Bulgarian Journal of Agricultural Science, 15 (No 5) 2009, 423-434
Agricultural Academy

WEED MANAGEMENT IN EARLY-SEASON POTATO PRODUCTION IN THE MEDITERRANEAN CONDITIONS OF TURKEY

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Abstract

UREMIS, I., M. E. CALISKAN, A. ULUDAG and S. CALISKAN, 2009. Weed management in early-season potato production in the Mediterranean conditions of Turkey. *Bulg. J. Agric. Sci.,* 15: 423-434

Early-season potato production is a profitable system in the Mediterranean part of Turkey. Weeds are problem in early-season potato production. The effect of combinations of extended season weed control techniques (none, hand-hoeing twice, black or clear plastic mulch placed at planting, or metribuzin POST and soil applied herbicides (none, trifluralin PPI, or a commercially formulated combination of pendimethalin and metolachlor PRE) on weed control and potato yield were compared. No weed species shift was observed due to treatments. Soil applied herbicides kept weeds under pressure through growing season in some extent, improved effect of black plastic mulch on weed control, caused bigger tubers and consequently higher class-A yield. Although hand-hoeing twice during the growing season resulted in the lowest percent weed cover at harvest and better yield, cost and availability of labor may not make this method feasible for a potato grower. Combinations of PPI or PRE soil-applied herbicides and plastic mulch will be necessary. Overall, black rather than clear plastic mulch seems to be the best choice for an extended-season control method following a PPI or PRE herbicide. Metribuzin controlled weeds in some extent but the effect did not translate to potato yield. Plastic mulches, especially clear one, caused earliness at emergence, which might help earlier harvest.

Key words: trifluralin, pendimethalin+metolachlor, metribuzin, clear plastic mulch, black plastic mulch, hoeing

Introduction

Potato, a temperate-cool season crop, is grown up to 4000 m of altitude above sea level. Potato is produced during the winter and the spring as an early crop in the Mediterranean-type environments which is characterized with hot and dry summers and warm and rainy winters. Early-season potato production is a profitable practice in Mediterranean region of Turkey due to ease of marketing the fresh potatoes at higher prices and scarcity of alternative crops for the early-season potato growing (Caliskan et al., 2002). However, there are several potential negative factors which limit early-season potato production areas and production season. Sowing time (Mid-December, mainly January and February) is rainy and tempera-

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ture is below 10^0C, which cause extension of emergence period unto 50 days. Rotten seeds, disease infestation and increasing weed cover result from slower emergence. After emergence, potato shoots do not be exposed to low temperatures, specifically to freezing temperatures. In addition, temperature passes optimum temperature for tuber production (>24^0C) in April in these type of environments (Caliskan et al., 2002), which imposes earliness in harvest.

Weeds in general interfere with crop production by reducing yield, encouraging diseases, harboring pests, and making agricultural practices difficult (Zimdahl, 2007). Potato yield can decrease 16% to 76% depending on weed composition if weeds in potato are not controlled whole growing season (Tripathi et al., 1989). Eliminating weeds early is the primary objective in potato production (Felix et al., 2008) because weeds emerging with potato crop or a week later can cause higher crop loss than weeds emerging 3 or more weeks later (Nelson and Thoreson, 1981). It is observed that weed problem in early-season potato growing is more restrictive due to several factors such as favourable conditions for germination of some weed species, and rains not permitting use equipment for weed control in the field. Both winter annuals such as wild mustard (*Sinapis arvensis* L.), Italian thistle (*Carduus pycnocephalus* L.), and corn chamomile (*Anthemis arvensis* L.) and summer annuals such as redroot pigweed (*Amaranthus retreoflexus* L.) and common cocklebur (*Xanthium strumarium* L.) can interfere in early-season potato production as well as perennials, Johnsongrass (*Sorghum halepense* (L.) Pers.) and field bindweed (*Convolvulus arvensis* L.). Furthermore, climatic conditions might not be favorable for potato growing and cause less competitive crop against weeds because the growing season for early-potato production has harsher climatical conditions than summer main crop season. In fact, temperatures in early-season potato growing are generally in lower limit for that potato requires. Weeds can delay potato growing via decreasing soil temperature. Rao (2000) reported that weeds can reduce soil temperature approximately 2-3^{o}C. Another factor increasing weeds in early-season potato production is that rapid degradation of herbicides such as pendimethalin and trifluralin in anaerobic soils (Vencill, 2002), which happens due to rains in early-season potato production.

