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Effects of Foliage Removal and Using Different Nitrogen Rates on Remobilization of Pre-anthesis Assimilates to the Grain in a Dual-purpose (Forage and Grain) Barley

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ABSTRACT
In order to study the source limitation and contribution of pre-anthesis assimilates to grain in dual-purpose (forage and grain) barley, a field experiment was carried out in Iran, Ahvaz region. The experimental design was split plot in randomized complete block with three replications. Application rates of nitrogen at four levels (60, 120, 180 and 220 $kg.ha^{-1}$ N) were as main plots, while sub plots were three harvesting levels (no cutting crop, cutting at five and 10 cm above ground level). Spikelet removal from one side of spike was done to determine source limitation. Results indicated that foliage removal (FR) from five and 10 cm above ground level reduced grain yield 32% and 15.8%, respectively. Highest grain yield (530 $g.m^{-2}$) was obtained by using 120 $kg.ha^{-1}$ N treatment. Source limitation was increased with harvesting 28% and 23% in cutting crop from 5 and 10 cm level, respectively. Grain yield was generally reduced with increasing source limitation in dual-purpose barley crop. In cutting treatments, minimum source limitation was obtained with 120 $kg.ha^{-1}$ N. The contribution of dry matter translocation pre-anthesis assimilates to grains was reduced by foliage removal treatments, due to reduction in vegetative growth at anthesis stage. Contribution of dry matter remobilization and current photosynthesis to grain yield were increased (11%) and reduced (8.7%) respectively by foliage cutting at 5 cm above ground level.

Keywords: *Dual-purpose, Fertilizer, Hordeum vulgare, Remobilization.*

INTRODUCTION
Barley (*Hordeum vulgare* L.) is grown mostly for grain production. Its potential as a dual-purpose crop (early season forage production followed by grain production) has been highlighted in recent studies (Rahimizadeh *et al*., 2010). Barley has produced similar foliage yields as wheat (Anbassa and Juskiw, 2012), triticale and oat (Gouarda *et al*., 2004, Egle *et al*., 2008).

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Additional studies have focused on the yield and forage productions, but investigation about physiological approach like source limitation and dry matter translocation to the grains in foliage removal or grazed barley are limited. Grain growth is supported by current photosynthesis and translocation of pre-anthesis stored reserves (Bahrani *et al*., 2011, Modhej, 2006). It has been reported that dry matter accumulation by cereals planted in winter to anthesis is of particular importance in south-west Iran, since grain filling generally takes place under hot conditions that limit photosynthesis and increase source limitation (Modhej and Bedarvandi, 2006b). Remobilization and source limitation in barley cultivars are effected by nitrogen fertilization and foliage removal (or grazing) due to influence on leaf area duration and assimilate rates (Beatty *et al*., 2010). Our objectives of this study were to study effects of foliage removal levels and different levels of nitrogen fertilization on remobilization of pre-anthesis assimilates to the grain and source limitation in spring barley planted in winter sowing date.

MATERIALS AND METHODS

Field and Treatment Information's

A field experiment was conducted in 2011 in Ahvaz, southwest of Iran. The area located at 20 m above sea level and $32^{\circ}20^{'}$ N, $40^{\circ}20^{'}$ E. The soil was clay loam in texture, alkaline in reaction, pH 8.0 and with less than 1 percent organic carbon, moderate phosphorus (7.2 ppm) and high potassium (220 ppm) level. The experiment site had a hot climate with a moderate winter, dry and hot summer. The experiment was a split plot based randomized complete blocks, with three replications. Nitrogen rates (60, 120, 180 and 220 kg.ha^{-1} N) were considered as main plots and three levels of foliage removal height (foliage removal from five and 10 cm above ground level and no foliage removal) were in sub plots. Jonoob cultivar was used in this experiment which is a six-rowed spring barley released at CYMMIT in 1997 and is most productive and most widely cultivated variety in western parts of Iran. It is also a good dual-purpose type for green stage grazing plus grain harvesting.

Field Management

Based on research recommendations, seeds were planted in rows 18 cm apart at about 300 seeds per m^2 on December 2nd. A nitrogen fertilizer was applied as ammonium nitrate. At all nitrogen application rates, half was applied before seed sowing (incorporated by disk) and the remaining nitrogen was applied as a top dressing at the beginning of barley tillering corresponding to stage 21 of Zadoks scale.

