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THE INVESTIGATION ON NITROGEN UPTAKE AT DIFFERENT GROWING STAGES OF WINTER AND SUMMER CULTIVATED BARLEY UNDER DRYLAND CENTRAL ANATOLIA CONDITIONS USING N-15 ISOTOPE TECHNIQUE

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ORTA ANADOLU KURU KOŞULLARINDA KIŞLIK VE YAZLIK OLARAK EKİLEN ARPA'DA FARKLI GELİŞME DÖNEMLERİNE AİT AZOT ALIMLARININ N-15 TEKNİĞİ İLE İNCELENMESİ

Abstract:

In order to determine the yield, N-15 uptake and nitrogen use efficiency values at the different growing stages which were H_1: heading, H_2: grain filling and H_3: harvesting stages of winter and summer cultivated barley (*Hordeum vulgare*) under dryland Central Anatolia, a field experiment was carried out. Experiments were conducted using randomized block design as split plot for 4 replications. Winter barley was sown in October and summer barley was in March as 200.0 kg/ha sowing rate and 20.0 cm row spacing. For winter barley 40.0 kgN/ha as 3.02 % N-15 atom excess and for summer barley 40.0 kgN/ha as 2.80 % N-15 atom excess ammonium sulphate fertilizer were applied. Plant samples were harvested at different growth stages and total nitrogen using by Kjeldahl method and % N-15 atom excess using by emission spectrometer analyses were done. Obtained results showed that the winter barley had higher dry matter yields (seed+straw), N-15 uptake and N-use efficiency values than summer barley. The highest amount of N-15 uptake and N-use efficiency were found at the grain filling stage. The average of nitrogen use efficiency values were found 66.0 and 24.1 % for winter and summer barley at harvesting stages, respectively.

Özet:

Orta Anadolu kuru koşullarında kışlık ve yazlık olarak yetiştirilen arpa (*Hordeum vulgare*) bitkisinin farklı büyüme dönemlerinde, H_1: başaklanma, H_2: dane dolum ve H_3: hasat'a ait verim, N-15 alımları ve gübre kullanma randıman değerlerini belirlemek amacıyla bir tarla denemesi kurulmuştur. Deneme tesadüf blokları deneme desenine göre bölünmüş parseller olarak 4 tekrarlı kurulmuştur. Kışlık arpa Ekim'de ve yazlık arpa Mart'ta, ekim oranı 200.0 kg/ha ve sıra arası 20.0 cm olarak ekilmiştir. Kışlık arpa'ya 40.0 kgN/ha hesabıyla 3.02 % N-15 atom excess ve yazlık arpa'ya 40.0 kgN/ha hesabıyla 2.80 % N-15 atom excess'lik amonyum sülfat gübresi uygulanmıştır. Bitki örnekleri farklı gelişme dönemlerinde hasat edildi ve toplam azot analizleri Kjeldahl metodu ile ve % N-15 atom excess analizleri N-15 emisyon spektrometresi ile yapılmıştır. Elde edilen sonuçlarda kışlık arpanın kuru madde verimleri (dane+sap), N-15 alımı ve N kullanma randımanı değerlerinin yazlık arpa'dan yüksek olduğu görülmüştür. En yüksek N-15 alımı ve N kullanma randımanı değerleri dane dolum döneminde

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bulunmuştur. Hasat döneminde ortalama azot kullanma randımanı değerleri kışlık ve yazlık arpa için sırasıyla % 66.0 ve % 24.1 bulunmuştur.

Key words: N-15 isotope technique, nitrogen use efficiency, different growing stages, barley
Anahtar Kelimeler: N-15 izotop tekniği, azot kullanma randımanı, farklı gelişme dönemleri, arpa

1.Introduction

Cereal crops are the major food the worldwide, contributing more than 50 % of total human feeding input directly. In terms of corn, wheat and rice, barley is the fourth number for the total grain production which in the average of 65.0 % is used for animal feed, 33.0 % for industry of beer, whisky, biodiesel and 2.0 % for food industry on the world. Malcolm J. Hawkesford (2014) stated that"crop production needs to continue to grow with increasing demand, and both improved yields and sustainability are major challenges current agriculture. Worldwide production systems vary greatly depending on climatic and soil fertility factors. In all agricultural systems there is a need for adequate nutrients, usually supplied as fertilizer in areas of higher production". Nitrogen plays an important role in the nutrition of barley and also protein content and therefore adoption of good N management strategies often results in large economic benefits to farmers. Barley is the most cultivated cereal after wheat under rainfed Central Anatolia conditions. About 90.0 % of total production is using for animal feed and remain part at malt industry for beer and food industry, and the annual average yield was around 8.0 million tons at 2015 in Turkey. It grows well in places where not too warm and cold. The highest degree of zero and not rise above the 18-20 ºC and the relative humidity around 70-80 % is suitable. Barley is sowing on both winter and summer time at the region. Sowing time for summer planting is in February-March, and winter planting is in September-October periods. Growing duration is about 120-180 days and sowing rate is 180-200 kg per hectare. Good aeration, good water holding capacity and well-fertilized heavy soils are suitable