Weed control practices in potato vary from chemical control to non chemical methods. Hand hoeing is common in small holder farms while cultivation is preferred by larger farms. Because of availabity of labor and/or family members with low cost in Turkey despite of hiring people for hoeing is getting more and more difficult and expensive, hand hoeing has been still an important practice for not only weed control but also other management requirements; but, some negative effects of hoeing have been already reported. Americanos (1994) found that hoeing more than three times has negative effect on potato yield. Nelson and Giles (1986) stated that hoeing causes lower yield, higher weed germination, and loss in soil humidity although it is an effective method to control weeds. Multiple cultivations significantly increased control of all weed species, A-size tuber production, and net returns (Bailey et al., 2001). Americanos (1994) suggested that shading is an effective method to control weeds in potato. Different cover materials have been used especially in vegetable production to regulate soil temperature (Teasdale and Abdul-Baki, 1995). Researches on potato showed that some cover materials cause earliness in maturity, increase tuber yield, regulate soil temperature and other micro climatic characters, prevent soil erosion, save soil humidity, and improve weed control (Ruiz et al., 1999; Edwards et al., 2000; Tarara, 2000; Caliskan et al., 2002). White and black-white plastic mulches affect potato yield positively due to providing proper temperature into soil while transparent and black plastic mulches have detrimental effect on potato via creating stress conditions for crop (Ruiz et al., 1999). On the contrary, transparent and black plastic mulches accelerated emergence and increased grade-A and total tuber production comparing to bare soil and some other treatments in early-season potato production in the Eastern Mediterranean part of Turkey (Caliskan et al., 2002). Plant growth and yield were highest as root zone temperature via heating colored mulches includ-

ing black one approached the optimal root zone temperature for the tomato plants (Diaz-Perez and Batal, 2002). Matheny (1992) compared the effect of plant straw mulches painted with different colors and concluded that white, pale blue, and stripped with blue-orange straw mulches gave 15 % more yield comparing to non-mulched check; no-paint and red colored ones yielded as much as non-mulched check.

Chemical techniques have been still preferred by growers due to less cost and easier implementation (Conley et al., 2001). Weed control with herbicides is limited to a few older compounds with the primary criterion for herbicide selection being previous weed problems, or standard routines not only in Turkey but also in the North America (Felix et al., 2008). Trifluralin has been a cost effective and well known herbicide by farmers, pendimethalin+metolachlor is thought to be a better alternative for soil application with a broader spectrum of weeds controlled. Few effective broad-spectrum herbicides are available for use POST such as linuron and metribuzin. Combination of techniques was more effective than application of each technique alone. In fact that pendimethalin with tillage resulted in better weed control, pendimethalin or tillage alone was not as effective as combination of techniques (Nelson and Giles, 1989). Boydston and Vaughn (2002) tested five weed management systems utilizing combinations of cover crops, herbicides, and cultivation and recommended a system, which is less herbicide depended when maintainig the tuber yield.

