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Physiological Response of Durum Wheat (*Triticum turgidum* L. var. Durum) Varieties to Nitrogen Fertilizer Rates at Vertisol in Ethiopia

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Abstract: Afield experiment was carried out in the 2021 main (mehere) cropping season to examine physiological trait response of durum wheat- varieties under different N fertilizer rates. The treatments consisted of five levels of N fertilizer (0, 46, 69, 92 and 115kg ha^{-1}) rates with recommended P_2O_5 (100 kg ha^{-1}) plus absolute control (without NP fertilizer application) and three durum wheat varieties (Utuba, Et cross-21, and Mangudo) arranged in factorial combination using randomized complete block design with three replication. The results revealed that, leaf chlorophyll content, normalized vegetative index at 30 days after sowing and stomatal conductance, were highly significantly (P<0.01) affected by the main effect of nitrogen fertilizer level. The highest chlorophyll content at 30 days after sowing (40.0%), at days after sowing (42.7%), normalized differences vegetative index at 30 days after sowing (64%), stomatal conductance (0.57 gswmol m^{-2}), were recorded at the rate of (115kg ha^{-1}) nitrogen. crop growth rate (CGR), relative growth rate (RGR) and normalized vegetative index (NDVI) at 60 and 90 days after sowing were significantly (P<0.01) affected by the interaction effect of N fertilizer and durum wheat varieties. Regarding varieties, the highest Soil Plant Analysis Development (SPAD) value at 90 DAS was recorded at Et cross -21 variety. From the current result, positive responses were observed between durum wheat physiological traits and N rates. However, it is valuable to carry out further research over locations and over seasons.

Keywords: Crop Growth Rate, Normalized Vegetative Index, Chlorophyll Content, Stomata Conductance

1. Introduction

In Ethiopia both bread and durum wheat is well growing under rain- fed condition. Bread wheat accounts for the outstanding 60% and durum wheat accounts 40% of production [1]. Mean durum wheat yields increased from 3 t ha^{-1} in 2019/20 to 3.46 t ha^{-1} in 2020/21 [2]. Durum wheat is the finest wheat for pasta product due to its strong gluten, excellent amber color and greater cooking quality. In Ethiopian primarily produced for making bread, 'injera', and other indigenous food preparations and for marketing. The straw after harvest is used as animal feed and as cover for roofs, and sometimes for sale. However, the yield obtained on farmers field is usually below from the yield obtained on-station over (5 t ha^{-1}) [3]. Lack of improved varieties and inappropriate fertilizer application, in addition reduction of soil fertility due to high use of nutrient uptake of the crop are among the major drawback to wheat production in Ethiopia. [4]

Many research shows that the physiological development in plant is highly affected by N rate, and N shortage has an influence on different physiological traits of crops like chlorophyll content, photosynthesis rate, biomass and crop yield. Physiological parameters such as, leaf chlorophyll content, normalized vegetative index, Photosynticaly active radiation, stomatal conductance are the most important parameter in extrapolation of yield, that affected by N fertilizer. [4]

In addition growth study it helps to detects interaction between fertilizer treatment and physiological stage of wheat growth. This will be beneficial for wheat crop management from the viewpoint of crop physiological process. Therefore this study was conducted to explore how different nitrogen fertilizer application rate and methods improve the physiological traits, biomass and grain yield of durum wheat.

Thus the present study was carrying out with the following objectives: to examine physiological traits reaction of durum wheat- varieties under different Nitrogen fertilizer rate in the study area.

2. Materials and Methods

2.1. Description of the Experimental Site

The field experiment was conducted at DZARC on station during 2021 main (mehere) cropping season under rain-fed condition. DZARC is located in the East Shewa Zone of Oromiya Regional State of Ethiopia. It is found 47 km away from south east of the capital city of Ethiopia, Addis Ababa. Its geographical location is 8^0 44′ N latitude and 38^0 58′ E longitudes.

The altitude is about 1900 meters above sea level. It is characterized by a moist tropical climate and experiences a mainly long rainy season extending from June to September with an average annual rain fall of 800 mm of which 85% is in the long rainy season (June to September). The dry season extends from October to February. While, the majority of trial fields are heavy soil *(Vertisol).* [5].

