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The Importance of Crop Rotations for Wild Oat (*Avena sterilis* L.) Resistance to Herbicides in Cukurova Region, Turkey

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ABSTRACT

This study was conducted between 2013 and 2015 to determine the changes in the populations of wild oat (*Avena sterilis* L.) coverages, resistance and weed coverages based on the crop rotation applied at fields where wheat was being grown in Osmaniye Province and to reveal the relationship between the crop rotations and the resistance developed in wild oat by Clodinafop-propargyl with the Acetyl-CoA Carboxylase (ACCase) mode of action, Mesosulfuron-methyl + Iodosulfuron-methyl sodium and Pyroxsulam of the Acetolactate Synthetase (ALS) effect mechanism. By determining crop rotation systems for May and August in 103 fields selected in the year 2013, the coverage changes in the populations of wild oat and weeds and the resistance in wild oat poulations were determined. As a result, 48 different crop rotation systems were determined, wild oat resistance disappeared in the wheat + sunflower + sunflower rotation which was one of the most frequently preferred rotation, while the resistance index *(RI)* of wild oat against the ACCase inhibitor fell *(RI<2.00)* in the two-crop rotations involving maize as wheat/maize + maize + maize, wheat/maize + wheat/maize + wheat, wheat + wheat/maize + wheat and wheat/maize + wheat/maize + maize. In the three-crop rotation systems, resistance against ALS decreased in wheat/peanut + wheat/sesame + wheat, and resistance against ACCase decreased in wheat/maize + maize/peanut + peanut. It was revealed that the producers did not prefer four crop rotation much, and fallow did not change resistance indices. The wild oat resistant populations and coverages in the Osmaniye Province were determined for the first time, and the interactions of crop rotations are presented.

Introduction

Whatever weed management or integrated management system is used, human activities and survival interactions with other species of the production system have always led to the emergence of new weed species in agriculture and the environment. In addition to alternative methods used

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for weed management, chemical herbicides are the most economical ones (Bridges, 1994). Yield losses in production caused by weeds, a worldwide problem, amount to 13.2% or 75.6 billion dollars per year (Oerke et al., 1994). In the United States alone, weeds account for 12% of the annual loss of crops and about 36 billion dollars of monetary losses. Furthermore, four billion dollars are spent on herbicides every year to control weeds (Pimentel et al., 1999). Cereals, main foods among cultivated plants, have great importance in Turkey as in everywhere around the world. The increase in cereal fields in Turkey has continued to the present day, and it has reached over 120 million acres in total. Some of the main limiting factors in production, like with other cultivated plants, are weeds (Wilson et al., 1990). Wild oat species from the Poaceae family, found in cereal fields in almost all countries around the world, are the main major harmful weed species for wheat (Kadıoğlu et al., 1990; Torner et al., 1991). In order to control wild oat species (*Avena* spp.) worldwide, the use of post-emergence ACCase and ALS inhibitor herbicides is increasing (Beckie et al., 2002; Owen and Powles, 2009; Torun, 2017). The most widely used herbicides for chemically controlling cereals are the ACCase (Acetyl-CoA carboxylase) and ALS (Acetohydroxy acid synthase) mechanisms, and excessive employment of these chemicals for wheat has shortened their lifespan in Turkey. One of the best examples is the problem of weed resistance against some herbicides in the Cukurova region (Yücel, 2004; Avcı, 2009; Ayata, 2014; Gürbüz, 2016; Torun and Uygur, 2019a). The resistance of wild oats (*Avena sterilis* L.) and foxtail (*Alopecurus myosuroides* L.) started locally in some wheat fields in the Cukurova region at the end of 1990s and has been observed to have spread during the 2000s. In the following period, a countrywide resistance of wild oats emerged in Turkey as it has been experienced all around the world (Uludağ, 2003; Türkseven, 2011; Torun and Uygur, 2019a).

The first aim of this study is to determine wild oat population coverages and resistance at fields in the Osmaniye Province between 2013 and 2015 against ACCase and ALS inhibitor herbicides. The other purpose of the study is to reveal weed coverages and crop rotation systems. Moreover, this study investigated that all the interaction changes which crop rotation system affected the weed population and the problematic wild oat population, mostly in determined fields and find out the selection of three year crop rotation alternatives to decrease coverages and resistance

Materials and Methods

Sampling of fields and population coverages

During the study period, mature wild oat seeds were collected from May to May of each consecutive year between 2013-2015. 103 different spots were determined to collect the species of wild oats to have a homogeneous and competent enough sample representing the region (Kadirli, Sumbas, Center, Düziçi, Toprakkale, Bahçe and Hasanbeyli) (Table 1, Table 2). Moreover, the effects of the weed populations on cultivated crops were observed one-by-one in the assigned fields over three years. Additionally, the field coverage areas of the harvested wild oat populations during each situation were noted. Sampling numbers based on the districts were determined according to wheat sown areas in the Osmaniye Province in 2013, and along a certain line, samples based on the wheat density areas were taken at every two kilometer (Uygur, 1997).

Table 1. Numbers of sampling wild oat populations for districts in the Osmaniye Province.

Osmaniye Districts (%)	Surveyed Numbers of Wild Oat Populations		
	2013	2014	2015
Kadirli (27%)	15	18	21
Sumbas (9%)	7	6	7
Center (24%)	9	15	18
Düziçi (27%)	14	13	22
Toprakkale (5%)	1	3	3
Bahçe (4%)	-	3	4
Hasanbeyli (4%)	3	5	5
Surveyed Population Number Total	49	63	80

Sampling fields were determined along a certain route in the wheat cultivation concentration areas of the Osmaniye Province in May 2013. In August, the fields that had been previously identified in May were visited again to detect what cultivated plants were present and observe changes in the wild oat and weed population. These processes were repeated in May and August of 2014 and 2015. This three-year-long observation revealed which crop rotations had an impact on the weed population, as well as the impact of crop rotation systems on the population coverage of wild oats (Torun and Uygur, 2019b). Changes in the population coverage of wild oats were detected at predetermined locations with the assistance of global positioning system (Table 2). Regardless of the plant cultured in the respective field, coverages were identified according to the population of wild oats. Population changes in the fields were modified according to Odum (1971). Determination of the weed and wild oat coverages was performed in 1 decare and 1 m^2 at three points that were specified randomly (TAGEM, 2008; Torun and Uygur, 2019a). The most suitable crop rotation systems and the effects of these systems on the coverage of the wild oat and weed populations were identified. It was aimed to determine the most prevalently preferred crop rotation system of the Osmaniye Province. Thus, the effects of the crop rotation systems on the population coverage of wild oats were determined.

