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Effects of Interseeding Cover Crops and Split Nitrogen Application on Weed Suppression in Forage Maize

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Abstract

Weeds are one of the major threats for crop production. Interseeding cover crops is an alternative to laborious intertillages and hand weeding. The objective of this study was to evaluate the effect of fertilization and interseeding cover crops on the yield of forage maize, number and dry weight of weeds. Three cover crops, fall rye (*Secale cereale* L.), hairy vetch (*Vicia villosa* L.) and berseem clover (*Trifolium alexandrinum* L.), were interseeded in maize furrows (Zea mays L.). Nitrogen fertilizer timing was consisting of two levels including, the first level (N_1= ½ at planting time + ½ in the 8 to 10 leaf stage of maize) and the second level (N_2= $^1/_3$ at planting time + $^1/_3$ in the 8 to 10 leaf +$^1/_3$ a week before tasseling. The number and dry weight of weeds and main crop yield were recorded at dough stage of main crop. The results showed that weeds growth was suppressed significantly by interseeding cover crops through increasing the soil covered area by main crop and cover crops also and high biomass production by cover crops. In addition, application of nitrogen fertilizer had positive effects on the main crop yield and weed suppression. Therefore, it is concluded, that weeds can be suppressed effectively by interseeding cover crops with sufficient fertilization.

Keywords: Cover, crops, interseeding, forage, maize, nitrogen, weed, suppression

1. Introduction

The risk of weeds not only reduces the main crops yield but also decreases their commercial quality and feeding palatability [34]. To date, weed management is primarily focused on curative control, since herbicides are highly effective and relatively cheap [18]. Increasing concerns regarding the negative side effects of herbicides on the environment and the growing interest in organic agriculture have, led to a growing demand for alternative weed control methods [4]. The intensive use of a limited number of herbicides creates a situation where herbicide resistance is more likely to develop [11]. This is another reason why there is an increasing need for knowledge on the design and functioning of cropping systems that rely on less extent of chemical inputs. Fertilization and weed control are crucial production issues in organic herbage cropping systems [15]. Weed control requires a complex approach to integrate the effect of different direct and indirect partially suppressive means [2;17]. Fertilization and weed control are closely related, as good crop nutrition and effective weed control enhance each other [22].

Farmers choose the kinds of cover crops on the basis of their needs and goals, influenced by biological, social, cultural and economic factors [27]. Cover crop is often referred to an interesting option, apart from weed suppression, and cover crop species reduce disease related to crop [13; 12] and soil erosion [35]. According to Teasdale et al. [29], cover crops improve the soil structure, increase its organic material and improve water infiltration. It also suppresses weeds growth by creating a physical barrier to growth and a change in microclimatic conditions [30].

Cover crops are grown primarily to produce large amounts of biomass and provide soil cover; they are not grown for market purposes [10]. It has mainly been used because of its rapid growth, high biomass production and weed control potential [37; 26]. Other effects of cover crops through rapid occupation of the open space between the rows of the main crop, which

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prevents germination of weed seeds and reduces the growth and development of weed seedlings. Germination of weed seeds may be inhibited by complete light interception [15] by the cover crop or by secretion of allelochemicals [36; 21]. After establishment of weed seedlings, resource competition becomes the main weed suppressing mechanism of the cover crop [28].

Cover crops can behave like weeds if not be managed well, by depleting inherent moisture and nutrient reserves and reducing yield of the following crop as noted by [25].

The two major requirements of a cover crop which is added to a main crop in order to improving weed management are: (i) providing a sufficient level of weed suppression and (ii) not having a too strong negative effect on the growth of the main crop. In other hand, selecting a cover crop species means searching for the plant with the best trade-off between competition against weeds and competition with the cultivated crop [9; 8; 24].

Cover crop species and/or cultivar is one of the important cover crop's features. Uchino et al. [33] compared the effectiveness of nine cover crop species for weed suppression. They reported that fall rye (*Secale cereale* L.) was the most suitable candidate for interseeding as a cover crop with main crops in snowy-cold Hokkaido region, located in the northern part of Japan, because of its high weed suppression and relatively low plant height. Among leguminous species, hairy vetch (Vicia villosa Roth) was found to be an effective cover crop for weed suppression. The effectiveness of these cover crops for weed suppression was also reported by Barberi and Mazzoncini [3] and Teasdale and Daughtry [31].

The aim of split nitrogen application to crop is to supply adequate N when the crop needs it, without supplying excess that can potentially be lost. The aim of this research was to test the hypotheses that (i) cover crops with a high biomass can significantly improve weed control. (ii) Also rely that whether cover crops can successfully suppress weeds, while leaving the main crop nearly unaffected.