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to take more products. Barley is the salt tolerans plant. Region soils generally have low soil organic matter and hence low nitrogen supply to plants. Other main factor is the availability of nitrogen fertilizers to plants, due to lack of sufficient moisture in the soil. Low and irregular rainfall can be affected to obtain high yield at the region. New cultivars optimised for traits relating to N-use efficiency rather than yield alone will be required. Measurements of nitrogen use efficiency relate production as a function of inputs, and given constant inputs, any yield increase will be reflected in greater nitrogen use efficiency (Malcolm, 2014). Application of other nutrients such as phosphorus, potassium besides nitrogen fertilizer is increase yield. Barley need to highest amount of potassium for grain yield. Phosphorus is the most beneficial to plants from the first moment. Super phosphate can be used for this purpose. 180-200 kgN/ha, 120-140 kg P_2O_5/ha and 140-180 kg K_2O/ha is suitable for production of barley. Vos et al. (1993) indicated that fertilizer use efficiency was mainly affected by the competition between crop uptake and microbial immobilization. Careful consideration of the time of fertilization, taking into account plant growth and weather conditions, can result in an increase in fertilizer use efficiency and minimal environment pollution.

2. Material and methods

In order to investigate on the yield, N-15 uptake and nitrogen use efficiency values at the different growing stages which were H_1: heading, H_2: grain filling and H_3: harvesting stages of winter and summer cultivated barley (*Hordeum vulgare*) grown on dryland central Anatolia, a field experiment was carried out at the experimental site of the Sarayköy Nuclear Research Center in Ankara. The soil characteristic was silty clay loam, low organic matter content and alkaline soil reaction with low N and P contents (Table 1). Parcel sizes were 4.0 m x 4.2 m = 16.8 m^2 and experiments were conducted using randomized block design as split plot for 4 replications. Winter sowing was done in October and summer was in March. Native barley variety Tokak was used at 200.0 kg/ha sowing rate and 20.0 cm row spacing for both sowing. In order to determine nitrogen uptake, 40.0 kgN/ha ammonium sulphate fertilizer were applied as 3.02 and 2.80 % N-15 atom excess for winter and summer barley, respectively. Fertilizer applications were done after sowing. Phosphorous fertilizer was applied to all plots at 60.0 kgP_2O_5/ha as triplesuperphosphate before sowing. During the vegetation period, total precipitation was 286 mm for winter and 125 mm for summer barley, respectively (Table 2). Harvesting was done by handling at three different growth stages inside of plot as 1.0 m x 4.0 m = 4.0 m^2 size. Fresh samples were weighted, sub-sampled and dried in an oven at 70^{O}C until constant weight. Dried sub-samples were finely grinded to pass a 1 mm sieve. Total N (using by Kjeldahl method) and % N-15 atom excess (using by emmission spectrometer) analyses were done (Faust 1981). Total N uptake (kgN/ha), % Ndff (percent nitrogen derived from fertilizer), fertilizer N uptake (kgN/ha), soil N uptake (kgN/ha), % NUE (percent nitrogen use efficiency) and A_N values were calculated using following formulas (Anonymous, 1990):

$$\text{Total N uptake (kgN/ha)} = \frac{\text{Dry matter yield (kg/ha)} \times \text{\% N}}{100}$$

$$\text{\% Ndff} = \frac{\text{\% N-15 atom excess (plant)}}{} \times 100$$

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% N-15 atom excess (fertilizer)

$$\text{Fertilizer N uptake (kgN/ha)} = \frac{\%\ \text{Ndff} \times \text{Total N uptake (kgN/ha)}}{100}$$

Soil N uptake (kgN/ha) = Total N uptake – Fertilizer N uptake

$$\%\ \text{NUE} = \frac{\%\ \text{Ndff} \times \text{Total N (kgN/ha) uptake}}{\text{Applied N rate (kgN/ha)}} \times 100$$

