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Responses of Corn to Plant Density and Weed Interference Period

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Abstract: Studies have shown there are major advantages to increasing crop density in integrated weed management programs. Research was conducted in Zanjan University research fields to evaluate the effect of weed interference period and crop density on corn yield and yield components (Rows per ear, Kernels per ear and 1000-grain weight). The experimental design was a randomized complete block design with a factorial arrangement replicated three times. The treatments were six periods of weed interference (0, 48, 62, 76, 90, 120 d after sowing) and two crop densities (7, 9 plants m^{-2}). Results showed that crop density had a significant effect on kernels per ear and grain yield ($p < 0.01$). Mean comparisons showed that increasing crop density increased grain yield from 7107.5 to 8511.5 kg ha^{-1} and this factor decreased the number of Kernels per ear significantly. Increasing weed interference period decreased grain yield and yield components. The highest grain yield was recorded for the whole-season weed-free treatment; the lowest grain yield was found for the whole-season weed-infested treatment. The effect of weed interference period on corn grain yield was higher at low than at high corn density. Yield of the corn was reduced more by low plant density and weed interference period than high corn density. The critical time of weed removal ranged from 21 to 19 day after planting for 7 and 9 plants m^{-2} respectively to prevent yield losses of 5%. Consequently, selection of corn density and a suitable time for removing weeds should be an integral part in the design of a weed management system.

Key words: Weed · Weed management · Grain yield · Yield components · Crop density

INTRODUCTION

Corn (*Zea mays* L.) is an important cereal crop globally after wheat and rice. It is a major source of food for humans and the leaves are components of animal feed and a source of income for farmers. Corn is also an important crop in Iran, where it is grown for human and animal consumption [1]. Weeds are critical factors affecting corn production in Iran [2]. Isik *et al.,* (2006) found that weeds cause an average yield loss worldwide of 12.8% where weed control is applied and 29.2% where no weed control is used. Water, nutrition and light are three factors affecting competition [3]. Crop yield decreases significantly upon weed interference; therefore, effective weed management depends on knowledge about the effect of competition on yield and yield components [4]. The response of yield and yield components to weed competition varies by crop species during the growth period. It is important to understand that yield loss is related to weed species and weed threshold can be used to optimize the economics of weed management. Plant density per unit area is an important yield determinant. Plant density is an efficient management tool for maximizing grain yield by increasing the capture of solar radiation within the canopy [5], which can significantly affect development of crop-weed association [6].[7] reported that the yield and yield components of corn are significantly affected by planting pattern, plant density and maize hybrid. The growth parameters of maize are those that are most affected, even under optimal growth conditions and are considered as major factors for determining the degree of competition between plants [8]. The objective of the present study was to evaluate the effect of weed interference periods and plant density on the yield and yield components of corn.

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MATERIALS AND METHODS

To study how weed interference periods and plant density effects the yield and yield components of corn, an experiment was carried out in the Zanjan University research fields. The soil texture was sandy loam with a PH of 8.18 and 1.21% organic matter. The land was prepared by first plowing in autumn and then disking before sowing. Soil analysis determined the amount of N, K and P fertilizers that were implemented. No pre-emergence or pre-plant herbicides were used. The corn cultivar used was Maxima (a common cultivar for the region). Corn seeds were inoculated with carboxin thiram prior to sowing, which was done on 29 May 2010. Corn is a summer irrigated crop in northwestern Iran; therefore, it is not dependent on seasonal rainfall. The seeds were covered with soft soil and irrigated using the traditional furrow method. Subsequent irrigation was conducted at 7-day intervals up to the grain harvest stage. The experimental design was a randomized complete block design with a factorial arrangement replicated three times. The first factor was six periods of weed interference (0, 48, 62, 76, 90, 120 d after sowing). Weed removal within and between the plant rows was carried out manually for each treatment. The second factor was plant density; low plant density was considered to be 7 plants m^{-2} and high plant density was 9 plants m^{-2}. In this case; the distance between plants in each row was 19 for low plant density and 14.8 cm for high plant density. There were 36 experimental plots and the area of each plot was 15 m^2. Each plot consisted of 5 planting rows 5 m in length. Ten plants (7 plants m^{-2}) and 14 plants (9 plants m^{-2}) were randomly selected from each plot for harvesting and the moisture content was adjusted to 14%. The following traits were statistically analyzed: grain yield, number of rows per ear, number of kernels per ear, thousand kernel weight, harvest index, ear diameter and ear length. The following equation was fitted to describe the effect of increasing the duration of weed interference and plant density on corn yield:

$$Y = y_0 + a\,(1/(1+\exp(-(x-x_0)/-b)))$$

where, Y is the maximum grain yield, A is the difference between maximum and minimum corn yield, b determines the shape of the curve, x is the time, x_0 is the length of the growth seson to achieve 50% dry matter and y_0 is minimum corn yield. All data were subjected to analysis of variance (ANOVA) with SAS. The means were separated using Duncan's multiple range test.

