Weed Growth in Response to Cover Crops During Fallow Period or Incorporated into The Soil at Different Times

A.M. Kakaeian, G.R. Mohammadi and M.E. Ghobadi*

Department of Crop Production and Breeding, Faculty of Agriculture, Razi University, Kermanshah, Iran

*Corresponding author, Email: mohammadi114@yahoo.com

Manuscript Received: 20 October 2015 Accepted: 4 May 2017

Abstract

The presence of the cover crops especially as mixed during fallow period significantly reduced weed density and dry weight as compared to control (no cover crop). The suppressing effect of cover crops on weeds was enhanced in response to increasing their duration until April. One month after the second incorporation practice (i.e May) weeds showed lower density and dry weight in the plots in which cover crops had been incorporated into the soil. However, the reductions were more obvious in the April incorporated plots (on the average, the reductions in weed dry weight were 66.2 and 85.9% for March and April incorporation times, respectively compared to control). It can be concluded that the establishment of suitable cover crop species during fallow period may effectively reduce weed infestation in subsequent crop.

Keywords: Competition, incorporation time, weed

Introduction

Crop rotation in many regions of Iran consists of a fallow period usually during fall and winter. This period can lead to soil erosion, nutrient losses (e.g. nitrate leaching) and offsite movement of pesticides (Kakaeian et al., 2015). In addition, weeds can germinate and grow without competition (Hartwig and Ammon, 2002). At the lack of the crops, there are many vacant (empty) niches which can readily be occupied by different weed species. This can lead to a higher weed infestation and a richer weed seed bank in the soil. The establishment of suitable cover crops during fallow period can be an efficient method to control weeds and reduce their detrimental effects in cropping systems.

Cover crops have high potentials for weed management in agroecosystems. Cover cropping has long and short-term weed control effects (Barberi, 2002) as a result of competition and/or allelopathy exerted by the crop (Randall et al., 1989; Boydston and Hang, 1995). These effects can enhance the effectiveness of other non-chemical weed control means in view of an effective integrated approach (Creamer et al., 1996; Bond and Grundy, 2001). The effect of a cover crop is achieved by a rapid occupation of the open space or generally, the niches that would normally be filled by weeds (Teasdale, 1998). This prevents germination of weed seeds and reduces the growth and development of weed seedlings. Generally, the weed suppressing ability of these systems is thought to be based on alleopathic properties, physical impedance of germination and seedling growth, and competition for light, water, and nutrients (Teasdale, 1993; Teasdale and Mohler, 1993).

Once established, cover crops can use the light, water, and nutritional resources that would otherwise be available to weeds during fallow period. This can result in the inhibition of weed seed germination and reduction in the growth and development of weed seedlings. Therefore, weeds attempting to establish along with a cover crop would be in competition for resources and may not develop sufficiently. Moreover, physical impediment to weed seedlings is another mechanism by which these crops suppress weeds (Facelli and Pickett, 1991; Teasdale, 1996; Teasdale and Mohler, 1993). However, the variability among cover crop species determines the importance and opportunities of species selection as a component in the design of a suitable weed management system (den Hollander et al., 2007). Cover crop species are significantly different in their ability to acquire the environmental resources and consequently suppress weeds. Therefore, the mixtures of cover crop species (e.g. a legume with a non-legume) can be planted to maximize the weed suppressing effects associated with cover crop use. Moreover, planting mixtures of cover crops can take advantage of the allelopathic potential of the cover crops to suppress weeds. Allelopathic suppression of weeds has been shown to be a species specific phenomenon; therefore a broader spectrum of weed control may be possible by growing a mixture of cover crop species, each contributing allelopathic activity towards specific weed species (Creamer and Bennett, 1997).

The goal of this study was to investigate the response of the growth of weeds to a non-legume (rye) and a legume (common vetch) cover crops planted as pure or mixed during fallow period and incorporated into the soil at different times.