Table 2. Location coordinates of determined fields for crop rotation in Osmaniye Province.

Districts	*Kode*	*Location*	*Coordinates*		*Altitude (m)*	*Field (ha)*
Kadirli	K1	Çukurköprü	37º20'38.15''N	35º55'59.75''E	37	2.5
	K2	Hardallık	37º21'44.45''N	35º58'3.57''E	46	1.5
	K3	Rıfatçiftliği	37º20'53.10''N	35º57'46.14''E	51	0.5
	K4	Dervişli – Aşağıçıyanlı	37º19'31.02''N	35º57'43.25''E	50	0.5
	K5	Aşağıçıyanlı	37º19'4.70''N	35º57'8.94''E	40	4.0
	K6	Aşağıçıyanlı – Yeniköy	37º17'34.88''N	35º56'48.57''E	39	6.0
	K7	Yeniköy – Tozlu	37º16'32.65''N	35º56'33.45''E	33	1.0
	K8	Tozlu	37º15'13.25''N	35º56'3.99''E	33	4.0
	K9	Mecidiyeköy	37º12'53.96''N	35º57'12.17''E	29	1.5
	K10	Kesikkeli	37º13'22.13''N	35º58'51.26''E	36	2.5
	K11	Kesikkeli – Tatarlı	37º14'1.69''N	35º59'50.16''E	41	6.0
	K12	Karabacak '1'	37º15'16.48''N	36º2'1.30''E	45	0.5
	K13	Karabacak '2'	37º15'57.78''N	36º2'7.70''E	52	1.5
	K14	Vayvaylı	37º17'26.63''N	36º2'47.34''E	52	2.5
	K15	Kümbet	37º19'29.99''N	36º3'31.12''E	58	6.0
	K16	Anberinarkı	37º20'9.10''N	36º3'59.97''E	70	1.0
	K17	Anberinarkı – Center	37º20'49.25''N	36º4'37.77''E	77	1.0
	K18	Center – Mezretli	37º21'15.26''N	36º5'36.89''E	90	6.0
	K19	Mezretli	37º20'2.92''N	36º5'37.45''E	114	10.0
	K20	Cığcık '1'	37º18'10.76''N	36º5'43.01''E	110	4.5
	K21	Cığcık '2'	37º17'21.79''N	36º5'51.67''E	96	3.0
	K22	Cığcık – Yukarıbozkuyu	37º17'2.37''N	36º6'2.63''E	110	2.5
	K23	Yukarıbozkuyu	37º16'6.94''N	36º6'35.26''E	119	3.0
	K24	Aşağıbozkuyu	37º15'18.41''N	36º6'54.19''E	119	6.5
	K25	Center – Bahçeciler	37º21'55.44''N	36º3'50.02''E	47	4.0
	K26	Bahçeciler	37º21'48.32''N	36º2'17.08''E	47	7.0
	K27	Bahçeciler – Aydınlar	37º21'43.59''N	36º1'12.90''E	59	1.0
	K28	Aydınlar '1'	37º21'30.68''N	36º0'40.44''E	59	4.0
	K29	Aydınlar '2'	37º20'56.34''N	36º0'18.72''E	56	2.0
	K30	Akova	37º20'29.85''N	35º58'58.04''E	39	4.0
Sumbas	S1	Kızılömerli – Reşadiye	37º24'11.57''N	35º0'27.32''E	60	1.5
	S2	Reşadiye	37º25'8.89''N	36º0'53.71''E	89	3.0
	S3	Sumbas	37º26'14.78''N	36º2'6.08''E	97	2.5
	S4	Mehmetli	37º28'56.93''N	36º2'47.77''E	130	1.5
	S5	Sumbas	37º27'35.12''N	36º0'58.52''E	133	1.5
	S6	Akçataş	37º27'50.99''N	35º59'31.07''E	117	0.5
	S7	Davutlu '1'	37º27'19.26''N	35º58'47.83''E	115	2.5
	S8	Davutlu '2'	37º26'50.15''N	35º58'2.38''E	63	2.5
	S9	Küçükçınar	37º25'6.66''N	35º59'24.10''E	71	3.5
	S10	Köseli	37º25'54.68''N	35º57'10.16''E	57	0.5

