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EFFECT OF CHEMICAL CONTROL ON WEED SEED BANK SIZE AND COMPOSITION IN CORN-BARLEY ROTATION SYSTEM

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ABSTRACT

Changes in weed seed bank due to crop production practices are an important determinant of subsequent weed problems. To study the effect of chemical control on agricultural rotation systems, a study was conducted at the University of Tehran research fields, Tehran, Iran during 2004 and 2005. Corn-barley was the selected rotation with and without applying of herbicide. Method of sampling was systematic (zigzag) and the time of the sampling stages were in two dates; before sowing and after harvesting of barley. To compare the diversity between farms, Shannon-Weiner diversity index was calculated. Based on results, weed seed bank densities in chemical managed farms (CMFs) was generally higher than those farms without chemical control (NMFs). At first sampling, average weed seed bank populations in CMFs, were 49 and 31 seeds kg^{-1} of soil, and for NMFs were 136 and 177 seeds kg^{-1} soil in 2004 and 2005, respectively. The weed seed bank density in second sampling date (post harvesting of barley) for CMFs were 33 and 30.5 seeds kg^{-1} soil, and for NMFs were 210 and 254 seeds kg^{-1} soil in 2004 and 2005, respectively. Seed bank density decreased over sampling times (growing season) for CMFs in 2004 as compared to NMFs. In 2005, the NMFs variation trend of the seed bank densities for managed farms, was constant between the two stages of sampling. But the trend of variation in NMFs was similar to the previous year. Shannon-Weiner diversity index in CMFs was higher than those of NMFs. Probably, herbicide application had reduced the seed production of weeds and the ultimate seed rain into the soil seed bank. Results of this study demonstrate the importance of weed control practices in reducing weed seed bank size.

Keywords: Seed bank, rotation system, chemical control, diversity.

INTRODUCTION

Although emerged weeds usually provide the primary indicator of the success of the weed management efforts, monitoring the seed bank can offer additional information about the long term prognosis for weed management. Seed bank acts as the memory of the population dynamics of weeds over several years, reflecting past and present management elements, and it in fact is an indicator of weed problems to come (Cavers, 1995; Dorado, *et al.*, 1999). Changes to the emerged weed populations represent relatively immediate impacts of changing farming practices, whereas changes to the seed

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bank may be more representative of long-term trends associated with changes in farming practices (Buhler, 1995; Vanasse and Leroux, 2000, Legere and Stevenson, 2002). Clements *et al.* (1996) noted that changes in farm management systems will influence weed species diversity. This could be a threat to crop yields if some weed species are superior competitors and there are few management options available to farmers. However, potential benefits of increased weed species diversity include more competition between weed species, more niches for natural enemies of weed, more weed-weed interactions, greater diversity of weed life histories, greater community stability and reduced incidence of herbicide resistance (Clements *et al.* 1996; Forcella and Durgan,. 1997; Swanton and Murphy, 1996; Dawit and David, 1997; Schellhorn and Sork, 1997; Zanine *et al.*, 1998; Miyazawa *et al.*, 2004).

Until a few years ago, weed management relied almost exclusively on herbicide applications. Over a several year period, the most dominant factor influencing species composition in the seed bank and weed flora is cropping sequence but this effect closely depends on herbicide use (Daniel and Ball, 1992). Herbicides influence seed number and species composition of the seed bank. Certain species decrease in the seed bank and others increase depending on herbicide use. Herbicide selected for use is partly dictated by chosen crop rotation sequences. In general, weed selection will be in favor of species that are less susceptible to applied herbicides. This in turn ultimately dictates species composition of the seed bank. Other researches have reported a steady decline in total seed bank densities in plots receiving repeated herbicide applications. However, weed seed number increased rapidly after herbicide use was discontinued (Manely *et al.* 2001; Aguilar *et al.*, 2003)

Our objective of this on-farm study was to determine the effect of applying herbicide on weed seed bank population changes in farms with corn-barley rotation system receiving identical other agripractices.