Materials and Methods

Plant materials

The study was carried out at the Agricultural Research Farm of Razi University, Kermanshah, western Iran (latitude 34◦ 18′ N, longitude 47◦ 4′ E, altitude 1350 m above sea level). The soil type was silty clay with a pH of 7.6 and 1.8% organic matter. The land was plowed and disked before planting. The cover crops including rye and common vetch were seeded on 11 November 2012 in the rates of 120 and 50 kg ha^{-1}, respectively as pure or mixed (rye + common vetch with a 0.5:0.5 ratio). The cover crop seeding rates were chosen according to the recommended values for these crops in most regions of Iran. A control plot (in which no cover crop was seeded) was also included.

Methods

The experiment was a randomized complete block design with three replications. The cover crop treatments (pure or mixed) were incorporated into the soil at two times (16 March or 14 April 2013). Weeds and volunteer crops (which in our study are assumed as weeds) were harvested at the ground level in two randomly selected 0.5 × 0.5 m quadrats in each plot immediately before each incorporation time. Weed species were initially distinguished, counted then separately dried at 80° C for 72 h to a constant weight and weighed. Weed parameters consisted of weed density and dry weight were determined. Moreover, the dominance indices for weed density (WDDI) and dry weight (WDWDI) and for each species were also calculated separately via the following equations:

$$WDDI = (ni/N)2 \quad (1)$$

Where, ni is the number of individuals of each species and N is the number of individuals of all the species.

$$WDWDI = (dwi/DW)2 \quad (2)$$

Where, dwi is the dry weight of individuals of each species and DW is the dry weight of individuals of all the species.

Moreover, one month after the second incorporation time (on 14 May 2013), the weed parameters for all cover crop and control treatments were also measured via the above-mentioned methods.

Data were tested for normality, then were subjected to ANOVA and means were compared by Duncan test at the 0.05 level of probability using SAS software (SAS Institute, 2003).

Results and Discussion

Results showed that In March, monocot species showed the higher density and dry weight dominance indices as compared to dicot ones (Table 1). These higher dominance indices were mainly related to the presence of Hordeum distichon. In April, the higher weed dry weight dominance index (WDWDI) was also recorded for the monocots but in the case of density dominance index (WDDI) dicots showed superiority (Table 2) mainly due to a flashed emergence of dicot species in this time. One month after the second cover crop incorporation (May) both WDDI and WDWDI were notably higher for dicot species (Table 3) probably due to more germination and growth of these species in response to increasing air temperatures (weather data not shown).

At March incorporation, the highest weed density occurred in rye and control plots and the lowest one was observed in mixed plot (Figure 2). In this incorporation time, rye or common vetch couldn't significantly influence weed density compared to control, probably due to weak ground covers produced by these cover crops (<20%) (Figure 1). However, mixed treatment (rye + common vetch showed a significant reducing effect on weed density (Figure 2).

Table 1 Dominance indices for weed density and dry weight determined immediately before the first incorporation time (March)

	Weed species	Dominance index for dry weight	Dominance index for density
Monocotyledon	*Hordeum distichon*	0.0823	0.0531
	Muscari comosum	0.0096	0.0145
	Triticum aestivum	0.0069	0.0017
	Allium sp.	0.0052	0.0053
	Agropyron sp.	0.0018	0.0004
	Aegilops sp.	0.00005	0.0001
	Total	0.1059	0.0751
Dicotyledon	*Euphorbia sp.*	0.0112	0.0409
	Turgenia latifolia	0.0058	0.0213
	Convolvulus arvensis	0.04	0.0284
	Lepidium draba	0.0024	0.0005
	Cephalaria syriaca	0.0023	0.0031
	Lamium amplexicaule	0.00083	0.0005
	Rumex crispus	0.0004	0.0001
	Medicago sp.	0.00007	0.0005
	Vicia sp.	0.00006	0.0005
	Thlaspi arvensis	0.00002	0.0001
	Total	0.0631	0.0959

Table 2 Dominance indices for weed density and dry weight determined immediately before the second incorporation time (April).

