EVALUATING THE COMPETITIVE ABILITY OF POTATO CULTIVARS WITH WEEDS

NOUROLLAHI, F.[1] – MOHAMMADDOUST-CHAMANABAD, H. R.[1*] – HASSANPANAH, D.[2] – ANVAR, M.[1]

[1]*Department of Agronomy and Plant Breeding, Faculty of Agriculture and Natural Resources University of Mohaghegh Ardabili, Ardabil, Iran*

[2]*Ardabil Agriculture and Natural Resources Research Center, Ardabil, Iran*

[*]*Corresponding author*
e-mail: hr_chamanabad@yahoo.com; phone: +98-915-108-2239

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Abstract. Using competitive cultivars can be an important integrated weed management (IWM) tool in sustainable agricultural systems and in cultivation of healthy products. Differential competitive ability of 10 potato cultivars was examined in 2015 and 2016 in the research field of the University of Mohaghegh Ardabili, Ardabil, Iran. Experiment was established using a randomized complete block design with three replications. 10 potato cultivars (Caesar, Kennebec, Banba, Markies, Hermes, Marfona, 397097-14, Difla, Satina, Natascha) were observed that has grown with and without natural weed flora. Potato cultivars differed in ability to reduce weed density and weed biomass. In weed conditions, tuber yield ranged from 19.27 in Hermes to 55.56 t ha^{-1} in Satina. Also yield loss ranged from 0 to 38.93%. Satina cultivar had the highest competitive index (CI) and could reduce the weed dry mass by 2 to 3 times more than Hermes as a poor cultivar. In general, the results of this study declare that Satina cultivar was considered as competitive and recommended more for cultivation in Ardabil region than other cultivars. It is more stable than weed, and could have greatly reduce the density and biomass of weed.
Keywords: *competitive ability, potato, healthy hazards, integrated weed management, sustainable agriculture, weed interference*

Introduction

Besides cereal, potato, *Solanum tuberosum* L., is an important crop in the world. Iran has the 13th place in potato production (FAO Statistic, 2016). Potato is the most important crop in the Ardabil area. Ardabil contains 23000 ha of arable land, of which 18500 ha was used for potato production in Iran in 2017, with an average yield of 23.7 t ha^{-1} (IRANSTAT, 2017), but weeds are the main barrier to potato production. Yield loss in potato due to weed interference has been reported 20-30% in Iran (Khalghani, 2010). Few herbicides and modes of action are usually available for use in potato cultivations, so the risk of developing herbicide-resistant weed populations can increase. On the other hand, weed control is one of the main limitations in sustainable agriculture. Efficient weed management is essential for successful organic crop protection, and finding crop cultivars that confer a high degree of competitive ability against weeds are highly desirable (Mason et al., 2006). Although competitiveness has not traditionally been considered a priority for breeding or farmer cultivar choice the challenge of managing herbicide- resistant weed populations, environmental concerns and the unmet needs of organic producers and smallholder farmers has, however, renewed interest in cultural weed control options, including competitive cultivars (Worthington and Rebery-Horton, 2013; Andrew et al., 2015). Many research in cereals have examined how cultivar selection may be used as a mean of weed control by choosing cultivars that are inherently more competitive with, or more tolerant of, commonly

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encountered or key weed species (Korres and Froud-Williams, 2002; Worthington and Rebery-Horton, 2013; Lemrele, 2015; Abdollahi and Mohammaddust-Chamanabad, 2017). Some findings presented in complement agronomic and physiological studies of crop- weed interactions in other species such as soybean (Vollman et al., 2010), potato (Nelson and Thoreson, 1981; Love et al., 1995; Khalegi et al., 2007; Colquhoun et al., 2009; Hutchinson et al., 2011; Bashiri-Majd, 2015), tomato (Gonzales-Ponce et al., 1996), canola (Hashem et al., 2010), field pea (Jacob et al., 2016).

