Turk J Agric For
33 (2009) 315-323
© TÜBİTAK
doi:10.3906/tar-0712-47

Research Article

Long-term effects of crop rotation and fertilizers on weed community in spring barley

Hamid Reza MOHAMMADDOUST CHAMANABAD[1], Ardavan GHORBANI[1,*],
Ali ASGHARI[3], Aleksander Mihailovic TULIKOV[4], Frouddin ZARGARZADEH[5]

[1]Department of Agronomy and Plant Breeding; University of Mohaghegh Ardabili, Ardabil, P.O. Box 179 - IRAN
[2]Department of Soil Science; University of Mohaghegh Ardabili, Ardabil, P.O. Box 179 – IRAN
[3]Department of Agronomy and Plant Breeding; University of Mohaghegh Ardabili, Ardabil, P.O. Box 179 - IRAN
[4]Department of Agronomy and Experimental Methods, Agricultural University of Timiriazev, Moscow, P.O. Box 127550 - RUSSIA
[5]Department of Plant Pathology; University of Mohaghegh Ardabili, Ardabil, P.O. Box 179 - IRAN

Received: 31.12.2007

Abstract: Integrated weed management programs require a clear understanding of the mechanisms influencing the establishment, growth, and reproduction of unwanted plants (weeds) in agro-ecosystems. This study evaluates the effect of long-term (95 years after the establishment of the site) crop rotation and chemical fertilizers on the weed community dynamics in spring barley at the Agricultural University of Timiriazev, Agricultural Site in Moscow. The weed community occurring on plots of spring barley (grown in crop rotation or continuous) was examined under nitrogen, potassium, phosphorus, NPK, and a control with no fertilizer treatments. Statistical analyses were conducted using analysis of variance (ANOVA) and principal component analysis (PCA). The results show that a) at the study sites, spring weeds are dominant components on agro-ecosystems; b) weed density, particularly of perennials, has significantly decreased under crop rotation; c) the combination of fertilizers (NPK) also decreased the weed density, d) weed density under separate N, P, and K applications was almost the same as that in the control plots. These results suggest that long-term crop rotation and NPK application can strongly affect and reduce weed density in spring barley.

Key words: Crop rotation, chemical fertilizer, spring barley (*Hordeum vulgare* L.), weed community

Introduction

Changes in weed community composition are the result of selection pressures imposed by agronomic practices. This procedure should be understood in the interaction of agronomic practices with weed species biology and environmental conditions (Aldrich, 1984; Altieri and Liebman, 1988). Each agricultural practice leads to proliferation of a particular weed species. Therefore, agricultural practices continuously affect weed communities (Hume, 1982; Schweitzer et al., 1988; Thomas and Frick, 1993; Maiksteniene and Arlauskiene, 2006). For example, Mennan and Isik

* E-mail: ardavanica@yahoo.com

(2003) found that the use of the same weed control methods, rotations, contaminated crop seeds, and fertilizers greatly altered weed species composition during a period of 25 years. The relative importance and most effective combinations of these weed control tactics, such as manipulation of soil fertility and dynamics in rotation sequences, have not been adequately addressed. The success of rotation systems for weed suppression appears to be based on the use of crop sequences that create varying patterns of resource competition, allelopathic interference, soil disturbance, and mechanical damage to provide an unstable and frequently inhospitable environment that prevents the proliferation of a particular weed species (Aldrich, 1984; Altieri and Liebman, 1988; Black and Bauer, 1990; Blackshaw et al., 1994). Crop rotation has been shown to affect the composition, density, and extent of weed communities (Tulikov and Sugrobov, 1984; Derksen et al., 1993). Growing winter wheat continuously resulted in severe downy brome (*Bromus tectorum* L.) infestations (Blackshaw et al., 1994), while continuous spring wheat led to high levels of foxtail species (*Setaria* spp.) and wild oats (*Avena fatua* L.) (Donald and Nalewaja, 1990).