	Weed species	Dominance index for dry weight	Dominance index for density
Monocotyledon	*Hordeum distichon*	0.3022	0.0611
	Muscari comosum	0.002	0.000036
	Triticum aestivum	0.0006	0.0001
	Allium sp.	0.0001	0.000046
	Total	0.3049	0.0613
Dicotyledon	*Euphorbia sp.*	0.0112	0.0409
	Turgenia latifolia	0.0058	0.0213
	Convolvulus arvensis	0.04	0.0284
	Lepidium draba	0.0024	0.0005
	Cephalaria syriaca	0.0023	0.0031
	Lamium amplexicaule	0.00083	0.0005
	Rumex crispus	0.0004	0.0001
	Medicago sp.	0.00007	0.0005
	Vicia sp.	0.00006	0.0005
	Thlaspi arvensis	0.00002	0.0001
	Total	0.0631	0.0959

Table 3 Dominance indices for weed density and dry weight determined one month after the second incorporation time (May).

	Weed species	Dominance index for dry weight	Dominance index for density
Monocotyledon	*Sorghum halepense*	0.0072	0.0434
	Triticum aestivum	0.0052	0.00005
	Hordeum distichon	0.0023	0.00097
	Cynodon dactylon	0.000009	0.002
	Total	0.0147	0.0464
Dicotyledon	*Convolvulus sp.*	0.2735	0.2785
	Euphorbia sp.	0.0275	0.0012
	Xanthium strumarium	0.0039	0.0147
	Vicia sp.	0.0003	0.000012
	Lepidium araba	0.00007	0.000012
	Turgenia latifolia	0.00002	0.00005
	Amaranthus sp.	0.0000007	0.0001
	Total	0.3053	0.2946

At the second incorporation time (April) all cover crops significantly decreased weed density when compared with control (no cover crop) treatment (Figure 2). This can be attributed to better growth and good ground cover produced by the cover crop treatments (Figure 1) in response to time progression. Teasdale et al. (1991) reported that when ground cover produced by rye and common vetch reached to about 90%, weed density was reduced by 78% compared to control.

Weed dry weight at the first incorporation time was also significantly reduced by mixed treatment (96.3% compared to control). However, rye or common vetch alone didn't show significant reducing effects on this trait (Figure 3). At the second incorporation time, all cover crop treatments drastically decreased weed dry weight. The reductions were by 76.7, 70.6 and 83.3% for rye, common vetch and mixed, respectively as compared with control (Figure 3).

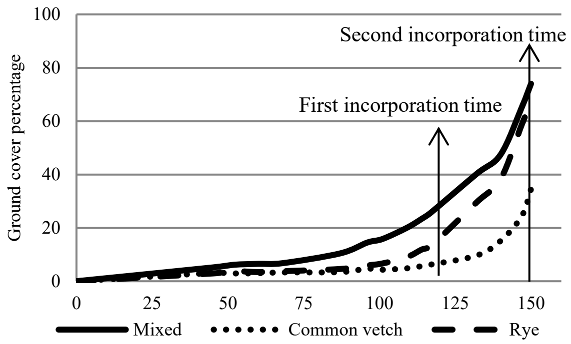

Figure 1 Ground cover percentage during the fallow period as influenced by different cover crop treatments and incorporation times.

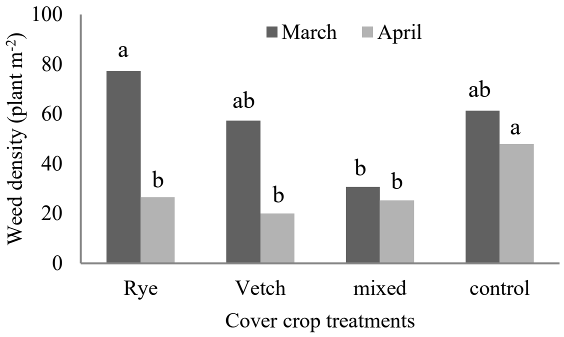

Figure 2 The effect of different cover crop treatments on weed density (measured immediately before each incorporation practice)**.** Within each incorporation time, columns with similar letters are not significantly different at the 0.05 level of probability (Duncan test).