Availability of soil nitrogen;

$$A_N\ \text{value} = \frac{100 - \%\ \text{Ndff}}{\%\ \text{Ndff}} \times \text{Applied N rate (kgN/ha)}$$

3. Tables

Table 1. Some soil characteristics of the experimental site

Depth (cm)	pH (H_2O)	$CaCO_3$ (%)	Organic Matter (%)	P kgP_2O_5/ha	Total N (%)	Field capacity (%)	Wilting point (%)	Texture
0-30	8.1	12.94	1.07	45.6	0.09	34.32	16.45	SiCL
30-60	7.9	14.82	0.87	37.4	0.07	31.75	15.98	CL
60-90	8.1	15.75	0.67	36.6	0.05	24.58	12.00	CL

Table 2. Total precipitation (mm) of the experimental site

Year	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
First	15.0	16.8	17.2	84.7	40.9	21.9	22.7	7.3	31.9	45.6	16.5	48.4
Second	12.6	38.4	10.4	48.6	38.1	27.8	5.5	8.0	15.6	56.2	15.7	86.0

Table 3. H_1: The average of heading stage results

Cultivars of barley	DM.yield (kg/ha)	Total N Uptake (kgN/ha)	Ndff (%)	Fert. N Uptake (kgN/ha)	Ndfs (%)	Soil N Uptake (kgN/ha)	NUE (%)
Winter	-	-	-	-		-	-

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Summer	4305±225	67.5±3.7	11.7±0.2	7.9±0.5	88.3±0.2	59.6±3.2	19.7±1.2

Table 4. H_2: The average of grain filling stage results

Cultivars of barley	DM.yield (kg/ha)	Total N Uptake (kgN/ha)	Ndff (%)	Fert. N Uptake (kgN/ha)	Ndfs (%)	Soil N Uptake (kgN/ha)	NUE (%)
Winter	10222±557	107.7±5.4	26.2±0.9	28.0±0.6	73.9±0.9	79.7±4.9	70.1±1.6
Sum.	5145±265	80.0±5.9	12.1±0.4	9.6±0.5	87.9±0.4	70.4±5.5	24.1±1.2

Table 5. H_3: The average of harvesting stage results

Cultivars of barley	DM.yield (kg/ha)	Total N Uptake (kgN/ha)	Ndff (%)	Fert. N Uptake (kgN/ha)	Ndfs (%)	Soil N Uptake (kgN/ha)	NUE (%)
Winter	10707±563	115.3±5.6	23.1±0.7	26.6±1.2	76.9±0.7	88.8±4.7	66.4±2.9
Sum.	5309±136	84.2±2.7	10.9±0.6	9.2±0.6	89.1±0.7	75.1±2.5	23.0±1.5

4. Results and Discussion

The averages of total dry matter yield were found at heading stage (H_1), grain filling stage (H_2) and harvesting stage (H_3) as 4305, 5145 and 5309 kg/ha for summer barley, and 0 (not sampled), 10222 and 10707 kg/ha for winter barley, respectively (Fig. 1). Total dry matter yield (kg/ha) values had significantly affected ($p < 0.05$) according to grain filling stage (H_2) and harvesting stage (H_3) for summer and winter barley.

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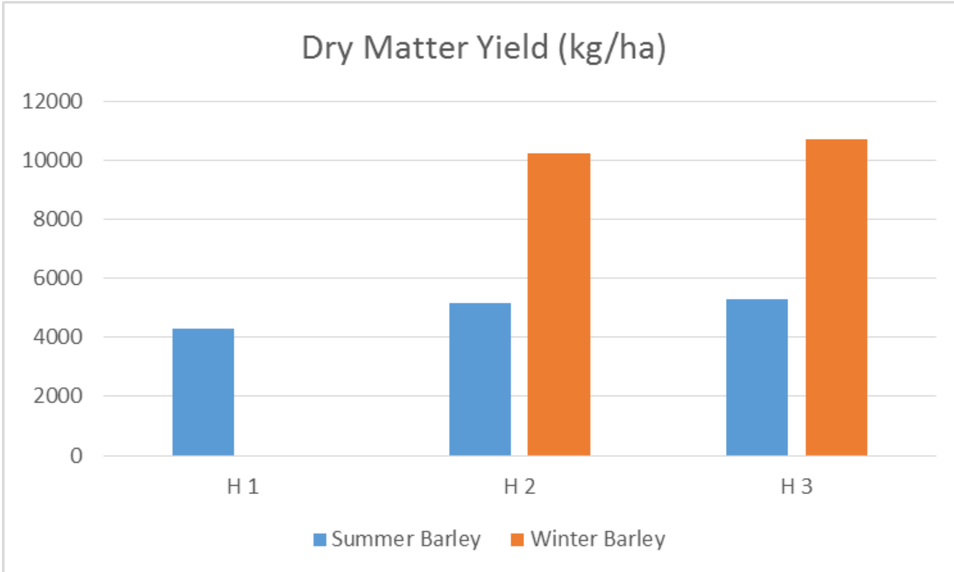

