Bulgarian Journal of Agricultural Science, 22 (No 6) 2016, 936–941
Agricultural Academy

WHICH COVER CROP SPECIES ARE BEST USED IN SEMI-ARID CONDITIONS?

M. SABET[1], N. M. HOSSEINI[2*] and H. R. MASHHADI[2]

[1] *Former PhD student at Department of Agronomy and Plant Breeding, College of Agriculture and Natural Resources, University of Tehran, P.O. Box 4111, Karaj 31587-77871, Iran*
[2] *Professor at Department of Agronomy and Plant Breeding, College of Agriculture and Natural Resources, University of Tehran, P.O. Box 4111, Karaj 31587-77871, Iran*

Abstract

SABET, M., N. M. HOSSEINI and H. R. MASHHADI, 2016. Which cover crop species are best used in semi-arid conditions? *Bulg. J. Agric. Sci.*, 22: 936–941

Cover cropping can cause many advantages to the cropping systems while little attention has been given to the utilization of cover crops in semi-arid climatic conditions. A 2-year field experiment was conducted in 2013–2014 growing seasons. The treatments consisted in three different winter cover crop species including cereal rye, rapeseed, hairy vetch and a weedy fallow (control), which were planted in a randomized complete block design with three replications. Growth, weed suppression and the amount of accumulated nitrogen in the biomass of cover crop species were evaluated at the time of incorporation. Both rapeseed and cereal rye produced the highest amount of aboveground biomass and showed a higher weed reduction compare with weedy fallow (85.88 and 78.3%, respectively), while the weed-suppressive ability of hairy vetch was 61.46% in compare to weedy fallow. In addition, cereal rye controlled the most dominant weed species (*Sisymbrium officinale L.*) more than 85% and declined its density to lower than 2 plants m^{-2}. The total nitrogen accumulation in the aboveground biomass was higher in cereal rye and rapeseed (148.97 and 135.87 kg N ha^{-1}, respectively) than in hairy vetch and weedy fallow (75.95 and 67.25 67.25, respectively). These results proposed that cereal rye and rapeseed were the most effective at biomass productivity, weed suppression and accumulating nitrogen and have great potential for using in semi-arid regions.

Key words: cover crop; semi-arid condition; weed suppression; weed density; nitrogen accumulation

Introduction

The use of large amounts of agrochemical inputs such as synthetic fertilizers, herbicides, pesticides and etc., which contributes to crop productivity (Ruegg et al., 2007), are becoming more limited, due to their environmental effects which has recently caused much concern (Oenema et al., 2009; Rice et al., 2001). Therefore, more sustainable agricultural practices are required to reduce the use of external inputs for assuring an adequate crop yield and for reducing environmental risks (Kruidhof et al., 2008; Uchino et al., 2011). Sustainable agronomic production, such as cover cropping can improve farm productivity, soil fertility and environmental conditions (Kruidhof et al., 2008) and recently various winter cover crop species have attracted interest as a new approach in sustainable agronomic production (Picard et al., 2010). As Finney et al. (2016) declared developing plant diversity in agroecosystems with cover crops is a proper program to enhance ecosystem services and increasing diversity of cover crops may provide more profits. In fact, the improvement of soil organic matter and soil structure (Ding et al., 2006; Sarrantonio and Gallangt, 2003), nutrient capturing and recycling (Hooker et al., 2008) and suppressing weeds and volunteer crops and producing additional forage (Blanco-Canqui et al., 2012) are among the main advantages of cover

**Corresponding author*: mhoseini@ut.ac.ir

crops. However, the quality and quantity of cover crop residues affect nutrient dynamics (Ruffo and Bollero, 2003) and weed establishment in different ways (Kruidhof et al., 2008). In order to significant weed suppression, a rapid emergence, quick soil coverage, fast growth and high dry matter production of cover crops are required (Brennan and Smith, 2005; Brust et al., 2014) and for this reason, the best choice of cover crop species based on climatic condition is a key management in the agricultural systems. Nevertheless, little attention has been given to the utilization of cover crops in semi-arid climatic conditions, because farmers face several challenges related to using of cover crops in these regions. The most important challenges include cover crop selection, establishment and growth, weed control and the availability of water to raise cover crops in the preceding fall and winter in these conditions. This study was conducted to: (1) evaluate total biomass productivity and growth of cover crop species (2) determining aboveground nitrogen accumulation and C:N ratios of cover crop species (3) assessing the relative effects of cover crops on the biomass and density of winter annual weed communities (4) selecting the most effective cover crops to use especially in semi-arid climatic conditions.