There are two aspects of cultivar competitive ability; the ability to compete with weed, is expressed as competitive index (CI) and the ability to tolerate weed interference, is expressed as weed interference tolerance index (WITI). A competitive cultivar (high CI) can maintain high yield in the presence of weeds and can reduce weed biomass or seed production (Tilman, 1987; Goldberg, 1990), while tolerant cultivars only maintain high yield in the presence of weeds. Suppressing weeds is beneficial for weed management in future growing seasons while tolerating weeds is only beneficial in the current growing season. However, the relationship between aspects has not been addressed in potato. According to Cory et al. (2016) it has been reported that pea cultivars that are ranked the highest for AWC were associated with lower weed fecundity, whereas the highest-yielding cultivars generally were those that had the highest CI variation in competitive ability of wheat cultivars (Blackshow, 1994; Lemerle et al., 2001; Mohammaddust-Chamanabad et al., 2014). Abdollahi and Mohammaddust-Chamanabad (2017) also reported positive relationship between the yield of wheat and WITI similarly with CI. Colquhoun (2009) observed that differences in yield among cultivars grown in the presence of weeds suggest differential tolerance of weed competition ability, however, the ability to suppress weeds was similar among cultivars. Khaleghi et al. (2007) reported significant differences among potato cultivars in tolerance of weed presence. According to Bashiri-Majd (2015) late potato cultivars had high competitive ability that produced more yield and reduced weed biomass.

Many long-term studies still conduce on determining cultivars resistance to disease and good combination of traits for logical conditions. While the evaluation of crop cultivars based on competitive ability is necessary. Large genotype by environment interactions may cause difficulties in selecting for competitiveness (Coleman et al., 2001) and selection for competitiveness could be at the expense of other important criteria (Brennan et al., 2001). Nevertheless, within a given climatic zone there appears to be sufficient genetic variation in crop competitive ability (Acciaresi et al., 2001; Coleman et al., 2001) for such selection to be introduced into breeding programs. The over goal of this study was to (1) evaluate the ability potato cultivars to suppress weed density and biomass, (2) rank these cultivars based on competitive ability index, and (3) compare the ability of the same cultivars to maintain tuber yield in the presence of weeds.

Materials and methods

The study was conducted at the Agricultural Research Farm of the University of Mohaghegh Ardabili, Ardabil, Northwestern Iran (longitude 48° 18′ E, latitude 38° 15′ N, 1338 m above sea level) in 2015 and 2016 on loamy clay soil with 1.57% organic matter, and 7.8 pH, EC 1008 μS cm^{-1}. The monthly average air temperatures and total rainfall and long-term averages (1976 to 2014) during the growing season are summarized in *Table 1*. Air temperature and precipitation was different between years compared with the long-term average data. Compared with the long-term averages, air temperatures were

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lower during both study years. In 2016, rainfall was generally higher during the studied growing season (May to September) compared to the long-term average in 2015, except for lower precipitation in August.

In both years, treatments were arranged in a randomized complete block design, with three replicates. Ten potato cultivars (Caesar, Kennebek, Banba, Markies, Hermes, Marfona, Difla, Satina and one advanced clone, 397007-14) were grown with and without weed interference. The selections were chosen, based on their differing growth attributes (*Table 2*).

Table 1. *Air temperature and rainfall for 2015 and 2016 growing seasons and Long-term averages (1976-2014) at Ardabil, Iran*

Month	Mean Temperature (°C)			Rainfall (mm)		
	Long term	2015	2016	Long term	2015	2016
May	14.8	8	7.5	34.3	35.7	59.6
June	18.8	12.9	15	48.6	27.7	29.7
July	22.8	17.9	17	26.8	7	14.2
August	26	19.9	19.6	8.1	3.6	0.1
September	25.5	20.4	19.8	5.1	0	1.2
October	23.5	16.9	18.5	10.4	48.9	6.4
November	19.3	13.3	12.2	25.3	58.3	4.8
December	13.3	7.6	7.1	37.5	46.6	40.3
January	7.2	2.5	-1	24.9	13.9	15.4
February	3.9	3.4	0.4	20.5	6.4	3.4
March	4	0.4	7.5	21.3	24.9	1.2

Plots measured 5 by 4.2 m, including 7 potato rows on 60 cm row spacing. Potato seed pieces were hand-planted with 7.5 plants m^{-2} density on May 1, 2015, and 16 May 2016. After the potato emergence, each plot was divided into two equal parts and in one half all weeds were hand-removed during the growing season as weed free plots. Fertilizer was applied at planting (75, 150, 75 kg ha^{-1} NPK) and at tuber initiation (75 kg N ha^{-1}). Supplemental overhead irrigation was supplied to meet crop water demands. Furrow irrigation during the growing season was carried out at the rate of 6000 m^3 ha^{-1} and 10 days.