The effect of fertilizer on the weed community and weed /crop interferences has been investigated to a lesser extent. Crop competitiveness can be improved using selective fertilization (Dusky et al., 1996; Blackshaw et al., 2002; Blackshaw et al., 2004; Mohammaddoust Chamanabad et al., 2006). Numerous studies found that crop yields improve following the application of fertilizers to soil, particularly N, P, and K (Dusky et al., 1996; Dhima and Eleftherohorinos, 2001; Blackshaw et al., 2002; Mohammaddoust Chamanabad et al., 2006). Although fertilizers clearly promote crop growth, many studies have shown that nutrients benefit weeds more than crops (Alkamper, 1976; Liebman and Robichaux, 1990; Sindel and Michael, 1992). In contrast, some studies found that the application of fertilizers to soil reduced the abundance of weeds and their dried mass (Tulikov and Sugrabov, 1984; Tollenaare et al., 1994; Mohammaddoust Chamanabad et al., 2006). This disagreement may be related to the different factors such as weed density and fertilizer combination. Where weed density is low, increasing the rate of N can markedly increase crop yields and minimize competition with weeds (Alkamper, 1976). Tulikov and Sugrobov (1984) reported that NPK application reduced weed density in comparison with the separate application of each of those fertilizers.

Moreover, fertilizer application can also affect weed composition. For example, N application can increase nitrophilous species such as common lambsquarters (*Chenopodium album* L.) (Haas and Streibig, 1982). Hume (1982) reported that the density of Canada thistle (*Cirsium arvense* L.) increased in non-fertilized plots, while green foxtail (*Setaria viridis* L.) was more prevalent in fertilized plots. In other studies, N application also favored green foxtail (Schreiber and Orwick, 1978; Peterson and Nalewaja, 1992) and wild oats (Carlson and Hill, 1986) over wheat, indicating that N application can favor some weeds over crops. Production systems are being developed that give crops a competitive advantage over weeds, minimize the density of weeds as crops are established, and keep weed communities out of equilibrium to reduce the long-term build up problem of weed species (Tulikov and Sugrabov, 1984; Derksen et al., 1993; Gill and Arshad, 1995).

Many short-term experiments have shown that crop rotation and the application of fertilizers (each separately) can affect weed communities (Schreiber and Orwick, 1978; Carlson and Hill, 1986; Hume et al., 1991). However, little is known about their combined effects in long-term experiments. This study examined the long-term (95 years after the establishment of the site) effects of crop rotation and fertilizers on weed communities.

Materials and methods

This study was conducted at the long-term experimental site at the Agricultural University of Timiriazev at Moscow in 2004 and 2005. The climate of the study area is humid-cold. The mean temperature and normal rainfall of the growing season (April to August) were 13.6 °C and 335 mm. In the study years (2004 and 2005), the mean temperature for the growing season was 13.6 and 15.3 °C and rainfall was 470.7 and 366.3 mm, respectively. The soil had a loamy-clay texture with a pH from 5.5 to 6.5.

The selected sites for experiments were situated on a long-term farm with 5 crops including winter rye, potato, spring barley, clover, flax, and fallow. These crops were cultivated since 1912 in continuous or crop rotation (Figure 1). The rates of fertilizers have been changed since 1912 (Table 1). The data of this study were only collected from the site of spring barley with the fertilizer treatments of N, P, K, NPK, and control (O) on the sites without lime (Figure 1). For clarification, this study did not include the combined fertilizers such as NP, NK, PK, NPK+H as treatments. The fertilizers had been incorporated into the soil before planting at 100 kg N ha^{-1} as ammonium nitrate (2/3 at pre-planting and rest at the full tillering stage), 150 kg P_2O_5 ha^{-1} as triple super phosphate, and 120 kg K_2O ha^{-1} as potassium chloride. During this period (1912-2005) weeds were conventionally controlled using mechanical or chemical methods. This study focused on weed communities in spring barley occurring on plots of N, P, K, and NPK application, and on control plots with no fertilizer (O).

Treatments were conducted as split plot on the basis of randomized complete block design with 3 replications. The individual plot size was 10 × 5 m (50 m^2). Zazercki spring barley was planted on May 3, 2004 and May 19, 2005. It was drilled in 15 cm rows at 5.5 million plants ha^{-1}. Immediately after seeding 3 permanent quadrats – each quadrat 50 × 50 cm – were staked in each plot. Prior to herbicide application, the quadrats were covered with polyethylene boxes (100 × 100 cm) to prevent its effects on the weeds. These boxes were removed after spraying.