Materials and Methods

Experimental site

The study was conducted along two consecutive growing seasons (2013–2014 and 2014–2015) at the Research Farm of the College of Agriculture and Natural Resources, University of Tehran, Karaj, Iran (N35°56' N, E50°58' E). The climate type of this site is considered as arid to semiarid with long-term (50-year) air temperature of 13.5°C, soil temperature of 14.5°C, and 262 mm of rainfall. The weather condition at the experimental site during the two growing seasons is shown in Fig. 1. Soil at the site is classified as a Typic Haplocambid (Afshar et al., 2014) in the USDA classification. Prior to planting, soil samples were taken from 0 to 30 cm depth and analyzed for physical and chemical properties. The soil characteristics of the experimental site are presented in Table 1.

Experimental setup

The experimental design was a randomized complete block design with three replications and plot sizes were 5 m by 5 m. The cover crop treatments included: cereal rye (*Secale cereal* L.), rapeseed (*Brassica napus* L.) and hairy vetch (*Vicia villosa* L.). In both years a control treatment with no winter cover crop was tested (weedy fallow), in order to evaluate the weed suppression ability of cover crops. The experimental farm was moldboard plowed at the depth of 30 cm and disked before cover crop sowing. Cover crops were hand sown on October 20, 2013 and October 22, 2014. Seed rates, weight and species are reported in Table 2. No fertilizers were applied in the experiments. The cover crops were allowed to grow during autumn, winter and until the first half of April, then they were incorporated into the soil on April.

Table 2
Seed weight and seeding rate of evaluated cover crop treatments used in both 2013 and 2014 years

Species	1000-seed weight (g)	Seeding rate (kg ha^{-1})
Cereal rye (*Secale cereal* L.)	25	160
Rapeseed (*Brassica napus* L.)	5	10
Hairy vetch (*Vicia villosa* Roth)	33	50

Measurements

In both years, before cover crop termination, weed species, weed density and aboveground biomass samples were collected in the middle of each cover crop plot and in the weedy fallow by harvesting the plants at ground level in a 0.25 m^2 quadrat placed randomly three times over each plot. The sampled aboveground biomass including cover crop and total weeds were oven dried at 70 °C until constant weight. Then their nitrogen and carbon contents were measured. The soil NO_3-N content was also measured at cover crop sowing and incorporating.

Statistical analysis

Data were subjected to analysis of variance (*ANOVA*) *using* the GLM *procedures* of SAS (SAS, 1996). The analysis

Table 1
General properties of the soil of the experimental site (depth of 0–30 cm)

Soil properties	2013	2014	Method
Soil texture	Clay loam	Clay loam	Hydrometer method
pH	7.85	7.5	1:2.5 soil–water suspension
EC (dS m^{-1})	1.4	1.2	1:2.5 soil–water suspension
Organic matter (g kg^{-1})	3.5	2.9	Wet-digestion method
Total N (g kg^{-1})	0.6	0.7	Kjeldahl method
Available P (mg kg^{-1})	11.23	8	Olsen P
Available K (mg kg^{-1})	140	128	Flame photometer

was conducted for the 2-year period, considering the year as a random effect, where the years were treated as the main factor and the cover crop treatments as a split factor. Moreover, the weed-suppressive effect of cover crops was evaluated with an exponential decay model of the form (Radicetti et al., 2013):

$$y = ae^{(-kx)}$$

where y is equal to the weed aboveground biomass, the intercept a is the amount of weed aboveground biomass in the weedy fallow, k is the suppression coefficient, and x is the cover crop aboveground biomass.