Restrictive factors on crop quality and quantity,

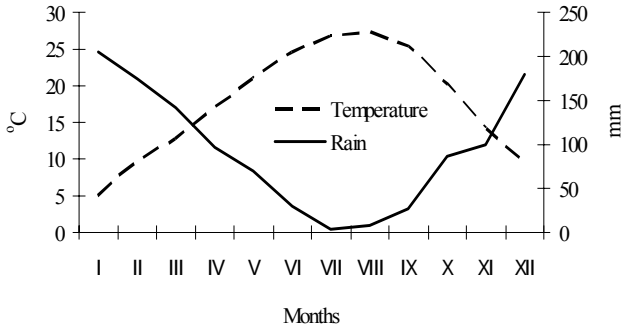

Fig. 1. Fifty years averages of rainfall and temperatures of the Hatay Province in Turkey (Regional Meteorological Station's data)

which impose early-season potato production more than the other potato production systems, should be eliminated. Weeds are among the foremost negative factors. Availabilty of few effective herbicides in potato requires alternative methods and integrating available control measures. Although there have been studies that focused on control weeds as early as possible in potato production, there has not been any study focused on weed control at early-season potato production. The aim of the current study is to compare weed control methods in early-season potato production in the Mediterranean conditions of Turkey.

Materials and Methods

Experiments were carried out at the Research Farm of Mustafa Kemal University, Hatay, Turkey in 2002 and 2003, which has typical Mediterranean climate (Figure 1).

The soil was clay silt loam (Chromoxeret) with 7.65 pH, 1.73% organic matter, 0.13% total nitrogen content, 0.34 cm^3 waterholding capacity, 0.13% salt content, and 58.68 me/100g CEC. The trial area was cultivated and leveled both years the day before planting cv Marabel potato seed tubers at a 0.25 m interval in rows spaced 0.7 m apart. Plot size was 4 rows wide by 10 m long. Treatments were a three by five factorial of three soil-applied herbicides - 1) none, 2) trifluralin pre-plant incorporated (PPI), or 3) a commercially formulated combination of pendimethalin and metolachlor applied preemergence (PRE), by five extended-season control methods - 1) none, 2) hand-hoeing twice during the growing season approximately two and three months after planting (MAP), 3) black (20 μm thickness) or 4) clear plastic mulch (30 μm thickness) placed at planting, or 5) metribuzin applied postemergence (POST) approximately 3 MAP. A weed-free check maintained during the growing season by hand hoeing not later than ten days interval was included for tuber yield and quality comparisons. Treatments were arranged in a randomized complete block with three replications.

Herbicides were applied with a motorized back-pack sprayer with 03F110 flat fan nozzles that deliv-

ered 300 L/ha under 200 kPa pressure (Lurmark). Trifluralin was applied just prior to planting on the same day and mechanically incorporated into the soil with a diskharrow to a depth of 10-15 cm followed by preparing ridges at 20-25 cm of height and planting seeds on ridges. Immediately after planting, the pendimethalin + metolachlor treatments were applied followed by setting plastic mulches onto ridges by hand. The edges of plastics buried into soil. There was no plastic cover between ridges. The trial area was irrigated twice following hand-hoeing. There was rain enough through growing seasons both years (Table 1).

Fertilizer, NPK 15-15-15, was applied at 600 kg/ha rate with potato planting and nitrogen at 184 kg/ha (urea 46 % at 400 kg/ha) just after the first hand-hoeing. Plastic mulches kept until harvest. When potato seeds emerged, plastic mulch swelled where the seed had been planted. Swelling points were cut with a knife to let the potato plants get out of the mulches. Metribuzin was applied before potato blooming when braod leaf weeds with 4 to 6-leaf stage and graminae weeds at 10 to 15 cm in height. Planting, plastic mulch placement, hand-hoeing, and harvest dates, and herbicide application rates and dates are shown in Table2.

Soil temperature at 10 cm was measured in weekly intervals at 7 am and 2 pm at 3 points and presented as average of 6 measurements for black plastic mulch, clear plastic mulch and baresoil.

