Effect of Defoliation Treatments and Nitrogen Rates on Yield, Yield Components and Seed Germination of Wheat (*Triticum aestivum*)

Hassan Heidari[1] ✉, Iraj Nosratti[1]

ABSTRACT

To determine the effect of leaf position and nitrogen rate on the yield and germination of produced seeds of wheat (*Triticum aestivum*), an experiment was conducted during 2011-2012. Four defoliation treatments (D1=0, D2= flag leaf, D3=all leaves except flag leaf, and D4= all leaves) and two nitrogen rates (N1=0 and N2=150 kg N ha^{-1}) were imposed on wheat plants. Seed germination was measured for the seeds produced from plants exposed to the defoliation and nitrogen rate treatments. Flag leaf removal significantly reduced seed yield compared with un-defoliated plants with the application of nitrogen treatment (D1N2), but removal of all leaves except flag leaf had no significant seed yield reduction compared with D1N2. Application of nitrogen fertilizer with complete defoliation of plant increased the weight of seedlings produced from those plants. It is recommended to clean the seeds produced from plants exposed to complete defoliation due to lower seed germination and vigor.

Keywords: Defoliation, flag leaf, leaf position, maternal plant effect, nitrogen, seed germination.

INTRODUCTION

Herbivores, hailstorms, diseases, herbicides and farm machinery are some causes for defoliation. Umashankara (2007) reported that defoliation at ten days after 50% of silking stage had minor effect on seed yield in maize (*Zea mays*) and the crop can be used as a green fodder. Erbas and Baydar (2007) observed negative correlation between seed yield and defoliation intensity in sunflower (*Helianthus annus*). Using nitrogen fertilizer or decreasing the defoliation interval can increase the nitrogen content of ryegrass (Zhang *et al.*, 1995). Nitrogen fertilizer increased dry matter yield and decreased plant morality at two cutting heights in *Phalaris tuberosa* (Grimmett, 1967). Application of nitrogen to maternal plants reduced germination rate of the produced seeds in *Sinapis arvensis* (Luzuriaga *et al.*, 2006). In *Vicia sativa*, seeds produced by plants exposed to different defoliation treatments had similar germination percentage and germination time (Koptur *et al.*, 1996). Ahmadi and Judi (2007) did not observe significant effect of flag leaf removal and removal of all leaves on seed yield compared to control. Brimavandi *et al* (2010) declared that maize plants (*Zea mays*) with defoliated leaves below ear had higher seed yield than those plants with defoliated leaves above the ear. A flag leaf is the last leaf in the upper part of wheat plant. Flag

[1]Department of Agronomy and Plant Breeding, Faculty of Agriculture, Razi University, Kermannshah, Iran.
✉ heidari1383@gmail.com
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leaf can contribute more to seed yield than other leaves, which might be due to the delay in the senescence of the flag leaf. So losses of the flag leaf may reduce seed yield. Wheat is a common cereal crop in west of Iran. Hail usually damages wheat farms in some years. To determine the cost of damage, insurance agent should know the percentage of seed yield losses by hail. Little information is available about effect of defoliated material plant nourished with nitrogen on the germination of the produced seeds. Application of nitrogen fertilizer as the most important nutrient in rapid growth of plant may reduce nitrogen-deficit stress and improve seed vigor. So, the goal of the experiment was to determine wheat seed yield, yield components and the germination of the produced seeds for plants exposed to defoliation treatments based on leaf position and nitrogen.

MATERIALS AND METHODS

A field experiment was conducted as a randomized complete block design (RCBD) with three replications at Chamchamal plain, Kermanshah, Iran during 2011-2012 (Latitude 34° N, longitude 47° E, and altitude 1300 m above sea level). Average annual rainfall of the region is 442 mm (IMO, 2012). Wheat plants were exposed to a combination of defoliation treatments and two nitrogen fertilizer rates. 1) Control, no leaf removal (D1); 2) Removal of flag leaf (D2); 3) Removal of all leaves except flag leaf (D3); 4) Removal of all leaves (D4); 5) Nitrogen rate of 0 kg ha^{-1} (N1); 6) Nitrogen rate of 150 kg ha^{-1} (N2).