Results

Weather conditions

Precipitation during cover crop establishment from October to April was lower in 2013–2014 (115.9 mm) than in 2014–2015 (162 mm) (Figure 1). In the same period the average daily air temperature was similar in the first (2013–2014) and the second (2014–2015) season of cover crop study, (9 and 9.42°C, respectively). A similar trend occurred for the maximum temperature during this period for both seasons (14.18 and 14.87°C, respectively) but in the first season minimum values was lower than the second season (3.41 and 4.14°C, respectively), especially, in December 2013 when the minimum temperature dropped slightly below 0°C 20 times. Low temperatures affected the cereal rye less than rapeseed and hairy vetch.

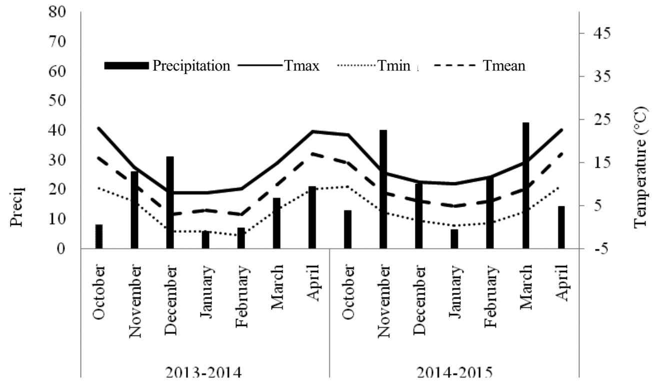

Fig. 1. Climatic data along the growth period of cover crops: (left) the first (2013–2014) and (right) the second (2014–2015) season of cover crop studies from a climatic station situated at the experimental site

Cover crop growth and biomass

In both years, various cover crop species emerged uniformly about 2 weeks after sowing and grew from October to mid-April. At the time of cover crop termination cereal rye and rapeseed were at the beginning of flowering stage and hairy vetch was at the early bloom stage. The total aboveground biomass (cover crop species + weeds) was significantly influenced by the year (Table 3) and was higher in 2014–2015 than 2013–2014 (4.41 vs. 3.98 ton ha^{-1} of dry matter, respectively). Likewise, the cover crop aboveground biomass was influenced by the year (Table 3) and was higher in 2014–2015 than 2013–2014 (3.92 vs. 3.38 ton ha^{-1} of dry matter, respectively). However for all cover crops the total aboveground dry matter was significantly higher than weedy fallow, and was the highest in cereal rye, intermediate in rapeseed and the lowest value was observed in hairy vetch (5.31, 3.80 and 1.86 ton ha^{-1}, respectively, Figure 1). The percentage of weed species aboveground in the total aboveground biomass (cover crop species + weeds) was influenced by the cover crop species but not by the year (Table 3). Actually, the weed aboveground biomass percent in hairy vetch was significantly higher and was about 31.2% on average over the years and significantly lower in rapeseed and cereal rye (average 7.49 and 8.19%, respectively, Figure 2).

Weed dry matter and density

Mostly hedge mustard (*Sisymbrium officinale* L.), Persian speedwell (*Veronica persica* L.), shepherd's purse (*Cap-*

Table 3

Analysis of variance on total aboveground biomass (including weedy fallow and cover crop) dry weight, weed percent, weed density, N percent and N accumulated in the aboveground biomass, NO_3-N content in the soil at cover crop sowing and at cover crop incorporation time and C:N ratio)

Source of variation	d.f.	Total biomass DW	Cover biomass	Weed percent	Weed density	N percent	N accumulation	NO_3-N at sowing	NO_3-N at incorporation	C:N ratio
Block	2									
Year (Y)	1	*	*	ns	*	ns	**	ns	ns	ns
Error a	2									
Cover crops (CC)	3	**	**	**	**	**	**	ns	**	**
Y × CC	3	ns	ns	ns	ns	ns	ns	ns	ns	ns
Error b	12									
Total	23									