RESULTS AND DISCUSSION

Grain Yield: Grain yield is the main target of crop production. The results of ANOVA (Table 1) showed a significant effect for weed interference period and plant density on grain yield ($p < 0.01$). The grain yield varied from 7107.5 kg ha^{-1} for low plant density and 8511.5 kg ha^{-1} for high plant density (Table 2). High plant density decreased the dry weight of the weeds (especially noxious weeds) and increased competition with corn for light, water and minerals consumed and increased grain yield. Suitable plant density increased economic yield and prevented the growth of other plants (weeds). [9] found that grain yield increased as density increased up to 9 plants m^{-2} and decreased at higher plant densities. It is well known that higher crop density limits the competitive effects of weeds [10]. [11] indicated that the growth of Agrostemma githago was strongly dependent on barley density. They concluded that crop density was more important for controlling weed growth than for obtaining normal grain yield. Grain yield decreased as the weed interference period increased. Decreased grain yield caused by increasing the length of the weed interference period was accompanied by concurrent reductions in the number of rows per ear, number of kernels per ear, ear diameter, ear length and thousand kernel weight. The highest yield was obtained for the full-season weed-free treatment (11498.1) and the greatest decrease in grain was shown for the full-season weed interference (4891) (Table 2). There was a significant difference between weed interference periods 48 d and 62 d in comparison with 76 d and 90 d after sowing (Table 2). Weed interference on grain yield began at 48 and 62 d after sowing and caused a decrease in grain yield of 20% and 28%, respectively; it became a strong

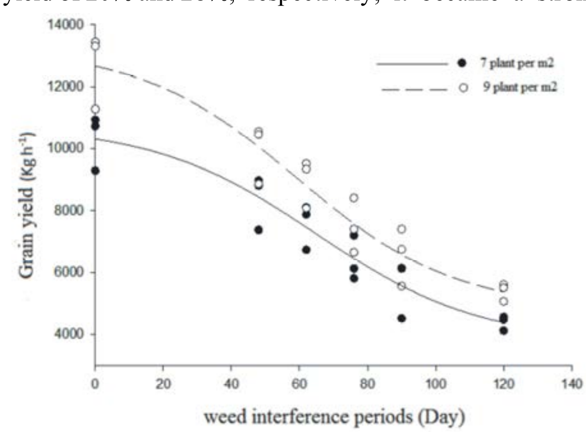

Fig. 1: Effect of weed interference period from 0 to 120 days after sowing and plant density on grain yield of corn

Table 1: analysis of variance for the Effect of weed interference period and crop density on evaluated traits in corn

	Mean of squares						
S.O.V.	Grain yield	Rows per ear	Kernels per ear	Harvest index	Ear length	1000-grain weight	Ear diameter
Density (D)	17742393.6**	52.837^{ns}	8326.8**	0.191^{ns}	6.304^{ns}	468.4^{ns}	4.1215^{ns}
Weed interference periods(W)	33533354**	116.083**	28399.4**	37.934**	20.056**	2796.4**	14.1645**
W×D	410495.9^{ns}	15.261^{ns}	1725.6^{ns}	11.828^{ns}	1.626^{ns}	185.9^{ns}	1.7131^{ns}
Error	704863.4	13.465	848.1	8.298	1.901	249.8	1.3639408
CV (%)	10.75	10.36	7.28	5.59	7.90	5.87	3.12

* And ** show significant differences at 0.05 and 0.01 probability level respectively

Table 2: mean comparison of studied characteristics of corn in different treatment