Wheat seeds (*Triticum aestivum*, CV Pishtaz) were sown on 24 October, 2011 at a seeding rate of 250 kg ha^{-1}. A 250 kg ha^{-1} of complete fertilizer (NPK) was applied as presowing. Urea fertilizer (N%=46, $CO(NH_2)_2$) was used as a nitrogen source for fertilizer treatments, applied as top dressing at anthesis stage. The nitrogen fertilizer was applied simultaneously with defoliation. Wild oats (*Avena fatua*), charlock (*Sinapis arvensis*) cheese rennet (*Galium verum*) and common reed (*Phragmites australis*) were common weed plants in wheat field. Weeds were controlled by 2, 4-D herbicide ((2, 4-dichlorophenoxy acetic acid in ammonium (amine) salt)).

Plot size was 1×1 m^2. The distance between plots and between replications was 1 m. Plants were well-watered during the growing season. Defoliation and nitrogen treatments were applied at anthesis stage (203 days after sowing).

Plants were harvested after yellowing (249 days after sowing) when grain moisture content was less than 13%. At harvest time, five plants per plot were cut for measuring yield components. Total dry matter (biological yield), seed yield, spike weight, seed number per spike, seed weight and leaf and stem weight were measured for the five plants. Spike and peduncle length were measured for three plants per plot. Harvest index was calculated as the ratio of seed weight to the biological yield.

The effect of the defoliation and nitrogen rate of the maternal plants on the germination and vigor of the produced seeds was measured in the lab. The research was carried out as a completely randomized design with three replications at Department of Agronomy and Plant Breeding, Faculty of Agriculture, Razi University in 2012. Seed germination was measured one week after seed harvesting. D3N1 data was missed so it excluded from measurement of germination.

Seeds were surface sterilized by treating them with sodium hypochlorite solution (1% active chlorine) for 10 min. Then twenty seeds were germinated on one filter paper in a Petri dish supplied with 10 ml of distilled water. Seeds were kept in the germinator at 25 ± 1^{o}C for 15 h light and 9 h dark. Seeds were considered germinated when they developed radicle and coleoptile with greater than 2 mm length. Seed germination traits were recorded after 10 days. Seed vigor estimated by the equation of Sharifzadeh *et al.* (2006):

Seed vigor (% cm) = [(Radicle length (cm) + Coleoptile length (cm)) * (Germination percentage (%))]

Statistical analysis

Analysis of variance was performed using the SAS (version 9.1) software package. Significant differences among the mean values were compared by the Multiple Range Test of Duncan ($P < 0.05$). Correlation coefficients were calculated using SPSS software (version 16.0).

RESULTS AND DISCUSSION

Stem and leaf weight

Defoliation treatments and nitrogen rates had no significant effect on stem and leaf weight (Table1). Plant vegetative growth is usually reduced at final growth stage. At that stage, produced carbohydrate by photosynthesis is consumed by growing seeds. In maize, stalk and leaf weight was affected by defoliation treatment (Brimavandi *et al*., 2010). Stem and leaf weight had a positive and significant correlation with spike weight, seed yield and biological yield (Table 2). This positive correlation confirms that stem reserves contribute to seed filling.

Peduncle length and spike length

Defoliation and nitrogen had no significant effect on peduncle and spike length (Table 1). The reason is the completion of peduncle and spike growth at the anthesis stage when treatments were applied. The result is consistent with Fasae et al. (2009) finding.

Seed number per spike and spike weight

Defoliation and nitrogen had no significant effect on seed number per spike and spike weight (Table 1). This could be due to the supply of reserve from the stem or the spike photosynthesis compensated for the insufficient leaf photosynthesis at anthesis stage (Ahmadi and joudi, 2007). In maize, only complete defoliation affected the kernel row number per ear (Barimavandi et al., 2010).