Districts	*Kode*	*Location*	*Coordinates*		*Altitude (m)*	*Field (ha)*
Center	C1	Köyyeri	37º14'35.65''N	36º6'40.93''E	83	1.0
	C2	Gültepe	37º13'51.47''N	36º7'19.43''E	92	1.5
	C3	Nohuttepe	37º6'43.66''N	36º13'53.55''E	101	4.0
	C4	Nohuttepe – Cevdetiye	37º7'17.96''N	36º12'53.17''E	100	1.0
	C5	Cevdetiye – Yeniköy	37º8'29.03''N	36º11'0.95''E	89	4.0
	C6	Yeniköy	37º9'3.16''N	36º9'26.51''E	58	1.0
	C7	Tecirli – Sakarcalık	37º9'50.24''N	36º6'11.56''E	47	0.5
	C8	Sakarcalık	37º10'21.37''N	36º5'21.29''E	47	2.0
	C9	Sakarcalık – Gökçedam	37º11'2.56''N	36º5'8.43''E	44	1.0
	C10	Gökçedam – Orhaniye	37º12'12.12''N	36º4'34.34''E	45	2.5
	C11	Selimiye	37º12'34.95''N	36º3'22.54''E	43	2.0
	C12	Koçyurdu	37º12'52.49''N	36º2'53.60''E	41	2.0
	C13	Gökçedam – Köyyeri '1'	37º12'41.22''N	36º5'33.27''E	43	3.0
	C14	Gökçedam – Köyyeri '2'	37º13'13.95''N	36º5'49.67''E	64	6.0
	C15	Gökçedam – Köyyeri '3'	37º13'42.21''N	36º6'17.93''E	74	3.0
	C16	Gültepe '1'	37º13'48.86''N	36º7'45.77''E	110	1.0
	C17	Gültepe '2'	37º13'44.21''N	36º8'3.24''E	135	5.0
	C18	Gültepe – Tülücüler	37º13'33.92''N	36º8'15.26''E	98	2.5
	C19	Tülücüler – Kırmacılı	37º13'6.94''N	36º8'25.61''E	91	10.0
	C20	Bahçe '1'	37º12'11.52''N	36º10'14.66''E	175	1.0
	C21	Bahçe '2'	37º11'26.46''N	36º10'48.09''E	124	20.0
	C22	Çamlıbel – Babaoğlu	37º12'39.45''N	36º11'42.85''E	126	2.0
	C23	Babaoğlu	37º13'34.56''N	36º11'39.82''E	154	1.5
	C24	Çamlıbel – Kesmeburun	37º10'51.36''N	36º10'53.81''E	91	2.0
	C25	Kesmeburun '1'	37º10'2.03''N	36º10'44.02''E	75	15.0
	C26	Kesmeburun '2'	37º9'14.83''N	36º11'6.34''E	60	1.0
Düziçi	D1	Yarbaşı – Karacaören	37º12'17.13''N	36º25'48.83''E	374	5.0
	D2	Karacaören	37º12'35.66''N	36º25'56.65''E	359	1.0
	D3	Karacaören – Ellek	37º12'37.93''N	36º25'10.34''E	339	4.0
	D4	Ellek '1'	37º12'34.56''N	36º23'22.39''E	341	4.0
	D5	Ellek '2'	37º13'9.34''N	36º21'25.98''E	308	7.0
	D6	Ellek – Ayşeler '1'	37º13'12.69''N	36º20'46.25''E	311	1.5
	D7	Ellek – Ayşeler '2'	37º13'0.46''N	36º20'17.75''E	317	1.0
	D8	Ayşeler	37º12'36.76''N	36º19'23.54''E	321	2.0
	D9	Selverler	37º12'21.44''N	36º17'47.08''E	283	1.0
	D10	Selverler – Karagedik	37º12'34.00''N	36º17'2.82''E	249	1.5
	D11	Karagedik	37º12'54.75''N	36º16'42.30''E	230	6.0
	D12	İkizler	37º13'56.92''N	36º16'40.69''E	150	2.0
	D13	İkizler – Koyuntaş '1'	37º14'32.95''N	36º16'29.53''E	97	2.0
	D14	İkizler – Koyuntaş '2'	37º14'39.09''N	36º16'45.36''E	152	2.0
	D15	İkizler – Koyuntaş '3'	37º14'45.31''N	36º17'0.76''E	425	2.0
	D16	Oluklu '1'	37º15'11.87''N	36º18'3.22''E	329	1.0
	D17	Oluklu '2'	37º15'54.01''N	36º18'59.46''E	280	1.0
	D18	Atalan '1'	37º16'0.53''N	36º20'9.41''E	276	2.5
	D19	Atalan '2'	37º15'22.49''N	36º21'1.85''E	289	1.0
	D20	Atalan '3'	37º14'59.70''N	36º21'11.92''E	282	5.0
	D21	Atalan – Yazlamazlı	37º14'33.07''N	36º21'19.02''E	283	4.0
	D22	Yazlamazlı	37º14'10.66''N	36º21'27.09''E	279	2.0
	D23	Yazlamazlı – Ellek	37º13'27.44''N	36º21'54.15''E	285	5.0
Toprakkale	T1	Mustafabeyli – Sazlık	37º4'7.41''N	36º5'43.79''E	53	0.5
	T2	Sazlık '1'	37º3'29.02''N	36º7'7.85''E	59	1.0
	T3	Sazlık '2'	37º3'18.45''N	36º7'58.65''E	65	2.0
	T4	Sazlık – Center	37º3'2.66''N	36º8'48.98''E	65	2.0
	T5	Sazlık	37º3'20.54''N	36º7'24.82''E	56	1.0

Districts	*Kode*	*Location*	*Coordinates*		*Altitude (m)*	*Field (ha)*
Bahçe	B1	Kalecik – Burgaçlı	37º10'22.20''N	36º28'40.72''E	518	3.5
	B2	Burgaçlı – Taşoluk	37º10'38.41''N	36º29'26.96''E	524	1.0
	B3	Nohut	37º10'51.50''N	36º31'33.31''E	537	4.0
	B4	Çolaklı	37º9'2.57''N	36º32'12.74''E	690	1.5
Hasanbeyli	H1	Aygır	37º8'44.90''N	36º31'59.69''E	765	5.0
	H2	Aygır – Center	37º8'33.62''N	36º32'5.71''E	768	10.0
	H3	Center	37º8'0.77''N	36º32'45.98''E	772	5.0
	H4	Center – Buğdaycık	37º8'58.10''N	36º31'20.04''E	714	10.0
	H5	Buğdaycık – Kalecik	37º9'23.76''N	36º29'34.13''E	702	10.0

Determination of wild oat population resistance

The studies were carried out between 2013 and 2015 in the greenhouses of the Department of Plant Protection at the Cukurova University. The main materials of this resistant study were mature wild oats seeds from sampling points in the Cukurova region of the Osmaniye province (Table 2). Tests were performed with rechargeable backpack sprayer working at a constant pressure of 3 atm (Matabi), and bark papers were used during greenhouse experiments. The three year temperature averages were above 25°C and relative humidity 65%. And also resistance tests were set during sunny days in October. The study was performed using the random blocks test design, with two replicates and four replications. The soil to produce the material used in the study was obtained at places where no herbicides had been used previously, and the soil material put in the trays had a 1:1:1 ratio of sand, fertilizer and soil. Every pail used was 5x5 cm. The prepared soil mixture was filled with equal amounts of seeds and then placed in the greenhouse. The seeds of the wild oats collected between 2013 and 2015 were inspected by spreading about 5 seeds per tray pit and watering the trays for plant germination. After one month, 3 of the wild oats, which were in their 2-4 leaf period were left in each of the tray pits. Then, herbicides (200 ml ha^{-1} Clodinafop-propargyl-ACCase inhibitor, 300 g ha^{-1} Mesosulfuron-methyl + Iodosulfuron-methyl sodium and 250 g ha^{-1} Pyroxsulam-ALS inhibitors) were applied to 10 m^2 areas by randomly applying the rechargeable backpack sprayer. The dry biomass of the weeds was measured prior to application of the herbicides and on day 1 and day 28 after its application. The weeds were harvested from the soil surface at the end of the 28th day when the effect of the herbicides was fully detectable. The plant material was then placed in paper bags, dried for 24 hours at 105°C, and then, weighed for dry biomass (Hitchcock, 1931). Six different doses of herbicides (N/4, N/2, N: Recommended dose, 2N, 4N, 8N, 0: Control) were applied to the weeds susceptible to resistance. During the greenhouse experiments, the populations of wild oats were dispensed with clodinafop, mesosulfuron + ıodosulfuron and pyroxsulam. The formula for the four-parameter dose-response curve was as follows:

