen taken up by the durum wheat plant. Generally speaking with increasing N rate of application there was increasing GSTCP content of the durum wheat plant. The overall mean GSTCP (13.98%) was higher than the control. Nitrogen rate timing showed no significant difference on the soil and yield quality parameters of this study (Table 5.4).This was in agreement with (Teklu and Teklewold, 2009; Abdo *et al*., 2012; Tolera *et al*., 2012, Girma *et al*., 2012; Haile *et al*., 2012; and Gerba *et al*., 2013).

Table 5.4. Effect of N rates on yield parameters of durum wheat under taken greenhouse experiment at SARC during 2011/2012 cropping season

N Rate (kg/ha)	OC (%)	pH (1:2.5 soil to H2O)	pH (1:2.5 soil to KCl)	Soil N (%)	STN (%)	ST CPS (%)	GN (%)	GCP (%)	GSTN (%)	GSTCP (%)
0	1.06a	6.41a	5.00ba	0.19a	0.61a	3.53a	1.80b	10.34b	2.41b	13.87b
23	1.07a	6.41a	4.97ba	0.20a	0.54a	3.13a	1.99a	11.45a	2.54ba	14.58ba
46	1.05a	6.41a	5.02ba	0.20a	0.49a	3.62a	1.59c	9.16c	2.08ba	11.98c
69	1.07a	6.43a	4.99ba	0.20a	0.63a	3.62a	1.98a	11.38a	2.61a	15.00a
92	1.06a	6.42a	5.05a	0.19a	0.51a	2.95a	2.00a	11.52a	2.52ba	14.47ba
Mean	1.06	6.42	5.00	0.20	0.55	3.21	1.87	10.77	2.43	13.98
CV(%)	3.35	1.06	1.54	5.59	27.80	27.80	9.45	9.45	7.95	7.95
LSD(%)	0.04	0.07	0.07	0.01	0.15	0.89	0.18	1.02	0.19	1.11
S0	1.06a	6.40a	4.99ba	0.19a	0.56a	3.21a	1.85a	10.63a	2.41a	13.83a
S1	1.06a	6.43a	4.97a	0.20a	0.57a	3.26a	1.93a	11.12a	2.50a	14.38a
S2	1.06a	6.41a	5.04b	0.19 a	0.55a	3.17a	1.84a	10.56a	2.39a	13.73a
Mean	1.06	6.42	5.00	0.200	0.55	3.21	1.87	10.77	2.43	13.98
CV(%)	3.35	1.06	1.54	5.59	27.80	27.80	9.45	9.45	7.948	7.95
LSD(5%)	0.03	0.05	0.06	0.01	0.12	0.69	0.14	0.79	0.15	0.86

NB: Means with the same letter are not significantly different. OC= organic carbon, Soil N= soil nitrogen; STN= nitrogen of straw, CPST = crude protein of straw; GN= grain nitrogen of durum wheat; GCP = grain crude protein; GSTN = grain straw nitrogen, GSTCP= grain and straw crude protein content, S0= All N rate applied at planting; S1 = N Rate Twice split applied 1/2at planting and ½ at tillering; S2 = N Rate Trice split (1/3 applied at planting, 1/3 at tillering and 1/3 at heading).

This increase in N uptake was needed to sustain the improvement of yield and HI. It is therefore possible to suggest that N accumulation plays a crucial role in both limiting yield and contributing to the determination of grain number in durum wheat. Similarly (Tilahun *et al.*, 1996; Teklu and Teklewold, 2009; Abdo *et al*., 2012; Haile *et al.*, 2012; Girma *et al*., 2012; Gerba *et al.*, 2013) reported that durum wheat exhibited the highest N concentration in grain and straw, resulted in a greater grain and total N uptake. In general, split application of N as N source enhanced grain and total N uptake, under severe water-logging stress.

Generally, with increasing nitrogen levels plant height, number of tillers per plant, spike length, number of seeds per plant, biomass, grain, and straw yields as well as grain crude protein content and TKW were increased with increasing nitrogen rate and application time.

CONCLUSION

Study results indicated that both applications of sole nitrogen rates and its application timing showed highly significant difference ($P<0.01$) on most of the studied durum wheat plant grain yield and yield components parameters. The analysis of soil samples from the experimental sites varied in total N from a mean of 0.19% to 0.20%; rated in low level or in deficient amount, indicating that application of N fertilizers have response on durum wheat plant parameters. The highest grain N content of 2.0% or 11.4% of grain crude protein, which was 11% higher over the control where obtained when treated with 92 kg ha^{-1} N. Moreover; the highest GSTN (2.61) was obtained with the application of 69 kg ha^{-1} N; which was 8% higher over the control. Generally with increasing N rate of application there was increasing grain and straw crude protein content of the durum wheat plant.This results are in agreement with (Tolera *et al*., 2012, Teklu and Teklewold, 2009; Abdo *et al*., 2012; Haile *et al*., 2012; Girma *et al*., 2012; Gerba *et al*., 2013). Similarly, applications of all N rates at planting and t wice split applications timing showed the same significance effect on grain yield (each 5.4 t ha^{-1}) of durum wheat and is 8% higher over trice split N application rates (5.0 t/ha). Twice split N timing of application rate gave the maximum straw yield (6.4 t ha^{-1}). High dose of nitrogen application at 92 kg ha^{-1} resulted in the highest plant height with 15%, number of tillers per plant with 180%, spike length with 45%; number of seeds $spike^{-1}$ with 59%, biomass yield with 113.7%, the grain yield with 152%, thousand kernel weights with 38.4% increase over the control. Similarly; N timing of double split application of 92 kg ha^{-1} at sowing and mid tillering (S_1) resulted in maximum: spike length (4.78 cm) with 9%; biomass yield (12.29 t ha^{-1}) with16% higher over the control treatment. Theses findings are in agreement with the findings of [Similarly]. Therefore;

application of sole 92 kg ha^{-1} of N rate and twice split of 92 kg ha^{-1} N fertilizer application timing were recommended to get the highest grain yield (7.3 t ha^{-1}) of durum wheat plant from this study. Finally; further on farm experiments along with the greenhouse results were recommended as bases of on farm N application rate determination in durum wheat production at larger scale by the end users.

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