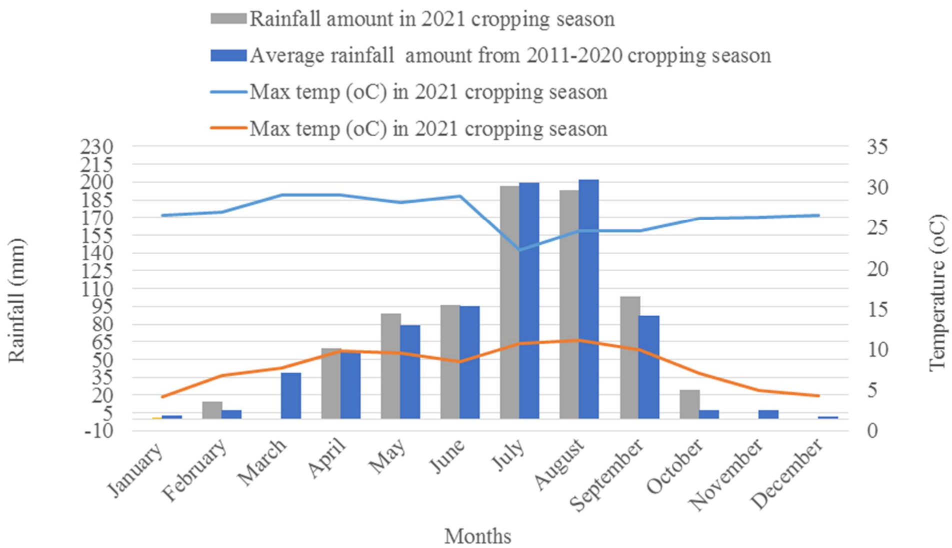

Figure 1. *Mean monthly minimum and maximum temperature and rainfall during the experimental year (2021) and average of 10 years (2011-2020) rainfall at DZARC (Bishoftu).*

During the cropping season (January to December 2021) the area received an annual rain fall of 775 mm considerably lower than the average annual rainfall (787.49mm) of the ten years (2011-2020) (DZARC, 2021). Average maximum and minimum temperature record at the station during the season were 26.5°C and 7.8°C, respectively. The area received a high amount of rain fall from May to September of the cropping season in which the highest amount (196.5 mm) was obtained in July (planting month) followed by August (193.2mm). Overall, the average monthly maximum and minimum temperature and rainfall distribution are suitable for durum wheat production.

2.2. Description of the Experimental Materials

Three recently released durum wheat varieties (*Utuba*, *ET cross -21,* and *Mangudo)* were used for this study. The seed of the varieties was obtained from DZARC of durum wheat breeding research program.

Table 1. *Experiment material used for the study.*

No	Durum Wheat varieties	Year of released	Altitude (m. a. s. l)	Rainfall (mm)	Maturity date	Yield on farmers Field (kg $ha^{-1)}$	Yield on research station (kg ha^{-1})
1	*Mangudo*	2012	1800 - 2650	800-1200	106-116	4500- 5000	5000-6000
2	*Utuba*	2015	1800 -2650	800-1200	105-118	2500 - 4000	3000 -5500
3	*Et cross- 21*	2021	1850-2800	800-1300	115-130	3000- 3500	4500-5000

Source: DZARC (2012, 2015, and 2021).

2.3. Treatments and Experimental Design

The treatments consists of five level of N fertilizer rates (0, 46, 69, 92 and 115 kg Nha^{-1}) with recommended P_2O_5 (100 kg ha^{-1}) plus absolute control (without any fertilizer application) and three durum wheat varieties (Utuba, ET cross-21 and Mangudo). The experiment was evaluated in RCBD with factorial arrangement and replicated three times. Each block was divided into 18 unit plots. Treatments combinations were allocated at random. The total number of unit plots in the experiment were 54 (18x3), each plot has a size of 3.2m x3m (9.6m^2). The distance between the plots and blocks was 0.5 m and 1.0 m respectively. Each plot consisted of 16 rows of 3m in length and was spaced 20cm part. 8 central rows of 3m length were harvested and used for yield determination.

2.4. Experimental Field Management

2.4.1. Experimental Land Preparation

The land was ploughed three times using tractor before planting however; breaking of clods and leveling the land were done manually.

2.4.2. Sowing Seeds

The seed was sown with hand drilling on the 16th of July 2021 at the rate of 150 kg ha^{-1}in 20 cm row spacing.

2.4.3. Fertilizer Application

The unit plots of the N-fertilizer were applied as per experimental specification. Two split applications of nitrogen fertilizer was applied (1/3 at the time of sowing, and 2/3 at tillering by top-dressing) as recommended by Bizuwork *et al.* [6]. For nitrogen fertilizer urea (46%N) and Triple superphosphate (TSP, with 46% P_2O_5) as a source of phosphorous at the rate of 100 kg ha^{-1} were applied at time of planting to all treatments, except the absolute control plot.