$$Y = C + \{(D - C) / [1 + exp[b(log(x) - log(ED50))]]\} \quad (1)$$

Formula C: lower limit, D: upper limit, b: slope and ED50: the dosage causing 50% reduction (1) using the *Curve Expert Program* (Seefeldt et al. 1994; Seefeldt et al. 1995). The recommended dose was compared to the untreated control plot by applying the herbicide at a rate of 50% of the population and at a higher value. Resistance index (*RI*) was calculated as the ED50 value of the resistant population divided by the ED50 value of the susceptible population. Resistance levels were classified as no resistance ($RI < 2.00$) and resistance ($RI \geq 2.00$) (Beckie and Tardif, 2012; Moss et al. 2007; Moss et al. 2019).

Results and Discussion

As combinations of the rotation systems in the region, a total of 48 different crop rotation were identified in the Osmaniye Province at 103 sampling points between 2013 and 2015. Thereof, the most prevalent rotation systems were wheat + wheat + wheat by 14.56%, wheat/corn + corn + corn by 8.74% and then wheat/corn + wheat/corn + wheat by 5.83%. This clearly showed that there were multiple crop systems in the Osmaniye Province, but sowing different crops was not preferred much (Table 3).

Table 3. Field combinations and sowing rates with 10 rotation systems which were significant for the Osmaniye sampling points between 2013 and 2015.

Significant Rotation Systems	Rotation Systems			Sowing Rates (%)
	2013 May/August	2014 May/August	2015 May	
1	Wheat	Wheat	Wheat	14.56
2	Wheat/Corn	Corn	Corn	8.74
3	Wheat/Corn	Wheat/Corn	Wheat	5.83
4	Wheat	Sunflower	Sunflower	4.85
5	Wheat/Corn	Wheat	Wheat	3.88
6	Wheat/Peanut	Wheat	Wheat	3.88
7	Wheat	Wheat/Corn	Wheat	2.92
8	Wheat/Corn	Wheat/Corn	Corn	2.92
9	Wheat/Peanut	Wheat/Sesame	Wheat	2.92
10	Wheat/Corn	Corn/Peanut	Peanut	2.92

From the viewpoint of different crops, it may be determined that the sowing rates were very low for sunflower which can be alternated with wheat, as well as peanuts, soybean and sesame as alternative crops to corn. However, within the crop rotation systems, the wheat + sunflower + sunflower combination was used at 4.85%, and wheat/corn + corn/peanut + peanut rotation was approximately 3.00%. Wheat and corn crops were determined to be preferred over almost all seasons, although the yield of different crops was the subject of the question, and the percentages of cultivation of other systems were found to be between 0.97% and 1.94% (Table 3).

Crop rotation effects towards weed and wild oat coverages and the resistance index

One crop rotation

Fifteen fields used wheat as the only cultivated crop in one crop rotation. While looking at fields with monoculture agriculture, only one field combination was observed within 15 fields, and its sowing percentage was 14.56% in total. Especially in wheat + wheat + wheat combinations, an increase of weed coverage and wild oat coverage was clearly detectable (Torun and Uygur, 2019b). The weed coverage of wheat + wheat + wheat in 2013 increased from 25.60% to 31.13%, and the coverage of wild oat increased from 16.00% to 23.07%, recorded as a rise of 44.17% in the total population. In every studied year, the Clodinafop herbicide showed resistance. Mesosulfuron + Iodosulfuron was found susceptible at 0.74 in 2013, while this RI rose to 2.41 in 2015. The other ALS, Pyroxsulam herbicide RI was close to 2.00 (Table 4). In Turkey, Ayata (2014) surveyed 679 wheat fields for wild oats in the Adana Province in 2011-2012. In the first year, 49.00% of 80 populations were found to be resistant. In 2012, they tested 62 populations, and 74.00% were detected to be resistant. The ACCase inhibitor resistance increased as well in Adana.

Table 4. One cultivated crop in rotation systems for the Osmaniye Province between 2013 and 2015.

May/ August	May/ August	May	Sampling Field Number	Coverage Changes (%)		Resistance Index (RI)							
				Weeds	*A.sterilis*	Clodinafop			Mesosulfuron + Iodosulfuron			*Pyroxsulam	
2013	2014	2015				2013	2014	2015	2013	2014	2015	2014	2015
Wheat	Wheat	Wheat	15	(+) 21.61	(+) 44.17	2.25	2.06	2.01	0.74	1.14	2.41	1.57	1.86

Average resistance indexes were given for sampling field numbers. *Pyroxsulam was not tested in 2013.

Two crop rotation

The total number of field combinations obtained with two crop rotation was 17 out of the 49 fields, and their total usage rate was 47.58%. While looking at the sampling fields, it could be observed that the producers gave importance to especially wheat and corn crops. The weed coverage rose at most from 19.25% in 2013 to 47.50% in 2015 with an increase of 146.75% (2.47 times) the for wheat/peanut + wheat + wheat combinations, and it was observed that peanut did not decrease the weed coverage. The combination of wheat/corn + wheat + corn was observed with a 93.75% decrease in weed coverage in the last year in comparison to the first year. Because of hoeing and sowing as a first crop, corn caused coverage changes in the fields (Table 5). As in other agricultural areas of Turkey, a failure of crop rotation systems with some herbicides has caused an increase of the population frequency and resistance formation of significant weed species in wheat cultivation in the Cukurova region (Yücel, 2004; Avcı, 2009; Ayata, 2014; Gürbüz, 2016; Torun and Uygur, 2019a).

Table 5. Two crop in rotation systems for the Osmaniye Province between 2013 and 2015.