Table 1. The change of the fertilizer rates in the long-term field in Moscow from 1912 to 2005 (Tulikov and Sugrobov, 1984).

Years	Rate of fertilizers (kg ha^{-1})		
	N	P_2O_5	K_2O
1912-1938	7.5	15	22.5
1939-1954	75	60	90
1955-1972	50	75	60
1973-2005	100	150	120

At the full tillering stage, the weeds in permanent quadrats were counted by species. At the maturity stage, weeds were cut at ground-level in permanent quadrats, separated by species, and counted.

To reduce the coefficient of variance, data for weed density were log-transformed prior to ANOVA. Means were separated at a 1% level of significance, using Tukey's test. Because of the effects of different weeds on each other and the existing high correlation

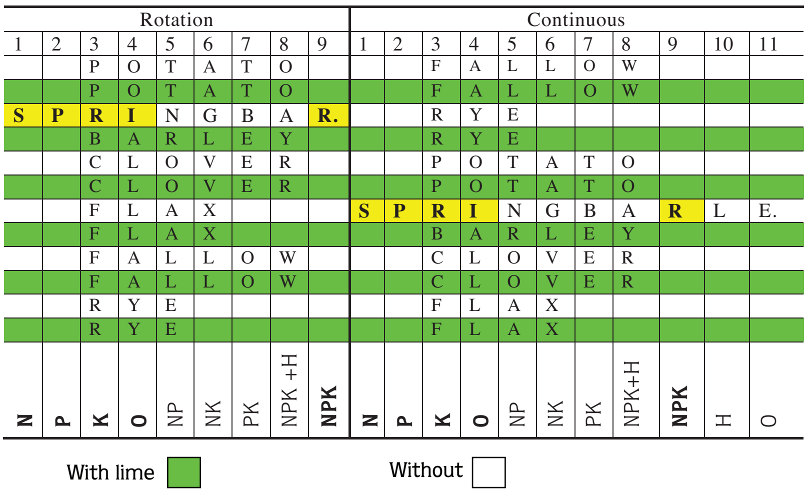

Figure 1. The schematic view of the long-term field experiment in Moscow; in rotation and continuous systems the spring barley sites without lime were the sites of this study for data collection as highlighted and bolded (N = Nitrogen, P = Phosphorus, K = Potassium, O = Control, and H = Organic materials).

between weed densities, PCA grouped the treatments based on the correlation coefficient matrix. Then the 2 first principal components (PC1and PC2) were used to group the treatments. The data were analyzed using SPSS v.12.0 (SPSS Inc., Chicago 2004).

Results

The analysis of climatic data indicated that 2005 was drier and warmer in comparison to 2004. Twenty-two weed species were observed in both stages (full tillering and wax maturity). From those, 16 were annual and 6 were perennial weeds (Tables 2 and 3) with the dominance of *Raphanus raphanistrum* L., *Spergula arvensis* L., *Gnaphalium uliginosum* L., *Matricaria inodora* L., and *Echinochloa crus-galli* L. Some species such as *Galeopsis speciosa* Mill., *Galinsoga parviflora* Cav., *Gnaphalium uliginosum* L., and *Lapsana communis* L. were only observed in 2005 due to the dry conditions.

Table 2. Spring, winter and perennial weeds density (plant m^{-2}) at the full tillering stage of spring barely under crop rotation and fertilization (average of 2004 and 2005), classified into ecophysiologocal groups / O = Control, N = Nitrogen, K = Potassium, P = Phosphorus.