** and ns: significant at P<0.01 and not significant, respectively

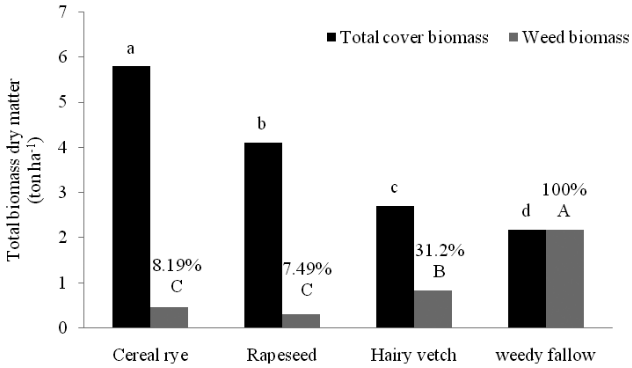

Fig. 2. Total cover biomass at cover crop incorporation (cover species + weeds) and weed percent at total cover biomass. Means without common letters are significantly different according to LSD (0.05) among biomass dry matter (total biomass or weed percent)

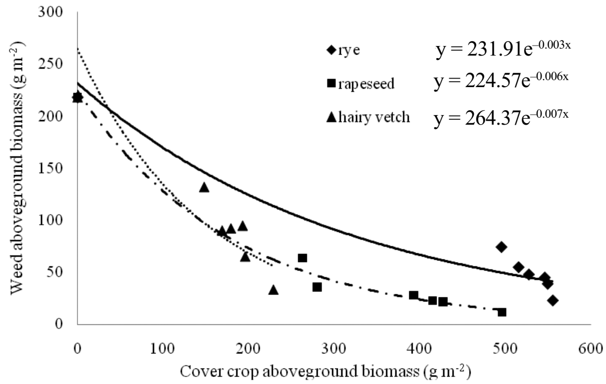

Fig. 3. Exponential decay model describing the relationships between the cover crop aboveground biomass and the total weed aboveground biomass measured at cover crop suppression. Equation for the model is $y = ae^{(-kx)}$

sella bursa-pastoris) and volunteer wheat and barley were observed in the experiment and at cover crop termination time. The aboveground biomass of weeds was not influenced by the year, but was different among cover crop species and the highest weed biomass among cover crop species was in hairy vetch (84.17 g m^{-2}, Table 4). *S. officinale* was the most dominant weed and its aboveground biomass was greater in hairy vetch (40.86 g m^{-2}), and followed by rapeseed (20.16 g m^{-2}).

According to an exponential model, the weed aboveground biomass in cover crop species decreased as the cover crop aboveground biomass increased (Figure 3). Both rapeseed and cereal rye were the most suppressive cover crops and showed a higher weed reduction compare to weedy fallow (85.88 and 78.3%, respectively), while the weed-suppressive ability of hairy vetch was 61.46% in comparison with weedy fallow.

The weed density prior to termination date was influenced significantly by the year and by cover crop species (Table 3). Obviously, the density of weed species was higher in weedy fallow (on average 27.55 plants m^{-2}), while it was lower in rapeseed and cereal rye (on average 5.2 and 6.30 plants m^{-2}, respectively). *S. officinale* was the most dominant species (on average 6.27 plants m^{-2}) generally present in weedy fallow, hairy vetch and rapeseed; which were followed by volunteer barley and wheat (on average 3.92 plants m^{-2}) mainly existing in weedy fallow, cereal rye and rapeseed. *V. persica and C. bursa-pastoris* were generally higher in weedy fallow and hairy vetch than cereal rye and rapeseed (on average 3.83 and 4.51 vs. 0.24 and 0.95 plants m^{-2}, respectively, Table 4).