Potato injury was observed visually through growing season. Percent weed cover was recorded 40 and 55 days after setting mulches/applying herbicides to soil, 11 days after the first hand hoeing in both years, 12 days after metribuzin application in 2002 and 16 days after metribuzin application in 2003. Just prior to harvest, percent ground cover by weeds was determined visually in whole plot. Potato tubers were hand-harvested from two central rows. Harvested tubers were classified as class-A or class-B if they were greater than 45 or 20 to 45 mm diameter, respectively according to Caliskan et al. (2002) and both sizes called marketable yield. Culls (non-marketable tubers) were less than 20 mm diameter. Tubers harvested were counted and average tuber size was calculated by dividing the total tuber yield in a plot by the number of tubers harvested from that plot. Plot yields were converted to t/ha.

Table 1
Total monthly rain in the experimental area in 2002 and 2003 in Hatay, Turkey

Months	Rain, mm	
	2002	2003
January	99.7	91.1
February	72.2	172.8
March	77.8	166.5
April	50.8	29.9
May	13.5	0
Total	314.0	460.3

Data were subjected to ANOVA using PROC GLM (PC-SAS) (SAS, 1997). The year by treatment interaction was significant for all parameters measured, so data were analyzed separately by year. Within years, the soil-applied herbicide by extended-season method interaction was significant for all parameters except class-A yield, marketable yield and total yield for 2002, so data were sorted by main factors and treatment means within each factor were separated using a Duncan's Multiple Range Test at the 0.05 probability level except parameters mentioned, which Duncan's Multiple Range Test at the 0.05 probability level was used for extended-season weed control and soil applied herbicide separately.

Results and Discussion

The most dominant weed species in the experimental area were wild mustard, canarygrass (*Phalaris canariensis* L.), and Johnson grass in both years. Corn chamomile, Italian thistle, and redroot pigweed were also present in 2002 whereas field bindweed and common cocklebur were found in the experimental plots in 2003. At the end of the season when percent weed cover was determined, weed populations in the treated and weedy check plots were composed of the same dominant and minor weed species (data not shown). Overall weed cover percentages in weedy checks were 50% and 60% in the 2002 and 2003, respec-

Table 2
Dates and/or rates of applications from planting to harvest in experiments in 2002 and 2003 at Hatay, Turkey

Application date and/or rate	Years	
	2002	2003
Planting date (Trifluralin and Pendimethalin + Metolacholor application date, plastic mulch placement date, fertilizer NPK application date)	18 January 2002	20 January 2003
Fertilizer NPK 15-15-15 rate	600 kg/ha	600 kg/ha
Trifluralin rate	960 g ai /ha	960 g ai /ha
Pendimethalin + Metolacholor rate	1000 + 1500 g ai /ha	1000 + 1500 g ai /ha
First hand-hoeing and irrigation and fertilizer urea application	20 March 2002	25 March 2003
Fertilizer urea rate	400 kg/ha	400 kg/ha
Second hand-hoeing and irrigation	17 April 2002	18 April 2003
Metribuzin application	3 April 2002	9 April 2003
Metribuzin rate	525 g ai /ha	525 g ai /ha
Harvest	20 May 2002	25 May 2003

tively (Table 3). The species composition results were parallel with that of Waterer (2000), i.e. no species shift was observed due to methods.

Some thickness were observed at underground stem of potatoes due to trifluralin application in the beginning of April and lasted by harvest. In fact, stubby appearance of roots with thickened tip is a typical symptom of trifluralin (Vencill, 2002). Some slight chlorosis at leaf margins after 5-7 days metribuzin application as well. The simptoms of metribuzin disappeared after 15 days herbicide application. Ackley et al. (1996) reported recovery from herbicide symptoms such as metribuzin. Phytotoxicity was not quantified. There was no clear evidence that herbicide injury caused some crop yield or quality loss. Injury from dimethenamid-p or metribuzin treatments did not reduce total tuber yields or quality reductions (Hutchinson et al. 2004a; 2004b).