Traits measure

Forages were removed at jointing stage at which the second node appears in 50% of the tillers. Total dry matter, relative grain yield and yield components were estimated after physiological maturity by harvesting two middle rows, excluding at least 0.5 m from either end of these rows. Grain yield and yield components were estimated after physiological maturity by harvesting interior rows but the outer rows excluding at least 0.5 m from either end of the rows. Harvested area was 1.2 m^2. Grain weight was estimated on a sample of 200 grain for calculating individual grain weight. One week after anthesis, 50% of spikelets were removed from all spikes from two randomly selected 0.5m sections of second and fifth sowing rows in each plot. Source limitation rate calculated by following equation (Ma *et al*., 1990; Ma *et al*., 1996):

Equ. 1. SL= [(a/b)-1] ×100

Where SL is source limitation, a, is grain weight in spikelet removal from spikes and b is grain weight in non-manipulated spikes. Source limitation was increased in foliage removal treatment compared to control (uncut plants). It was calculated using following equation (Modhej, 2006; Naderi, 2000):

Equ. 2. S'L'= (a'/b'–1).100

Where S'L' is source limitation aggravation in foliage removal compared to source potential in control, a' is grain weight in 50% spikelet removal spike in control and b' is grain weight in non-manipulated spikes in foliage removal treatments. One week after anthesis plant samples were taken from 50 cm – long rows in each plot. The number of plants in each sample was recorded and five representative plants per plot were selected at anthesis and physiological maturity. The samples were oven dried at 70$^{°C}$ for 72 h and weighted. Average grain weight per plant was determined by threshing five individual plants per plot at ripening. Chaff at physiological maturity was determined as the differences between total dry matter TDM of the spikes per plant and grain weight per plant at ripening. Remobilization of pre-anthesis assimilates was assessed according to three alternatives. Rates of TDM translocation to grain yield (RDMT), contribution of remobilization (CR %) and current photosynthesis (CCP %) to grain yield were calculated as below (Royo *et al.*, 1999):

Equ. 3. RDMT= $TDM_{anthesis}$- [$TDM_{maturity}$ – grain yield]

Equ. 4. CR (%)= (RDMT/grain yield).100

Equ. 5. CCP (%) =100-CR

Statistical analysis

Statistical analysis was performed using SAS software (Ver. 8). The treatment means were compared using Duncan multiple range test at 5% probability level.

RESULTS AND DISCUSSION

The results indicated that both harvesting level and nitrogen fertilization treatments showed highly significant effects on grain yield (P<0.01). Also grain yield and 1000-grain weight were significantly affected by nitrogen and harvesting treatments interaction (Table 1). Foliage removal (FR) from five and 10 cm above ground level reduced grain yield 32 percent and 15.8 percent, respectively (Fig. 1). The highest grain yield was obtained by using 120 kg.ha^{-1} N. Increasing N more than 120 kg.ha^{-1} N up to 220 kg. ha^{-1} N decreased grain yield due to lodging (Fig. 1). Similar results reported by Sedlar *et al.* (2011). FR at 10 and 5 cm reduced 1000-grain weight 13.8 percent and 17.8 percent than un cutted plants, respectively. An effect of nitrogen treatments on 1000-grain weight was not significant. The highest source limitation was in 10 cm FR treatment (Table 2). 1000-grain weight was correlated negatively (r=-0.40**) with source limitation. Also, grain yield showed positively and significant correlation with 1000-grain weight (r=0.63**). Therefore, grain yield reduction in foliage removal might be related to 1000-grain weight reduction due to source limitation enhancement (Modhej and Behdarvandi, 2006a). Although, source limitation was decreased with N utilized up to 180 kg.ha^{-1} N. Applying 220 kg.ha^{-1} N increased source limitation due to lodging and shading effects. Results also indicated that, 1000-grain weight reduction with FR treatments was associated with source limitation aggravation (S′L′) (Table 2). The lowest amount of source limitation aggravation was in harvesting foliage at 10 cm and applying 120 kg N ha^{-1}.