Cover crop nitrogen accumulation and soil nitrate

The total nitrogen content in the biomass of cover crops was not significantly influenced by the year but was different between cover crop species (Table 3). The highest value was

Table 4
Weed aboveground biomass and weed number per species and total at cover crop termination. Data were combined for both cover cropping season (2013–2014 and 2014–2015)

Parameters	Weed species	Cover crop treatments			
		Cereal rye	Rapeseed	Hairy vetch	Weedy fallow
Weed aboveground biomass (g m^{-2})	*S. officinale*	12.98 c	20.16 bc	40.86 b	91.08 a
	C. bursa-pastoris	13.28 bc	2.91 c	17.71 b	45.81 a
	V. persica	1.497 c	0.402 c	18.47 b	44.24 a
	Volunteer Crops	19.65 b	7.347 c	7.408 c	41.26 a
	Total	47.40 c	30.83 c	84.17 b	218.4 a
Weed density (no m^{-2})	*S. officinale*	1.85 c	3.3 bc	5.63 b	9.89 a
	C. bursa-pastoris	1.41 bc	0.50 c	2.53 b	6.5 a
	V. persica	0.33 b	0.16 b	4.27 a	3.39 a
	Volunteer Crops	2.7 b	1.31 c	1 c	7.77 a
	Total	6.30 c	5.2 c	10.11 b	27.55 a

Numbers followed by different letter within a row of a set are significantly different according to LSD (0.05)

Table 5
Total N content and N accumulation in the aboveground dry biomass at the time of incorporation of cover crops, soil NO_3-N at cover crop sowing and incorporation and C:N ratio, averaged over both 2013 and 2014 years

Cover crops	Total N content (%)	Total N (Kg/ha)	Soil nitrate content mg NO_3-N kg^{-1} dry soil		C:N ratio
			At cover crop sowing	At cover crop incorporation	
Cereal rye	2.8140 c	148.97 a	8.15 a	6.48 c	16.98 a
Rapeseed	3.5173 b	135.87 a	8.16 a	6.23 c	13.03 b
Hairy vetch	4.0930 a	75.95 b	8.48 a	10.6 a	10.73c
Weedy fallow	3.0777 c	67.25 b	8.15 a	8.58 b	13.36 b

Numbers followed by different letter within a column of a set are significantly different according to LSD (0.05)

in hairy vetch, followed by rapeseed and it was lower in the weedy fallow and rye (4.09, 3.51, 3.07 and 2.81%, respectively, Table 5). The total nitrogen content accumulated in the cover crop biomass was significantly influenced by the year and by cover crop species. The higher value was observed in cereal rye and rapeseed (148.97 and 135.87 kg N ha^{-1}, respectively) and the lower value was in hairy vetch and weedy fallow (75.95 and 67.25 67.25, respectively, Table 5). Moreover, the ratio of C:N was different among cover crop species and the highest value was observed in cereal rye (16.98) followed by weedy fallow and rapeseed (13.36 and 13.03), and the lowest value was obtained in hairy vetch (10.73, Table 5).

Nitrate content in the soil at cover crop sowing was not influenced by the year and by cover crop species and showed a mean value of 8.23 mg NO_3-N kg^{-1} dry soil. Nitrate content at cover crop incorporation was not influenced by the year but was different among cover crop species. Higher value was observed in hairy vetch (10.6 mg NO_3-N kg^{-1} dry soil) followed by weedy fallow (8.58 mg NO_3-N kg^{-1} dry soil) and lower values found in cereal rye and rapeseed (6.48 and 6.23 mg NO_3-N kg^{-1} dry soil, Table 5).

Discussion

Although the cover crop species emerged regularly in both 2013–2014 and 2014–2015 growing seasons, total aboveground biomass of cover crop treatments was higher in 2014–2015 than in the previous growing season, probably due to more amount of precipitation occurred during cover crop growing season. At cover crop termination, the cereal rye and rapeseed were more suppressive than hairy vetch, due to their greater growth potential together with a strong competitive ability for nitrogen, which presumably minimized the niche of the weeds (Campiglia et al., 2009; Silva, 2014). In fact, cover crop species that are characterized by fast growth and high dry matter accumulation such as cereal rye and rapeseed also ensure the highest weed suppressive ability (Brennan and Smith, 2005; Teasdale and Mohler, 2000; White and Weil, 2010). This confirms the results found by Finney et al. (2016) showing that increasing cover crop biomass is positively correlated with several ecosystem services, such as weed suppression, nitrate leaching prevention, and aboveground biomass nitrogen. In contrast, cover crop species with a low dry matter accumulation like hairy vetch only offered reduced weed control efficacy (Brust et al., 2014). In particular the cereal rye controlled the most dominant weed species (*S. officinale*) more than 85% and decreased its density lower than 2 plants m^{-2}. This weed suppression ability may be in relation with production of secondary metabolites, e.g., (DIBOA), that are known to inhibit weed seedling germination and growth (Hooker et al., 2008).