MATERIALS AND METHODS

Experiments were conducted at the University of Tehran research fields, Tehran, Iran during 2004 and 2005. Fields were selected based on their similarity of management history, crop grown, rotation used, amendments used, and proximity within a geographic location (Table-1). The fields were 100m by 100m and have been used in corn-barley rotation over a long period of time (approximately 10 years). Our main variable across farms was herbicide application. Most other variables were relatively constant across farms, which reduced confounding effects. These mentioned agronomic practices and management methods had been carried out more than ten years before conducting of our research. The soil in experimental fields was a silt loam. For each turn, soil samples were collected from forty 1-m^2 quadrates using systematic method (zigzag). Five random samples per quadrates were taken 15 cm deep by auger with the 5 cm of diagonal and bagged individually. Samples were collected in late October (pre-sowing of barley) and mid March (post harvesting of barley) in 2004 and 2005. Samples were stored at -5^0 C until seeds were extracted from the soil by washing the soil through two sieves with sizes 40 and 60 meshes. Remainders were allowed to air dry at room temperature for 1 day. Only the seeds that were intact physically and resistant to the slight pressure with the forceps were counted as viable seeds that were firm when pressed with a forceps. This method has its limitations because only physical properties of the seeds are taken into account. However, it is a useful and fast method when the number of samples is high (Dorado *et al.*, 1999). The number of seeds data were recorded by species for each soil sample.

Table-1. Crop rotation scheme and agronomic practices applied in selected farms.

Rotation	Seed bed preparation	Seed rate	fertilizer	Herbicide used
Corn-Barley	Mold board Disk Leveler	150 kg ha^{-1} barley 40 kg ha^{-1} corn	Ammonium phosphate (pre-planting) 150 kg ha^{-1} Top dressed urea 50 kg ha^{-1} Muriate of potash 100 kg ha^{-1}	Farms 1 and 2 with chemical control(CMFs) 2,4-D (1.5 Lit ha^{-1}) + fenoxaprop-p-ethyl (1 lit ha^{-1}) for barley 2,4-D+MCPA (1.5 lit ha^{-1}) for corn Farms 3 and 4 With none herbicide (NMFs)

Estimation of diversity index

Alpha-diversity measures the amount of diversity within a community type. Shannon-Wiener index is one of the prevalent method to calculate the diversity of a community. If it be calculated for a large number of samples, the values will have a log-normal distribution. So the t-test and analysis of variance (ANOVA) easily work to compare the diversity between the communities. This index is based on proportional abundance of each species. The Shannon-Wiener diversity index (H') was calculated using the fallowing formula (Booth *et al.* 2003):

$$H' = -\Sigma[Pi\ (Ln\ Pi)] \qquad (1)$$

Where pi= proportional abundance of a given species (pi=ni/N). ni was the number of *i*th species and N was total numbers of individuals of all species in the community.

To interpret the value of this index, higher number indicates a more diverse community.

Statistical analysis

Chi-square test was used to compare seed bank densities between farms. Data analysis was done using both univariate and multivariate techniques. Principal component analysis (PCA) was performed using PRINCOMP procedure of SAS (SAS Institute, 2001). Pair-wise comparison of diversity indices was carried out by calculating an observed t as described by Booth *et al.*, (2003). The formula for calculating the observed t-test was:

$$t_{obs} = (H'_a - H'_b)/\ (H'_{var(a)} - H'_{var(b)})^{0.5} \qquad (2)$$

Where t_{obs} is the statistical observed t, H'_a and H'_b are Shannon-Weiner diversity index for community a and b, and H_{var} is the variance for each community and the formula to calculate was:

$$H'_{var} = 1/N \{(\Sigma Pi (Ln\ Pi)^2) - (\Sigma Pi (Ln\ Pi))^2\} \quad (3)$$

where N was the total number of individuals of all species in the community.

