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FULL LENGTH ARTICLE

Effects of cover crops and weed management on corn yield

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Abstract One of the most important replacement methods used instead of chemical herbicide and conventional tillage is cover and companion crops' application which is a major factor in sustainable agriculture. In order to determine the best cover crop in controlling weeds of corn field and its further effects on corn yield, an experiment was carried out in a factorial arrangement based on RCB design with three replicates. The treatments of this experiment included companion crops (clover, hairy vetch, basil and dill) as first factor and time of sowing cover and medicinal plant (synchronic sowing with corn and sowing 15 days after corn sowing) as second factor. The results showed that ear weight, ear length, leaf weight, grain length and yield were significantly influenced by companion crops and sowing date. Whereas, weed biomass was influenced by cover crop type × sowing date interaction. Also, the results indicated that increasing biomass weed resulted in linear reduction of grain yield. The highest ear weight, ear length, leaf weight, grain length and yield were obtained for cultivation of clover with corn. Synchronic cultivation of companion crops with corn had higher grain length and yield compared with cultivation 15 days after corn. The lowest weed biomass was recorded for concurrent cultivation of corn with clover due to rapid growth and high competitive power of clover in the early stage of growth.

1. Introduction

Corn is C_4 plant and high production of grain and biomass to feed has increased areas under this crop in many developing countries. Improper and overuse of chemical herbicides may lead to problems such as: herbicides remain in soil, resistance of weeds to them and groundwater pollution. Studies showed that about 25–30 annual and perennial weed species grow in corn field (Evans et al., 2003).

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Crop yield loss could be caused in high extent by increase in the weed biomass, weed density and weed species (Blackshaw et al., 2002). Weeds are one of the greatest limiting factors to efficient crop production. As a consequence of structural and financing problems the cultural condition of the soil deteriorates and weeds proliferate; many species are hard to kill (Farkas, 2006). Weed infestation, results in severe reduction in crop yield as in the condition of pure corn culture, corn losses of 40–60% have been reported (Thobatsi, 2009).

Today weed control is performed by a very advanced technology and knowledge control operations properly require thorough knowledge of plants, soil crop management system and many environmental parameters associated with weed control operations (Bolandi Amoghein et al., 2013). A factor that is currently used as an index for evaluation of crop management in each country or even each field is the amount of attention on weed management. Choice of this index is for reason that in the case of the absence of a correct management damage caused by these weeds is more than the damage caused by infestation and disease (Gupta, 2006).

Environmental pollution and contamination of surface water and groundwater by herbicides is one of the most important human concerns (Abdin et al., 2000). The most commonly used alternative methods rather than herbicides and plowed, are cover crops. There is a wide agreement in the literature that vigorous living cover crops will suppress weeds growing at the same time as the cover crop (Brennan and Smith, 2005). Cover crops can prevent the development of weed population, control the soil disease, soil enrichment through nitrogen fixation in soil, improve soil structure, preventing absorption of nitrogen, increase the soil organic matter and decrease the soil, for these reasons they are cultivated (Kruidhof et al., 2008). A legume cover crop, such as common vetch, can supply most of N required for maximum maize yield (Clark et al., 1997; Bayer et al., 2000). In addition, vetch can improve soil water quality compared with bare fallow by reducing erosion during fall, winter, spring, and increasing organic matter (Sainju and Singh, 1997). Therefore, the objective of this research is to investigate the effects of companion crops on weed control and corn yield in the Tabriz climatic condition.

2. Materials and methods

This research was conducted in 2010 at the Research Farm of the University of Tabriz, Iran (latitude 38°05′N, longitude 46°17′E, altitude 1360 m above sea level). The climate of research area is characterized by mean annual precipitation of 271.3 mm, mean annual temperature of 10 °C, mean annual maximum temperature of 16 °C and mean annual minimum temperature of 2.2 °C. The soil is sandy loam with EC of 0.68 ds m^{-1}, pH of 8.1 and field capacity of 28.8%. Treatments including companion crops (synchronic sowing of corn–red clover, synchronic sowing of the corn–vetch, synchronic sowing of corn–basil, and synchronic sowing of corn–dill) and sowing date (T_1: synchronic sowing of cover crops with corn and T_2: sowing cover crops 15 days after planting of corn) were allocated in plots as a factorial based on RCB design with 3 replications. Each plot consisted of 10 rows with 4 m length, spaced 25 cm apart. In each plot one row of corn was planted with one of companion crops in the specified sowing date. Density of corn, red clover, vetch, basil and dill, were 8, 100, 75, 38 and 30 plants per m^2, respectively.

