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Source-sink manipulation effects on wheat seed yield and seed germination characteristics

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Abstract. Source-sink manipulation effects on seed yield and germination traits of produced seed in wheat (*Triticum aestivum*) were studied in a field experiment and a laboratory experiment. The field experiment was comprised of four defoliation treatments (D1=no defoliation, D2= flag leaf removal, D3=removal of all leaves except flag leaf, and D4= removal of all leaves) at anthesis stage and two sink manipulation treatments (S1=no spike removal and S2=50% spike removal at anthesis stage). Results showed that under no spike removal, removal of flag leaf and complete defoliation resulted in higher seed yield than that in untouched plants. Manipulation of sink (50% spike removal) and source (defoliation) had no significant effect on seed weight. Removal of 50% spike reduced harvest index. Sink and source manipulation had minor effect on produced seed germination traits.

Key words: defoliation, flag leaf, maternal plant effect, seed vigor, source-sink relation.

Introduction

Sink- source relations can regulate biomass production and assimilate allocation in plants (Ahmadi et al. 2004). Sink limited seed yield of winter wheat (*Triticum aestivum* L.) under both high and moderate soil water content, but sink restriction was mostly observed under high soil water content (Madani et al. 2010). Some researchers reported that source limited seed yield (Mohammadi 2012). In wheat, removing one quarter of spikelets increased grain mass whereas removing one quarter of leaves had little effect on spike weight at anthesis (Wang et al. 1998). Removal of 50% spikelets decreased wheat grain yield per main spike by 37% while increased 100-grain weight by 9% (Alam et al. 2008).

Leaf position can play an important role in wheat seed filling thus various pattern of defoliation may influence sink-source relation. It has been reported that flag leaf removal and/or removal of all leaves at anthesis had no significant effects on wheat seed yield (Ahmadi & Joudi 2007). Defoliating leaves lower the ear had higher detrimental effects on corn seed yield than removal of upper ear leaves (Barimavandi et al. 2010).

Seed quality is a noticeable factor for seed production in crop plant. Produced seed quality in maize (*Zea mays*) was affected by different defoliation treatments on maternal plants (Umashankara 2007). In *Vicia sativa*, seeds produced by plants in different defoliation treatments had similar germination percentage and germination time (Koptur et al. 1996). Wheat is the most important cereal crop in the world. Little information is available about effect of treatments on maternal plant such as defoliation and spike removal on seed germination traits of wheat. So, the objective of this study was to determine wheat (*Triticum aestivum*) seed yield and germination traits of produced seed under sink and source manipulation treatments.

Materials and Methods

Experiment 1

The field experiment was conducted in a factorial arrangement based on a randomized complete block design (RCBD) with three replications at Chamchamal plain, 47 km from Kermanshah in 2011-2012 (Latitude 34° N, longitude 47° E, and altitude 1300 m above sea level). Average annual rainfall of the zone is 442 mm (IMO 2012). There were two experimental factors: leaf removal (source manipulation) with four levels and spike removal (sink manipulation) with two levels:

D1: Control, no leaf removal
D2: Removal of flag leaf
D3: Removal of all leaves except flag leaf
D4: Removal of all leaves
S1: No spike removal
S2: 50% spike removal

Wheat (cv Pishtaz) was sown on 24 Oct 2011 at a rate of 250 Kg ha^{-1}. Prior to planting, 250 kg ha^{-1} NPK fertilizer (20-20-20) was applied. Wild oats (*Avena fatua*), Charlock (*Sinapis arvensis*) and Cheese rennet (*Galium verum*) were superior weed plants at the field. 2, 4-D herbicide ((2, 4-dichlorophenoxy acetic acid in ammonium (amine) salt)) was used to control broad leaf weeds.

Plot size was 1m by 1m. The distances between plots and between replications were both 1 m. Wheat plants were watered through furrow irrigation. Experimental treatments were imposed at anthesis stage (203 days after sowing).

Plant sampling and measurements: Plants were harvested on 29 Jun 2012 (249 days after sowing). Seed yield, total dry matter (biological yield), spike weight and leaf and stem weight were measured as gram per plant by selecting five plants per plot. Seed number per spike and seed weight were measured on five plants per plot. Peduncle length was measured on three randomly selected spikes per plot. Harvest index was calculated as the ratio of the seed yield to the biological yield.

Experiment 2

Wheat seeds were harvested from maternal plants under defoliation and spike removal treatments. Germination traits of produced seed were tested in a standardized germination test. The experiment was conducted at the Physiology Laboratory, College of Agriculture, Razi University, Kermanshah, Iran in 2012. The research was carried out as a factorial experiment based on a completely randomized design with three replications.

Wheat seeds were surface sterilized in sodium hypochlorite solution (1% active chlorine) for 10 min. Then twenty sterilized seeds were transferred to each glass petri dish containing 10 ml of distilled water. Petri dishes were transferred to a germinator and kept at 15 h lightness, 9 h darkness and 25 ± 1°C for 10 days. After 10 days, seed germination traits were recorded.