RESULTS AND DISSCUSSION

Mean seed bank densities in chemical managed farms (CMFs) were generally higher barley), average weed seed bank population in kg/soil for farms 1 and 2 (CMFs), were 49 and 31 seeds, and for NMFs indeed farms 3 and 4 with none herbicide, were 136 and 177 seeds in 2004 and 2005, respectively. The weed seed bank densities in the second sampling date (post harvesting of barley) for farms 1 and 2 were 33 and 30.5 seeds , and for farms 3 and 4 were 210 and 254 seeds in kilogram of soil, in 2004 and 2005, respectively

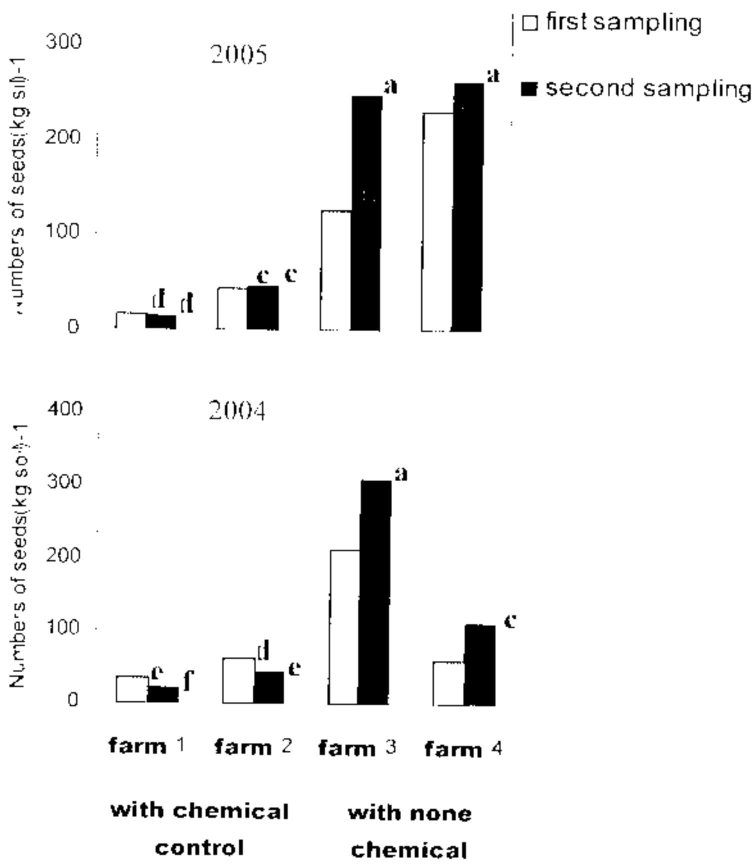


Figure-1. Comparing the trend of seed bank size differences between two stages of sampling (pre-sowing date and post harvesting sampling) in corn-barley rotation system with and without chemical control during 2004 and 2005 (In each farm, the bars with similar letters had non significant difference using chi-square test).

The main factor of differentiation between farms was using of herbicides. Today, herbicides are recognized as the principal factor that affects weed population in farms. The rotation systems provide integration of different herbicides and increase the magnitude of control spectrum. Results indicated that the sizes of soil seed banks were significantly different between farms with and without chemical control. In CMFs, applying 2,4-D and fenoxaprop-p-ethyl decreased seed bank density within season in 2004 (Table-2). The efficient herbicide performance in controlling weeds drastically prevented seed production by weeds, which resulted in more depleted soil seed bank in managed farms. Forcella and Durgan (1997) observed that with hampering of weed seed producing the size of seed bank declined exponentially. Contrary to 2004, in 2005 there were non significant differences between sampling dates with seed bank densities. Herbicide application was delayed this year. Apparently, the lag time due to late application of herbicides provided an enough time for some weed species to escape from chemical control, eventually producing a large number of seed introduced into soil seed banks. Consequently, the preceding decline in seed bank was compensated by the seed rain of successfully reproducing weeds.

Table-2. Mean seed bank density of weed species in farms with spraying practice at two sampling dates (CMFs).

