Effect of defoliation intensity on maize yield, yield components and seed germination

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Abstract: A field experiment and a laboratory experiment were conducted in 2011 to determine the effect of intensity of defoliation on yield of maize (*Zea mays*). The field experiment included seven defoliation intensities (0, 2, 4, 6, 8, 10 and whole leaves per plant) from top to bottom leaves. Seeds of the field experiment were used for the laboratory experiment. In the laboratory experiment, germination traits of seed produced from maternal plant under defoliation treatment were tested. Results showed that defoliation had a significant effect on seed yield, rows number per ear, seed number on row, cob length, cob weight and harvest index (P<5%). Seed yield was reduced by increasing defoliation intensity. The results suggest that the two upper leaves should not be defoliated, because this treatment has a remarkable negative effect on the seed and biological yield. Severe removal of leaves (T7) increased seed germination percentage, rate and vigor providing aevidence for maternal environmental effects on germination.
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Key words: Defoliation; harvest index; maternal effect; seed vigor

1. Introduction

There are many causes for defoliation such as herbivores, hailstorms, wind, insect, diseases, herbicides and farm machinery. Use of leaves for feeding animal or human consumption can be considered in poor country. Erbas and Baydar (2007) reported that sunflower (*Helianthus annuus* L.) yields were reduced by 42% when 25 leaves per plant were removed at the preflowering stage. In cowpea (*Vigna unguiculata*), defoliation at podding stage and at intensity below 50% is recommended (Ibrahim et al. 2010). Maturity in maize was significantly affected by defoliation treatments and soluble-solid content in the stem reduced quickly after leaf removal (Tollenaar and Daynard 1987). Luzuriaga et al. (2006) reported that in *Sinapis arvensis*, addition of nitrogen to maternal environment reduced germination rate of seeds. In other research, seed germination percentage reduced due to increasing maternal nutrient and light levels (Galloway 2001). In *Vicia sativa*, seeds produced by plants in different defoliation treatments had similar germination percentage and germination time (Koptur et al. 1996). Maize is one of the most important warm season crop in west of Iran. In The area, foliage loss from some insects, diseases and hail result in economical problems for farmers. There are a few studies about effect of material plant environment such as defoliation on seed germination of crop plant, so the objective of this study was to determine maize (*Zea mays*) seed yield and seed germination traits at different levels of artificial defoliation.

2. Materials and Methods

2.1 Experiment 1

1. Site, experimental design and cultural practices: The field experiment was conducted at Chamchamal plain, 47 km from Kermanshah, west of Iran in 2011 (Latitude 34° N, longitude 47° E, and altitude 1300 m above sea level). Average annual rainfall of the zone is 442 mm (IMO 2012). The study was conducted as a randomized complete block design (RCBD) with three replications. There were seven defoliation levels:

T1: Control, no leaf removal
T2: removal of 2 leaves
T3: removal of 4 leaves
T4: removal of 6 leaves
T5: removal of 8 leaves
T6: removal of 10 leaves
T7: removal of all leaves

At summer after harvesting the wheat (*Triticum aestivum*), the soil was plowed by mouldboard plowing. Maize seeds (*Zea mays*, CV S.C. 704) were sown on April 18, 2011 using a pneumatic maize seeder. Row spacing and plant spacing within row were 75 and 17 cm, respectively. Seed emerged by rain water. Irrigation interval was 8-day and plants were irrigated 8 times. 625 $kgha^{-1}$ of urea fertilizer (46=N%, CO $(NH_2)_2$), was applied as split application and top dressing. 375 $Kgha^{-1}$ of triple super phosphate (P_2O_5%=46, Ca $(H_2PO_4)_2$) was applied as presowing.

Weeds were controlled by hand weeding and Nicosulfuron (Cruz) herbicide (3-Pyridimecarboxamide,2-[[(4,6-Dimethoxy-pyrimidin-2-yl) amino-carbonyl]aminosulfonyl]-N,N-dimethyl).

Plot size was 3 m wide and 3 m long. The distances between plots and between replications were both 1.5 m. Plants were well-watered during the growth season and defoliation treatments were imposed at silking stage (93 days after sowing).