Dry weight of ear, ear length, leaf weight, grain length, grain yield and weed biomass were recorded. Ear length and weight were measured at the time of maximum ear delivery (shortly after pollination). At maturity, when seed moisture content was about 14%, plants from two middle rows in each plot were harvested and grain yield of corn was counted and subsequently biomass of common weeds in corn field including *Amaranthus retroflexeus*, *Convolvulus arvensis*, *Acroptilon repens*, and *Cuscuta* Sp was calculated by randomly sampling on 0.5×0.5 m^2 in each plot.

Statistical analysis was performed with MSTATC and SPSS software and Excel software was used to draw the figures. Duncan test was applied to compare means of each trait at 5% probability.

3. Results and discussion

3.1. Weed biomass

The analysis of variance of data showed significant effects of companion crops and sowing date on weed biomass. The interaction of companion crops × sowing date was also significant for this trait (Table 1). The lowest and the highest weed biomasses were achieved with corn planting simultaneously with clover (13.75 g m^{-2}) and planting of dill 15 days after corn (60.2 g m^{-2}), respectively. Delayed planting of cover crops in corn field resulted in increasing weed biomass (Fig. 1). Forage plants such as clover and vetch due to rapid establishment and growth capacity in field compared with medicinal plants such as basil and dill are more suitable and effective for weed control. In fact, medicinal plants due to low growth rate and establishment especially in early growing season cannot compete with weeds as well as forage plants. Increasing weed biomass also resulted in linear reduction of corn grain yield

Table 1 Analysis of variance of the data of corn plants under treatments.

S.O.V.	MS						
	df	Weed biomass	Seed length	Leaf weight	Ear length	Ear weigh	Grain yield
Replication	2	59.16^{ns}	0.082^{ns}	215.96^{**}	3.65^{**}	0.053^{ns}	171.22^{ns}
Companion crops	3	1516.01^{**}	0.44^{**}	1305.12^{**}	24.81^{**}	11.2^{**}	11705.4^{**}
Sowing date	1	178.89^{**}	0.54^{**}	507.84^{**}	6.01^{**}	0.33	7518.25^{**}
Sowing date × companion crops	3	125.41^{*}	0.70^{ns}	45.35^{ns}	0.668^{ns}	0.077^{ns}	4.56^{ns}
Error	14	37.38	0.20	4.44	0.413	0.62	35,202
C.V. (%)	–	17.6	3.7	1.2	2.2	2.7	5.4

ns, *,**: non-significant and significant at $p \leqslant 0.05$ and $p \leqslant 0.01$, respectively.

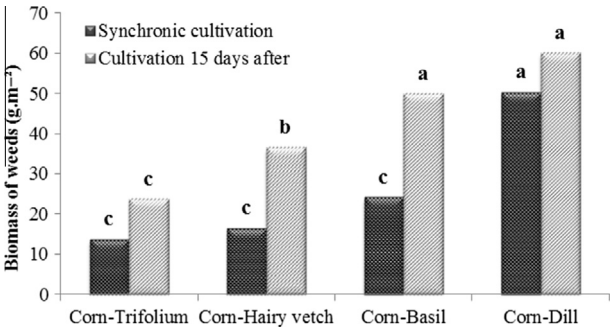

Figure 1 Mean comparison of interaction effects of companion crops × sowing date on biomass of weeds. Means, for each planting date, followed by similar letter are not significantly different at the 5% probability level using Duncan's Multiple Range Test.

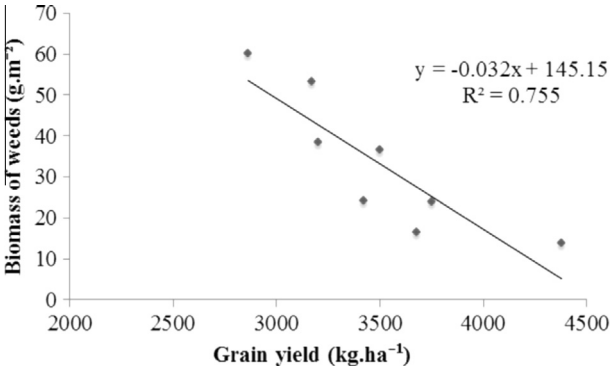

Figure 2 Corn grain yield affected by weed-infested.