2.4.4. Weed and Disease Control

All broadleaf and grass weeds were weeded manually to all treatments uniformly. To avoid damage and variability due to an outbreak of rust and fusarium head light disease which often occur in the area, fungicide (Rex Duo) was applied at the rate of 0.5 L ha^{-1} immediately at the start of disease appearance.

2.5. Data Collection and Measurements

Crop growth rate: It is defined as the rate of dry matter production per unit area, (Warren Wilson, 1981). It was calculated by the formula given by Brown, [7]

$$\text{CGR (gm}^{-2}\ ^\circ\text{C d}^{-1}) = \frac{(W2-W1)}{(T2-T1)}\ x\ \frac{1}{GA} \quad (1)$$

Where W1and W2 is dry weight, T2 and T1 are time intervals and GA is ground area.

Relative growth rate: The relative growth rate is the rate of dry matter accumulation.

Per unit of existing dry matter (Warren Wilson, 1981). It was calculated as described by Gardner *et al.* [8] as follows.

$$\text{RGR (gg-1}^\circ\text{C d}^{-1}) = \frac{\ln(W2)-\ln(W1)}{(T2-T1)} \quad (2)$$

Where W1and W2 is dry weight, T2 and T1 are time intervals and ln is the natural logarithm.

Calculations based on the time are appropriate for an experiment as long as it is recognized that environmental conditions are confounded with treatment [9]. The thermal time was used in the analysis and determined using the following equation. Daily thermal time (tT, °C d) was calculated as

$$tT= ((Tmax+Tmin)/2 - Tb) \times \Delta t \quad (3)$$

Where, T max, is the maximum daily air temperature with an upper limit of 30°C. Tmin is the minimum daily air temperature with a lower limit of 10°C and 10°C is the base temperature for wheat growth and Δt is the time interval (day). Therefore, the thermal time accumulated (GDD) for a given time interval (Δti) was calculated as:

$$GDD= \sum \_(i=1)\ \hat{}t\ ((Tmax +Tmin)/2 - Tb) *\Delta t \quad (4)$$

Leaf chlorophyll content: It was measured at 30 days intervals started at tillering (at tillering, ear emergence, and grain fill period) until physiological maturity using chlorophyll meter (Model SPAD 502 Plus 2900P, 2900 PDL) by taking five readings from middle part of matured leaf at each plot, and then average SPAD chlorophyll content was measured.

Normalized difference vegetation index (NDVI): The NDVI measurement using pocket handheld sensor was taken by Green Seeker optical sensor (Model -Trimble). NDVI readings were taken at 30 days interval (at tillering, ear emergence, and grain fill period) after sowing, the middle 8 rows of the 16 rows per plot in all replication by fleeting the optical sensor twice over each row with up on pulling the trigger, the sensor held at the height of approximately 60 cm overhead the crop canopy so that the sensed width was 1.6 m^2 perpendicular to the row as described by Trimble, [9].

Photosynthetically active radiation (PAR): It was measured at 60 days (ear emergence) after sowing by plant canopy imager (Model CI- 110) by taking readings from the middle 8 rows of the 16 rows per plot in all replication by passing the instrument on the top of the canopy at a height of 50 cm, and then average PAR was calculated. Ridao *et al.,* [10].

Stomatal conductance: It was measured by Infrared Gas Analyzer Portable Photosynthesis System (IRGA) (Model LI-COR- 6800), at 60 days (ear emergence) after sowing by putting the middle part of matured leaf into the chamber and regulating its leaf area, and when the value become persistent, it was recorded. The average of five samples were taken as measured and calculated by as described by Ball *et al.* [11].

$$gs= a\ \frac{An\ hs}{Cs} + Go \quad (5)$$

Were subjected to arcsine transformation describe for percentage data by Gomez and Gomez [12].

2.6. Statistical Analysis

Data on physiological traits were subjected to analysis of variance (ANOVA) using SAS software (version 9). Means of significant treatment effects were separated by Least Significant Difference (LSD) test at 5% level of significance.