2. Materials and methods

This experiment was carried out at the Research Field of Agricultural Faculty of Ardabil Agricultural Research Station, Iran. The field was located in north-east of Iran (38°28′N, 48°15′W and 1350 m upper than sea level, average 1300 mm rainfall in 20 years, 30% of which falls between March and September; -6 and 35°C minimum and maximum average of annual temperature, respectively). Soil texture was sandy clay and some soil characteristics were measured at planting time: [pH=7.3, N (%) = 0.11, P_2O_5 (ppm) =9.0, K_2O (ppm) =282, EC (dS/m) = 0.67 and O.C. (%) = 1.1]. All the above mentioned statistics were managed uniformly in a continuous maize system for three consecutive years. The experiment was arranged as factorial based on randomized complete block design with three replications. Each plot was 3m×4m, and consisted of five maize rows planted 75 cm apart with 15 cm between plants. Cover crop seeds, were sown in furrows of main crop at a rate of 160, 45 and 30 kg ha^{-1} for fall rye (*Secale cereal* L.), hairy vetch (*Vicia villosa* L.) and berseem clover (*Trifolium alexandrinum* L.), respectively. The cover crops were hand broadcast between rows of each plot at their respective densities. Cover crop treatments were conducted as follows: (a) no cover crop (NoC – nitrogen fertilizer was applied but cover crops were not sown). This was the control treatment to evaluate the effects of cover crops type on crop productivity and weed dynamics; (b) fall rye (nitrogen fertilizer was applied and fall rye was sown as a cover crop); (c) hairy vetch (nitrogen fertilizer was applied and hairy vetch was sown as a cover crop); and (d) berseem clover (nitrogen fertilizer was applied and berseem clover was sown as a cover crop). In each treatment (including NoC and WithC), hand weeding was done just before sowing cover crops and main crop. Hand weeding treatment (NoC + W) was examined for checking the effect of weeding on main crop productivity.

Nitrogen fertilizer timing was consisting of two levels including, the first level (N_1= ½ at planting time + ½ in the 8 to 10 leaf stage of maize) and the second level (N_2= $^1/_3$ at planting time + $^1/_3$ in the 8 to 10 leaf +$^1/_3$ a week before tasseling). Nitrogen fertilizer was applied as urea with a total amount of 225 kg ha^{-1}.

Also at the planting time, 72 kg ha^{-1} P_2O_5 and 100 kg ha^{-1} K_2O were applied. The first irrigation was done after planting and next irrigations were performed each 5 to 8 days once, regarding soil moisture. Dry weight of cover crops, weeds and the number of weeds were recorded at the dough stage of main crop. Weeds were counted separately and placed in paper bags for drying. The samples were dried to a constant weight at 70°C in a forced air dryer, after which they were weighed and their biomass recorded. Fresh forage weight of main crop was recorded at the dough stage of main crop. Whole maize plants were harvested by hand from the two center rows of each plot leaving 0.5 m unsampled at each end. Statistical analysis was conducted using the SPSS software (version 16). The differences between treatments were tested by the least significant difference (LSD) in probability of 5 percent when ANOVA was significant.

Abbreviations:

N_1, N_2: first and second level's of nitrogen application time; NoC: no cover crop treatment; WithC: with cover crop treatment; NoC + W: hand weeding with no cover crop treatment.

3. Results and Discussion

Data collected regarding to the influence of temperature and precipitation on plant growth are as follows: total precipitation was 94 mm. precipitation distribution during plant growth season was different. The daily average temperature was relatively lower from April to August in 2013 (Table 1).

Table 1. Monthly air temperature and precipitation during growing period of the main crop in 2013.

Month	Air temperature (ºC)	Precipitation (mm)
April	17.0	54.0
May	21.1	15.5
June	24.6	9.0
July	26.4	7.5
August	24.7	8.0

Multiple analysis of variance among treatments showed that there was significant difference between three cover crop treatments (i.e., fall rye, hairy vetch and berseem clover) for biomass of the measured variables (data not shown). The multiple comparison of cover crops biomass showed that fall rye significantly produced higher amount of biomass compared to hairy vetch and berseem clover (Table 2).

Table 2. Mean comparison of the main effects of cover crops biomass

Cover crops	Dry weight (gr m^{-2})
Fall rye	631.08 a
Hairy vetch	474.64 b
Berseem clover	292.72 c

Means with common letters are not significantly different with each other

Weed number and dry weight

The main weed species were redroot pigweed (*Amaranthus retroflexus* L.) and common lambsquarters (*Chenopodium album* L.). A perennial weed, field bindweed (*Convolvulus arvensis* L.) was also observed. Among these weed species, common lambsquarters and field bindweed grew continuously until stage of the main crop and were dominant throughout the study period.