Treatment	Grain yield(kg ha^{-1})	Rows per ear	Kernels per ear	Harvest index (%)	Ear length(cm)	1000-grain weight	Ear diameter (mm)
			Density (plant m^{-2})				
7	7107.5^{b}	36.62^{a}	415.325^{a}	44.806^{a}	17.865^{a}	265.77^{a}	37.73^{a}
9	8511.5^{a}	34.197^{a}	384.908^{b}	44.952^{a}	17.029^{a}	272.984^{a}	37.054^{a}
			weed interference periods				
0	11498.1^{a}	42.258^{a}	498.99^{a}	42.516^{b}	20.182^{a}	309.18^{a}	39.54^{a}
48	9172^{b}	37.435^{b}	436.52^{b}	42.439^{b}	18.281^{b}	271.49^{b}	37.619^{b}
62	8277.7^{b}	35.723^{b}	421.16^{bc}	43.217^{b}	17.547^{b}	269.54^{b}	37.78^{b}
76	6935^{c}	34.353^{b}	391.23^{c}	45.565^{ab}	17.242^{b}	261.47^{bc}	37.885^{b}
90	6083.1^{c}	33.727^{b}	350.65^{d}	47.516^{a}	16.83^{b}	259.13^{bc}	36.612^{b}
120	4891^{d}	28.953^{c}	302.15^{e}	48.024^{a}	14.6^{c}	245.43^{c}	34.915^{c}

Mean with the same letters are not significantly difference at the 0.05 probability level according to duncans multiple test.

inhibitor of yield after 76 and 90 d, decreasing height 39% and 47%, respectively. The fitted regression function for grain yield by weed interference period and plant density is shown in Fig. 1. In the full-season weed-interference and high plant density treatment, weed density decreased and resulted in greater grain yield for high plant density than for the low plant density treatment. When a yield loss of 5% was acceptable, the weed free period ranged from 21 to 19 day after planting for 7 and 9 plants m^{-2} respectively (Fig. 1).

Yield Components: The number of ears per plant was not affected by plant density or weed interference period (Table 1). These findings are in agreement with those reported by [12, 13], who reported that the number of ears per plant was not significantly affected by plant density.

Weed interference period had a significant effect ($p < 0.01$) on the number of rows per ear, but plant density had no significant effect (Table 1). The number of rows per ear decreased as the weed interference period increased. It can be clearly seen that the greatest number of rows per ear were obtained for the full-season weed-free treatment and the lowest number of rows per ear were found for the full-season weed-interference treatment. There was no significant difference for the other levels of weed interference (48, 62, 76, 90 d after sowing).

Plant density and weed interference period had a significant effect ($p < 0.01$) on the number of kernels per ear (Table 1). This is one of the most influential criteria for total grain yield and the results showed that this criterion was strongly influenced by weed interference. The largest decrease in the number of kernels per ear was found for the full-season weed-interference treatment (302.15) compared to the full-season weed-free treatment (498.99). The number of kernels per ear decreased as the delay to weed removal increased. There was a significant difference between the other levels of weed interference (48, 62, 76, 90 d after sowing). These results are in accordance with the findings of [14]. For planting density, the maximum number of kernels per ear was recorded for the low plant density treatment (415.3) and the minimum was recorded for the high density treatment (384.908). The number of kernels per ear increased as plant density decreased. The decrease in the number of kernels per ear at the highest plant density (384.908) may have resulted from fewer flowers being formed initially, poor pollination resulting from asynchrony of tasseling and silking and the abortion of kernels after fertilization [15, 16]. The results of this study are in agreement with those obtained by [17, 18] who reported that the number of kernels per ear decreased as plant density increased.

Thousand kernel weight (TKW) is an important yield component for cereals and decreased ($p < 0.01$) as weed interference increased, but the effect of plant density on

TKW was not significant. Table 1 shows the effect of weed interference period and plant density on TKW. Maximum TKW was obtained for the full-season weed-free treatment and the lowest TKW was obtained for the full-season weed-interference treatment. A 20% reduction in TKW for corn was recorded for full-season weed-interference treatment in comparison with the weed-free treatment (Table 2). The same results were obtained by [19].

The physiological efficiency and ability of a crop to convert the total DM into economic yield is known as the harvest index (HI). The effect of plant density on HI was not significant, but the weed interference period had a significant effect ($p < 0.01$). As seen, increasing the weed interference period increased HI significantly. HI increased by almost 11% for the full-season weed-interference treatment.

Plant density had no significant effect on ear diameter, but weed interference period was highly significant (Table 1). Ear diameter may be more affected by genetic components. As the period of weed interference increased, ear diameter decreased (Table 2). The largest ear diameter was obtained for the full-season weed-interference treatment; there was no significant difference for the other levels of weed interference (48, 62, 76, 90 ds after sowing). This result is confirmed by the findings of [20].

The weed-interference period had a highly significant effect on ear length (Table 1), but plant density had no significant effect. [20] showed that ear length decreased in competition with chenopodium album, which is in accordance with this the results of this study.

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