Figure 1. Total dry matter yield (kg/ha)

The averages of total N uptake were found at heading stage (H_1), grain filling stage (H_2) and harvesting stage (H_3) as 67.5, 80.0 and 84.2 kgN/ha for summer barley, and 0 (not sampled), 107.7 and 115.3 kgN/ha for winter barley, respectively (Fig. 2). Total N uptake (kgN/ha) values had significantly affected ($p < 0.05$) according to grain filling stage (H_2) and harvesting stage (H_3) for summer and winter barley.

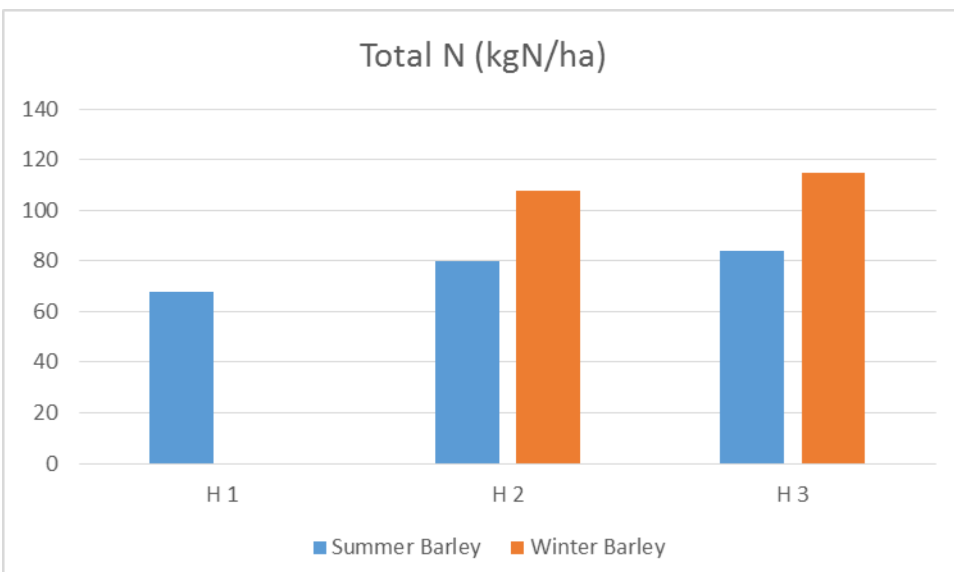

Figure 2. Total N uptake (kgN/ha)

The averages of % Ndff (percent nitrogen derived from fertilizer) were found at heading stage (H_1), grain filling stage (H_2) and harvesting stage (H_3) as 11.7, 12.1 and 10.9 % for summer barley, and 0 (not sampled), 26.2 and 23.1 % for winter barley, respectively (Fig. 3). %

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Ndff values had significantly affected ($p < 0.05$) according to grain filling stage (H_2) and harvesting stage (H_3) for summer and winter barley.