As expected the nitrogen content in the aboveground biomass of hairy vetch was higher than the rapeseed and cereal rye, and was reported by Campiglia et al. (2010), but cereal rye and rapeseed accumulated more nitrogen than hairy vetch mostly due to production of more aboveground biomass. This result is against other researcher's findings which reported the nitrogen accumulation in the aboveground biomass of legume cover crops was significantly greater than cereal rye and rapeseed (Campiglia et al., 2014; Holderbaum et al., 1990). In addition, the ratio of C:N was lower in hairy vetch in compare to cereal rye and rapeseed which leads to fast release of nitrogen content into the soil after incorporation. In contrast incorporated cereal rye immobilizes soil nitrogen due to its high ratio of C:N (Finney et al., 2016). The soil nitrate content at cereal rye and rapeseed incorporation was found lower in compare to hairy vetch. This confirms the result which was reported by Campiglia et al. (2009), showing that Graminaceae and Cruciferae species are more efficient than legumes cover crops in intercepting soil nitrogen.

Conclusion

Based on field observations and according to the results obtained by other researchers the reduction in weed abundance during cover crop growth period, leads to decrease in weed abundance in subsequent cash crops and can be an important method to reduce the use of chemical inputs. This study concluded that there is a positive relationship between cover crop biomass, weed suppression and biomass nitrogen content. Over the two years of this study, we saw that cereal rye and rapeseed had the most weed suppressive ability and accumulated more nitrogen in their biomass. Hairy vetch was less effective in weed suppression and in nitrogen accumulation due to its low aboveground biomass. Therefore, in semi-arid climatic conditions where there is no enough rainfall in the fall and winter seasons to guarantee the establishment and growth of cover crops, it is important to select the most effective options in weed suppression and biomass production. These results proposed that cereal rye and rapeseed have great potential for using in semi-arid regions especially where winter annual weed control is a primary purpose.

Acknowledgment

The financial support of the University of Tehran is gratefully acknowledged.

References

Afshar, R. K., M. A. Jovini, M. R. Chaichi and M. Hashemi, 2014. Grain sorghum response to *Arbuscular Mycorrhiza* and phosphorus fertilizer under deficit irrigation. *Agronomy Journal*, **106**: 1212-1218.

Blanco-Canqui, H. H., M. M. Claassen and D. R. Presley, 2012. Summer cover crops fix nitrogen, increase crop yield, and improve soil-crop relationships. *Agronomy Journal*, **104**: 137-147.

Brennan, E. B. and R. F. Smith, 2005. Winter cover crop growth and weed suppression on the central coast of California. *Weed Technology*, **19**: 1017-1024.

Brust, J., W. Claupein and R. Gerhards. 2014. Growth and weed suppression ability of common and new cover crops in Germany. *Crop Protection,* **63**: 1-8

Campiglia, E., F. Caporali, E. Radicetti and R. Mancinelli, 2010. Hairy vetch (*Vicia villosa Roth.*) cover crop residue management for improving weed control and yield in no-tillage tomato (*Lycopersicon esculentum* Mill.). *European Journal of Agronomy*, **33**: 94-102.

Campiglia, E., R. Paolini, G. Colla and R. Mancinelli, 2009. The effects of cover cropping on yield and weed control of potato in a transitional system. *Field Crops Research*, **112**: 16-23.