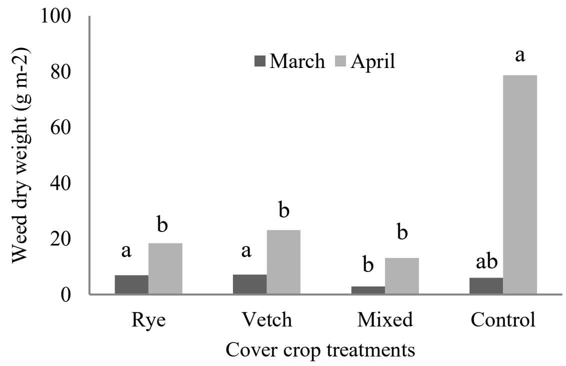

Figure 3 The effect of different cover crop treatments on weed dry weight (measured immediately before each incorporation practice). Within each incorporation time, columns with similar letters are not significantly different at the 0.05 level of probability (Duncan test).

For all treatments, weed density showed a decreasing trend and weed dry weight had an increasing trend in response to progressive time between the two incorporation dates. This can be explained by self-thinning ability of weed plants which ultimately led to the formation of a weed community with a lower density and large-sized individuals. However, decreasing weed density was higher and increasing weed dry weight was notable lower in the cover crop treatments than in control plot (Figure 2 and Figure 3). Cover crops can effectively suppress weeds by competition for light, water and nutrients (Teasdale, 1993; Teasdale and Mohler, 1993). According to Fisk et al. (2001) cover crops reduce light and moisture available to fall germinating seeds. Weeds attempting to establish along with a cover crop would be in competition for resources and may not develop sufficiently to survive the winter. Moreover, the suppressing effect of cover crops can be achieved due to their allelopathic effects. Cover crop root exudations produce allelopathic compounds that are actively secreted directly into the soil rhizosphere by living root systems. The allelochemicals then move through the soil by diffusion and come into contact neighboring plants.

In our study, mixed treatment had a more suppressing effect on weeds compared to rye or common vetch alone. Rye and common vetch are belonging to different plant families with divers growth habits and essential needs. Common vetch can also fix atmospheric N_2 and then does not compete with rye to acquire this important element. Therefore, a synergetic interaction and a complementary effect can be expected when these cover crops are grown together. This consequently lead to the enhanced their suppressing effects on weeds.

One month after the second incorporation practice (May), the highest weed dry weight observed in control plots (Figure 4). All cover crop treatments significantly reduced weed dry weight as compared to control, although the second incorporation treatments (April) showed higher reducing effects (Figure 4). At this sampling time, weed density was also reduced by cover crop treatments but these reductions were not significant from a statistical viewpoint with the exception of common vetch incorporated in April which notably reduced weed density compared to the control treatment (Figure 5).

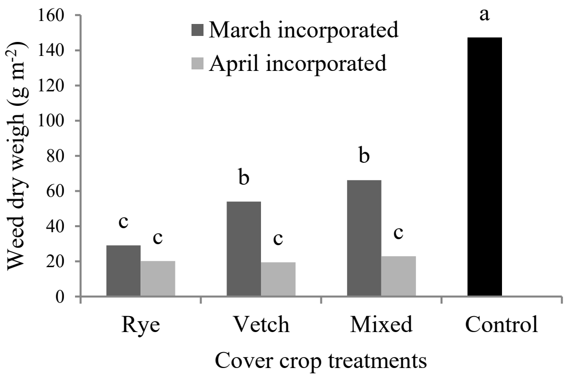

Figure 4 The effect of different cover crop treatments on weed dry weight measured in May (one month after the second incorporation practice). Columns with similar letters are not significantly different at the 0.05 level of probability (Duncan test)

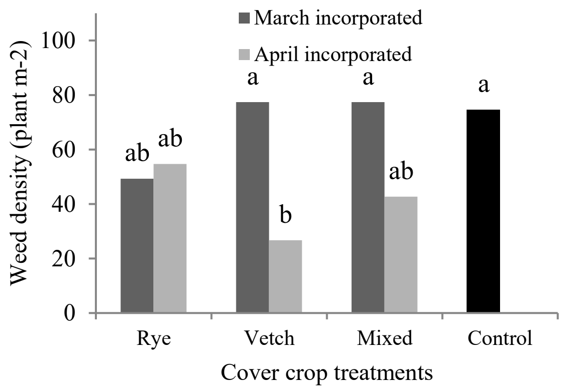

Figure 5 The effect of different cover crop treatments on weed density measured in May (one month after the second incorporation practice). Columns with similar letters are not significantly different at the 0.05 level of probability (Duncan test)