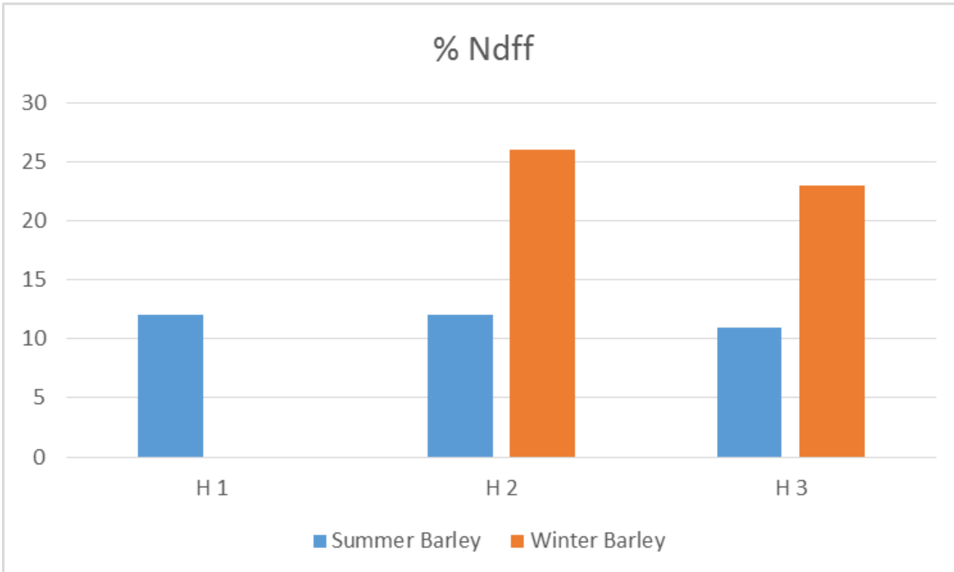

Figure 3. % Ndff (percent nitrogen derived from fertilizer)

The averages of fertilizer N uptake were found at heading stage (H_1), grain filling stage (H_2) and harvesting stage (H_3) as 7.9, 9.6 and 9.2 kgN/ha for summer barley, and 0 (not sampled), 28.0 and 26.6 kgN/ha for winter barley, respectively (Fig. 4). Fertilizer N uptake (kgN/ha) values had significantly affected ($p < 0.05$) according to grain filling stage (H_2) and harvesting stage (H_3) for summer and winter barley.

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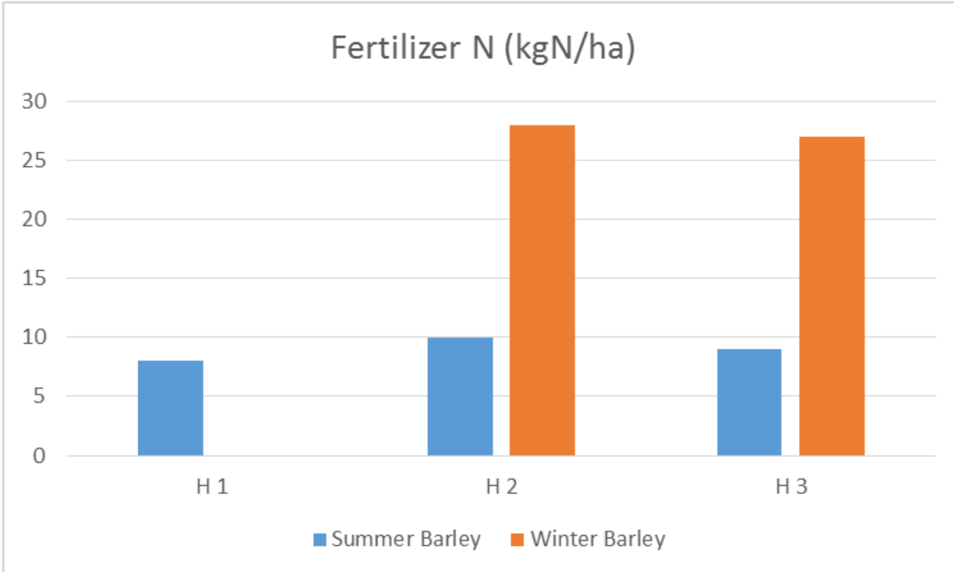

Figure 4. Fertilizer N uptake (kgN/ha)

The averages of % Ndfs (percent nitrogen derived from soil) were found at heading stage (H_1), grain filling stage (H_2) and harvesting stage (H_3) as 88.3, 87.9 and 89.1 % for summer barley, and 0 (not sampled), 73.9 and 76.9 % for winter barley, respectively (Fig. 5). % Ndfs values had significantly affected ($p < 0.05$) according to grain filling stage (H_2) and harvesting stage (H_3) for summer and winter barley.