May/ August	May/ August	May	Sampling Field Number	Coverage Changes (%)		Resistance Index (RI)							
				Weeds	*A.sterilis*	Clodinafop			Mesosulfuron + Iodosulfuron			*Pyroxsulam	
2013	2014	2015				2013	2014	2015	2013	2014	2015	2014	2015
Wheat Corn	Corn	Corn	9	(-) 83.55	(-) 90.00	1.50	4.34	1.35	0.75	1.18	5.15	0.92	0.66
Wheat Corn	Wheat Corn	Wheat	6	(-) 32.38	(-) 28.30	2.03	1.78	1.98	0.79	1.08	3.49	1.19	0.72
Wheat	Sunflower	Sunflower	5	(+) 70.91	(-) 72.50	4.00	0.88	1.50	1.14	0.53	1.82	3.11	0.77
Wheat Corn	Wheat	Wheat	4	(+) 98.80	(+) 111.67	1.95	1.00	1.93	0.94	1.01	1.78	0.96	0.69
Wheat Peanut	Wheat	Wheat	4	(+) 146.75	(+) 1450.00	3.04	2.45	2.09	0.92	0.97	1.80	1.49	0.74
Wheat	Wheat Corn	Wheat	3	(+) 116.00	(+) 1790.00	**	5.26	1.97	**	1.01	2.94	1.16	0.78
Wheat Corn	Wheat Corn	Corn	3	(-) 68.18	(-) 90.00	3.67	0.51	1.62	0.84	0.87	1.84	1.25	0.73
Wheat	Wheat Sesame	Wheat	2	(+) 30.43	(+) 66.67	6.00	2.67	1.71	0.84	1.71	1.94	1.20	0.70
Wheat Peanut	Wheat Peanut	Wheat	2	(-) 44.21	(+) 13.75	2.19	1.31	1.53	1.29	1.31	1.80	0.99	0.60
Wheat	Corn	Corn	2	(-) 90.67	(-) 100.00	0.95	**	**	0.76	**	**	**	**
Wheat	Corn	Wheat	2	(-) 25.00	(-) 20.00	1.17	**	1.88	0.75	**	1.99	**	0.78
Wheat Corn	Corn	Wheat	2	(-) 20.00	(+) 100.00	**	**	1.06	**	**	3.06	**	1.01
Wheat	Wheat	Sunflower	1	(-) 33.33	No change	**	**	**	**	**	**	**	**
Wheat Corn	Wheat	Corn	1	(-) 93.75	(-) 90.00	1.34	4.27	0.88	1.72	2.29	1.78	0.60	0.61
Wheat	Wheat Peanut	Wheat	1	No change	No change	1.63	2.67	1.87	0.84	0.76	1.80	0.94	0.84
Wheat	Fallow	Wheat	1	(-) 53.85	(-) 60.00	8.00	**	2.12	0.84	**	1.59	**	0.75
Wheat	Fallow	Fallow	1	(-) 75.00	(-) 86.67	1.60	**	2.01	0.71	**	1.80	**	0.71

Average resistance indexes were given for sampling field numbers. *Pyroxsulam was not tested in 2013. **Not enough population.

The wheat + wheat/corn + wheat combination was observed with a maximum wild oat coverage of 1790% (18.75-fold). The coverage was below 1.00% in the first year and up to 11.81% in the last year. In Cukurova, different cropping systems have not been applied in fields for suppressing wild oat populations that have started to spread locally in some wheat fields since the 2000s. It was recorded that the wheat + corn + corn combinations showed a decrease of 100.00% by keeping the wild oat coverage below at least 5.00% (Table 5). In Canada, Blackshaw et al. (2001) observed weed density changes for crop systems that were designated at 15 weeds/m^2 with wheat + canola, 5 weeds/m^2 with wheat + flax, 6 weeds/m^2 with wheat + fallow and 98 weeds/m^2 in only wheat sown plots. Another Canadian study was conducted as well to determine the effects of cultural and chemical practices on wild oat (*Avena fatua* L.) populations. In four year long experiments, short tall barley at double seeding rates was combined with a barley + canola + barley + pea rotation system with three herbicide rate regimes. Wild oat seed production with a quarter dose of the herbicide rate was reduced by 91.00%, 95.00% and 97.00% in 2001, 2003 and 2005, respectively, because tall barley cultivars at double seeding rates were changed with canola and pea compared to short barley cultivars at normal seeding rates (Harker et al. 2009).

The wheat + sunflower + sunflower, wheat/corn + wheat/corn + corn, wheat/corn + corn + corn, wheat + corn + corn and wheat/corn + wheat + corn combinations reduced the wild oat coverage most. Corn was determined during all sowing seasons in two crop system. The wheat/corn + wheat/corn + wheat and wheat + corn + wheat combinations with lower reduction coverage rates in the population followed these (Table 5). Anderson et al. (2007) tried out crop rotations that could be alternatives to winter wheat, investigated eight different crop combinations and reviewed weed species in crop rotation systems. The least amount of weed germinations occurred with winter wheat + fallow and spring wheat + winter wheat + corn + sunflower combinations, whereas they also determined that weed germination was 6 times higher with a winter wheat + grey millet rotation compared to these rotations. They revealed at least 4 crops for rotations in weed management. A study in Iran examined the effects of rice sown with different crop rotations with rice and rice + soybean + rice combinations. Rice + soybean + rice was determined to reduce weed density by 62.50% and by 80.00% for the weed biomass, and crop rotation increased the rice yield (Filizadeh et al. 2007).

The wheat + sunflower + sunflower system's wild oat RI was found to be 4.00 with the ACCase herbicide, and the 3.11 ALS Pyroxsulam herbicide disappeared during the last year. For wheat/corn + wheat/corn + corn rotation, the ACCase RI was 3.67 in 2013, but during the last year, no resistance was observed in the fields. In the wheat/corn + wheat + corn system, resistance was not observed in 2015, whereas the resistance with wheat/corn + corn + corn against Mesosulfuron + Iodosulfuron was found to be 5.15 in the last year (Table 5). Gürbüz (2016) identified ALS inhibitor resistance in Adana against wild oat and wild mustard (*Sinapis arvensis* L.) populations. They found that 90 wild oats and 22 wild mustard populations were resistant to Pyroxsulam, while 37 wild oat and 26 wild mustard populations were detected to be resistant to Mesosulfuron + Iodosulfuron. In 2015, the resistance of wheat/peanut + wheat + wheat against Clodinafop and the resistance of the wheat + wheat/corn + wheat, wheat/corn + wheat/corn + wheat and wheat/corn + corn + wheat combinations against Mesosulfuron + Iodosulfuron were determined (Table 5). In Canada, Beckie and Kirkland (2003) reported that different crops had decelerated resistance, and they revealed that limited crop sowing over four years strengthened the population of susceptible individuals. The wheat + fallow + wheat and wheat + fallow + fallow combinations showed a decrease in the coverage of weeds and wild oat during the last year in comparison to the first year. However, there was no benefit of laying the fields fallow, because resistance against the ACCase or ALS herbicides was determined in these systems, or it increased again (Table 5). A sampling of 62 wild oat populations was picked in Canada, and the ACCase inhibitor Imazamethabenz and the ALS inhibitor Triallate were applied to test the resistance levels for confirmation. Because of using the same herbicides in the fields with no crop rotation, a resistance clearly occurred (Beckie et al., 2004).