Seed vigor was estimated using the following equation (Sharifzadeh et al. 2006):

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

Statistical analysis

Field and laboratory experiment data were analyzed using a factorial analysis of variance by SAS (version 9.1). Duncan's test separated means at $P < 0.05$. Prior to analyses the data were tested for normality using MINITAB (version 14.0). Pearson correlation coefficients were calculated using SPSS (version 16.0).

Results

Experiment 1

Defoliation treatments and 50% spike removal had no significant effect on stem and leaf weight and peduncle length (Table1). Under no spike removal, removal of all leaves increased seed number per spike (Table 1). 50% spike removal had lower seed number per spike than no spike removal. This shows that source restrictions at anthesis perform its effect on seed number per spike rather than seed weight (Table 1). D4S1 had higher spike weight than D1S1 (Table 1). It is due to higher seed number per spike. Seed number per spike had a remarkable effect on seed yield, spike weight, biological yield and harvest index (Table 2). Under no ½ spike removal, removal of flag leaf and complete defoliation had higher seed yield than untouched plants (Table 1). Higher seed number per spike, spike weight, harvest index and biological yield can increase seed yield (Table 2). Manipulation of sink (50% spike removal) and source (defoliation) had no significant effect on seed weight (Table 1). Under each defoliation level, removal of 50% spike had no significant effect on biological yield except under D3 (Table 1). Removal of 50% spike reduced harvest index except under flag leaf removal (Table 1). It is probably due to that when sink strength reduces, demand for assimilates reduces, this had a feedback on assimilation, so current photosynthesis and remobilization of carbons reserves from vegetative organs like stem towards grain reduces. This partitioning of carbohydrates decreases harvest index.

Experiment 2

Under removal of 50% spike, flag leaf removed plants produced seeds with a lower germinability than completely defoliated plants and all leaves removed except flag leaf plants (Table 3). Sink and source alteration in maternal plants had no significant effects on the shoot length and had minor effect on root length of the produced seeds (Table 3). D3S1 and D2S2 had higher root length than D4S2. It is probably due to that under complete defoliation, natural seed growth, especially embryo, fails. D4S1 produced heavier seedling than D2S1 (Table 3). D4S1 produced higher seed number per spike than D2S1 (Table 1). It shows that higher assimilates move toward spike, however seed weight did not reduce (Table 1). So this condition may improve seedling weight and seed vigor (Table 3). Seed vigor had a positive and significant correlation with root length (Table 4).

Discussion

Experiment 1

At the end of plants growth cycle, vegetative part growth reduced and plant initiated to store carbohydrate into reproductive organs such as seed. Under 50% spike removal, seed number per spike and spike weight were not affected by defoliation. Maybe stem reserves and spike photosynthe-

Table 1. Effect of defoliation and 50% spike removal treatments on wheat traits.

Treatments	[b] Stem and leaf weight (g/plant)	Peduncle length (cm)	Seed number per spike	Spike weight (g/plant)	Seed yield (g/plant)	Seed weight (g)	Biological yield (g/plant)	Harvest index (%)
D1S1 [a]	0.600 a	14.99 a	16.9 b	0.950 bc	0.727 bc	0.0445 a	1.46 ab	50.82 ab
D1S2	0.690 a	15.15 a	9.5 c	0.557 c	0.407 d	0.0433 a	1.36 ab	37.98 c
D2S1	0.533 a	15.81 a	20.6 b	1.200 ab	1.050 a	0.0417 a	1.73 ab	49.97 ab
D2S2	0.573 a	16.54 a	10.9 c	0.633 c	0.493 cd	0.0460 a	1.21 b	40.65 bc
D3S1	0.680 a	16.70 a	22.8 ab	1.320 ab	0.927 ab	0.0460 a	2.00 a	52.07 a
D3S2	0.613 a	17.59 a	9.6 c	0.633 c	0.380 d	0.0393 a	1.25 b	30.81 c
D4S1	0.650 a	17.17 a	27.5 a	1.367 a	1.073 a	0.0390 a	2.02 a	53.39 a
D4S2	0.735 a	16.65 a	10.0 c	0.650 c	0.440 cd	0.0433 a	1.43 ab	36.18 c

[a] D1: no leaf removal, D2: flag leaf removal, D3: removal of all leaves except flag leaf, D4: removal of all leaves S1: no spike removal, S2: 50% of spike removal.
[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 50% spike removal treatments.

	Stem and leaf weight	Peduncle length	Seed number per spike	Spike weight	Seed yield	Seed weight	Biological yield	Harvest index
Stem and leaf weight	1							
Peduncle length	.128	1						
Seed number per spike	-.159	.114	1					
Spike weight	-.175	.117	.984**	1				
Seed yield	-.312	-.003	.965**	.972**	1			
Seed weight	.076	-.446	-.192	-.139	-.149	1		
Biological yield	.116	.156	.940**	.948**	.893**	-.147	1	
Harvest index	-.238	-.252	.907**	.897**	.917**	.145	.812*	1

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

Table 3. Effect of defoliation and 50% spike removal treatments on wheat seed traits.