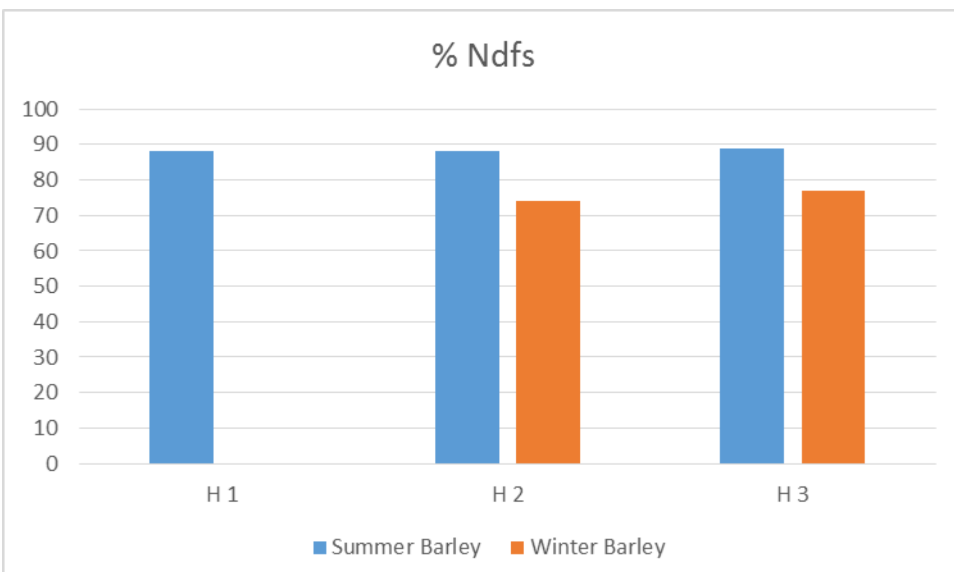

Figure 5. % Ndfs (percent nitrogen derived from soil)

The averages of soil N uptake were found at heading stage (H_1), grain filling stage (H_2) and harvesting stage (H_3) as 59.6, 70.4 and 75.1 kgN/ha for summer barley, and 0 (not sampled), 79.7 and 88.8 kgN/ha for winter barley, respectively (Fig. 6). Soil N uptake (kgN/ha) values had

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significantly affected ($p < 0.05$) according to grain filling stage (H_2) and harvesting stage (H_3) for summer and winter barley.

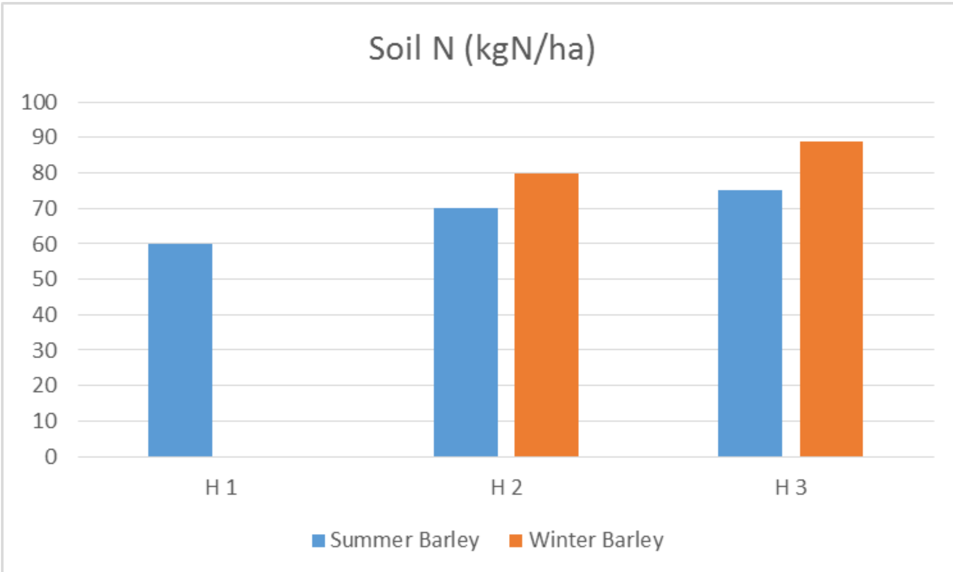

Figure 6. Soil N uptake (kgN/ha)

The averages of % NUE (percent nitrogen use efficiency) were found at heading stage (H_1), grain filling stage (H_2) and harvesting stage (H_3) as 67.5, 80.0 and 84.2 kgN/ha for summer barley, and 0 (not sampled), 107.7 and 115.3 kgN/ha for winter barley, respectively (Fig. 7). % NUE values had significantly affected ($p < 0.05$) according to grain filling stage (H_2) and harvesting stage (H_3) for summer and winter barley.