Three crop rotation

The highest number of fields used a combination of 27 crops in three crop systems. At 103 sampling points, 34.95% of the total sowing percentage was seen in 36 fields. It was observed that even in the case of three different crops, resistance was constant or increased with some crop rotations, despite a decrease in the coverage of weeds and wild oats (Torun and Uygur, 2019b). In the Cukurova region, Yücel (2004) observed different levels of resistance to ACCase inhibitors and tested wild oat populations with the ALS inhibitor Mesosulfuron whose RI was found to be 11.34. In another study on wild oat populations from the Eastern Mediterranean Region of Turkey, it was revealed that Fenoxaprop usage was intense, and resistance was determined in wild oat populations (Uludağ, 2003). The weed coverage of the wheat/soybean + wheat/corn + wheat combinations showed an increase of 2.50% to 26.00%, totalling 940% (10.4-fold), the whereas wheat/corn + peanut/corn + wheat combinations contrived a decrease of 96.25%, from 80.00% to 3.00%, during the last year (Table 6).

The highest increase in the wild oat coverage was observed in the wheat/peanut + wheat/corn + wheat combinations with 266.67% (3.67-fold), increasing from 7.50% to 27.50%. The wheat/soybean + corn/soybean + corn, wheat/peanut + corn/peanut + peanut and wheat/corn + peanut/corn + wheat combinations caused a 100.00% decrease in wild oat coverage (Table 6). Preston and Powles (2002) deduced ryegrass (*Lolium rigidum* L.) population changes with the ALS inhibitors Sulfometuron-methyl and Imazapyr in organic farming in Australia. They exposed collected susceptible populations to herbicides, and so, they detected that susceptible populations could easily resist over shorter times. Owen and Powles (2009) found that wild oat populations (*Avena fatua* L.) were resistant to the ACCase inhibitor Diclofop-methyl in 71.00% of the sowing areas in Australia. They emphasized breaking resistance by applying different mode of action rotations and by sowing different crops. In spite of a decrease in the weed and wild oat coverage, resistance against ACCase was unchanged in crop rotation using the wheat + sunflower + barley, wheat/soybean + corn + corn and wheat + soybean/peanut + wheat combinations, while the RI increased from 1.72 to 2.23 for wheat + wheat/sesame + sunflower.

Table 6. Three crop cultivation in rotation systems for the Osmaniye Province between 2013 and 2015.

May/ August	May/ August	May	Sampling Field Number	Coverage Changes (%)		Resistance Index (RI)							
				Weeds	*A.sterilis*	Clodinafop			Mesosulfuron + Iodosulfuron			*Pyroxsulam	
2013	2014	2015				2013	2014	2015	2013	2014	2015	2014	2015
Wheat Peanut	Wheat Sesame	Wheat	3	(+) 11.57	(+) 15.00	1.63	1.35	1.53	0.65	2.09	1.06	1.45	0.77
Wheat Corn	Corn Peanut	Peanut	3	(-) 75.00	(-) 70.00	2.44	**	1.35	1.04	**	1.87	**	0.58
Wheat Soybean	Wheat Corn	Wheat	2	(+) 940.00	(+) 100.00	**	0.86	1.52	**	0.72	3.19	1.45	5.53
Wheat Peanut	Wheat Corn	Wheat	2	(+) 6.67	(+) 266.67	3.50	2.91	1.52	1.19	0.92	1.85	1.65	0.76
Wheat	Wheat Sesame	Sunflower	2	(-) 74.12	(-) 96.92	1.72	1.00	2.23	0.78	0.98	1.31	1.80	0.66
Wheat Corn	Wheat Sesame	Wheat	2	(+) 14.46	(+) 21.43	1.63	1.25	2.25	0.69	1.84	1.73	0.98	0.62
Wheat Soybean	Corn	Corn	2	(-) 95.65	(-) 98.33	2.82	1.29	2.16	0.90	1.16	2.37	0.68	0.64
Wheat	Sunflower	Barley	1	(-) 92.31	(-) 97.00	4.00	**	2.23	1.12	**	2.44	**	0.84
Wheat Peanut	Wheat	Barley	1	(-) 55.56	(-) 57.14	1.50	**	1.56	0.77	**	2.43	**	0.76
Wheat Peanut	Wheat	Sunflower	1	(+) 500.00	(+) 100.00	**	2.00	2.10	**	0.86	3.16	1.20	0.77
Wheat Corn	Wheat Corn	Barley	1	(+) 650.00	(+) 100.00	**	2.67	2.04	**	1.47	0.74	0.84	0.70
Wheat Corn	Wheat Corn	Peanut	1	(-) 81.82	(-) 95.56	1.34	0.61	1.90	1.25	2.29	3.33	0.84	0.80
Wheat Peanut	Wheat Corn	Corn	1	No change	(+) 100.00	**	0.89	1.12	**	1.43	2.55	0.54	0.61
Wheat Corn	Wheat Soybean	Corn	1	No change	(+) 100.00	**	0.50	1.23	**	0.95	0.83	2.40	0.59
Wheat Corn	Wheat Soybean	Wheat	1	No change	(+) 100.00	**	0.67	2.03	**	0.76	3.38	1.20	0.61
Wheat Sesame	Wheat Soybean	Wheat	1	(-) 25.00	No change	4.67	1.00	1.67	0.58	0.86	2.47	1.68	0.77
Wheat Peanut	Wheat Soybean	Wheat	1	(-) 55.56	(-) 57.15	1.75	10.67	1.80	1.00	0.95	1.22	0.56	0.79
Wheat Corn	Wheat Peanut	Corn	1	(-) 95.00	(-) 99.00	1.80	**	1.35	2.78	**	2.47	**	0.55
Wheat	Corn	Barley	1	No change	(+) 100.00	**	**	1.48	**	**	1.41	**	0.63
Wheat Corn	Corn	Peanut	1	(+) 400.00	No change	**	**	**	**	**	**	**	**
Wheat Peanut	Corn	Corn	1	No change	No change	**	**	**	**	**	**	**	**
Wheat Soybean	Corn Soybean	Corn	1	(-) 95.00	(-) 100.00	1.50	**	**	0.97	**	**	**	**
Wheat Corn	Corn Peanut	Wheat	1	(-) 40.00	No change	**	**	**	**	**	**	**	**
Wheat Corn	Corn Peanut	Corn	1	(+) 200.00	No change	**	**	**	**	**	**	**	**
Wheat Peanut	Corn Peanut	Peanut	1	(-) 90.00	(-) 100.00	2.00	**	**	0.42	**	**	**	**
Wheat	Soybean Peanut	Wheat	1	(-) 20.00	(-) 50.00	8.00	**	2.02	0.94	**	0.63	**	0.77
Wheat Corn	Peanut Corn	Wheat	1	(-) 96.25	(-) 100.00	4.00	**	**	1.20	**	**	**	**

Average resistance indexes were given for sampling field numbers. *Pyroxsulam was not tested in 2013. **Not enough population.