3. Results and Discussion

3.1. Soil Physio-Chemical Properties

The result of the pre sowing composite soil sample analyses showed that the soil of the experimental site contained 45.6% clay, 10.8% silt, and 43.6% sand. Thus the textural class of the soil was clay according to Rowell [13] classification. The pH (H_2O) of the soil was 6.61 which were closer to the neutral. According to FAO [14] the preferable pH ranges for most crops and productive soil are from 4.01 to 8. Thus the pH of the experimental soil is within the range for productive soils. The experimental soil was found to have a CEC of 15.28cml (+) kg soil. According to Landon [15] tops oils having CEC 15-25 mol (+)/kg are rated to have medium CEC. Accordingly, the soil of the experimental area has medium CEC, which is an indication of good farming soil. The organic matter content of the experimental field was 1.60% which is low according to the rating of Tekalign [16] who rated soils having organic matter value in the range from 0.86-2.59 as low. Total nitrogen content and available phosphorous status of the experimental area were low according to the rating of Tekalign [16] who described the N content of soil between 0.05-0.12% as low and between 0.12-0.25% as high. According to Jones [17] soil with P availability of 1 to5 ppm, 6 to 10 ppm, 11 to 16 ppm, 16 to 20 ppm, and > 20ppm are classified as very low, low medium, high, and very high, respectively. Therefore, the experimental soil has very high available P content (22.24mg/kg).

3.2. Physiological Parameters

3.2.1. Crop Growth Rate

The ANOVA result showed that CGR was highly significantly ($p<0.01$) influenced by the main effect of N rate and durum wheat varieties at 30 to 60 and 60 to days after sowing. The interaction effect of the two factors was also highly significant ($p< 0.01$) both at 30to 60and 60to 90 days after sowing.

The application rate of 92 kg N ha^{-1}with *Mangudo* variety result in significantly higher CGR (3.4532gm^{-2} ^{o}Cd^{-1}) at 30 to 60 DAS but statistically at par with the rate of 92 and 115kg N ha^{-1}.

On *Et cross -21* variety 69 kg N ha^{-1} with *Mangudo* and *Utuba* variety.

The lowest CGR (1.3157gm^{-2} ^{0} Cd^{-1}) was obtained from control N with *Utuba* variety. At 60 to 90 days after sowing, the highest CGR (7.4710 gm^{-2} °C d^{-1}) was recorded from the combined treatment of 115 kg N ha^{-1}and *Mangudo* variety but statistically at par with 115 kg N ha^{-1} with *Utuba* and *Et cross -21*varieties. While the lowest 60 to 90 days after sowing CGR result was found from the combined treatments of control N with *Utuba* and *Et cross -21* varieties, respectively, and control NP with *Utuba* and *Et cross -21*varieties, respectively (Table 2).

The result indicated that the highest CGR was recorded from the combined treatments of the three durum wheat varieties at the highest N fertilizer rate. Rapid CGR at the highest rate of N fertilizer might be due to the plants absorbed sufficient nutrients which resulted higher photosynthesis and dry matter accumulation ultimately resulting in a high crop growth rate. This result agreed with the finding of Hokmalipour and Darbandi [18] reported significantly highest CGR (52.7gm^{-2}days^{-1}) and lowest CGR (24.8g m^{-2}days^{-1}) from 180 kg N ha^{-1}+ 46 kg P_2O_5 ha^{-1}and control (0 N/P2O5) respectively, in corn (*Zea mays* L.) during 60 to 80 DAS. Nataraja *et al.* [19] also reported application of 100 kg N +75 kg P_2O_5+ 50 kg K_2O ha^{-1} resulted higher crop growth rate (0.227g dm^{-2} days^{-1}) during 60 to 90 DAS of durum wheat.

Table 2. *Interaction effect of N fertilizer and durum wheat varieties on crop growth rate (CGR) of durum wheat at 30-60 and 60 -90 DAS in 2021 cropping season.*

Variety	Nitrogen level (kg ha^{-1})	CGR (gm^{-2}°C days^{-1}) at 30 to 60	CGR (gm^{-2}°C days^{-1}) at 60 to 90
Utuba	Without NP	2.8037^{bcd}	3.3937^{gh}
	Without N	1.3157^{i}	2.6825^{h}
	46	2.7896^{bcd}	2.8151^{h}
	69	3.0905^{ab}	4.5937^{def}
	92	2.9003^{bc}	4.4550^{defg}
	115	2.5792^{cd}	7.2220^{ab}
Et cross -21	Without NP	1.6703^{ghi}	2.9825^{h}
	Without N	1.9235^{fgh}	2.6413^{h}
	46	2.0428^{fg}	6.1183^{bc}
	69	1.9358^{fgh}	6.6309^{ab}
	92	3.1046^{ab}	4.9364^{de}
	115	3.3578^{a}	7.2046^{ab}
Mangudo	Without NP	2.0464^{hi}	3.5148^{fgh}
	Without N	2.0126^{hi}	4.1644^{defg}
	46	2.0569^{f}	4.2107^{efg}
	69	3.1003^{ab}	4.3547^{defg}
	92	3.4532^{a}	5.4032^{cd}
	115	2.1725^{ef}	7.4710^{a}
LSD (5%)		0.37	1.14
CV (%)		9.1	14.2

CGR = Crop growth rate: DAS= days after sowing, CV (%) = Coefficient of variation

3.2.2. Relative Growth Rate

The main effect of N fertilizer rate and durum wheat varieties as well as their interaction effect highly significantly (P<0.01) affected the RGR both at 30 to 60 and 60 to 90 days after sowing.