	Continuous					Rotation				
	O	N	P	K	NPK	O	N	P	K	NPK
Chenopodium album L.	2	1	3	1	13	3	6	4	6	2
Echinochloa crus-galli L.	2	8	0	0	8	0	0	0	0	0
Erysimum cheiranthoides L.	0	0	0	0	0	14	1	0	7	61
Fumaria officinalis L.	0	0	3	2	5	0	0	0	0	0
Galeopsis speciosa Mill.	8	20	13	8	2	2	14	8	6	0
Galinsoga parviflora Cav.	0	0	0	0	6	0	2	0	0	0
Gnaphalium uliginosum L.	7	34	24	11	18	62	0	0	0	14
Polygonum sp.	0	0	0	0	0	0	0	2	0	0
Raphanus raphanistrum L.	106	121	48	65	28	2	14	9	6	1
Spergula arvensis L.	185	89	114	126	36	22	26	17	25	19
Total	310c	272c	205b	213b	116a	105a	87a	83a	78a	97a
Capsella bursa-pastoris L.	0	0	0	0	6	2	1	2	4	1
Centaurea cyanus L.	0	0	0	0	0	0	0	0	0	0
Lapsana communis L.	0	0	0	0	1	0	0	0	0	0
Matricaria inodora L.	67	68	106	164	29	90	121	69	64	62
Poa annua L.	5	2	8	8	5	16	29	9	5	10
Thlaspi arvense L.	0	0	0	0	0	1	0	0	0	0
Viola arvensis L.	0	6	22	8	1	3	16	10	10	10
Total	72ab	76ab	136c	180c	42ab	112b	167c	91ab	83ab	83ab
Agropyron repens L.	6	32	6	0	1	0	0	0	0	0
Cirsium arvense (L.) Scop.	0	0	0	18	0	0	0	0	0	0
Equisetum arvense L.	2	2	70	2	0	0	0	0	0	0
Plantago major L.	0	3	1	0	0	7	9	4	5	0
Sonchus arvensis L.	7	2	39	32	5	0	0	0	0	0
Vicia cracca L.	0	0	5	2	8	0	0	0	0	0
Total	15ab	39c	121d	54c	14ab	7ab	9ab	4ab	5ab	0a

Table 3. Spring, winter and perennial weeds density (plant m^{-2}) in the wax maturity stage of spring barely under crop rotation and fertilization (average of 2004 and 2005), classified into ecophysiologocal groups / O = Control, N = Nitrogen, K = Potassium, P = Phosphorus.

	Continuous					Rotation				
	O	N	P	K	NPK	O	N	P	K	NPK
Chenopodium album L.	1	0	2	0	6	6	6	9	7	4
Echinochloa crus-galli L.	8	44	16	8	26	0	0	0	0	0
Erysimum cheiranthoides L.	0	0	0	0	1	0	0	0	0	0
Fumaria officinalis L.	2	24	14	0	2	14	3	4	2	2
Galeopsis speciosa Mill.	6	20	27	4	3	4	15	18	6	1
Galinsoga parviflora Cav.	0	0	0	0	0	0	0	0	0	0
Gnaphalium uliginosum L.	1	3	3	6	8	0	0	0	0	0
Polygonum sp.	0	0	0	0	0	1	2	0	0	1
Raphanus raphanistrum L.	43	88	38	21	18	4	7	2	0	2
Spergula arvensis L.	108	128	116	86	31	63	54	54	59	48
Total	169b	307c	216bc	125b	95a	92a	87a	87a	74a	58a
Capsella bursa-pastoris L.	0	0	4	0	5	2	1	1	2	4
Centaurea cyanus L.	1	1	0	0	0	0	0	0	0	0
Lapsana communis L.	1	3	2	0	8	0	0	0	0	0
Matricaria inodora L.	70	93	118	130	22	29	8	19	14	18
Poa annua L.	0	6	15	8	6	11	26	26	18	20
Thlaspi arvense L.	1	2	0	1	9	2	1	2	2	2
Viola arvensis L.	1	11	16	0	4	2	3	3	2	2
Total	74ab	116b	155b	139b	54a	46a	39a	51a	38a	46a
Agropyron repens L.	17	15	15	25	0	0	0	0	0	0
Cirsium arvense (L.) Scop.	0	1	0	8	0	0	0	0	0	0
Equisetum arvense L.	1	1	92	2	0	0	0	0	0	0
Plantago major L.	1	10	1	4	4	5	4	6	9	6
Sonchus arvensis L.	6	2	39	23	4	1	0	2	0	2
Vicia cracca L.	0	0	8	1	2	0	0	0	0	0
Total	25ab	29ab	155c	63b	10ab	6a	4a	8a	9a	8a

Effect of crop rotation on weed community

The results of ANOVA show that significant differences ($P < 0.01$) exist among the weed density in continuous and rotation systems for spring, autumn, and perennial weeds. The weed density in the rotation system on average was 2 to 3 times higher, particularly in the case of perennial weeds, and was lower than the continuous system.