Additionally, the Clodinafop RI in the wheat/sesame + wheat/soybean + wheat combinations ranged from 4.67 to 1.67, and the RI for wheat/corn + corn/peanut + peanut decreased from 2.44 to

1.35. In many European countries, slender meadow foxtail (*Alopecurus myosuroides*Huds.) was found to be resistant to ACCase and ALS inhibitors. To prevent resistance, one should (1) reduce the use of ACCase and ALS inhibitor herbicides that are employed due to a development of herbicide resistance, (2) use different mechanisms of action by identifying different weed management strategies and mix herbicides at different ratios against resistance formation and (3) employ cultural measures such as ploughing, crop rotation and delayed tillage (Moss et al. 2007).

The Mesosulfuron + Iodosulfuron effect towards the wheat/corn + wheat/peanut + corn RI was constant, but resistance increased at the end of three years for wheat + sunflower + barley to 2.44, for wheat/peanut + wheat + barley to 2.43, for wheat/corn + wheat/corn + peanut to 3.33, for wheat/sesame + wheat/soybean + wheat to 2.47 and for wheat/soybean + corn + corn to 2.37 (Table 6). Based on rotation systems with three different crops, Koocheki et al. (2008) conducted some comparative research in Iran and determined that seed density was 26.00% higher in fields where only wheat was grown. While the density of grass weeds in wheat fields was 90.00%, this density decreased to 43.00% in the wheat + sugar beet rotations. Besides, the seed density was also found to be lower in the wheat + corn and wheat + sugar beet rotations. In Australia, Martin et al. (1993) employed a questionnaire on farmers who had reported complaints and revealed that 96.00% of the 150 participants were aware of the problem of herbicide resistance, while only 57.00% of them reported that they had knowledge about proper herbicide usage. When the wild oat population coverage increased, Mesosulfuron + Iodosulfuron and ACCase inhibitors encountered resistance in the wheat/peanut + wheat + sunflower, wheat/corn + wheat/soybean + wheat and wheat/corn + fallow/sesame + wheat combinations. The wheat/corn + wheat/corn + barley and wheat/corn + wheat/sesame + wheat combinations showed resistance to only Clodinafop, whereas the wheat/soybean + wheat/corn + wheat and wheat/peanut + wheat/corn + corn combinations demonstrated resistance to Mesosulfuron + Iodosulfuron. In the last year, Pyroxulam RI was 5.53 and RI was recorded only for the wheat/soybean + wheat/corn + wheat combination (Table 6). Cardina et al. (2002) looked at only corn, corn + soybean and corn + wheat + dry grass rotations in three different rotation systems at different locations. They found 40.00% more seed bank reserves in fields of only corn in comparison to corn + wheat + dry grass rotations. In crop rotation fields, the number of seed bank reserves and seeds in soil were found to be the least in America.

Four crop rotation

Four different crops were found to be sown at only 3 fields along with all sampling sites. It was observed that there were 3 different combinations sown in total, amounting to 2.91%. Four different crops did not reduce the resistance against any ACCase or ALS inhibitor, while also not reducing the weeds and wild oat coverage (Table 7). Cultivation of the same crops in the same fields, as in a study by Tardif and Powles (1993), has shown that resistance to ACCase inhibitors used against wild oat populations may be seen in less than three years. Due to steady applications of tillage, irrigation or fertilizers in the fields, the wild oat density in the wheat fields sustained their detrimental effect and became even more harmful except for fallow periods.

Table 7. Four crop rotation systems for the Osmaniye Province between 2013 and 2015.

May/ August 2013	May/ August 2014	May 2015	Sampling Field Number	Coverage Changes (%)		Resistance Index (RI)							
				Weeds	*A.sterilis*	Clodinafop			Mesosulfuron + Iodosulfuron			*Pyroxsulam	
						2013	2014	2015	2013	2014	2015	2014	2015
Wheat Corn	Soybean Peanut	Corn	1	(-) 93.75	(-) 100.00	1.60	1.34	**	0.67	1.00	**	1.60	**
Wheat Corn	Fallow Sesame	Wheat	1	(+) 11.11	(+) 50.00	1.71	**	8.93	0.49	**	2.50	**	0.80
Wheat Corn	Fallow Peanut	Wheat	1	No change	(+) 100.00	**	**	1.43	**	**	3.46	**	0.57

Average resistance indexes were given for sampling field numbers. *Pyroxsulam was not tested in 2013. **Not enough population. F: Fallow counted as a crop.

The RI of wheat/corn + soybean/peanut + corn was constant, but a Mesosulfuron + Iodosulfuron resistance was determined for the wheat/corn + fallow/sesame + wheat and wheat/corn + fallow/peanut + wheat combinations. In the last year, the RI against Clodinafop was found to be 8.93 for wheat/corn + fallow/sesame + wheat (Table 7). In Romania, Pop et al. (2009) observed that 305-365 weeds/m^2 were found in corn + wheat rotation areas, whereas 213-236 weeds/m^2 were observed for soybean + corn + wheat + sunflower combinations. Liebman and Dyck (1993) addressed crop rotation and cultivation of different crops in terms of sustainable agriculture and noted that application of crop rotation acts like an automated control system for wild oats, and the density of harmful wild oats decreases.