Weed species		Group	2004		chi-square (X^2)	2005		chi-square (X^2)
Common name	**Scientific name**		Pre-sowing sampling	Post harvesting sampling		Pre-sowing sampling	Post harvesting sampling	
Redroot pigweed	*Amaranthus retroflexus*	Summer Annual broad leaf	7	8	ns	5	3.5	ns
Common purslane	*Portulaca oleracea*	Summer Annual broad leaf	11	9	ns	7	5	ns
Fumitory	*Fumaria vailanti*	Annual broad leaf	2	–	**	-	-	-
Barnyard grass	*Echinochloa crus-galli*	Summer Annual grass	3	3	ns	1	1	ns
Common chickweed	*Stellaria media*	Annual broad leaf	4	1	**	2	4	ns
Wild mustard	*Sinapis arvense*	Annual broad leaf	13	3	**	10	11.9	ns
Lambsquarters	*Chenopodium album*	Summer Annual broad leaf	5	5.8	ns	3	2	ns
Prostrate pigweed	*Amaranthus belitoides*	Summer Annual broad leaf	4	5	ns	2.6	3	ns

** : The number of weed species are different between two sampling dates at $p \leq 0.01$, ns= non-significant ($p \geq 0.05$).

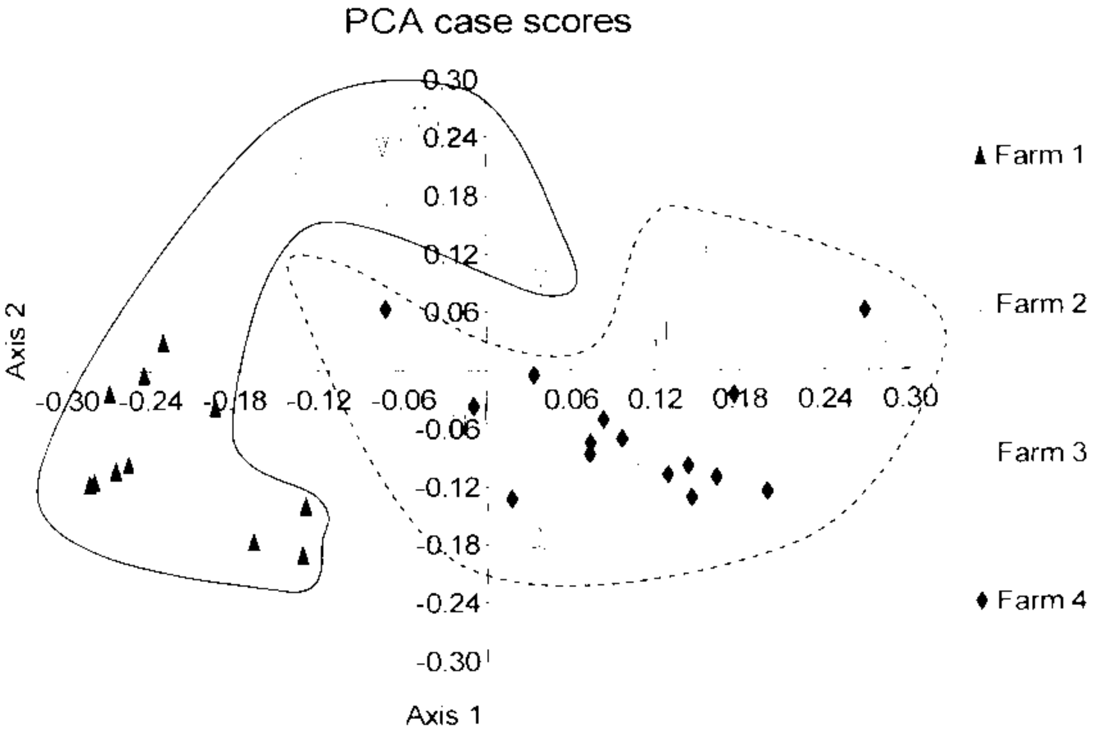
In NMFs higher weed seed densities were observed (Figure 1). No certain management program (low input) in these farms, caused the emerged weeds to complete their life cycle. The rain of seeds into soil intensified the seed bank density. The summer annual species had a main proportion in differences observed between farms with and without spraying (Table-3). This was due to the increased population of weed between corn rows, in the absence of spraying practices.

Table-3. Mean seed bank density of weed species in farms without spraying at two sampling dates (NMFs).