Seed yield and seed weight

Removal of flag leaf in plants with or without nitrogen application reduced seed yield compared to un-defoliated plants with nitrogen application of 150 kg ha^{-1} (Table 1). These results indicated the importance of flag leaf to seed filling. Even application of nitrogen cannot compensate for the damage caused by removal of the flag leaf. Flag leaf emerges after other leaves and is the last leaf that dries. This leaf has a close relationship with spike and probably its assimilate directly enters into spike. Complete defoliation without nitrogen (D4N1) reduced seed yield compared to D1N2, but after nitrogen application, retained its seed yield. Some leaves are consumers. At end of plant growth cycle, leaves located at the lower part of the plant can be consumers. This is the reason for retaining seed yield in D4N2 compared to D1N2. Losing leaf area reduces sources for seed filling (Koptur *et al.*, 1996). Higher stem and leaf weight and biological yield can increase seed yield (Table 2). Defoliation and nitrogen had no significant effect on seed weight (Table 1). Maposse and Nhampalele (2009) reported that as the intensity of defoliation increased, 100-seed weight decreased. It seems that seed weight depends on genetic factors rather than environmental factors. Environmental stresses and cultural factors are not able to reduce seed weight much due to compensatory attribute of yield components (Heidari Zolleh *et al.*, 2009). It can be concluded that seed growth of studied cultivar is more sink- than source-limited.

Biological yield and harvest index

Plants with complete defoliation and without nitrogen application (D4N1) had lower biological yield than the un-defoliated plants with nitrogen application of 150 kg ha^{-1} (D1N2) (Table 1). Lower biological yield of D4N1 was due to its lower seed yield compared to D1N2 (Table 1). The differences among treatments in biological yield were little. The results are consistent with Ahmadi and Joudi (2007) findings. D3N1 had higher harvest index than D4N2. We observed that when plants were completely defoliated, they retained their green color. So when nitrogen fertilizer was applied at anthesis stage and simultaneously plants were completely defoliated, there was a competition between reproductive and vegetative parts for absorbing assimilate and plant reserves in stem could not be mobilized for grain filling. Presence of flag leaf helps in grain filling and applying nitrogen fertilizer at this stage may stimulate vegetative growth. Heidari (2012) reported harvest index was not affected by studied treatments, but Seghatoleslami *et al*. (2005) reported that harvest index was changed by studied treatments. Our results are in contrast to Seghatoleslami *et al*. (2005) findings.

Seed germination percentage

Complete defoliation reduced seed germination compared to un-defoliated plants under application of 0 kg N ha $^{-1}$ (Table 3). Seed germination percentage positively correlated with seed vigor (Table 4). Luzuriaga *et al*. (2006) observed that seed germination decreased in seeds from nitrogen-enriched conditions. The results are in contrast to Koptur *et al*. (1996) findings in common vetch (*Vicia sativa*). They declared that seeds produced by defoliated plants had no germination reduction compared to that of un-defoliated plants. It is probably due to that complete defoliation affects seed embryo and coat. Seed coat is usually thickened by stresses (Galloway, 2001). However, in our study, seed weight reduction was not significant (Table 1). Another reason for the reduction in germination of the seeds produced from defoliated plants might be due to the induction of dormancy in the seeds produced from plants exposed to defoliation. Further research is needed to verify this factor.

Shoot and root length

Under application of 150 kg N ha^{-1}, plants with complete defoliation had lower seedling shoot length than un-defoliated plants (Table 3). It was probably due to that under complete defoliation seed growth especially embryo was incomplete. Defoliation and nitrogen had no significant effect on root length (Table 3), which might be due to the similar seed weight of the seeds produced from different defoliation and nitrogen rate treatments (Table 1). Severe water stress during lettuce (*Lactuca sativa* L.) seed growth on maternal plant, increased seedling radicle length (Contreras, 2007).

