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ORIGINAL ARTICLE

Corn (*Zea mays* L.) seed vigour and quality as influenced by weed interference and living mulch

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ABSTRACT

Seed vigour and quality can be influenced by environmental factors during the growth and development of the mother plant. In order to study the effects of weed interference and living mulch on subsequent seed vigour and quality of corn an experiment was conducted at the Agricultural Research Farm of Razi University, Kermanshah, Iran. The experiment was a factorial with three factors based on a randomized complete block design with four replications. The first factor was the weed treatments (weedy and weed-free for the entire growing season), the second factor was three berseem clover interseeding times (15 days before, simultaneous with and 15 days after corn planting) and the third factor was three berseem clover interseeding rates (0, 20 and 40 kg ha-1). The results indicated that full season weedy condition decreased seed vigour and quality indices including 100-seed weight, seed germination percentage, mean germination rate, radicle dry weight, plumule dry weight, seedling vigour index and seed protein content of the produced seeds by 21.0, 14.2, 10.5, 33.7, 32.2, 40.6 and 9.7% respectively, when compared with the entire weed free condition. In weed free condition, berseem clover interseeded at different rates or times didn't significantly influence the traits under study. However, in weedy condition, corn seed vigour and quality indices were significantly higher when the living mulch was interseeded 15 days before corn planting as compared with other two interseeding times. This was probably due to the higher suppressive effect of berseem clover on the weeds and consequently the reduced harmful effects of the weeds on corn during seed development stage. Moreover, the variation in seed weight was compatible with the variations in the seed vigour and quality indices. It can be concluded that the environmental factors may influence corn seed vigour and quality via affecting the seed weight.

Key words: corn, living mulch, seed quality, seed vigour, weed interference.

Introduction

Corn production has notably been extended during recent years in Iran, especially in some regions such as Kermanshah province. In addition to human nutrition, corn grain is a valuable source of poultry feed. Therefore, corn grain quality particularly its protein content is very important. Moreover, the success of a corn production system highly depends on the vigour of the seeds which are planted. High vigour seed lots can improve crop yield in two ways: first because seedling emergence from the seedbed is rapid and uniform, leading to the production of vigorous plants, and second because percentage seedling emergence is high, so optimum plant population density could be achieved under a wide rang of environmental conditions [9]. Thus the production of the seed with high quality and vigour is an important goal for corn producers.

In general, seed quality and vigour are influenced by various factors experienced during development and maturation [28,26]. Weed competition can cause yield reductions of up to 70% in corn grain yields [25]. Weeds can suppress corn yield by competing for environmental resources such as light, water and nutrients [19] and production of allelopathic compounds [20,3]. However, there is a little information on the effect of environmental factors such as weed on subsequent seed vigour and quality of corn. For example, Saayman and Van De Venter [22] reported that both germination and vigour of corn seeds decreased with an increase in weed density. They also observed an increase in the mean time to corn seedling emergence with an increase in weed density indicating reduced seed vigour. Living mulches are cover crops that are planted between the rows of a main crop and are maintained as a living ground cover throughout the growing season of the main crop. In addition to

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providing adequate cover to reduce soil erosion [27] and to increase soil water infiltration [5], legume living mulches improve the soil nutrient status through the addition of organic nitrogen [4,10] via fixed atmospheric nitrogen, which improves the physical properties of soil [12,15]. Moreover, interseeded legume living mulches can enhance the yield of the companion main crop especially under weedy condition [16]. Berseem clover (*Trifolium alexandrinum* L.) is a high yielding, nutritious, cool season forage legume crop thought to have originated in the Middle East [11]. Berseem clover has potential as a cover crop or annual forage in living mulch cropping systems [21]. Intercropping berseem clover with cereals increased yield and quality of cereal crops and reduced fertilizer needs and increased subsequent crop yields [21].

However, we didn't find any report on the effect of living mulch on subsequent seed vigour and quality of the companion corn. Therefore, this study was conducted to evaluate the interaction effects of weed interference and berseem clover as a living mulch on subsequent seed vigour and quality of corn.