2. Plant sampling and measurements: Plant samples were taken by selecting five plants per plot. Up to 50 cm of primer line and edge line were discarded. In order to measure the seed yield and total dry matter, five plants were cut and after drying, dry matter (biological yield) and seed yield were measured as gram per plant. Plants were harvested when they yellowed (140 days after sowing). Row number per cob, seed number per row and cob length were measured on three ears per plot by random selection. Harvest index was computed as the ratio of the grain to the aboveground dry matter at harvest. In this study, the effects of varying defoliation levels on stem and leaf weight, cob weight, ear skin weight, ear weight and100-seed weight were also evaluated. These traits were measured by random selection of five plants per plot and they were weighed after drying.

2.2. Experiment 2

After harvesting seeds from maternal plants, they were stored at 25^{o}C for three months. Seeds of the field experiment were used for the laboratory experiment. In the laboratory experiment, germination traits of seed produced from maternal plant under different defoliation treatments were tested to study the effect of maternal environment. The study was conducted as a factorial experiment in a Randomized Complete Block Design with three replications in 2011.

Before starting the trial, seeds were sterilized using sodium hypochlorite solution (1% active chlorine) for 10 min to avoid fungal contamination. Twenty seeds were then placed in each Petri dish and 10 mL of distilled water added. Temperature during experiment was kept at 26 ± 1^{o}C. Two millimeters growth of coleoptile was the criterion for germination. Following formula estimated germination rate (GR, Zareyan et al. 2010):

GR = a/1 + b/2…+ n/N

Where a, b, n are germinated seed number and 1, 2, N are day after trial beginning. Seed vigor estimated by these equations (Sharifzadeh, 2006; Abasian, 2010):

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

Seed vigor (% g) = [(Radicle weight (g)+ Caulicle weight (g)) * (Germination percentage (%))]

The trial period was 7 days and germination percentage was recorded every day.

2.3. Statistical analysis

Analysis of variance (ANOVA) was used to determine significant differences. The Multiple Range Test of Duncan performed the separation of means ($P < 0.05$). Correlation coefficients were calculated for the relationship between several crop parameters. All statistics were performed with the program MINITAB (version 14.0), SAS (version 9.1) and SPSS (version 16.0).

3. Results and Discussions

3.1. Experiment 1

1. *Stem and leaf weight*: Defoliation did not have significant effect on stem and leaf weight of maize (Table 1). It is probably due to that stem and leaf weight growth was partially completed at silking stage and defoliation at this stage only had a negative effect on seed filling, because seed yield was reduced by increasing defoliation intensity (Table 1). Ahmadi and Joudi (2007) did not observe significant difference among grain yields of wheat (*Triticum aestivum*) under defoliation treatments.

2. Ear skin weight and ear weight: Control, no leaf removal had the highest ear skin weight (except compared to T2,) and the difference among other treatments was not significant (Table 1). T1 had the highest ear weight and T6 and T7 had the lowest ear weight (Table 1). The result shows that presence of two above leaves is important to form ear with thick and big skin. This skin photosynthesis and reserves had a remarkable effect on row number per ear, cob length, cob weight (Table 2). Barimavandi et al.(2010) reported that the upper leaves should not be defoliated, due to their negative effect on the seed yield. This leaves are more efficient in absorbing light than lower leaves.

3. Row number per ear and seed number per row: T1 had higher row number per ear than T5, T6 and T7 (Table 1). T6 had lower seed number per row than other treatments and the difference among other treatments was not significant (Table 1). Barimavandi et al. (2010) reported that the row numbers per ear only was affected by complete defoliation; it is due to that stem reserves can compensate insufficient photosynthesis from leaves. Row number per ear had a remarkable effect on seed yield (Table 2).

4. Cob length and cob weight: T1 had higher cob length than T6 and T7 (Table 1). With increasing defoliation intensity, cob weight was decreased. This negative correlation was reported by other researchers (Zewdu and Asregid 2001). Cob length and weight had an important role in increasing seed yield and harvest index (Table 2). Fasae et al. (2009) reported that defoliation at 12 and 16 weeks after maize planting had no significant effect on cob length.

5. Seed yield and biological yield: Seed yield and biological yield were reduced as defoliation increased. Control, no leaf removal had the highest seed yield (Table 1). This shows the importance of upper leaves in absorbing light. Hassen and Chauhan (2003) reported similar results. Some reasons for higher seed yield of T1 is increasing cob length and row number per ear (Table 1, Table 2). Reduction in leaf area reduces resources for grain filling (Koptur et al. 1996).