Seedling weight and vigor

Under complete defoliation, the application of nitrogen to defoliated plants increased the seedling weight of the produced seeds (Table 3) indicating the importance of nutrient in producing heavier seedling for competition with weeds and overcoming unfavorable condition of the field, especially when mother plant losses its leaves. Adverse effect of flag leaf removal on seedling weight was as much as removal of all leaves. Seed vigor was decreased under complete defoliation (D4N1 and D4N2) compared to un-defoliated plants without nitrogen application (D1N1). Contreras (2007) reported that watering treatments during lettuce (*Lactuca sativa* L.) seed production did not affect seed vigor index.

CONCLUSION AND RECOMMENDATION

This paper emphasizes the importance of flag leaf in seed filling and seed yield of wheat. Complete defoliation significantly reduced seed germination, seedling weight and vigor. So to achieve favorable plant stand and vigorous seedling, it is recommended to clean the seeds produced from plants exposed to complete defoliation. Another suggestion is to study the dormancy of the seeds produced from plants exposed to complete defoliation.

Table1. Effect of defoliation and nitrogen rate treatments on wheat traits

[a] Treatments	Stem and leaf weight (g/plant)	Peduncle length (cm)	Seed number per spike	Spike length (cm)	Spike weight (g/plant)	Seed yield (g/plant)	Seed weight (g)	Biological yield (g/plant)	Harvest index (%)
D1N1	0.64 a	16.2 a	20.0 a	6.3 a	1.21 a	0.93 ab	0.047 a	1.86 ab	50.3 ab
D1N2	0.87 a	16.5 a	24.6 a	6.4 a	1.59 a	1.40 a	0.050 a	2.46 a	50.0 ab
D2N1	0.61 a	15.4 a	17.7 a	6.0 a	1.14 a	0.84 b	0.048 a	1.75ab	47.9 ab
D2N2	0.70 a	15. 7 a	18.1 a	6. 6 a	1.29 a	0.87 b	0.049 a	1.79 ab	49.1 ab
D3N1	0.57 a	15.5 a	21.5 a	6.3 a	1.17 a	0.98 ab	0.044 a	1.74 ab	55.1 a
D3N2	0.69 a	14.9 a	23.8 a	6.4 a	1.46 a	1.10 ab	0.046 a	1.92 ab	51.1 ab
D4N1	0.65 a	16.1 a	27.8 a	7.2 a	1.37 a	0.67 b	0.038 a	1.39 b	48.3 ab
D4N2	0.61 a	16.4 a	18.6 a	7.0 a	1.34 a	0.91 ab	0.049 a	1.95 ab	42.2 b

[a] D1, D2, D3 and D4 are defoliation treatments (0, flag leaf, all leaves except flag leaf and all leaves per plant, respectively). N1 and N2 are nitrogen rates of 0 and 150 kg ha $^{-1}$.
[b] Means followed by the same letter within each column are not significantly different at P < 0.05 as determined by Duncan's Multiple Range Test.

Table 2. Pearson's correlation coefficients among studied traits in wheat under different defoliation and nitrogen treatments

	Stem and leaf weight	Peduncle length	Seed number per spike	Spike length	Spike weight	Seed yield	Seed weight	Biological yield	Harvest index
Stem and leaf weight	1	.238	.379	-.093	.839**	.741*	.366	.735*	.036
Peduncle length	.238	1	.245	.569	.278	.177	.024	.312	-.388
Seed number per spike	.379	.245	1	.576	.613	.149	-.678	-.074	.276
Spike length	-.093	.569	.576	1	.348	-.272	-.560	-.261	-.457
Spike weight	.839**	.278	.613	.348	1	.642	.104	.594	-.124
Seed yield	.741*	.177	.149	-.272	.642	1	.563	.938**	.271
Seed weight	.366	.024	-.678	-.560	.104	.563	1	.765*	-.254
Biological yield	.735*	.312	-.074	-.261	.594	.938**	.765*	1	-.022
Harvest index	.036	-.388	.276	-.457	-.124	.271	-.254	-.022	1