Materials and methods

The study was carried out in 2009 at the Agricultural Research Farm of Razi University, Kermanshah, western Iran. The soil type was a silty clay with a pH of 7.8 and 0.8% organic matter. The land was plowed and disked before planting. Fertilizers were applied according to the soil test recommendation. The corn cultivar used was "KSC 704" (a grain corn cultivar which is commonly planted in the region). In order to protect against soil-borne diseases, prior to seeding, the corn seeds were treated with benomyl at 0.2% (w/w). The crop was planted on 15 May 2009. Corn is an irrigated crop in western Iran; therefore, it is not dependent on seasonal rainfall. Irrigations were carried out as needed throughout the growing season (at 7–9 day intervals). The experiment was conducted in a factorial arrangement based on a randomized complete block design with four replications. The first factor was the weed treatments (weedy and weed-free for all of the growing season), the second factor was three berseem clover interseeding times (15 days before, simultaneous with and 15 days after corn planting) and the third factor was three berseem clover interseeding rates (0, 20 and 40 kg ha- 1). Dominant weed species were *Amaranthus retroflexus* L. (redroot amaranth), *Chenopodium album* L. (lamb's quarters), *Xanthium strumarium* L. (cocklebur), *Sorghum halepense* L. (johnson grass) and *Purtulaca oleracea* L. (common purslane), which are common weed species in corn fields in the region. In the weed-free plots, manual weeding was carried out throughout the growing season. Each plot consisted of six corn rows of 6 m length, with a row spacing of 75 cm and with 20 cm between plants in the same row. Berseem clover was manually broadcasted over the plots at the predetermined seeding rates and times.

At maturity the corn plants which were located 5 m from the two center rows of each plot were harvested manually, allowed to dry to a constant weight then threshed and cleaned. 100- seed weight (SW) was measured according to the recommendation of the International Seed Testing Association (ISTA) [7]. To evaluate seed germination and vigour, four replicates of twenty five seeds of each plot were placed in sterilized petri dishes containing two layers of filter papers (Whatman # 41). The petri dishes were moistened with distilled water and then were placed in a germinator at 20±1°C. Seed germination was recorded daily up to day 7 after the start of the experiment. A seed was considered germinated when radicle emerged by about 2 mm in length. Then the mean germination rate (MGR) was calculated according to the following equation [8]:

$$MGR = \Sigma n / \Sigma Dn$$

Where MGR is the mean germination rate, n is the number of seeds germinated on day and D is the number of days from the start of test.

Moreover, seed germination percentage (SGP) was recorded in the end of test. To determine radicle dry weight (RDW) and plumule dry weight (PDW), after the 7th day, normal radicles and plumules produced in each petri dish were separated from the seeds, then dried at 70°C to the constant weights and weighed. Seedling vigour index (SVI) was calculated by multiplying the germination percentage with seedling length and then divided by 100 [1]. Seed protein content (SPC) was determined by multiplying total nitrogen content with factor 6.25 (AOAC 2000). Total nitrogen content was determined by the micro-Kjeldahl method. The data analyses were carried out by using SAS software [23].

Results and discussion

According to analysis of variance (data not shown) all of the studied traits including 100-seed weight (SW), seed germination percentage (SGP), mean germination rate (MGR), radicle dry weight (RDW), plumule dry weight (PDW), seedling vigour index (SVI) and seed protein content (SPC) were significantly affected by the weed treatments (at the 0.01 level of probability). Moreover, there was a significant three-way interaction (weed treatment × berseem clover interseeding time × berseem clover interseeding rate) for the traits under study with the exception of SGP and SPC. However, a significant two-way interaction (weed treatment × berseem clover interseeding time) was observed for SPC.

Weed interference for all of the growing season decreased SW, SGP, MGR, RDW, PDW, SVI and

SPC of the produced seeds by 21.0, 14.2, 10.5, 33.7, 32.2, 40.6 and 9.7% respectively, when compared with the entire weed free condition (Table 1). This can be explained by the weed-crop competition to obtain the environmental resources such as light, water and nutrients. Vieira *et al*. [26] suggested that environmental stresses such as drought and lack of fertilization reduced subsequent seed germination of soybean. In another study, wild mustard interference reduced seed protein content in wheat [6]. This reduction was attributed to wild mustard competing with wheat for available nitrogen.

Table 1: Means comparison of the weed treatment effects on the traits under study.