Results show that the continuous system produced a substantially different weed community in comparison with the rotation system. Differences were qualitative and quantitative. The number of observed species at the full tillering and wax maturity stages in the continuous system were 18 and 21 respectively, while in rotation system the numbers were 14 and 13. Most weed species were observed in greater numbers under the continuous system. *Echinochloa crus-gali* L., *Fumaria officinalis* L., *Gnaphalium uliginosum* L., *Agropyron repens* L., *Cirsium arvense* L., and *Equisetum arvense* L. almost grew exclusively in the continuous system. In the continuous system in both stages 6 perennial weeds (*Agropyron repens* L., *Cirsium arvense* L., *Equisetum arvense* L., *Sonchus arvensis* L., *Plantago major* L., and *Vicia cracca* L.) were observed. By contrast, in the rotation system only 2 species (*Sonchus arvensis* L. and *Plantago major* L.) were collected. These results support the results of previous studies (Hume, 1982; Tulikov and Sugrobov, 1984; Hume et al., 1991).

Effect of fertilizer on weed community

Fertilizer had a significant influence on the weed density ($P < 0.01$). Analyses show that NPK application reduced the annual and perennial weed density in comparison with the control at both stages, while N and P application significantly increased both groups' density (Tables 2 and 3). Nitrogen application increased nitrophilous species density such as *Fumaria officinalis* L. and *Raphanus raphanistrum* L. Plots that received P had significantly higher counts of phosphophilous species such as *Matricaria inodora* L. and *Equisitum arvense* L. These results support the results of previous studies (Haas and Streibig, 1982; Hume, 1982; Tulikov and Sugrobov, 1984; Carlson and Hill, 1986; Peterson and Nalewaja, 1992).

On the other hand, fertilized treatments and the control in the rotation system showed no significant differences (Tables 2 and 3). Moreover, the NPK treatment in the continuous system had no significant difference with the other fertilized treatments in crop rotation (Tables 2 and 3). These results emphasize that using crop rotation or complete fertilization to improve growth conditions for spring barley is of considerable significance in increasing the competition ability of crops against weeds, which eventually can decrease the weed density. Many studies (Peterson et al., 1993; Thomas and Frick, 1993; Blackshaw et al., 1994; Dhima and Eleftherohorinos, 2001; Blackshaw et al., 2002) have already demonstrated crop rotation, management of the chemical fertilizers, planting pattern, crop density, and mixed culture can reduce weed density.

PCA analyses

Treatment grouping using PCA (by all weed species) showed that the rotation system and the continuous system with NPK application were substantially different from the rest, as demonstrated by the scatter diagrams (Figures 2 and 3). These results indicate that continuous cropping with NPK application reduced weed density in the same way as crop rotation does. The PCA for treatment grouping was performed based on weed density in 2 stages: full tillering and wax maturity stages.

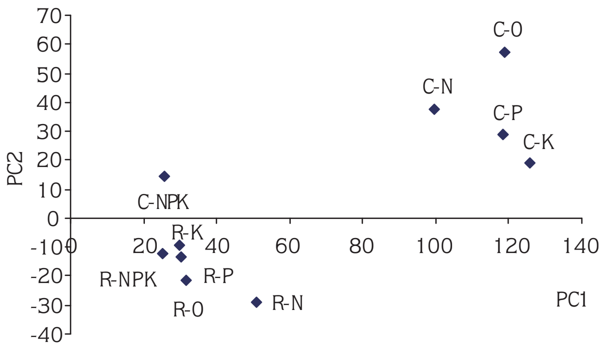

Figure 2. Results of PCA performed using all weed density in the full tillering stage C = Continuous, R = Rotation, O = Control, N = Nitrogen, K = Potassium, P = Phosphorus.