Weed species		Group	2004		Chi square (X^2)	2005		Chi square (X^2)
[illegible]	[illegible]		[illegible] sowing sampling	[illegible] harvesting sampling		[illegible] sowing sampling	[illegible] harvesting sampling	
Redroot pigweed	*Amaranthus retroflexus*	Summer Annual broad leaf	[illegible]	14	ns	[illegible]	[illegible]	[illegible]
Common purslane	*Portulaca oleracea*	Summer Annual broad leaf	32	27	ns	41	98	ns
[illegible]	[illegible]	Annual broad leaf	[illegible]	24	**	14	[illegible]	**
Barnyard grass	[illegible]	Summer Annual grass	[illegible]	[illegible]	[illegible]		4	[illegible]
Common chickweed	*Stellaria media*	Annual broad leaf	20	36	**	[illegible]	29	**
[illegible]	[illegible]	Annual broad leaf	[illegible]	[illegible]	**	54	[illegible]	**
[illegible]	[illegible]	Summer Annual broad leaf	[illegible]	32	**	[illegible]	[illegible]	**
Prostrate pigweed	*Amaranthus* [illegible]	Summer Annual broad leaf	3	2	ns	[illegible]	4.5	ns

** The number of weed species are different between two sampling dates at $p \leq 0.01$, ns non significant at $p \geq 0.05$

Principal component analysis (PCA) is one of the simplest methods of multivariate analysis that can classify species and sits along the axes of a so-called biplot. Similar species and sits will be located closer together on the biplot. With the environmental data we can then correlate environmental variables to the distribution pattern of species (Kernel *et al.* 2002). But in this method we don't yet have a direct measure of what environmental variables influence species grouping. In this research herbicide application was the main factor of divergence between farms. As regards the differences observed in the size and composition of species in PCA diagram, the farms with chemical control located closer together in one group and the farms with no chemical control are classified in one segregated group. As depicted in Figure-2, NMFs were located on the negative side of PCA1 with no clear segregation of farms 3 and 4 on the contrary, managed farms 1 and 2 clumped separately on the positive side of PCA1 CMFs (1 and 2) were more separated along PCA2.



farms with different method of control were different significantly These values in CMFs were higher than the NMFs.

Table -4. Shannon-Weiner diversity index (H) in farms under spraying (CMFs) and farms without chemical control (NMFs) during two years sampling

Shannon-Weiner diversity index(H)	2004	2005	t-test 0.1
CMFs	1.63	1.47	n.s
NMFs	1.14	1.09	n.s

Table- 5. T-observed values between the calculated Shannon-Weiner diversity indices (H') in chemical controlled (CMFs) and non chemical controlled farms (NMFs) during 2004 and 2005.

Management		CMFs		NMFs	
		2004	2005	2004	2005
CMFs	2004	-	0.6^{ns}	1.893*	2.026**
	2005	-	-	1.125^{ns}	1.226^{ns}
NMFs	2004	-	-	-	0.79^{ns}
	2005	-	-	-	-

** : are different at p= 0.05. * are different at p= 0.1, ns: non-significant by t-test.

Very likely the type of control practice was affected on species diversity. By applying 2,4-D and fenoxaprp-p-ethyl, it was expected that with entering herbicide selection pressure to species populations, the value of diversity index will decrease. But contrary to anticipation, the rate of Shannon-wiener diversity indices raised. The determinative factors on diversity rate not include only the numbers of species. One of the other effective factors is the evenness of proportional abundance of each species that can change the diversity index value. So the species with negligible numbers have not important influence to intensify the diversity index. Probably in CMFs, the abundance of winter species e.g. wild mustard, turnip weed and common chickweed was modified with efficient performance of herbicide and increased similarity of species populations. Herbicide selection pressures cause shifts in the weed community from one species to another by decreasing susceptible weed species from the existing population. In crop rotations, weed management program is a large important environmental filter in determining weed density and diversity. The seed bank, then, is both a cause and a result of the existing vegetation, reflecting past and current management while providing a picture of potential future vegetation.

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