Weed treatment	SW (g)	SGP	MGR (per day)	RDW (mg)	PDW (mg)	SVI	SPC (%)
WI	26.15 b	83.19 b	0.27 b	33.06 b	38.32 b	9.63 b	7.75 b
WF	33.12 a	96.94 a	0.30 a	49.85 a	56.50 a	16.20 a	8.58 a

Dissimilar letters in each column indicate a significant difference at the 0.05 level of probability (Duncan test).
Abbreviations: WI and WF: weedy and weed free for the entire growing season, respectively; SW: 100-seed weight; SGP: seed germination percentage; MGR; mean germination rate; RDW: radicle dry weight; PDW: plumule dry weight; SVI: seedling vigour index; SPC: seed protein content.

In general, there are decreases in vigour and quality for the seeds developing in stress conditions and weed interference can impose multiple stresses (light, water and nutrients limitations as well as allelopathic effect) on the crop. Similar results were obtained by Saayman and Van De Venter [22] who reported that both germination and vigour of corn seeds decreased with an increase in weed density. They also observed an increase in the mean time to corn seedling emergence with an increase in weed density indicating reduced seed vigour.

In weed free condition, berseem clover interseeded at different rates or times didn’t significantly influence SW, MGR, RDW, PDW and SVI as compared with the weed free control treatment (the weed free plot in which no living mulch was interseeded) (Table 2). In other words, interseeding of the living mulch at different rates or times had no notable positive or negative effect on these traits when the field was kept free of weeds for the entire growing season. This can be due to the lack of a severe competition between berseem clover and corn especially during the seed development stage of corn. In general, corn is a highstature and C4 crop vs. berseem clover which is a C3 legume with nitrogen fixing ability and a lower stature. Therefore, the absence of a strong competition between these crops particularly after corn tasselling stage is commonly expected.

Although, full season weedy condition significantly reduced corn seed vigour and quality, but in this condition the earlier interseeding of the living mulch (15 days before corn planting) notably improved SW, MGR, RDW, PDW and SVI when compared with the weedy control treatment (the weedy plot in which no living mulch was interseeded) (Table 2). It may be due to the sooner establishment of berseem clover and consequently more efficient competition with the emerging weeds. It seems when the field is kept un-weeded for the entire growing season, the earlier establishment of living mulches can enhance their suppressive effects on weeds and subsequently reduce the harmful effects of weeds on the main crop during seed development stage. In general, living mulches can suppress weeds by competing for light [25], water and nutrients [14], as well as through the production of allelopathic compounds [29] and the interseeding time of a living mulch is an important factor which determines its suppressive ability against weeds. Moreover, in weedy condition, increasing berseem clover interseeding rate from 20 to 40 kg ha-1 slightly enhanced the studied traits but in most cases this enhancement was not statistically significant (Table 2). It seems that in weedy condition interseeding time of the living mulch had more obvious effect on the traits as compared with its interseeding rate. However, in weed free condition the evaluated traits were not significantly influenced by different berseem clover interseeding rates or times (Table 2).

Seed protein content was also significantly affected by weed treatment × berseem clover interseeding time interaction. In weed free condition, different berseem clover treatments had no significant effect on SPC (Fig. 1). Full season weedy condition notably decreased SPC. However, in this condition, SPC was significantly higher when berseem clover was interseeded 15 days before corn planting as compared with other two interseeding times (Fig. 1). This was probably due to the higher weed suppressive effect of the living mulch at the earliest interseeding time. In general, nitrogen is a substantial element of the protein structure and weeds severely compete with corn to obtain this element. Therefore, the reduced SPC in weedy condition is usually expected. Similar results were reported by Manthey *et al.* [13] and Burrows and Olsen [6]. However, in weed free condition the interseeded living mulch didn’t significantly influence SPC. This can be explained by the atmospheric nitrogen fixing ability of berseem clover and consequently the absence of a competition between this living mulch and corn for nitrogen.

Generally, in this study the variation in seed weight was according to the variations in the evaluated traits. This was supported by the positive and significant correlations between SW and other traits under study (Table 3). It means that the reduction of seed weight by the environmental factors such as weed can depress seed vigour and quality indices. Perry [18] found that different sizes of seeds having different levels of food storage may be the important factor which influences seed vigour. Vieira *et al*. [26] also reported that when stress was intense enough to cause underdeveloped and wrinkled seeds a reduction in seed vigour was evident.

Table 2: Means comparison of the weed treatment × berseem clover interseeding rate ×berseem clover interseeding time interaction for the traits under study.