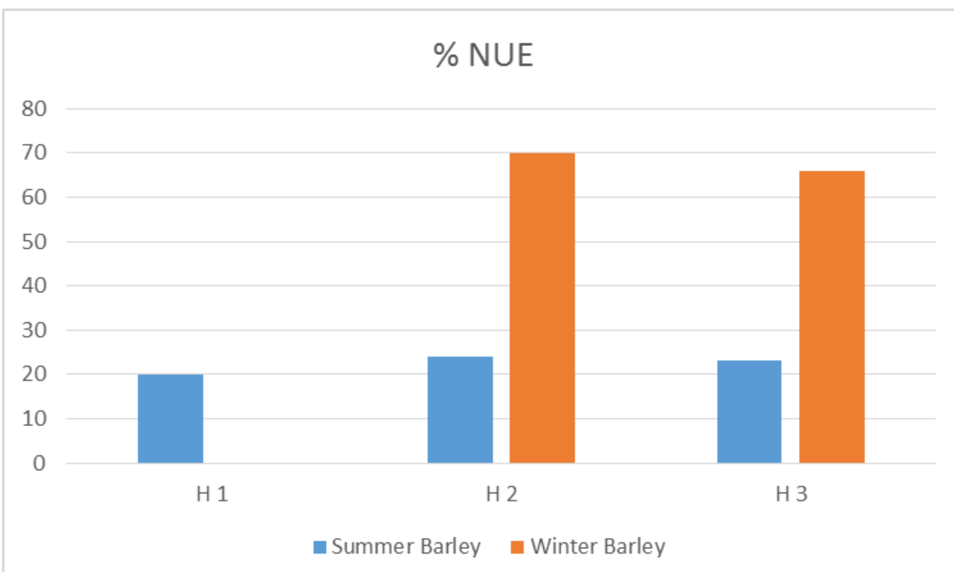

Figure 7. % NUE (percent nitrogen use efficiency)

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The averages of A_N value were found at heading stage (H_1), grain filling stage (H_2) and harvesting stage (H_3) as 303, 292 and 331 kgN/ha for summer barley, and 0 (not sampled), 114 and 134 kgN/ha for winter barley, respectively (Fig. 8). A_N (kgN/ha) values had significantly effected ($p < 0.05$) according to grain filling stage (H_2) and harvesting stage (H_3) for summer and winter barley.