6. Harvest index and 100-seed weight: T1 had higher harvest index than T6 and T7 (Table 1). This shows that with severe removal of leaf, partitioning of assimilate changes and less assimilate moves from reserves such as stem toward seeds. Increasing of 100-seed weight, cob length, cob weight and row number per ear resulted in higher harvest index (Table 2). There was minor difference among defoliation treatments in terms of 100-seed weight and only removal of whole leaves reduced 100-seed weight. Maposse and Nhampalele (2009) reported that as the intensity of defoliation increased, 100-seed weight decreased. It seems that seed weight is more dependent on genetic factors than environmental factors and environmental stresses and cultural factors can not reduce seed weight a lot because the plant provides the least required nutrients for each seed by reducing the number of seed (Heidari Zolleh et al. 2009).

Table 1. Effect of defoliation treatments on maize traits

[a]Treatments	[b]Stem and leaf weight (g/plant)	Ear skin weight (g/plant)	Ear weight (g/plant)	Row number per ear	Seed number per row	Cob length (cm)	Cob weight (g/plant)	Seed yield (g/plant)	100-seed weight (g)	Biological yield (g/plant)	Harvest index (%)
T1	86 a	8.6 a	186.3 a	117.0 a	42.6 a	54.0 a	24.1 a	159.1 a	27.0 a	280.9 a	0.57 a
T2	83.5 a	6.66 ab	138.8 b	86.3 ab	37.0 a	45.3 ab	18.3 ab	117.8 b	30.0 a	228.9 b	0.51 ab
T3	76.7 a	4.86 b	120.1 b	82.3 ab	42.6 a	43.0 ab	15.4 bc	103.6 b	28.6 a	201.6 bc	0.51 ab
T4	91.6 a	5.06 b	100.7 b	83.0 ab	42.0 a	41.3 ab	12.3 bc	87.6 b	27.0 a	195.8 bc	0.51 ab
T5	82 a	5 b	95.4 b	65.6 bc	40.6 a	42.0 ab	12 c	83.2 b	29.0 a	182.4 cd	0.45 ab
T6	119.3 a	4.2 b	28.8 c	28.6 c	10.0 b	33.9 b	5.1 d	25.06 c	23.6ab	144.4 de	0.37 bc
T7	77.8 a	5.8 b	34.7 c	47.3 bc	32.0 a	38.5 b	6.1 d	30.32 c	17.6b	118.3 e	0.27 c

[a] T1, T2, T3, T4, T5, T6, T7 are defoliation intensities (0, 2, 4, 6, 8, 10 and whole leaves per plant, respectively)
[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 maize under different defoliation treatments

	SLW	ESW	EW	RNE	SNR	CL	CW	SY	HSW	BY	HI
SLW	1	-.359	-.430	-.514	-.841*	-.497	-.421	-.434	-.142	-.239	-.182
ESW	-.359	1	.752	.762*	.442	.890**	.799*	.745	.119	.743	.455
EW	-.430	.752	1	.971**	.719	.953**	.995**	1.000**	.697	.979**	.908**
RNE	-.514	.762*	.971**	1	.808*	.952**	.961**	.973**	.583	.931**	.865*
SNR	-.841*	.442	.719	.808*	1	.711	.678	.727	.476	.583	.609
CL	-.497	.890**	.953**	.952**	.711	1	.965**	.952**	.473	.920**	.757*
CW	-.421	.799*	.995**	.961**	.678	.965**	1	.993**	.650	.977**	.874*
SY	-.434	.745	1.000**	.973**	.727	.952**	.993**	1	.700	.978**	.911**
HSW	-.142	.119	.697	.583	.476	.473	.650	.700	1	.705	.859*
BY	-.239	.743	.979**	.931**	.583	.920**	.977**	.978**	.705	1	.929**
HI	-.182	.455	.908**	.865*	.609	.757*	.874*	.911**	.859*	.929**	1

SLW, ESW, EW, RNE, SNR, CL, CW, SY, HSW, BY, HI are stem and leaf weight, ear skin weight, ear weight, row number per ear, seed number per row, cob length, cob weight, seed yield, 1000-seed weight, biological yield, harvest index.
*.Correlation is significant at the 0.05 level
**.Correlation is significant at the 0.01 level