Treatments [a]	Germination (%)	Shoot length (cm)	Root length (cm)	Seedling weight (mg)	Vigor (% cm)
D1S1	82.5 ab	4.53 a	7.73 abc	8.75 ab	6.65 bc
D1S2	81.2 ab	4.52 a	5.40 bc	6.80 b	5.15 c
D2S1	85.0 ab	4.60 a	8.40 abc	6.80 b	11.05 ab
D2S2	93.3 a	5.55 a	9.80 ab	10.73 a	12.71 a
D3S1	85.0 ab	4.83 a	10.30 a	8.13 ab	11.14 ab
D3S2	61. 7 b	5.43 a	7.45 abc	8.10 ab	7.15 bc
D4S1	73.3 ab	5.03 a	7.30 abc	11.10 a	8.88 abc
D4S2	60.0 b	4.97 a	4.20 c	9.33 ab	7.33 bc

[a] D1: no leaf removal, D2: flag leaf removal, D3: removal of all leaves except flag leaf, D4: removal of all leaves S1: no spike removal, S2: 50% of spike removal.

[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 50% spike removal treatments.

	Germination percent	Shoot length	Root length	Seedling weight	Seed vigor
Germination percent	1				
Shoot length	-.191	1			
Root length	.683	.254	1		
Seedling weight	-.033	.598	.122	1	
Seed vigor	.566	.402	.786*	.317	1

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

sis compensate insufficient leaf photosynthesis at heading stage. Maintenance respiration may also be affected by defoliation. Defoliation reduces plant dry weight. At the end of wheat growth many leaves become senescent and their respiration rate increase. So removal of leaves may decrease plant maintenance respiration (Ahmadi & Joudi 2007). Some researchers reported that defoliation decreased seed yield (Erbas & Baydar 2007). In maize (*Zea mays* L.) only removal of all leaves affected row numbers per ear (Barimavandi et al. 2010). Wang et al. (1998) and Genter et al. (1997) declared little effect of source reduction on seed number per spike and seed number per pod, respectively.

Based on the results, it can be concluded that presence of leaves (sources) at anthesis stage not only had no positive effect on grain filling but also reduced seed yield. Probably, leaves became consumers at the stage and required assimilate for grain filling is supplied from stem reserves or from spike photosynthesis. Of course, we observed that stem of completely defoliated plants were green for a longer period than other plants. So maybe defoliation increased photosynthesis period. Source manipulation had no significant effect on seed yield under 50% spike removal. Alam et al. (2008) reported that 50% spikelet removal in wheat had significant effect on 100- seed weight and seed yield that are in contrast with our findings. Our results are in contrast with Alam et al. (2008), Maposse & Nhampalele (2009) and Gregorutti et al. (2012) findings. Fasae et al. (2009) reported that defoliation did not reduce maize (*Zea mays* L.) grain yiled at 12 weeks after planting. Difference between our results and other results may be attributed to differences between genotypes and time of treatment imposition. If treatments were imposed before anthesis, they could change seed weight. It was expected that by removal of 50% spike, seed weight changed, but manipulation of sources (leaves) under no spike removal showed that seed number per spike changed. It may be attributed to cultivar or assimilates remobilization from stem and other parts toward seed. It can be concluded that seed yield of the studied cultivar is more sink-limited than source-limited. Reduction in biological yield of D3S2 compared to D3S1 is due to removal of some seeds.

<u>Experiment 2</u>

Reduction of seed germination percentage of severely defoliated plants under removal of 50% spike, maybe attributed to the fact that under severe defoliation, natural seed growth, especially embryo, fails. Another reason could be that defoliation may induce dormancy in seed by increasing seed coat thickness (Galloway 2001) that should be studied at the future researches. Grazed *Nassella pulchra* produced small seed with low seed germination rate (Dyer 2002). The results are in contrast to Koptur et al. (1996) findings in common vetch (*Vicia sativa*). Minor difference among treatments in terms of root and shoot length may be due to the fact that seed weight was not changed by maternal plant treatments (Table 1). Maize plants under complete defoliation produced seed with higher germination percentage than control (Heidari 2013). Under no ½ spike removal, removal of all leaves produced heavier seedling than flag leaf removal. Probably the stress caused by complete defoliation increased germination hormone level. During seed development on maternal plant, seed dormancy and germination hormones induce, the hormonal content depends on environmental conditions (Liu et al. 2013). Umashankara (2007) reported that defoliation decreased seedling vigor of maize compared to control that was due to less food reserves in seed. The difference between our work and the Umashankara (2007) finding is due to difference between treatments. Increasing seed vigor was only observed under spikeler removal.

Conclusion

Under no spike removal, removal of all leaves increased seed number per spike. Under no spike removal, removal of flag leaf and complete defoliation had higher seed yield than untouched leaves. Source manipulation had no significant effect on seed yield under 50% spike removal. Sink and source manipulation had minor effect on produced seed germination traits. It is suggested to breed wheat cultivars with a larger sink size than the studied cultivar to increase wheat yield potential under irrigated farming condition of west of Iran.

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