*.Correlation is significant at the 0.05 level
**.Correlation is significant at the 0.01 level

Table 3. Effect of defoliation and nitrogen rate treatments on wheat seed traits

[a] Treatments	[b] Germination (%)	Shoot length (cm)	Root length (cm)	Seedling weight (mg)	Vigor (% cm)
D1N1	88.33 a	6.4 ab	7.5 a	10.3 ab	12.567 a
D1N2	67.50 ab	7.8 a	5.6 a	11.9 a	8.475 abc
D2N1	86.67 a	5.2 ab	5.4 a	8.0 cd	11.780 ab
D2N2	76.67 ab	5.2 ab	8.2 a	8.9 bc	10.287 abc
D3N1	--------	-----	------	------	------
D3N2	92.50 a	5.6 ab	6.3 a	7.4 cd	12.040 a
D4N1	45.00 b	7.0 ab	6.8 a	6.5 d	6.135 bc
D4N2	46.67 b	4.5 b	7.1 a	11.0 ab	5.977 c

[a] D1, D2, D3 and D4 are defoliation treatments (0, flag leaf, all leaves except flag leaf and all leaves per plant, respectively). N1 and N2 are nitrogen rates of 0 and 150 kg ha^{-1}.
[b] Means followed by the same letter within each column are not significantly different at P < 0.05 as determined by Duncan's Multiple Range Test.

Table 4. Pearson's correlation coefficients among studied traits in wheat seed under defoliation and nitrogen treatments

	Germination percent	Shoot length	Root length	Seedling weight	Vigor
Germination percent	1	-.104	-.127	-.097	.989**
Shoot length	-.104	1	-.307	.130	-.110
Root length	-.127	-.307	1	.016	-.057
Seedling weight	-.097	.130	.016	1	-.125
Vigor	.989**	-.110	-.057	-.125	1

*.Correlation is significant at the 0.05 level
**.Correlation is significant at the 0.01 level

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تأثير العلاجات لتساقط الأوراق ومعدل النيتروجين على المحصول، ومكوناته، وإنبات بذور القمح (*Triticum aestivum*)

حسن حيدري* وايراج نصراتي*

ملخص

لتحديد تأثير وضع الورقة ومعدل النتروجين على المحصول وإنبات البذور المنتجة من القمح (*Triticum aestivum*) فقد أجريت تجربة خلال 2011−2012. أربعة علاجات ل تساقط الأوراق تم استخدامها (D1 = 0، ورقة العلم = D2 ، جميع الأوراق باستثناء ورقة العلم =D3 ، و جميع الأوراق= D4) واثنين من معدلات النيتروجين (N1=0 و N=150 كغم نتروجين/ هكتار) و تطبيقها على نباتات القمح . وقد تم قياس إنبات البذور للبذور المنتجة من النباتات المعرضة لعلاجات تساقط الأوراق ونسبة النيتروجين. إزالة ورقة العلم ادت الى انخفاض كبير في محصول البذور مقارنة مع النباتات غير معالجة لتساقط الورق مع تطبيق العلاج بالنيتروجين(D1N2) ، ولكن كان إزالة جميع الأوراق باستثناء ورقة العلم ليس له أي انخفاض كبير على محصول البذور مقارنة مع تطبيق العلاج بالنيتروجين D1N2 . تطبيق استخدام الأسمدة النيتروجينية مع علاج تساقط الأوراق كاملة للنبات أدت الى زيادة وزن الشتلات المنتجة من تلك النباتات. و هذا يعد من الأمور الموصى بها لتنظيف البذور المنتجة من النباتات المعرضة لعلاجات تساقط الأوراق الكاملة وذلك بسبب انخفاض إنبات البذور وحيويتها.

الكلمات الدالة: تساقط الأوراق، الورقة العلم، وضع ورقة، تأثير النبات الأم، النيتروجين، انبات البذور.

*كلية الزراعة، جامعة رازي، ايران.

owais@mutah.edu.jo

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