3.2. Experiment 2

1. Seed germination percentage and rate: T7 had the highest germination percentage and rate (Table 3). This shows that severe removal of leaves increased seed germination and rate. Seed germination percentage and rate had a positive and significant correlation with whole traits except seedling weight (Table 4). Galloway (2001) reported that increasing maternal nutrient and light levels decreased seed germination percentage and Luzuriaga et al. (2006) reported similar results. Koptur et al. (1996) reported that defoliation treatments on maternal plant did not have significant effect on days to germination in the common vetch (*Vicia sativa*). Increasing seed germination percentage and rate maybe due to that under severe defoliation, more light can penetrate in canopy that can increase evaporation from soil and

dry it. Water-stressed plants produce lower seed mass but with higher seed germination (Luzuriaga, 2006).

2. Shoot length and root length: Defoliation treatments had no significant effect on seedling shoot length, but T7 had the highest root length (Table 3). Shoot length and root length had a positive and significant correlation with whole traits except seedling weight (Table 4). Contreras (2007) reported that severe water stress during lettuce (*Lactuca sativa* L.) seed production on maternal plant increased seedling radical length.

3. Seedling weight and vigor: T2 and T7 had the highest seedling weight except compared to T6 (Table 3). T2 and T7 had the highest vigor based on weight and T7 had the highest vigor based on length (Table 3). Seedling weight had a positive and significant correlation with vigor based on weight (Table 4). Contreras (2007) reported that watering treatments during lettuce (*Lactuca sativa* L.) seed production on maternal plant did not affect seed vigor index. Removal of whole leaves (T7) produced the lowest 100-seed weight (Table 1) but with the highest seed germination percentage, seed germination rate, seedling root length and seed vigor. This shows that under environmental stresses such as defoliation, plant produces lower and lighter seed but with higher seed germination traits. It may be a mechanism for survival.

4. Conclusions and suggestions

Seed yield and biological yield were reduced as defoliation increased. No leaf removal had the highest seed yield, biological yield and ear weight. Removal of whole leaves (T7) had the lowest seed yield and biological yield, but had the highest seed germination percentage, rate, seed vigor and seedling root length providing evidence for maternal environmental effects on germination. Regarding few reports about maternal environment effects on seed traits, it is recommended to study effect of other environmental factors such as light by defoliation leaves under and at the top of ear, nutrients and water on seed germinability and storability.

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Table 3. Effect of defoliation treatments on maize seed traits

[a]Treatments	[b]Germination (%)	Germination rate (no/day)	Shoot length (cm)	Root length (cm)	Seedling weight (g)	Vigor (% g)	Vigor (% cm)
T1	43.33 bc	3.0300 bc	5.370 a	10.250 b	0.183 c	0.086 b	9.276 bc
T2	65.00 b	4.5533 b	6.253 a	11.153 b	0.297 a	0.192 a	11.184 b
T3	43.33 bc	3.1600 bc	5.460 a	7.093 b	0.187 c	0.078 b	5.266 cd
T4	43.33 bc	2.7000 bc	5.707 a	9.920 b	0.1737 c	0.078 b	8.197 bc
T5	48.33 bc	3.5933 bc	5.662 a	7.870 b	0.1837 c	0.096 b	9.328 bc
T6	25.00 c	1.5267 c	5.387 a	9.050 b	0.197 bc	0.052 b	3.672 d
T7	98.33 a	7.4033 a	7.660 a	17.967 a	0.2637 ab	0.259 a	25.186 a

[a] T1, T2, T3, T4, T5, T6, T7 are defoliation intensities (0, 2, 4, 6, 8, 10 and whole leaves per plant, respectively)

[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 maize seed under different defoliation treatments

	Germination percent	Germination rate	Shoot length	Root length	Seedling weight	Vigor (weight)	Vigor (length)
Germination percent	1	.996**	.962**	.874*	.713	.972**	.965**
Germination rate	.996**	1	.950**	.852*	.689	.960**	.961**
Shoot length	.962**	.950**	1	.933**	.714	.952**	.959**
Root length	.874*	.852*	.933**	1	.631	.873*	.940**
Seedling weight	.713	.689	.714	.631	1	.854*	.594
Vigor weight	.972**	.960**	.952**	.873*	.854*	1	.919**
Vigor length	.965**	.961**	.959**	.940**	.594	.919**	1

*.Correlation is significant at the 0.05 level

**.Correlation is significant at the 0.01 level

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