Data collection included weed density and biomass at end of the season in the weedy plots and tuber yield in all plots. At the end of the season before tuber harvest, weeds were collected from two 0.5×0.6 m quadrates in each weedy plots. Weeds were counted, dried at 75°C for 48 hours and weighed. Potato tuber yield was quantified at season-end by harvesting the three rows in each plot. The following Equations (*Eqs.1 and 2*) were used for the evaluation of the competitive ability (CI) and tolerance ability (WITI) of potato cultivars (Mohammaddust-Chamanabad, 2011).

$$WITI = \frac{(Yp)(YS)}{(\bar{Y}p)^2} \quad \text{(Eq.1)}$$

where Yp is each cultivar yield from the weed free plot, Ys is each cultivar yield from weedy plot. $\bar{Y}$p mean is the average yield of all potato cultivars from the weed free plot.

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Table 2. *Traits of potato cultivars used in this study (ECPD, AHDB and PPA 2018)*

S.No.	Popular name	Developing center	Parentage	Year of released	Characteristics								
					Tuber				Botanical Description				
					Shape	Color of skin	Color of flesh	Depth of eyes	Maturity	Height*	Foliage development	Color of flower	Yield potential**
1	Banba	Irish Potato Marketing Ltd	Slaney$_x$Estima	2001	Oval-long	Yellow	Light yellow	Shallow	Early	Medium-tall	Fairly good	White	Very high
2	Caesar	HZPC UK Limited	Monalisa$_x$RopB1178	1990	Oval-long	White to yellow	Yellow	Very shallow-shallow	Intermediate	Medium	Dense	White	Very high
3	Difla	Germicopa-France	Sylvia$_x$cara	1992	Oval	Yellow	White	Shallow-medium	Medium late	Tall	Very good	White	Very high
4	Hermes	GB seed industry	DD 5158$_x$SW 163/55	1973	Round-oval	Yellow	Fairly yellow	Moderately deep	Medium early to medium late	Medium to tall	Fairly good	Red violet	High
5	Kennebek	USDA	((Chippewa$_x$Katahdin)$_x$(3895-13$_x$earlaine))	1941	Round-oval	Pale yellow	White	Shallow	Medium early to medium late	Medium to tall	Good	White	High
6	Markies	Agrico UK ltd	Agria$_x$Fianna	1984	Oval to long oval	Yellow	Pale yellow	Shallow	Late to very late	Tall	Very good to good	White	High
7	Marfona	Agrico UK ltd	Primora$_x$Ko51-123	1975	Round-oval	Yellow	Pale yellow	Rather shallow	Medium early to medium late	Tall	Good	White	Very high
8	Natascha	Marabel$_x$91-050-4	CO.KG,Gmbh	1998	Oval	Yellow	Deep yellow	Shallow	Early	Tall	Good	White	High
9	Satina	Canadian Food Inspection Agency	Puntila$_x$H99/73	1971	Round oval-oval	Yellow	Yellow	Shallow	Medium early	Tall	Rapid-medium	White	Very high
10	397097-14	CIP	397009	-	Round-oval	Yellow	Yellow	Shallow	Intermediate	Tall	Medium	White	High

* Medium (60-70 cm), medium to tall (70- 100cm), Tall (100-150 cm), ** High (40-50 t ha $^{-1}$), very high ($\geq$ 50 t ha $^{-1}$)