The effect of extended season weed control on percent weed cover depended on soil applied herbicide treatments in both years (Table 3). In 2002 and 2003, hand-hoeing twice during the growing season with or without either soil-applied herbicide resulted in 5% weed cover at harvest (Table 3). In other words, a PPI or PRE herbicide would not be needed if the grower planned to hoe at least twice during the season approximately 2 and 3 MAP. Clear or black plastic mulch without a soil applied herbicide gave unsatisfactory control while black plastic mulch with a soil applied herbicide gave the best weed control in 2003 and highly effective control in 2002. These findings are consistent with the findings of Ricketson and Thorpe (1983) that weeds growth under the transparent plastic mulch was substantially greater than any other treatments. Clear plastic mulches warm the soil and conserve soil moisture while transmits light, resulting in conditions ideally suited for weed development (Ricketson and Thorpe, 1983). At 10 to 15 or 5 percent weed cover in 2002 or 2003, respectively, soil-applied herbicides combined with black plastic mulch resulted in less percent weed cover than the 25 or 35 percent in plots covered with black plastic only (Table 3). Black plastic mulch combined with a soil applied herbicide might be an effective choice for weed control in early-season potato production. Soil applied herbicides did not decrease weed cover sufficiently under clear plastic mulch or followed by metribuzin POST (Table 3).

Soil applied herbicides caused significantly less weed cover at the end of the season comparing to

Table 3
The effect of extended season weed control and soil applied herbicides on weed density at the end of the growing season in 2002 and 2003 at Hatay, Turkey

Soil applied treatment	Extended season weed control method				
	None	Hand hoeing	Black plastic mulch	Clear plastic mulch	Metribuzin
	Percent weed cover				
2002					
None	50 a*	5 a	25 a	15 a	15 a
Pendimethalin + Metolachlor	20 b	5 a	10 b	20 a	20 a
Trifluralin	20 b	5 a	15 c	15 a	10 a
2003					
None	60 a	5 a	35 a	30 a	15 ab
Pendimethalin + Metolachlor	25 b	5 a	5 b	15 b	10 b
Trifluralin	30 b	5 a	5 b	30 a	20 a

*Means for each year within a column followed by the same letter do not differ according to Duncan's multiple range test at $P \leq 0.05$

no-soil-applied-herbicide treatment without any extended season treatment, i.e. the effect of soil applied herbicides lasted to the end of the season in some extent. The weed cover in soil applied herbicide treatments was 20% or less in 2002 and 30% or less in 2003 (Table 3). Pendimethalin+Metolachlor application with clear plastic mulch or metribuzin in 2003 and with black plastic mulch in 2002 resulted in significantly less weed cover than trifluralin application with that extended season weed control techniques; but, there was no significant difference between two soil applied herbicides under combinations with all other extended season weed control treatments. There have been reports stating that herbicides did not improve weed control (Felix et al., 2008).

During the cropping season, percent weed cover was recorded. Percent weed cover at 40 days after application of herbicides to soil and set of plastic mulches was 5% in 2002 and 1-2% in 2003 at no herbicide and mulch treated plots. Less weed cover in both years might be resulted from lower temperatures, which average daily temperature and soil temperature did not exceed 10 ^{0}C during the first 40 days of season especially in 2003. The weed cover in herbicide applied or plastic mulched areas were 1% or less in both years (data not shown). The average weed cover at non-treated plots 55 days after soil applications was 15% and 8% in 2002 and 2003, respectively (Table 4).

The effect of black plastic mulch was increased with either soil applied herbicides while the effect of herbicides under clears plastic mulch erratic between years (Table 4). Although percent weed cover increased over all experiment area, the effect of soil applied herbicides showed similar trend in the weed assessment 11 days after the first hoeing i.e. 75 days after experiment set (Table 4). Approximately 2 weeks after metribuzin application, percent weed cover was less than 3% in metribuzin applied plots not in regarding to soil applied herbicide. On the other hand weed cover has increased in other plots comparing to previous assessment. In 2002, weed cover assessment after metribuzin application was done before the second hoeing. A rapid increase at percent weed cover between two hand hoeing can be seen at Table 4. During the last month of the growing season, high weed cover was occurred (Table 3)