RGR of durum wheat at 30 to 60 days after sowing significantly influenced by interaction of the two factors. (Table 3). The highest RGR (0.1877 g $g^{-10}Cd^{-1}$) was found at the combined treatment of 92 kg N ha^{-1} with *Mangudo*, but statistically at par with RGR (0.1825 and 0.1688g $g^{-10}Cd^{-1}$) at the rates of 115 and 92 kg N ha^{-1} with *Et cross -21* variety respectively, and 69 kg N ha^{-1} with *Mangudo* and *Utuba* varieties (Table 3).

The lowest RGR (0.0908 g g^{-1} $^{0}Cd^{-1}$) was obtained at the control NP with Et cross -21 variety, which was statistically at par with treatment combination of control N with Utuba and control N with Mangudo variety with the RGR of 0.0913 g g^{-1} °C d^{-1} and 0.1098 g g^{-1}°C d^{-1}, respectively.

At 60 to 90 days after sowing, the highest RGR (0.2911 g g^{-1} °C d^{-1}) was recorded from the treatment combination of 115 kg N ha^{-1} with *Mangudo* but statistically similar with 115 kg N ha^{-1} with *Utuba* and *Et cross-21* varieties with RGR of 0.2763 and 0.2618 g g^{-1} °C d^{-1} respectively, and 69 kg N ha^{-1} with *Et cross -21* variety with RGR of 0.2563 g g^{-1} °C d^{-1}, 92 kg ha^{-1} with *Et cross-21* variety with RGR of 0.25983 g g^{-1o} Cd^{-1} and 115 kg N ha^{-1} with *Et cross-21* variety with RGR of 0.2618 g g^{-1} °C d^{-1}. whereas the lower RGR (0.0067 g g $^{-1}$°C) was recorded from the combined treatments of control N with Utuba variety with statistically similar with control N with *Et cross -21* treatment with RGR of 0.0152 g g -1°C d^{-1}.

The current result indicated that the RGR was more influenced by both N fertilizers and durum wheat varieties which might be due to the high concentration of nutrients in fairly fertilized plots and the varietal utilization efficiency causing the production of more leaves which in turn contributes to the production of high dry matter which resulted in more RGR [19]. This result is in agreement with that of Hokmalipour and Darbandi [18] who reported significantly highest RGR (0.073 g $^{g-1}$ days $^{-1}$) from 120 kg N+ 75 kg P_2O_5 ha^{-1} at 50 days after planting of corn (*Zea mays*).

Table 3. *Interaction effect of N fertilizer and durum wheat varieties on the relative growth rate (RGR) of durum wheat at 30-60 and 60-90 DAS in 2021 cropping season.*

Variety	Nitrogen Level (kg ha^{-1})	RGR (g $g^{-1o}C$ $days^{-1}$) At 30 to 60 DAS	RGR (g g^{-1} °C $days^{-1}$) at 60 to 90 DAS
Utuba	Without NP	0.1524^{bc}	0.0395^{ghi}
	Without N	0.0913^{ef}	0.0067^{i}
	46	0.1516^{bc}	0.0855^{ef}
	69	0.1680^{ab}	0.0238^{hi}
	92	0.1577^{bc}	0.0580^{fgh}
	115	0.1402^{c}	0.2763^{ab}
Et cross -21	Without NP	0.0908^{ef}	0.1039^{e}
	Without N	0.1046^{def}	0.0152^{i}
	46	0.1110^{def}	0.2349^{c}
	69	0.1052^{def}	0.2563^{abc}
	92	0.1688^{ab}	0.25983^{abc}
	115	0.1825^{a}	0.2618^{abc}
Mangudo	Without NP	0.1143^{d}	0.0678^{efg}
	Without N	0.1098^{ef}	0.2504^{bc}
	46	0.1118^{de}	0.1532^{d}
	69	0.1685^{ab}	0.1438^{d}
	92	0.1877^{a}	0.0366^{ghi}
	115	0.1181^{d}	0.2911^{a}
LSD (5%)		0.02	0.03
CV (%)		9.8	16.2

RGR= relative growth rate; DAS= days after sowing

3.2.3. Leaf Chlorophyll Content

The main effect of N fertilizer level highly significantly (P<0.001) influence the leaf chlorophyll content at 30, 60, and 90 days after sowing date. The main effects of varieties on leaf chlorophyll content at 90 days after sowing was also highly significant (P< 0.001). However, in the main effect of varieties at 30 and 60 days after sowing and the interaction of the two factors was not significant.