Campiglia, E., E. Radicetti, P. Brunetti and R. Mancinelli, 2014. Do cover crop species and residue management play a leading role in pepper productivity? *Scientia Horticulturae*, **166**: 97-104.

Ding, G. W., X. Liu, S. S. Herbert, J. J. Novak, D. D. Amarasiriwardena and B. S. Xing, 2006. Effect of cover crop management on soil organic matter. *Geoderma*, **130**: 229-239.

Finney, D. M., Ch. M. White and J. P. Kaye, 2016. Biomass Production and Carbon/Nitrogen Ratio Influence Ecosystem Services from Cover Crop Mixtures. *Agronomy Journal*, **108**: 39-52.

Holderbaum, J. F., A. M. Decker, J. J. Meisenger, F. R. Mulford and L. R. Vough, 1990. Fall seeded legume cover crops for notillage corn in the humid East. *Agronomy Journal*, **82**: 117-124.

Hooker, K. V., C. E. Coxon, R. Hackett, L. E. Kirwan, E. O'Keeffe and K. G. Richerds, 2008. Evaluation of cover crop and reduced cultivation for reducing nitrate leaching in Ireland. *Journal of Environmental Quality*, **37**: 138-145.

Kruidhof, H. M., L. Bastiaans and M. J. Kropff, 2008. Ecological weed management by cover cropping: effects on weed growth in autumn and weed establishment in spring. *Weed Research*, **48**: 492-502.

Oenema, O., H. P. Witzke, J. P. Klimont, J. P. Lesschen and G. L. Velthof, 2009. Integrated assessment of promising measures to decrease nitrogen losses from agriculture in EU-27. *Agriculture Ecosystems & Environment*, **133**: 280-288.

Picard, D., M. Ghiloufi, P. Saulas and S. de Tourdonnet, 2010. Does under sowing winter wheat with a cover crop increase competition for resources and is it compatible with high yield? *Field Crops Research,* **115**: 9-18.

Radicetti, E., R. Mancinelli and E. Campiglia, 2013. Influence of winter cover crop residue management on weeds and yield in pepper (*Capsicum annuum* L.) in a Mediterranean environment. *Crop Protection,* **52**: 64-71.

Rice, P. J., L. L. McConnell, L. P. Heighton, A. M. Sadeghi, A. R. Isensee, J. R. Teasdale, A. A. Abdul-Baki, J. A. Harman-Fetcho and C. Hapeman, 2001. Runoff loss of pesticides and soil: a comparison between vegetative mulch and plastic mulch in vegetable production systems. *Journal of Environmental Quality,* **30**: 1808-1821.

Ruegg, W. T., M. Quadranti and A. Zoschke, 2007. Herbicide research and development: challenges and opportunities. *Weed Research*, **47**: 271-275.

Ruffo, M. L. and G. A. Bollero, 2003. Modelling rye and hairy vetch residue decomposition as a function of degree-days and decomposition-days. *Agronomy Journal*, **95**: 900-907.

Sarrantonio, M. and E. Gallandt, 2003. The role of cover crops in North American cropping systems. *Journal of Crop Production*, **8**: 53-74.

SAS, 1996. SAS User's Guide: Statistics. SAS Institute, Cary, NC.

Silva, E. M., 2014. Screening Five Fall-Sown Cover Crops for Use in Organic No-Till Crop Production in the Upper Midwest. *Agroecology and Sustainable Food Systems*, **38**: 748-763.

Teasdale, J. R. and C. L. Mohler, 2000. The quantitative relationship between weed emergence and the physical proprieties of mulches. *Weed Science*, **48**: 385-392.

Uchino, H., K. Iwama, Y. Jitsuyama, K. Ichiyama, E. Sugiura and T. Yudate, 2011. Stable characteristics of cover crops for weed suppression in organic farming systems. *Plant Production Science*, **14**: 75-85.

White, C. M. and R. R. Weil, 2010. Forage radish and cereal rye cover crop effects on mycorrhizal fungus colonization of maize roots. *Plant and Soil*, **328**: 507-521.

Received April, 20, 2016; accepted for printing November, 1, 2016