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$$CI = \left(\frac{Vi}{\bar{V}}\right) / \left(\frac{Di}{\bar{D}}\right) \qquad \text{(Eq.2)}$$

where Vi is each cultivar yield from the weedy plot, $\bar{V}$ is the average yield of all potato cultivars from the weedy plot. D_i is weed dry biomass in each potato cultivar and $\bar{D}$ is average weed dry biomass from weedy plots. Relative Yield Loss was calculated as (*Eq.3*):

$$\%Relative\ Yield\ Loss = 100(Yweed\ free - Yweedy)/(Yweed\ free) \qquad \text{(Eq.3)}$$

Data were subjected to ANOVA, normality was checked using the graphical method in Statistical Package for the Social Sciences (SPSS). Means were separated by Duncan multiple rang test ($P \leq 0.05$). Interaction between treatment and years, as well as between cultivars and weed competition levels were observed for several parameters; therefor, results are presented by year.

Results

Weed density and biomass

The dominant weed species in both years were Turnipweed (*Rapistrum rogosum* L.), Bindweed (*Convolvulus arvensis* L.), common lambsquarters (*Chenopodium album* L.) and red root pigweed (*Amaranthus retroflexus* L.). The cultivars effect was significant for weed density and weed biomass in both years (*Table 3*).

Table 3. *ANOVA for the effect of potato cultivar on weed density and weed biomass*

Source of variation	Mean Square (MS) values			
	2015		2016	
	Weed density		Weed biomass	
Cultivar	94**.3136	4484.41*	11**.154127	**02.10030
Error	867.30	3257.01	23772.97	3657.48
C.V. (%)	43.93	44.71	2.58	30.74

**,* significant at the $p \leq 0.01$ and $p \leq 0.05$, respectively

Results showed that weed density ranged from 15.6 to 128.9 plant m^{-2} in both years depending on potato cultivar. In both years Satina and Natascha cultivars had the lowest weed density so weed density was lower than 25 plant m^{-2} (*Table 4*). Caesar and Hermes cultivar had the highest weed density. Weed biomass ranged from a minimum of 224.38 for Satina to a maximum of 998.96 for Caesar (*Table 4*). Natascha had consistently a minimum value for weed density in both years. Some cultivars differed substantially in weed biomass among years. For example, Satina, Natascha and Banba had higher ranking in 2015 compared to 2016. Kennebek, Satina, Markies and 397097-14 had higher ranking for weed biomass in 2016 compared to 2015. Results showed that in 2016, all cultivars significantly had less weed biomass. So this may be due to more rainfall in 2016. Regarding the average throughout both year, the highest and the lowest weed biomass was observed in Caesar and Satina cultivars, respectively (*Table 4*).

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Table 4. *Potato cultivar weed density and weed biomass in 2015 and 2016*

Cultivar	Weed density (plant/m^2)			Weed biomass (gm^{-2})		
	2015	**2016**	**Mean**	**2015**	**2016**	**Mean**
Caesar	101.0 ^{f}	98.7 ^{c}	99.85	998.96 ^{g}	210.10 ^{bc}	604.5
Kennebek	70.8 ^{def}	84.7 ^{ab}	77.75	738.44 ^{fg}	128.00 ^{a}	433
Banba	61.4 ^{abc}	88.9 ^{ab}	75.15	398.02 ^{ab}	205.64 ^{bc}	302
Markies	89.6 ^{ef}	82.2 ^{ab}	85.9	537.81 ^{ef}	147.38 ^{a}	343
Hermes	102.1 ^{f}	128.9 ^{c}	115.5	741.25 ^{fg}	271.51 ^{c}	506.5
Marfona	85.4 ^{ef}	106.2 ^{c}	95.8	457.60 ^{abc}	222.22 ^{bc}	340
397097-14	87.5 ^{ef}	84.9 ^{ab}	82.2	492.50 ^{def}	150.09 ^{a}	321.5
Difla	34.9 ^{ab}	76.9 ^{ab}	55.9	472.76 ^{def}	302.04 ^{c}	387
Satina	21.9 ^{a}	22.3 ^{a}	22.1	224.38 ^{a}	140.89 ^{a}	182.6
Natascha	15.6 ^{a}	26.3 ^{a}	20.95	343.75 ^{ab}	189.96 ^{bc}	304

In each column, means followed by the same letter do not differ significantly according to a Duncan test performed at $p \leq 0.05$

Potato yield and yield loss

The cultivars effect was significant for potato yield in both years, except for yield in weed free plots in 2015 (*Table 5*). In weed free plots, tuber yield ranged from 29.58 t ha^{-1} for Kennebek cultivar to 57.06 t ha^{-1} for Satina cultivar in 2015 compared with 24.44 t ha^{-1} for Difla cultivar to 38.64 t ha^{-1} for Satina cultivar in 2016 (*Table 6*).