Treatment	SW(g)	MGR (per day)	RDW (mg)	PDW (mg)	SVI
WF0 (weedy control)	24.84 cd	0.268 cde	29.87 c	34.86 c	9.36 d
WID1T1	28.94 b	0.263 de	45.7 a	52.00 a	13.03 c
WID1T2	24.10 d	0.255 e	26.97 c	31.71 c	8.38 de
WID1T3	26.61 c	0.261 de	25.18 c	29.78 c	7.19 e
WID2T1	29.40 b	0.271 bcde	47.65 a	54.12 a	13.30 c
WID2T2	26.40 c	0.263 de	36.81 b	42.38 b	9.73 d
WID2T3	25.36 cd	0.267 cde	25.64 c	30.28 c	6.91 e
WI0 (weed free control)	32.90 a	0.295abc	49.67a	56.31 a	17.15 a
WFD1T1	32.03 a	0.289 abcd	49.03 a	55.62 a	15.72 ab
WFD1T2	32.62 a	0.306 a	46.94 a	53.35 a	15.78 ab
WFD1T3	33.67 a	0.282 abcde	49.15 a	55.74 a	15.78 ab
WFD2T1	32.90 a	0.297 ab	51.66 a	55.47 a	15.10 abc
WFD2T2	33.09 a	0.303 a	49.65 a	56.27 a	16.32 ab
WFD2T3	34.10 a	0.305 a	53.24 a	60.17 a	16.59 ab

Dissimilar letters in each column indicate a significant difference at the 0.05 level of probability (Duncan test).
Abbreviations: WI and WF: weedy and weed free for the entire growing season, respectively; D1 and D2: berseem clover interseeded at 20 and 40 kg ha-1, respectively; T1, T2 and T3: berseem clover interseeded 15 days before, simultaneous with and 15 days after corn planting, respectively SW: 100-seed weight; MGR; mean germination rate; RDW: radicle dry weight; PDW: plumule dry weight; SVI: seedling vigour index.

Table 3: Correlation coefficients between the traits under study.

	SW	SGP	MGR	RDW	PDW	SVI	SPC
SW	1						
SGP	0.72 **	1					
MGR	0.64 **	0.84 **	1				
RDW	0.82 **	0.78 **	0.80 **	1			
PDW	0.82 **	0.70 **	0.78 **	0.98 **	1		
SVI	0.86 **	0.89 **	0.86 **	0.96 **	0.91 **	1	
SPC	0.75 **	0.64 **	0.52 **	0.71 **	0.71 **	0.72 **	1

**: Significant at the 0.01 level of probability.
Abbreviations: SW: 100-seed weight; SGP: seed germination percentage; MGR; mean germination rate; RDW: radicle dry weight; PDW: plumule dry weight; SVI: seedling vigour index; SPC: seed protein content

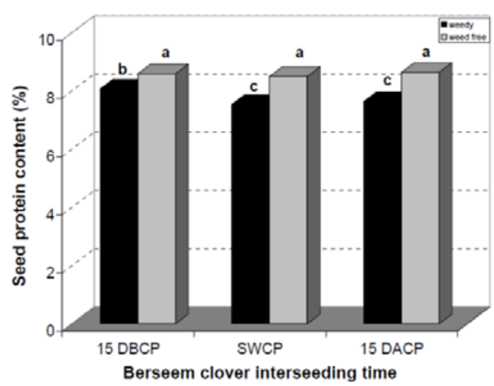

Fig. 1: Corn seed protein content under different weed treatments and berseem clover interseeding times. Abbreviations: DBCP days before corn planting; SWCP: simultaneous with corn planting; DACP: days after corn planting

Conclusion:

The results of the present study revealed that weed interference for the entire growing season significantly decreased seed vigour and quality indices of corn. The living mulch interseeded at different rates or times didn't notably influence the traits under study when the field was kept free of weeds for the entire growing season. However, in weedy condition, corn seed vigour and quality indices were significantly higher when the living mulch was interseeded 15 days before corn planting as compared with other two interseeding times. This was probably due to the higher suppressive effect of berseem clover on the weeds and consequently the reduced harmful effects of the weeds on corn during seed development stage. Moreover, the variation in seed weight was compatible with the variations in the seed vigour and quality indices. It can be concluded that the environmental factors may influence corn seed vigour and quality via affecting the seed weight.

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