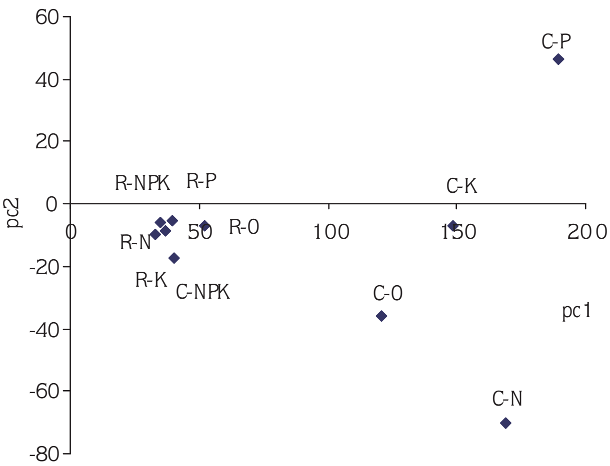

Figure 3. Results of PCA performed using all weed density in wax maturity stage C = Continuous, R = Rotation, O = Control, N = Nitrogen, K = Potassium, P = Phosphorus.

Full tillering stage

In this stage, the first and second principal components (PCs) that explained 80.05% of the weed density variation were used for the grouping of treatments. In this grouping, the rotation system was discriminated from the continuous system (Figure 2). In the rotation system, the density of weeds such as *Chenopodium album* L., *Polygonum* sp., *Capsella* *bursa-pastoris* L., *Poa annua* L., and *Plantago major* L. was greater than that in the continuous system. Therefore, based on these differences, the rotation and continuous systems were discriminated from each other.

In the rotation system, the plots without fertilizer (O) were no different from the weed density perspective with other treatments, and they were classified in the same group (Figure 2). From this, it was concluded that the form of fertilizer with the appropriate rotation system had no significant effect on the weed density. This means that crop rotation can control weeds appropriately (Table 2 and Figure 2). Although spring and perennial weed density in a continuous system with NPK application was less, autumn weeds were higher than the rotation system, and the mean weed density was similar to the rotation system (Table 2 and Figure 2). In the continuous system, NPK application was completely discriminated from the other treatments (Table 2 and Figure 2). It was similar to the rotation system. Therefore it can be concluded that in the continuous crop with NPK application the weeds can be controlled by crop rotation. Thus it is possible to control weeds in the continuous crop with the management of fertilizer application. In the continuous system, plots without fertilizer or with the separate application of N, P, and K were discriminated and classified almost in the same group. However, the distances of grouped treatment plots (Table 2 and Figure 2) were not close to each other. Separate treatment grouping with the use of annual spring, winter, and perennial weeds was also considered, but the same results were often obtained.

Wax maturity stage

Treatment grouping in the wax maturity stage using PC1 and PC2, which explained 56.67% of weed density variation, showed the same results as the full tillering stage. Fertilizer treatments of the rotation system were almost classified in the same group (Figure 3). It should be noted that the density of weeds in fertilizer treatments of the rotation system had on average low weed density (Table 3). The continuous system with NPK application was placed almost in the same treatment group (Figure 3). The continuous system plots without fertilizer and with N, P, and K application alone had more weed density, and so they were classified in a separate group. In rotation and continuous systems, on average weed density in the plots with NPK application was lower than the other types of treatments. However, weed density in the fertilized treatments in the continuous system was significantly different (Table 3).

Effect of crop rotation and fertilizer on barley yield

Crop rotation and fertilizer application had significant ($P < 0.01$) effects on the spring barley yield. Because of the low weed density in the rotation system, barley's yield was higher in comparison with all of the fertilizer treatments in the continuous system (Table 4). As was expected, spring barley responded positively to crop rotation. In the continuous system, complete fertilization also increased spring barley's yield 2 to 4 times in comparison with the other treatments. Complete fertilization stimulates crop growth and thus weed density was lower in comparison with the control and the separate application of N, P, and K.