At 30 days after sowing, the highest leaf chlorophyll content means SPAD value of 40.0%, 39.0%, and 37.8% were obtained in the application of 115, 92 and 69 kg N ha^{-1}, respectively, which was statistically with parity, while the lowest mean leaf chlorophyll content (28.4%) was recorded in control N plot (Table 4). Increasing the rate of nitrogen fertilizer from control N to 69 kg ha^{-1} increased the leaf chlorophyll content by about 24.8%. Increasing the rate of nitrogen further from 69 to 92 and 115 kg N ha^{-1} increased the leaf chlorophyll content by about 3% and 5.5% respectively. Although the change was non- significant (Table 4). This showed that supply of N at the rate of 69 kg ha-1 is found to be adequate for enhancing this parameter at 30 days after sowing.

At 60 days after sowing, the highest leaf chlorophyll content means SPAD value of (45.7%) was obtained in the application of 92 kg N ha^{-1} which was statistically at par with the application of 115 kg N ha^{-1} with means SPAD values of 42.7%. The lowest mean leaf chlorophyll content (35.5%) at 60 days after sowing was recorded in the control N plot which was statistically at par with the control NP plot and the SPAD value of 36%. This result showed that increasing N rate from 69 to 92 kg N ha-1 was found to be important with the increasing of days after sowing from 30 to 60 or more nitrogen fertilizer is needed at 60 days after sowing than 30 days after sowing to further improve the greenness of the wheat leaf. Because at this stage, the crop has better up takes and utilize the soil N fertilizer and synthesized.

Regarding 90 days after sowing, the highest leaf chlorophyll content means SPAD value of 44.3% was obtained in the t application of 115 kg N ha^{-1} which is statistically at par with the application of 92, 69, and 46 kg N ha^{-1} means SPAD values of 41.9%, 41.4%, and 39.4%, respectively, while the lowest means leaf chlorophyll content 32.2% at 90 days after sowing was recorded in control N plot. This result showed that increasing days after sowing from 30 to 60 leaf chlorophyll content increased with increasing N rate but after these stages even though there increasing N rate, leaf chlorophyll content had not increased. The result showed that N was effective on the chlorophyll content.

The possible reasons might be since N is one of the constitute elements of chlorophyll and a major component of all enzymes and hence it plays important role in chlorophyll formation, photosynthesis, chloroplast, development, and respiration of plants and other biochemical and physiological activities [20].

Approving the result of this study, Brian *et al*. [21] and Ali *et al.* [22] reported significant increment in chlorophyll content at flag leaf stage in response to increasing the rate of nitrogen application, in which case they found that the highest numbers 38.31and 35.4 SPAD value in % were recorded for treatment that received 210 and 200 kg N ha^{-1}, respectively comparing from N control treatment. Prasad [23] also reported that significant variation in chlorophyll content in bread wheat was found at all the growth intervals by the application various rate of NPK fertilizer. It has been reported that chlorophyll content had changed throughout the growing season of wheat, and chlorophyll content of plants begins to decline at the start of aging in plant leaves [24]. Regarding to varieties, the highest leaf chlorophyll content means SPAD value of 42.4% was recorded in the durum wheat variety (*Et cross-21*) and the lowest leaf chlorophyll content means SPAD value of 37.8% was recorded in durum wheat variety *Utuba* but statistically at par with *Mangudo* variety, leaf chlorophyll content means SPAD value of 38.5%. It has been reported in a number of studies that there broadly exist a difference of chlorophyll content among different wheat genotypes under similar climatic, soil and farming condition [25].

Table 4. *Effect of N fertilizer level and durum wheat varieties on the chlorophyll content at 30, 60 and 90 days after sowing in 2021 cropping season.*

Treatments	**Chlorophyll content (SPAD value in %)**		
Variety	30 DAS	60 DAS	90DAS
Utuba	33.8	38.5	37.8^{b}
Et cross-21	36.8	40.9	42.4^{a}
Mangudo	35.2	40.3	38.5^{b}
LSD (5%)	NS	NS	3.6
Nitrogen Level (kg ha^{-1})			
Without NP	31.3^{cd}	36.3^{cd}	38.1^{b}
Without N	28.4^{d}	35.5^{d}	32.2^{c}
46	35.2^{bc}	39.5^{bc}	39.4^{ab}
69	37.8^{ab}	39.9^{b}	41.4^{ab}
92	39.0^{ab}	45.7^{a}	41.9^{ab}
115	40.0^{a}	42.7^{ab}	44.3^{a}
LSD (5%)	4.0	3.5	5.2
CV (%)	12.0	9.3	13.7

Means with the same letter in columns are not significantly different at 5% level of significant; LSD= least significance at 5%; CV= Coefficient of variation

3.2.4. Normalized Difference Vegetation Index

The ANOVA result revealed that the main effect of N fertilizer level had highly significant (P<0.001) influenced the NDVI at 30, 60 and 90 days after sowing.