For the comparison of weed growth between the treatments, the data related to NoC + W was omitted from the statistical analysis, because weed growth was zero due to hand weeding during the growing period.

Table 3 shows the weed number and dry weight at the dough stage of main crop. The main effect of cover crop treatment was significant in all measured traits. The weed number and dry weight were significantly higher in NoC compared to WithC, indicating the significant weed suppression by cover crops interseeding particularly in fall rye. Although the main effect of split nitrogen was not significant, weed number and dry weight tended to be higher in first level (N_1) of split nitrogen application compared to the second level (N_2). The interaction of cover crop and split nitrogen application was not significant on weed number and dry weight (Table 3).

Olasantan et al. [20], showed the significant reduction of weed dry weight by fertilizer application in maize and cassava (*Manihot esculenta Crantz*) production systems. Abu-Irmaileh [1] also reported the decrease of hemp broomrape (*Orobanche ramosa* L.) infestation on tobacco (*Nicotiana tabacum* L.) and tomato (*Lycopersicon esculentum* Mill.) by fertilizer application.

However, some studies reported the adverse effect of fertilization on competition between main crops and weeds. Carlson and Hill [7] showed that dry weight of wild oat weed (*Avena fatua* L.) was increased by fertilizer application in wheat (*Triticum aestivum* L.) production system. This discrepancy in the effect of fertilization on crop-weed competition may be attributed to the variation in the response to soil fertility levels among weed species. Blackshaw et al. [6] compared the response of 23 weed species including wild oat to different nitrogen application levels and revealed that wild oat increased drastically its shoot biomass as nitrogen application increased, compared to other weed species. On the other hand, field bindweed, which was dominant perennial weed in the present study, has advantages in low soil fertility, because it can be reproduced by creeping roots as well as spores, resulting in the significant increase of weed growth without fertilization. It is considered, therefore, that sufficient fertilization is one of the important managements to reduce the risk of severe weed infestation where field bindweed is dominated.

Cover crops with high biomass production caused more rapid canopy closure and overcome the weeds [32];[16]. Canopy development and structure of cover crop species might have had profound effects on weed suppression that are not tested in this study. In the present study dry matter accumulation of cover crops made it possible to make good comparisons between cover crop species. Fall rye was fast in accumulating dry matter over the time.

Although three cover crops had significantly more biomass than the weeds, fall rye produced significantly more biomass than the hairy vetch and berseem clover. Significantly more cover crops biomass was produced in fall rye compared to hairy vetch and berseem clover, there were significant differences in weed number and dry weight. In the other hand the high biomass levels achieved from fall rye resulted in better weed suppression. The berseem clover treatment had the least biomass value compared to the two other cover crop species. This can explain the higher weeds dry weight measured in this treatment. Although soil temperature was not measured in the experiment, it is possible that fluctuations in soil temperature over the three cover crops could have contributed to some of the reductions recorded for weeds emergence as soil temperature could have been lower under cover crops canopy. Other competitive mechanisms involving resource acquisition and toxic exudates to suppress weeds during their growth could have been influential [19], [14]. Different results showed that light competition of main crops and cover crops with weeds affected strongly the weed growth, and the weed suppression was enhanced by increasing LAI of main crop and cover crops by fertilization and interseeding cover crops. In other hand there is a negative correlation between covered soil ratio of main crop and the weed dry weight, and the soil covered ratio of main crops can be increased by fertilization and interseeding cover crops. Teasdale and Mohler [30], Bilalis et al. [5] had also reported that degree of weed suppression depended significantly on the soil covered ratio by main crops and/or cover crops.

Table 3. The number (No.) and dry weight (DW) of weeds at the

	Density (m^{-2})	DW ($g\ m^{-2}$)
Nitrogen split (N)		
N_1	18	76
N_2	13	50
LSD (0.05)	-	-
Treatment (T)		
Fall rye	7	8
Hairy vetch	9	12
Berseem clover	13	15
NoC	30	218
LSD (0.05)	3	27
ANOVA		
N	NS	NS
T	**	**
N × T	NS	NS

[a] Abbreviations of treatments: N1, N2: first and second level's of nitrogen application time; NoC: no cover crop

[b] *Significant at 5% level of probability; **significant at 1% level of probability; NS: not significant

Main crop yield

Table 4 shows the fresh forage yield of maize at the dough stage. The fresh forge yield of maize tended to be little. This lower yield of main crop was probably caused by lower air temperature and precipitation (Table 1). Comparison of the cover crop species showed significant differences in fresh forage yield of maize. Maize fresh forage yield in the three cover crop treatments was significantly more compared to the NoC treatment. Comparison of the cover crop treatments indicated that maize fresh forage yield in the fall rye cover crop was less compared to the hairy vetch and berseem clover treatments and the least reduction in maize fresh forage yield occurred in the hairy vetch treatment. It is possible in treatments, competition from cover crops may be attributed to differences in fresh forage yield between plots with cover crops, especially fall rye, and those without cover crops.