The duration for emergence of potato differed due to mulching. It was 45, 41, and 35 DAP in 2002 and 48, 46, and 40 DAP in 2003 under non-mulched soil, black plastic mulch, and clear plastic mulch, respectively. The difference among mulching treatments might

Table 4

Effect of extended season weed control and soil applied herbicides on percent weed cover during growing season in 2002 and 2003 at Hatay, Turkey

Soil applied treatment	Extended season weed control method											
	None			Hand hoeing		Black plastic mulch			Clear plastic mulch			Metribuzin
	Percent weed cover											
	A	B	C	B	C	A	B	C	A	B	C	C
2002												
None	15	23	35	3	15	10	13	15	3	5	8	1
Pendimethalin+ Metolachlor	12	16	15	3	10	3	5	6	10	12	14	1
Trifluralin	8	9	15	3	10	5	8	10	5	8	10	3
2003												
None	8	20	40	1	1	5	10	25	10	15	20	1
Pendimethalin+ Metolachlor	10	15	15	3	1	0	1	3	5	8	10	1
Trifluralin	7	13	15	1	1	0	1	3	10	15	20	3

A Weed cover assessment 55 days after experiment set

B Weed cover assessment 11 days after first hoeing

C Weed cover assessment after metribuzin application

Table 5

Temperatures at 10 cm depth of soil under mulches and no mulching plots in 2002 and 2003 at Hatay, Turkey

2002				2003			
Dates	No Mulching	Black Plastic Mulch	Clear Plastic Mulch	Dates	No Mulching	Black Plastic Mulch	Clear Plastic Mulch
	Soil tempearture at 10 cm				Soil tempearture at 10 cm		
5 February	7.5	7.6	9.5	7 February	7.9	8.5	10.1
12 February	8.3	8.2	9.6	14 February	7.3	7.7	8.9
19 February	8.4	7.7	9.9	21 February	9.4	6.0	8.2
29 February	10.1	10.2	13.2	28 February	11.1	7.7	9.8
5 March	11.1	12.1	13.5	7 March	10.1	11.2	12.5
12 March	12.6	13.3	14.2	14 March	9.7	9.5	11.5
19 March	11.5	11.6	13.4	21 March	8.5	9.1	9.6
26 March	11.8	12.2	14.1	28 March	8.2	11.1	12.9
2 April	12.1	12.3	16.1	4 March	12.2	14.5	16.4
9 April	14.5	15.2	17.6	11 April	13.3	15.4	16.7
16 April	15.2	14.5	16.4	18 April	13.1	15.1	16.4
23 April	17.4	18.3	20.1	25 April	19.6	20.7	21.2
30 April	18.1	19.1	21.1	2 May	16.9	17.5	18.2
7 May	19.3	20.1	22.1	9 May	17.5	18.3	19.4
14 May	21.2	22.1	22.9	16 May	18.4	19.7	20.9

resulted from differences at soil temperature (Table 5).

The temperature at 10 cm of soil depth was generally the highest under clear plastic mulch followed by temperature under black plastic mulch. Both clear and black mulches increased soil temperature comparing to bare soil; however, higher temperature increase depending on mulch color was related to how tight mulch setting was (Tarara, 2000). Germination increase in bermudagrass under clear plastic mulch and earlier flowering and high early yield at pepper and watermelon production under black plastic mulch were reported (VanDerwerken and Wilcox-Lee, 1988; Decoteau and Rhodes, 1990). Earliness at emergence under mulches, especially under clear mulch, gives a chance to farmers bringing their crop earlier to the market and getting higher price. In early-season potato market, which is approximately two weeks earlier than normal season potato production, each early day adds some extra value to farmers' income. Delay in emergence in 2003 comparing to 2002 might be attributed to lower temperatures in March 2003. Dean (1994) reported that potato emergence kept 29 days at temperatures 10-13°C and severely slowed at temperatures below 12°C.