The effects of herbicide resistance on wild oat populations during transition to polyculture crop rotations from monoculture crop rotations

Continuously sowing the same crops increases the frequency of weeds and wild oats, and only an increase in the number of different crops may cause a reduction of these frequencies. The most important reason is that application of contention mechanisms against weeds in cultivated crops is limited. For example, while chemical control is applicable exclusively for wheat fields, hoeing is important in reducing the density of existing weed species in crops such as corn, peanut and sunflower. In monocultural rotation, using the same crops in the same fields, a sampling between 2013 and 2015 showed an increase in the weed and wild oat frequency and weed resistance, while variable cropping with two, three and four crops decreased the resistance (Liebman and Dyck, 1993; Anderson et al. 2007; Filizadeh et al. 2007; Owen and Powles, 2009; Pop et al. 2009).

The most preferred crop rotation, wheat only over three years, increased the coverage of weeds and wild oats, as well as increasing the resistance against herbicides, especially ACCase and ALS inhibitors, eventually leading to removal of wheat sown in these fields. For wheat + wheat + wheat, resistance against only Clodinafop was detected every year. However, addition of sunflower, an alternative to wheat, and employing wheat + sunflower + sunflower combinations resulted in reduction of wild oat coverages and even a break in resistant populations. Because of changes in tillage, irrigation or fertilizer use in wheat fields, the possibility of wild oat population resistance decreases (Table 8). One study showed that the same crop sown in a field increases the resistance of wild oat populations against ACCase inhibitors in less than three years (Tardif and Powles, 1993). For the wheat + sunflower + sunflower combinations, although the weed coverages increased, the wild oat population decreased in the last year due to cultivation of sunflowers. The resistance against the herbicide Clodinafop disappeared (Liebman and Dyck, 1993; Blackshaw et al. 2001; Cardina et al. 2002; Anderson et al. 2007; Owen and Powles, 2009; Pop et al. 2009; Ahmad-Hamdani et al. 2013; Torun and Uygur, 2019a) (Table 8).

The one crop system of wheat instead of corn and peanut caused a consistency of the existing resistance or created new resistance. The coverages decreased in wheat/corn + corn + corn rotation systems, which were two-crop rotations. However, resistance against ALS Mesosulfuron + Iodosulfuron was detected. This was because the resistance was triggered by the fact that the current herbicides used with corn employ the same mechanism of action. In a similar study, Beckie and Kirkland (2003) concluded that different crop rotations discouraged resistance in certain wild oat grass populations, which are resistant to herbicides, and the resistant individuals became much stronger among the resistant and sensitive populations as a result of cultivated crops limited to a four-year application period. Because of hoeing in combinations of corn and peanut in wheat/corn + wheat/corn + wheat, wheat/corn + wheat/corn + corn and wheat/corn + corn/peanut + peanut with three crop rotations and because wheat, which is the main host of wild oat, cannot be grown in May, the coverage of the population of weeds and wild oats decreased in the last year (Blackshaw et al. 2001; Anderson et al. 2007; Harker et al. 2009; Pop et al. 2009).

Table 8. Recommended crop rotation systems, weed coverage change, wild oat coverage change and ACCase and ALS herbicide resistance index (RI) between 2013 and 2015.

May/ August	May/ August	May	Crop Numbers	Coverage Changes (%)		Resistance Index (RI)							
				Weeds	*A.sterilis*	Clodinafop			Mesosulfuron + Iodosulfuron			*Pyroxsulam	
2013	2014	2015				2013	2014	2015	2013	2014	2015	2014	2015
Wheat	Wheat	Wheat	1	Rise	Rise	+	+	+	-	+	+	+	+
Wheat Corn	Corn	Corn	2	Decrease	Decrease	+	+	-	-	-	+	-	-
Wheat Corn	Wheat Corn	Wheat	2	Decrease	Decrease	+	+	+	-	+	+	+	-
Wheat	Sunflower	Sunflower	2	Rise	Decrease	+	-	-	-	-	+	+	-
Wheat Corn	Wheat	Wheat	2	Rise	Rise	+	+	+	-	-	+	-	-
Wheat Peanut	Wheat	Wheat	2	Rise	Rise	+	+	+	-	-	+	+	-
Wheat	Wheat Corn	Wheat	2	Rise	Rise	**	+	+	**	-	+	-	-
Wheat Corn	Wheat Corn	Corn	2	Decrease	Decrease	+	-	-	-	-	-	-	-
Wheat Peanut	Wheat Sesame	Wheat	3	Rise	Rise	+	+	+	-	+	-	-	-
Wheat Corn	Corn Peanut	Peanut	3	Decrease	Decrease	+	**	-	-	**	-	**	-

Average resistance indexes were given for sampling field numbers. *Pyroxsulam was not tested in 2013. **Not enough population. NOTE: (+) sign added if there is resistance even one field for wild oat populations of crop rotation sampling fields.

The resistance to the ACCase inhibitor in the wheat/corn + wheat/corn + wheat combination was persistent only in the last year. It was also determined that wheat/peanut + wheat/sesame + wheat, which is a three-crop rotation with peanut and sesame cultivated after wheat, did not affect the coverages in the rotations. In 2015, resistance to Clodinafop and Mesosulfuron + Iodosulfuron was detected in wheat. Wheat/corn + corn/peanut + peanut showed the reason for the decrease in wild oat coverage as the fact that introduction of different crops in the crop rotation does not constitute resistance (Torun and Uygur, 2019b). In wheat/peanut + wheat/sesame + wheat, the coverage of weeds and wild oats decreased, but resistance against Clodinafop was recorded (Table 8).

Conclusion

In determining crop rotation systems in fields sowing wheat has continuously developed the coverages and resistance in one and two crop rotation between 2013-2015 in Osmaniye province. It shows that the use of ACCase and ALS inhibitors herbicides should be highly used and preferred in wheat fields. Because of limiting licensed same effects mechanisms against wild oats in wheat is critical level where resistance has been created and rised in Osmaniye Province and ensure its sustainability in a long time is necessary. In some rotation systems have been observed that the number of resistance indices may decrease over time in three years. Of course managing weeds and wild oat populations with the diversification of field crops have decreased the coverages and frequencies on a different date of irrigation, fertilization and tillage times. Monoculture one crop rotation includes wheat have developed the resistance of wild oats and is also insufficient to decrease to resistance levels. Polyculture crop rotations have decreased the resistance indices. Moreover, correct and long crop rotation systems for fields must apply and need to be planned. Instead of cultivating the same crop in the fields in the short term, planned crop rotation systems with different field crops are healthy, reliable and correct in the long term with its rotation should be contributed. Crop rotation and agricultural ecosystem should be together for sustainable agriculture.

Conflicts of Interest

The authors have declared no conflicts of interest.

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