The interaction of split nitrogen application×cover crop had no significant effect on fresh forge yield of maize; however, yield was mainly affected by split nitrogen application and cover crop treatment (Table 4). The fresh forage yield of maize in second level (N_2) of split nitrogen application was more than the first level (N_1). It seems that in the second level split nitrogen application treatments (N_2), nitrogen use efficiency during vegetative growth, compared to first level (N_1) have some advantages.

The combination of main crop and cover crop species maybe one of the important factors causing the stability of weed suppression in various environmental conditions. Main crop used in the present study was a summer annual crop, which prefer warm weather, whereas cover crops were fall annual crops, which prefers cool weather. However, our results were based only on the combination of summer main crop with winter cover crops. Therefore, further investigations are needed to validate our hypothesis by evaluating, for example, the stability of weed suppression with the combinations of summer main crops with summer cover crops.

Table 4. Fresh forage yields (ton ha^{-1}) of maize.

	Fresh forage (ton/ha)
Nitrogen split (N)	
N1	43.05
N2	45.21
LSD (0.05)	1.60
Treatment (T)	
Fall rye	44.12
Hairy vetch	48.77
Berseem clover	45.59
NoC+W	51.3
NoC	30.81
LSD (0.05)	1.40
ANOVA	
N	**
T	**
N ×T	Ns

[a] Abbreviations of treatments: N1, N2: first and second level's of nitrogen application time; NoC, no cover crop; NoC + W: hand weeding with no cover crop treatment.
[b] *Significant at 5% level of probability; **significant at 1% level of probability; NS: not significant

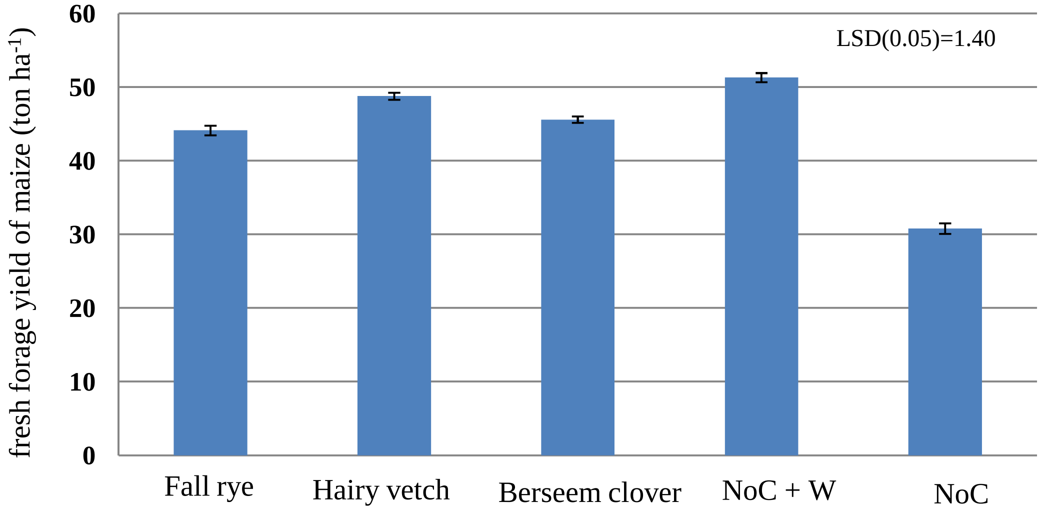

Figure 1. Effect of cover crops on the fresh forage yield of corn

4. Conclusions

Our study revealed that weed could be suppressed effectively by interseeding cover crops and proper fertilization. These stabilities of weed suppression were mainly caused by the compensatory role of cover crops interseeding. Our results were based on a field which was dominated by a few specific weeds (i.e., common lambsquarters and field bindweed), and, therefore, further investigations were needed to confirm the stability of weed suppression to the various dominant weed species and to generalize the usefulness of cover crops interseeding as an effective weed management method.

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