Total yield, marketable yield and class-A tuber yield were 23.36 t/ha, 22.81 t/ha, and 17.09 t/ha in 2002, respectively and 22.22 t/ha, 21.63 t/ha, and 15.20 t/ha in 2003 in season long weedless plots. The yield lost obtained comparing to season long weedy plots with weedless ones was 29% in 2002 and 60% in 2003. Especially yield loss was more in class-A tubers, which was 38% in 2002 and 72% in 2003. These findings suggest that weedeness not only effecting crop amount but also crop quality. Comparison of average tuber weights from weedy and weedless treatments supports the conclusion. Average tuber weight in

Table 6

Effect of extended season weed control on Class-A, marketable and total potato yield in 2002 at Hatay, Turkey

Yield	Extended season weed control method				
	None	Hand hoeing	Black plastic mulch	Clear plastic mulch	Metribuzin
	t/ha				
Class-A yield	11.26 C*	17.07 A	15.11 B	15.31 B	12.00 C
Marketable yield	16.11 C	22.27 A	20.68 B	19.87 B	16.54 C
Total yield	16.66 C	22.85 A	21.26 B	20.39 B	17.00 C

* Means within a row followed by the same letter do not differ according to Duncan's multiple range test at $P \leq 0.05$

Table 7

Effect of soil applied herbicides on Class-A, marketable and total potato yield in 2002 at Hatay, Turkey

Soil applied treatment	Yield		
	Class-A yield	Marketable yield	Total yield
	t/ha		
None	13.49 b*	18.72 b	19.30 b
Pendimethalin + Metolachlor	14.49 a	19.81 a	20.34 a
Trifluralin	14.46 a	18.75 b	19.25 b

* Means within a column followed by the same letter do not differ according to Duncan's multiple range test at $P \leq 0.05$

weedless plots was 67.5 g, and 63.2 g in 2002 and 2003, respectively while in weedy plots 57.5 and 44.2. Nelson and Thoreson (1981) found that weed competition reduced both size and number of tubers. On the other hand, few treatments such as hand hoeing twice with soil applied pendimethalin+metolachlor or some black plastic mulch plots gave better Class-A, marketable and total yield than season long weeded plots.

The effect of extended season weed control on class-A, marketable and total potato yield was independent from effect of soil applied herbicides in 2002 but in 2003. So, effects of extended season weed control and soil applied herbicides for 2002 were pooled. Effect of tratments can change by year and/or location (Felix et al., 2008). In 2002, class-A, marketable and total yield showed similar trends. Hand hoeing gave the highest yield and followed by plastic mulch applications (Table 6).

Among soil applied treatments, pendimethalin+metolachlor caused better yield in 2002 (Table 7).

Trifluralin did not increase total potato yield and marketable potato yield while it gave higher class A tuber yield in 2002 (Table 7). Actually, the effect of trifluralin on weed cover lasted season long in some extent (Tables 3 and 4). Similar results were reported in earlier literature. Richardson et al. (2004) found that weeds were controlled by herbicides but there was no significant yield difference among treatments including weedy check. The yield results in 2003 supported findings from 2002. Hand hoeing twice and season long plastic mulches gave the better class-A, marketable and total potato yields and their effect on yield was not depended on soil applied herbicides (Table 8).

The effect of mulches on potato yield might be resulted from not only better weed control but also increasing soil temperature, especially under transparent one. In fact transparent and black mulches increase soil temperatures (Galambosi and Szebeni-Galambosi, 1992), but black plastic provides effective weed control (Ricketson and Thorpe, 1983). Soil applied herbicides without any extended season control method significantly increased class-A, marketable and total

Table 8

The effect of extended season weed control and soil applied herbicides on clas- A, marketable and total potato yield in 2003 at Hatay, Turkey