Table 4. The average yield (kg ha^{-1}) of spring barley for 2004 and 2005 under long-term crop rotation and fertilizer application. The same letters shows the insignificant difference ($P < 0.01$). O = Control, N = Nitrogen, K = Potassium, P = Phosphorus.

Treatments	O	N	P	K	NPK
Continuous	270b	520b	550b	310b	1380a
Rotation	1630ab	2150a	1900a	1870a	2140a

Discussion

This study shows that crop rotation substantially changes the weed community. Changes are qualitative and quantitative. Crop sequences that create varying patterns of resource competition, allelopathic interference, and application of different herbicides can change the weed community. Many studies (Hume, 1982; Hume et al., 1991; Blackshaw et al., 1994) have also reported that crop rotation reduces weed density, particularly perennial weeds, by improving the growth condition for crops and increasing the competition ability.

Despite the fact that many weed species are more responsive to fertilizer than crops are, the phenomenon is not universal. Our study showed that combined fertilizer application substantially reduced weed density. Other studies (Tollenaare et al., 1994; Blackshaw et al., 2002; Blackshaw et al., 2004) have already demonstrated that management of chemical fertilizers can reduce weed density or change weed's flora. Tollenaare et al. (1994) reported that increasing the N rate applied to maize resulted in less biomass in weeds and a greater maize yield. Moreover, many weeds are high N or P consumers (Qasem, 1992; Blackshaw et al., 2003); thus the growth of many weed species is enhanced by higher soil N or P levels.

Conclusions

The results of this study indicate that any factor that can improve the crop growth can reduce weed infestation. Crop rotation and combining fertilizer generally produced similar effects on the weed community, concurring with the alternative hypothesis. Moreover, designing a more weed suppressive cropping system with less dependence on herbicide use may be achieved. These findings also have interesting implications for developing cropping systems that are ecologically sound, especially when the aims are reducing agriculture pollution, as well as conserving and restoring plant diversity.

Acknowledgments

The authors are highly grateful to Prof. N. F. Hohlov, Head of the Department of Agronomy and Experimental Methods, Moscow, Russia, for providing necessary laboratory facilities.

References

Aldrich, R.J. 1984. Crop production practices and weeds. In: Weed-Crop Ecology: Principles in Weed Management. (Ed. R.J. Aldrich), Breton Publ., North Scituate, MA. pp. 373-398.

Alkamper, J. 1976. Influence of weed infestation on effect of fertilizer dressings. Pflanzen.-Nachr. Bayer. 29: 191-235.

Altieri, M. A. and M. Liebman. 1988. Weed management in agroecosystem: Ecological approaches. CRC Press Inc. Boca Raton, Florida.

Black, A. and A. Bauer. 1990. Sustainable cropping systems for the Northern Great Plains. In: Proceeding of the Great Plains Conservation Tillage Symposium Bismarck, ND, pp. 15-21.

Blackshaw, R.E., F.O. Larney, C.W. Lindwall and G.C. Kozub. 1994. Crop rotation and tillage effect on weed populations on the semi-arid Canadian prairies. Weed Technol. 8: 231-237.

Blackshaw, R.E., G. Semach and H.H. Janzen. 2002. Fertilizer application method affects nitrogen uptake in weeds and wheat. Weed Sci. 50: 634-641.

Blackshaw, R.E., R.N. Brandt, H.H. Janzen, T. Entz, C.A. Grant and D.A. Derksen. 2003. Differential response of weed species to added nitrogen. Weed Sci. 51: 532-539.

Blackshaw, R.E., Molnar, L.J. and Janzen, H.H. 2004. Nitrogen fertilizer timing and application method affect weed growth and competition with spring wheat. Weed Sci. 52: 614-622.

Carlson, H.L. and J.E. Hill. 1986. Wild oat (*Avena fatua*) competition with spring wheat: effects of nitrogen fertilization. Weed Sci. 34: 29-33.

Derksen, D.A., G.P. Lafond, A.G. Thomas, H.A. Loeppky and C.J. Swanton. 1993. Impact of agronomic practices on weed communities: tillage systems. Weed Sci. 41: 409-417.