Reduced weed growth after the incorporation practices can mainly be attributed to the allelochemicals released by cover crop tissues into the soil. According to Dhima et al. (2006) cover crop ability to release toxic substances in the environment can creat an unfavorable environment for weed germination and establishment. Allelopathic potentials of rye and vetch species have been documented in several studies (Fujii, 1999; Sung et al., 2010; Soltys et al., 2011). Barnes et al. (1987) suggested that allelopathic potential of rye is related to two major compounds: DIBOA [2,4-dihydroxy-1,4-(2H) benzoxazine-3-one] and its breakdown product BOA [(3H)-benzoxazolinone)]. As the amount of DIBOA and BOA possibly released by rye in the field has been estimated to 13.5-16 kg ha-1 (Barnes and Putnam, 1987; Mwaja et al., 1995). Ngouajio and Mennan (2005) reported that incorporation of cover crops such as hairy vetch into the soil significantly reduced weed dry weight and density. This can be attributed to the release of phenolic compounds (Inderjit and Asakawa, 2001) and cyanamide acid (Soltys et al., 2011) from vetch tissues.

Moreover, weed suppressing effect of the cover crops after their incorporation into the soil was drastically lower for the treatments incorporated in March than in April. This can be explained by the presence of a longer period in which the cover crops incorporated in March can be decomposed by soil microorganisms which may overcome the toxicity of the released allelochemicals. Moreover, it is probably due to a higher leaching rate of the allelochemicals released by the cover crops incorporated in March caused by the precipitation occurred in late winter and early spring. However, among the March incorporated treatments, rye showed a more vigorous reducing effect on weed dry weight and density measured in May (Figure 4 and Figure 5) indicating a higher stability of rye plant tissues over against decomposer factors which can be led to the delayed release of its allelochemicals into the soil. This can be attributed to a higher C/N ratio for rye plant material as a non-legume cover crop compared to legume cover crops such as common vetch.

Conclusion

This study revealed that cover crops established during fallow period (fall and winter) can effectively control weeds. The controlling effect was higher when the presence of cover crops was continued until April. Moreover, weeds were suppressed better when rye and common vetch were seeded as mixed. The cover crops also showed a notable weed suppressing effect even after their incorporation into the soil probably due to their allelopathic potentials. However, this was more obvious for the cover crops incorporated in April. From a practical viewpoint, it can be concluded that the establishment of suitable cover crop species during fallow period may effectively reduce weed infestation in subsequent crop.

References

Barberi, P. 2002. Weed management in organic agriculture: are we addressing the right issues. Weed Res. 42: 177–193.

Barnes, J.P., A.R. Putnam, B.A. Burke and A.J. Aasen. 1987. Isolation and characterization of allelochemicals in rye herbage. Phytochemistry 26: 1385–1390.

Barnes, J.P. and A.R. Putnam. 1987. Role of benzoxazinones in allelopathy by rye (*Secale cereale* L.). J. Chem. Ecol. 13: 889–906.

Bond, W. and A.C. Grundy. 2001. Non-chemical weed management in organic farming systems. Weed Res. 41: 383-405.

Boydston, R.A. and A. Hang. 1995. Rapeseed (*Brassica napus*) green manure crop suppresses weeds in potato (*Solanum tuberosum*). Weed Technol. 9: 669–675.

Creamer, N.G., M.A. Bennett, B.R. Stinner, J. Cardina and E.E. Regnier. 1996. Mechanisms of weed suppression in cover crop-based production systems. Hort. Sci. 31: 410-413.