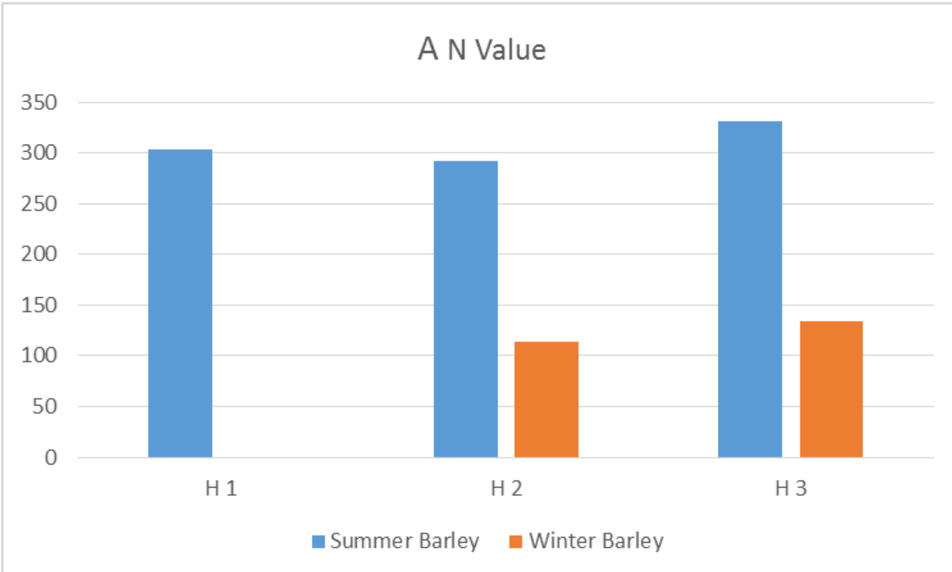

Figure 8. A_N (kgN/ha) value

5. Conclusion

Total dry matter yield (kg/ha) and total nitrogen uptake (kgN/ha) values of winter barley were higher at different growing stages comparing to summer barley. Mainly, total rainfall at the vegetation period was effected these results which were 292 mm and 130 mm for winter and summer barley, respectively. Yield responds will positively vary based on soil water content, soil properties and rainfall distribution within the season (Nielsen et al. 2002; Sadras, 2002; Anderson, 2010). In rainfed winter wheat areas, farmers generally apply uniform rates of N, with approximately 30% at sowing and 70% at the time of early stem elongation without taking into consideration the spatial variability of soil or rainfall distribution (Saseendran, Nielsen, Ma, Ahuja and Halvorson, 2004). This can lead to over or under fertilization, decreasing the efficiency of the fertilizer use (Mulla, Bhatti, Hammond, and Benson, 1992). Basso, Cammarano, Fiorentino and Ritchie (2013) indicated that "farmers obtain high yield when proper crop management is matched with favourable weather. Nitrogen (N) fertilization is an important agronomic management practice because it affects profitability and the environment. In rainfed environments, farmers generally apply uniform rates of N without taking into account the spatial variability of soil available water or nutrient availability. Uniform application of fertilizer can lead to over or under-fertilization, decreasing the efficiency of the fertilizer use. Nitrogen derived from fertilizer (%) and fertilizer N uptake (kgN/ha) values were higher at grain filling stage (H_2) comparing to other growing stages, besides nitrogen derived from soil (%) and soil N uptake (kgN/ha) values were higher at harvesting stage (H_3) for both winter and summer barley. Halitligil et al. (2000) found that

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same results as % Ndff values for two wheat varieties increased from tillering up to grain filling, but decreased between grain filling and harvest. Nitrogen use efficiency (%) values were higher at harvesting stage (H_3) for winter and summer barley. % NUE values were higher at all growing stages for winter barley than summer barley, due to received more rainfall at the growing period. Availability of soil nitrogen (A_N) values (kgN/ha) were higher at harvesting stage (H_3) for winter and summer barley. These values were higher at all growing stages for summer barley than winter barley. In comparison to winter growing period that low rainfall was received at the growing period of summer barley. Therefore, the availability of fertilizer nitrogen decreased, but the uptake of soil nitrogen at the deeper zone increased. Olson (1984) found same results for wheat plant takes much less N from the applied fertilizer at later stages due to a more established root system in the deeeper part of the soil profile and the dry top layer. Therefore, wheat is more dependent on soil N than on fertilizer N in the later part of the growing season. Another reason for this may be the restricted movement of applied N in the soil profile under rainfed conditions. They were also reported that N did not move beyond 50 cm of soil depth at later growth stages due to limited precipitation. Uniform application of fertilizer can lead to over or under-fertilization, decreasing the efficiency of the fertilizer use. Proper N management is important for rainfed agriculture (annual rainfall between 200 and 600 mm). In rainfed environments, if N is available, crops can use much of the available soil water prior to anthesis, leaving the soil dry during the grain filling with resulting low yield and poor grain quality without adequate rainfall during the grain filling period. Basso, Ritchie, Cammarano and Sartori (2011) indicated that increasing the efficiency of N fertilization, maximizing crop N uptake, and minimizing N losses by taking into account the spatial and temporal N need of the crop. Thorup-Kristensen, Cortasa and Loges (2009) stated that the longer growing period for winter wheat allows for deeper roots to be formed, important to prevent winter leaching losses of N for increasing nitrogen use efficiency and has reducing N losses to the environment, also the availability of N has impacts throughout crop development, affecting seedling establishment, tillering, canopy development as well as grain filling, all of which have the potential to influence final yield and together determine the N requirements of the crop. The optimization of crop production and NUE is a complex problem and will require a complex set of solutions to achieve improvement. Kostadinova, Ganusheva and Marcheva (2016) found that the obtained mean values of nitrogen utilization efficiency were 81.6 kg biomass and 34.0 kg grain per kg N, respectively barley growers in western. Anbessa and Juskiw (2012) stated that performed barley at Canada had over the years improved NUE by adopting soil testing and adjusting rate of N fertilization accordingly, switching from fall application to spring application of N fertilizers, and adopting sidedressing placement of N that gives plant roots easier access to N nutrition. Agegnehu, Nelson and Bird (2016) had an experiment result that the application of N fertilizer resulted in significant responses of N uptake at both sites. At Holetta there were significant ($p < 0.01$) linear responses for grain and straw N concentration, grain and straw N uptake, and linear and quadratic ($p < 0.001$) responses for grain and straw $\delta^{15}N$ and grain protein content. Bingham (2011) observed that the contributions of grain and total biomass to the variations in NUE of barley were reported to be 60 % and 40 % respectively.

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