DM translocation, CR and CCP were significantly depended on harvesting level, N and N×H interaction (P<0.01) (Table 1). Translocation pre-anthesis reserved materials to the grain yield (g.spike^{-1}) was reduced 15.4% by both *FR* treatments (Fig. 2). The decreased of RDMT in FR treatments were due to reduction in accumulated DM at anthesis (Rayn *et al.*, 1991, Beatty *et al.*, 2010).

Table 1. Analysis of variance for dry matter parameters, grain yield and 1000-grain weight**.**

S.O.V	df	Means of square					
		Grain yield	1000- grain weight	Source limitation	RDMT	CCP	CR
Block (B)	2	1862	1.69	48	0.001	0.95	0.95
Nitrogen (N)	3	1802**	8.20^{ns}	714**	0.018**	268.00**	268.52**
Error $_N$	6	1628	1.47	113	0.002	0.06	0.06
Harvesting level (H)	2	62027**	103.00**	88**	0.014**	307.00**	307.33**
H´N	6	2726**	5.60**	13**	0.025**	376.00**	376.65**
Error	16	1093	4.50	45	0.001	0.89	0.89

$^{**, ns}$ Significant at the 0.01 probability level and non-significant, respectively. CR, CCP and RDMT, Rates of DM translocation to the grain yield, contribution of remobilization and current photosynthesis in grain yield, respectively.

Table 2. Source limitation aggravation and 1000-Grain weight reduction in foliage removal treatments compared to control (uncut barley).

Nitrogen treatments (N Kg.ha^{-1})	1000-Grain weight reduction (%)			Source limitation aggravation (%)		
	Mean	5 cm FR	10 cm FR	Mean	5 cm FR	10 cm FR
60	10.0	10.0	10.0	17.2	17.2	17.2
120	8.4	10.3	6.6	15.2	17.2	13.3
180	14.0	14.3	14.0	19.1	21.0	17.2
220	31.0	36.0	26.0	50.0	56.0	44.0
Mean	16.0	17.0	14.0	25.0	28.0	23.0

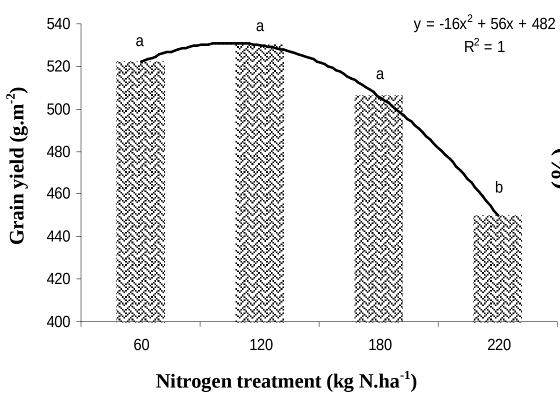

Fig. 1. Grain yield for different rates of nitrogen fertilization

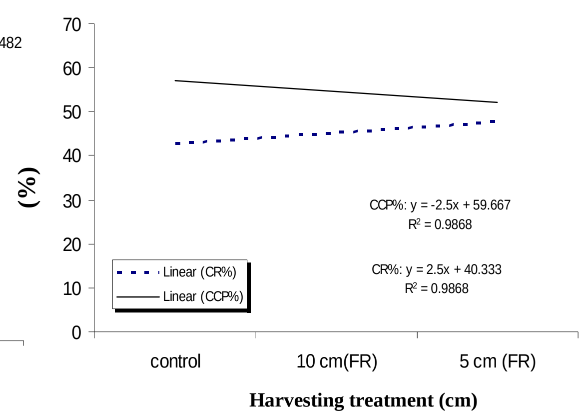

Fig. 2. Contribution of the remobilization (CR %) and current photosynthesis (CCP %) to grain yield for deferent foliage removal treatments

CONCLUSION

Although, contribution of current photosynthesis in grain yield was reduced 5.7 percent and 3.6 percent in foliage harvesting at 5 and 10 cm, respectively (Fig. 2). In fact, the later anthesis dates in foliage removal treatments indicated that plants in these treatments filled their grains under hotter conditions (Modhej, 2006, Albrizio *et al*., 2010). It seems that leaf photosynthesis was decreased more after anthesis, while source limitation increased and grain growth depended increasingly on contribution of vegetative reserved materials (Satore and Slafer, 2000, Modhej and Behdarvandi, 2003b).

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