Creamer, N.G. and M.A. Bennett. 1997. Evaluation of cover crop mixtures for use in vegetable production systems. Hort. Sci. 32: 866–870.

den Hollander, N.G., L. Bastiaans and M.J. Kropff. 2007. Clover as a cover crop for weed suppression in an intercropping design I. Characteristics of several clover species. Europ. J. Agronomy 26: 92–103.

Dhima, K.V., I.B. Vasilakoglou, I.G. Eleftherohorinos and A.S. Lithourgidis. 2006. Allelopathic potential of winter cereals and their cover crop mulch effect on grass weed suppression and corn development. Crop Sci. 46: 345–352.

Facelli, J.M. and S.T.A. Pickett. 1991. Plant litter, It's dynamics and effects on plant community structure. Bot. Rev. 57: 1–32.

Fisk, J.W., O.B. Hesterman, A. Shrestha, J.J. Kells, R.R. Harwood, J.M. Squire and C.C. Sheaffer. 2001. Weed suppression by annual legume cover crops in no-tillage corn. Agronomy J. 93: 319-325.

Fujii, Y. 1999. Allelopathy of hairy vetch and Macuna; their application for sustainable agriculture. pp.289-300. In C.H. Chou et al. Biodiversity and Allelopathy from Organisms to Ecosystems in the Pacific. Academia Sinica, Taipei.

Hartwig, N.L. and H.U. Ammon. 2002. Cover crops and living mulches. Weed Sci. 50: 688–699.

Inderjit and C. Asakawa. 2001. Nature of interference potential of hairy vetch (*Vicia villosa* Roth) to radish (*Raphanus sativus* L.): does allelopathy play any role. Crop Prot. 20: 261–265.

Kakaeian, A.M., G.R. Mohammadi, M.E. Ghobadi and A. Najaphy. 2015. Effects of rye and common vetch cover crops as pure and mixed on soil physicochemical characteristics. J. Agric. Sci. Sustain. Prod. 25: 47-63. (In Persian)

Mwaja, V.N., J.B. Masiunas and L.A. Weston. 1995. Effects of fertility on biomass, phytotoxicity, and allelochemical content of cereal rye. J. Chem. Ecol. 21: 81-96.

Ngouajio, N. and H. Mennan. 2005. Weed populations and pickling cucumber (*Cucumis sativus*) yield under summer and winter cover crop systems. Crop Prot. 24: 521-526.

Randall, H.W., D. Worsham and W. Blum. 1989. Allelopathic potential of legume debris and aqueous extracts. Weed Sci. 37: 674–679.

SAS Institute. 2003. SAS/STAT. User's Guide. Version 9.1. SAS Inst., Inc., Cary, NC.

Soltys, D., A. Rudzinska, W. Kurek, A. Gniazdowska, E. Sliwinska and R. Bogatek. 2011. Cyanamide mode of action during inhibition of onion (*Allium cepa* L.) root growth involves disturbances in cell division and cytoskeleton formation. Planta 234: 609– 621.

Sung, J.K., J.A. Jung, B.M. Lee, S.M. Lee, Y.H. Lee, D.H. Choi, T.W. Kim and B.H. Song. 2010. Effect of incorporation of hairy vetch and rye grown as cover crops on weed suppression related with phenolics and nitrogen contents of soil. Plant Production Science 13: 80-84.

Teasdale, J.R. 1993. Reduced-herbicide weed management systems for no-tillage corn (*Zea mays*) in a hairy vetch (*Vicia villosa*) cover crop. Weed Technol 7: 879–883.

Teasdale, J.R., C.E. Best and W.E. Potts. 1991. Response of weeds to tillage and cover crop residue. Weed Sci. 39(2): 195–199.

Teasdale, J.R. 1996. Contribution of cover crops to weed management in sustainable agricultural systems. J. Prod. Agric. 9: 475–479.

Teasdale, J.R. and C.L. Mohler. 1993. Light transmittance, soil temperature, and soil moisture under residue of hairy vetch and rye. Agron. J. 85: 673-680.

Teasdale, J.R. 1998. Influence of corn (*Zea mays*) population and row spacing on corn and velvetleaf (*Abutilon theophrasti*) yield. Weed Sci. 46: 447–453.