The interaction effect of the two factors was also highly significant (P<0.001) influenced only at 60 and 90 DAS. However, the main effect of varieties at 30, 60, and 90 days after sowing as well as the interaction of the two factors at 30 days after sowing was not significant.

At 60 days after sowing, the highest NDVI reading values of 82% was obtained in the application of 115 kg N ha^{-1} combined with *Et cross-21* variety which was statically at par with115 kg N ha^{-1} combined with *Utuba* variety with NDVI reading value of 81%, while the lowest mean NDVI reading values (50%) were recorded in Utuba variety was grown in control N plot.

At 90 days after sowing, the highest NDVI reading values of 63% were obtained in the application of 115 kg N ha^{-1} combined with Utuba variety statistically at par with 115 kg N ha^{-1}.

Combined with *Et cross-21,* with NDVI reading values of 61%, while the lowest NDVI reading values (40%) was recorded in a treatment control N combined with Utuba variety and statistically at par with treatment of control NP combined with *Utuba* variety. From these results, a clear difference was observed in NDVI values at 30, 60, and 90 days after sowing of durum wheat variety with the application of different N rates.

This difference could be the result of higher nutrient demand as growth continues particularly after 30 days after sowing, in addition to that it might be due to low level of N and low chlorophyll having a higher reflection in the visible electromagnetic spectrum region (400-700nm), and lower reflectance in the near –infrared region, resulting in decreased NDVI values at the low level of N rate. In conformity with this result, Babar *et al*. [26] reported increasing N fertilizer application as the N-level rise NDVI readings from the NDVI sensor become higher and NDVI score showed improved values after 30 days after sowing and the maximum NDVI at 60 days after sowing and then decreased with progression to maturity under similar climatic conditions.

At 30 days after sowing, the highest NDVI reading values of 64% was recorded at the application of 115 kg N ha^{-1}, while the lowest NDVI reading values (41%) was recorded in control N and there was no statistically different with the control NP plot, mean NDVI reading value of 43% (Table 5).

This result is in contiguity to that of Kizilgeci *et al*. [27] who reported that nitrogen fertilization levels significantly influenced the NDVI value of durum wheat, the highest values of NDVI were in 150 kg N ha^{-1}, while 50 kg N ha^{-1} recorded the minimum values of NDVI.

Table 5. *Interaction effects of N fertilizer level and durum wheat varieties on NDVI reading value at 60 and 90 days after sowing in 2021 cropping season.*

Variety	Nitrogen Level (kg ha^{-1})	NDVI reading values in (%) at 60 DAS	NDVI reading values in (%) at 90 DAS
Utuba	Without NP	0.60^{ghi}	0.44^{fg}
	Without N	0.50^{i}	0.40^{fg}
	46	0.70^{cdef}	0.53^{de}
	69	0.74^{abcde}	0.54^{bcde}
	92	0.80^{abc}	0.61^{ab}
	115	0.81^{ab}	0.63^{a}
Et cross -21	Without NP	0.64^{efgh}	0.53^{cde}
	Without N	0.58^{hi}	0.38^{g}
	46	0.70^{bcde}	0.55^{abcd}
	69	0.71^{bcde}	0.55^{abcd}
	92	0.76^{abcd}	0.58^{abcd}
	115	0.82^{a}	0.61^{ab}
Mangudo	Without NP	0.59^{hi}	0.48^{ef}
	Without N	0.59^{hi}	0.48^{ef}
	46	0.70^{defg}	0.47^{ef}
	69	0.78^{abcd}	0.61^{abc}
	92	0.77^{abcd}	0.54^{bcde}
	115	0.78^{abcd}	0.59^{abcd}
LSD (5%)		0.1	0.07
CV (%)		8.9	8.3

3.2.5. Photosynthetically Active Radiation

Photosynthetically active radiation (PAR) of 400 to 700 nm is the most important source of energy for plants. However, a too high or a too low PAR I intensity may become a stress factor, causing photo – inhibition and disturbing the functioning of the photosynthetic apparatus [28].