(Fig. 2). Density and biomass of weeds in mixed culture systems diminished significantly compared with single culturing of each component of a mixture (Banik et al., 2006). Cover crop can affect weed establishment through effects on the radiation and chemical environment of weed and inhibit weed emergence by physically impeding the progress of seedlings from accessing light (Teadale and Mohler, 2000) as well as by releasing phytotoxins that inhibit seedling growth (Blackshaw et al., 2001).

3.2. Seed length

The effects of companion crops and sowing date on seed length were significant. However, interaction of companion crops × sowing date had no significant effect on seed length (Table 1). The highest and the lowest seed lengths were recorded for corn–clover and corn–dill, respectively (Table 2). Seed length of corn plants which were grown under T_1 was considerably higher than that under delayed planting of cover crops (Table 2). Delayed flowering, reduction of leaves number and plant length and deduction of flowering period due to weed-infested treatments resulted in 100 seeds weight and seed size deduction. (Noormohammadi and Siyadat, 2001).

3.3. Leaf weight

The analysis of variance of the data showed significant effects of companion crops and sowing date on leaf length. The interaction of companion crops × sowing date was also significant for this trait (Table 1). The highest (306.5 g) and the lowest (207.2 g) leaf weights were obtained for corn planting with clover at the same time and dill planting 15 days after corn, respectively (Table 2). Synchronic planting also resulted in more yield of corn leaves compared with planting cover crops 15 days after corn (Table 2). Mahmoodi, 2003 reported that the presence of weeds caused weight loss of corn leaves.

3.4. Ear length

The results showed that the ear length was significantly affected by companion crop's type and sowing date. However, the interaction of these variables was not significant (Table 1). Corn-clover intercropping had the highest mean of ear length (32.02 cm) and corn-dill had the lowest mean of ear length (27.43 cm). The highest ear length was recorded for simultaneous planting (Table 2).

3.5. Ear weight

Companion crops and sowing date had significant effects on ear weight. However, interaction of companion crops × sowing date was not statistically significant (Table 1). There was significant difference between different planting times of compan-

Table 2 Means of some physiological and morphological parameters of corn affected by cover crops and sowing date.

Treatments	Seed length (mm)	Leaf weight (g)	Ear length (cm)	Ear weight (g)	Grain yield (kg/ha)
Companion crops					
Corn–Clover	12.57^{a}	306.5^{a}	32.02^{a}	22.18^{a}	4062.9^{a}
Corn–Vetch	12.23^{b}	277.4^{b}	29.62^{b}	21.46^{b}	3690.6^{b}
Corn–Basil	12.03^{bc}	263.3^{b}	28.1^{c}	23.27^{b}	3291.7^{c}
Corn–Dill	11.93^{c}	207.2^{c}	27.43^{c}	20.75^{c}	3034.2^{d}
Sowing date					
T_1	12.27^{a}	289.5^{a}	29.57^{a}	23.53^{a}	3671.3^{a}
T_2	12.14^{b}	229.3^{b}	29.01^{b}	23.30^{b}	3317.8^{b}

a and b are signs for Duncan test.
Different letters at each column indicate significant difference at $p \leqslant 0.05$.
T_1 and T_2: synchronic planting and 15 days after sowing corn.

ion crops (Table 2) a significant difference between companion crops was observed, as the highest and lowest ear weights were observed in corn treatment with clover by a mean of 23.18 g and corn with dill by a mean of 20.57 g, respectively, that is due to reduction of weeds by clover and consequently reduction of competition between corn plants so the ear weight was the highest among others.

3.6. Grain yield

The results of the analysis showed that companion crops and different planting dates (synchronic and 15 days after corn planting) had significant effects on the corn grain yield (Table 1). The highest and the lowest grain yields were obtained from corn growing with clover (4062.9 kg/ha) and with dill (3034.2 kg/ha), respectively (Table 2). Cover crops intercropped with crops can improve soil nitrogen status (Chalk, 1998) when reducing tillage with crop residue retention conserved soil moisture and increased crop yields (Kue and Jellum, 2002). Also corn grain yield under synchronic planting was more than that under planting of companion crops 15 days after corn (Table 2). Earlier emergence and growth of weeds in field could diminish corn yield due to better utilization of weeds from environmental resources and higher density (Cavero et al., 1999).

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