Dhima, R.V. and I.G. Eleftherohorinos. 2001. Influence of nitrogen on competition winter cereals and sterile oat. Weed Sci. 49: 77-82.

Donald, W.W. and J.D. Nalewaja, 1990. Northern Great Plains. In: Systems of Weed Control in Wheat in North America. (Ed. W.W. Donald), Weed Sci. Soc. Am. Champaign IL., pp. 90-126.

Dusky, J.A., J.W. Shrefler, D.G. Shilling, B.J. Brecke, D.L. Colvin, C.A. Sanchez and W.M. Stall. 1996. Influence of phosphorus fertility on competition between lettuce and *Amaranthus spinosus* L. In: Proceeding of the 2nd International Weed Control Congress, Denmark, pp. 141-145.

Gill, K.S. and M.A. Arshad. 1995. Weed flora in early growth period of spring crops under conventional, reduced, and zero tillage systems on a clay soil in northern Alberta, Canada. Soil tillage Res. 33: 65-79.

Haas, H. and J.C. Streibig, 1982. Changing patterns of weed distribution as a result of herbicide use and other agronomic factors. In: Herbicide Resistance in Plants. (Eds.: H.M. LeBaron and J. Gressel). John Wiley and Sons, New York. pp. 57-79.

Hume, L. 1982. The long-term effects of fertilizer application and three rotations on weed communities in wheat (after 21 years at Indian Head, Saskatchewan). Can. J. Plant Sci. 62: 741-750.

Hume, L., S. Tessier and F.B. Dyck. 1991. Tillage and rotation influences on weed community composition in wheat (*Triticum aestivum* L.) in southwestern Saskatchewan. Can. J. Plant Sci. 71: 783-789.

Liebman, M. and R.H. Robichaux. 1990. Competition by barley and pea against mustard: Effects on resource acquisition, photosynthesis and yield. Agric. Ecosyst. Environ. 31: 155-172.

Maiksteniene, S. and A. Arlauskiene. 2006. The effect of agricultural management systems on the weed incidence in cereals. Agron. Res. 4: 281-285.

Mennan, H. and D. Isik. 2003. Invasive weed species in onion production systems during the last 25 years in Amasya, Turkey. Pak. J. Bot. 35: 155-160.

Mohammaddoust Chamanabad, H.R., A.M. Tulikov and M.A. Baghestani. 2006. Effect of Long-term fertilizer application and crop rotation on the infestation of fields by weed. Pak. J. Weed Sci. Res. 12: 221-234

Peterson, D.A. and J.D. Nalewaja. 1992. Environment influences green foxtail competition with wheat. Weed Technol. 6: 607-610.

Peterson, G.A., D.G. Westfall and C.V. Cole. 1993. Agroecosystem approach to soil and crop management research. Soil Sci. Soc. Am. J. 57: 1354-1360.

Qasem, J.R. 1992. Nutrient accumulation by weeds and their associated vegetable crops. J. Hortic. Sci. 67: 189-195.

Schreiber, M.M. and P.L. Orwick. 1978. Influence of nitrogen fertilizer on growth of foxtail (Setaria) taxa. Weed Sci. 26: 547-550.

Schweitzer, K., B. Mullin, D. Wichman and J. Nelson. 1988. Survey of weeds in conservation and conventionally tilled grain fields in Montana. Proc. West. Soc. Weed Sci. 41: 133-143.

Sindel, B.M. and P.W. Michael. 1992. Growth and competitiveness of *Senecio madagascariensis* Poir. (Fireweed) in relation to fertilizer use and increases in soil fertility. Weed Res. 32: 399-406.

Thomas, A.G. and B.L. Frick. 1993. Influence of tillage systems on weed abundance in Southwestern Ontario. Weed Technol. 7: 699-705.

Tollenaare, M., S.P. Nissanka, A. Aguilera, S.F. Weise and C.J. Swanton. 1994. Effect of weed interference and soil nitrogen on four maize hybrids. Agron. J. 86: 596-601.

Tulikov, A.M. and V.M. Sugrobov. 1984. Role of long-term application fertilizer, lime and crop rotation in change infestation field by weeds. Izvestia TCXA. 2: 32-36.