The analysis of variance revealed that main effect of N fertilizer level and durum wheat varieties, and the interaction of two factors, did not significantly affect the PAR. Even though the result of the photosynthetically active radiation shows a lack of statistical difference between N rates, there was a numerical difference between N rates as indicated in (Table 6).

3.2.6. Stomatal Conductance

The ANOVA result revealed that the main effect of N fertilization level highly significantly (P< 0.001) affects the stomatal conductance (SC) of the plant at 60 days after sowing. However the main effect of varieties at 60 days after sowing and the interaction of the two factors were not significant.

At 60 days after sowing, the highest SC of plant values of 0.57mmol m^{-2}s^{-1} was recorded in the application of 115 kg N ha^{-1} which was statistically similar with 92 kg N ha^{-1} with the value of 0.54mmol m^{-2}s^{-1}, while the lowest mean SC of plant values (0.30 mmolm^{-2}s) was recorded in the control N plot and it was statistically par with control NP and 46 kg N ha^{-1} plots with SC value of 0.34 mmolm^{-2}s^{-1} and 0.3957 mmolm^{-2}s^{-1}, respectively (Table 6).

These might be due to nitrogen fertilizer treatment resulting in improving root growth and higher leaf water content similarly; soil nitrogen addition also caused considerable changes in stomatal parameters, mainly including stomatal pore length and width at the middle of the stoma. In addition stomatal opening status and thickness improve the rate photosynthesis and water use during the crop growing period. These could be the critical determinant of crop yield and productivity.

On the other hand, stressful condition like low nitrogen caused in declined stomatal conductance and a reduced net photosynthetic rate. These results in line with Ainsworth *et al.*

[29]. Reported that a significant difference was found for stomatal conductance (gs) of physiological characteristics with N fertilizer treatments, revealed that it was maximum stomatal conductance (0.80 mmol $m^{-2}s$) at 100kg N ha^{-1}, while the minimum stomatal conductance (0.75mmol m^{-2} s) was observed for the 50 kg N ha $^{-1}$ treatment of wheat.

Table 6. *Effects of N fertilizer level and durum wheat varieties on NDVI value at 30 days after sowing, stomatal conductance, and Photosyntiticaly Active Radiation (PAR) at Bishoftu in 2021 cropping season.*

Treatments	NDVI readings value in (%) at 30 DAS	Stomatal conductance (Mol m^{-2} s^{-1})	Photosynthetically Active radiation (PAR) (µmol m^{-2} m^{-1})
Variety			
Utuba	0.54	0.45	533.5
Et cross-21	0.55	0.43	540.1
Mangudo	0.52	0.42	540.0
LSD (5%)	NS	NS	NS
Nitrogen Level (kg ha^{-1})			
Without NP	0.43^{d}	0.34^{cd}	540.2
Without N	0.41^{d}	0.30^{d}	538.0
46	0.55^{c}	0.39^{cd}	540.3
69	0.59^{b}	0.46^{bc}	544.4
92	0.60^{b}	0.54^{ab}	534.6
115	0.64^{a}	0.57^{a}	529.7
LSD (5%)	0.03	0.1	NS
CV (%)	7.4	27.3	2.8

4. Conclusions

The result of this study indicated that application of different rate of nitrogen fertilizer have helpful effects on physiological traits of durum wheat.

The highest normalized difference of vegetative index at 30 days after sowing i. e. NDVI reading value (64%), stomatal conductance (0.57gswmol-$^{2}s^{-1}$), and leaf chlorophyll content means SPAD values of 40% was recorded at the rate of 115 kg N ha^{-1}. Moreover, the highest normalized difference of vegetative index at 60 DAS with NDVI reading value (82%) and (81%), were obtained at the application 115 kg N ha^{-1} with *Et cross-21* and 115 kg N ha^{-1} with *Utuba* variety respectively. At 90 DAS also the highest normalized difference of vegetative index with NDVI reading value (63%) were obtained at the application of 115 kg N ha^{-1} with *Utuba* variety.

Therefore, physiological traits of crop, N rate and growth stage have a significant strong relationship with crop dry matter and grain yield of durum wheat. In this investigation the optimal N application rate and its timing could benefit the crop to express the optimum physiological traits. This will finally help to enhance physiological traits of crop and grain yield under different N rate condition at these variable fields sites.

However, a convincing recommendation may not be drawn from this research result, because, the present result came from a single-year experiment involving one location. Therefore, it is desirable to further research across soil types, environment, cropping sequence, and locations to appeal comprehensive recommendations at large, for longer duration and variable cropping systems.

Data Availability

The row data are the properties of the author, so the row data cannot be shared.

Conflict of Interest

The authors declare that they have no conflict of interest.

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