Soil applied treatment	Extended season weed control method				
	None	Hand hoeing	Black plastic mulch	Clear plastic mulch	Metribuzin
	t/ha				
Class-A yield					
None	03.97 c	14.79 a	14.03 b	13.08 b	08.43 c
Pendimethalin + Metolachlor	11.32 a	16.16 a	15.84 ab	15.09 a	13.97 a
Trifluralin	09.25 b	14.11 a	17.69 a	13.77 ab	09.72 b
Marketable yield					
None	08.47 b	21.37 a	19.46 a	19.42 a	14.95 c
Pendimethalin + Metolachlor	16.87 a	22.34 a	21.60 a	20.48 a	20.15 b
Trifluralin	15.64 a	20.69 a	22.57 a	18.42 a	16.22 a
Total yield					
None	08.87 b	22.14 a	20.04 a	19.82 a	15.47 c
Pendimethalin + Metolachlor	17.38 a	23.09 a	22.31 a	21.30 a	20.77 a
Trifluralin	16.27 a	21.45 a	23.32 a	19.01 a	16.77 b

* Means for each yiedl type within a column followed by the same letter do not differ according to Duncan's multiple range test at $P \leq 0.05$

Table 9
The effect of extended season weed control and soil applied herbicides on average potato tuber weight in 2002 and 2003 at Hatay, Turkey

Soil applied treatment	Extended season weed control method				
	None	Hand hoeing	Black plastic mulch	Clear plastic mulch	Metribuzin
	Average tuber weight, g				
2002					
None	57.47 b*	58.50 c	68.37 a	74.03 b	58.23 c
Pendimethalin + Metolachlor	64.70 a	67.93 b	65.70 a	76.33 ab	70.33 a
Trifluralin	65.37 a	78.87 a	68.93 a	78.60 a	65.97 b
2003					
None	44.20 c	66.30 b	69.87 c	66.83 c	62.30 b
Pendimethalin + Metolachlor	73.03 a	78.67 a	80.00 b	78.97 b	66.03 a
Trifluralin	64.40 b	77.73 a	96.40 a	94.17 a	65.33 ab

* Means for each year within a column followed by the same letter do not differ according to Duncan's multiple range test at $P \leq 0.05$

potato yield. This is not consistent with results from 2002 for trifluralin but pendimethalin+metolachlor. Metribuzin POST with soil applied herbicides improved class-A, marketable and total potato yield but not as much as the other extended season weed control methods.

Soil applied herbicides caused bigger tubers under all extended season weed control techniques, including no extended season control treatment (Table 9).

This suggest that early control of weeds cause bigger tubers although soil applied herbicides did not improved yield in combination with extended season weed control techniques (Table 8). Covering especially transparent or black plastic mulch caused heavier tubers in general. In fact, less weed cover through the season was obtained under plastic mulches.

Conclusion

The results showed that there were clear effect of soil applied herbicides, which used on planting time. If a soil applied herbicide had been applied closer to emergence time, the effect would be better than current results. In spite of that, the effect of soil applied herbicides lasted through growing season in some extent, improved effect of black plastic mulch on weed cover, and caused bigger tubers and consequently higher class-A yield. Although hand-hoeing twice during the growing season resulted in the lowest percent weed cover at harvest, cost and availability of labor may not make this method feasible for a potato grower. As a result, combinations of PPI or PRE soil-applied herbicides and plastic mulch will be necessary. Overall, black rather than clear plastic mulch seems to be the best choice for an extended-season control method following a PPI or PRE herbicide. Metribuzin applied early rather than late postemergence may provide better weed control and result in relatively higher tuber yields and quality than what we observed in our trial. The length of time weeds compete with the potato crop could possibly be reduced with an early metribuzin application. More research on this matter is needed, however. In addition 8-10 days earlier emergence potato crops under clear plastic mulch comparing to bare soil and 2-4 days earliness comparing to black plastic mulch might cause earlier harvest, which is the targeted time span at early-season potato production is 1-2 weeks earliness.

Acknowledgements

Authors thank to The Scientific Research Project Center of Mustafa Kemal University (Project No: 02-B-0403) and the Ministry of Agriculture and Rural

Affairs of Turkey for their supports and helps in the study.

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Received December, 18, 2008; accepted for printing June, 23, 2009.