Table 5. *ANOVA for the effect of potato cultivar on yield and competition indices*

Source of variation	2015				2016			
	Yield weed free	**Yield weedy**	**CI**	**WITI**	**Yield weed free**	**Yield weedy**	**CI**	**WITI**
Cultivar	325.730^{ns}	459.517**	2.08**	1.01**	65.303*	56.930*	0.56*	0.17^{ns}
Error	996.304	391.118	0.34	0.21	148.32	202.56	0.29	0.13
C.V. (%)	45.40	87.28	49.77	49.25	57.17	47.18	45.63	38.22

**,* and ns: significant at the $p \leq 0.01$ and $p \leq 0.05$ and non significant, respectively

In weedy plots, tuber yield ranged from 24.33 t ha^{-1} for Hermes cultivar to 55.56 t ha^{-1} for Satina cultivar in 2015 compared with 19.27 t ha^{-1} for Hermes cultivar to 34.53 t ha^{-1} for Satina cultivar in 2016 (*Table 6*). Satina and 397097-14 cultivars had the highest tuber yield in weedy and weed free plots in both years, so their yield loss was down to 9%. In 2015 year, yield loss of Kennebek cultivar was about zero, but it’s yield was low too (*Table 6*).

Weed competition indices

The cultivars effect was significant for CI and WITI in both years, except for WITI in 2016 (*Table 5*). Values for CI ranged from 0.31 to 3.15 in 2015 compared with 0.54 to

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1.88 in 2016. Results showed that Satina had the highest CI in both years followed by 397097-14 cultivar, so in both cultivar weed biomass were lower and tuber yield was more than the rest (*Tables 4 ,6 and 7*).

Values for WITI ranged from a minimum of 0.36 for Caesar to a maximum of 2.16 for 397097-14 cultivar in 2015. 397097-14 and Satina had higher ranking in this year (*Table 7*). There were no significant variety for WITI value within cultivars in 2016 (*Table 5*).

***Table 6.** Potato cultivar yield in weed-free and weedy condition, relative yield loss in 2015 and 2016*

Cultivar	2015			2016		
	$Yield_{wf}$ (t ha^{-1})	$Yield_{w}$ (t ha^{-1})	%YL	$Yield_{wf}$ (t ha^{-1})	$Yield_{w}$ (t ha^{-1})	%YL
Caesar	37.00	29.39 ^{d}	17.74	35.86 ^{ab}	23.38 ^{cd}	27.45
Kennebek	29.58	29.78^{d}	0	29.23 ^{abc}	25.31 ^{ab}	17.02
Banba	47.39	35.39 ^{bc}	23.40	36.76 ^{ab}	25.94 ^{ab}	22.48
Markies	49.72	31.06 ^{c}	31.42	27.47 ^{ef}	27.58 ^{ab}	0.56
Hermes	44.11	24.33 ^{d}	38.93	28.44 ^{def}	19.27 ^{d}	18.77
Marfona	34.44	28. 00 ^{d}	10.01	31.03 ^{abc}	25.60 ^{ab}	6.10
397097-14	48.06	46.00 ^{a}	4.29	36.73 ^{ab}	29.08 ^{ab}	8.31
Difla	57.06	51.22 ^{ab}	10.5	24.44 ^{f}	22.31 ^{d}	8.6
Satina	55.89	55.56 ^{a}	0.14	38.64 ^{a}	34.53 ^{a}	0
Natascha	38.11	34.17 ^{bc}	10.46	30.97 ^{def}	24.74 ^{cd}	5.22

In each column, means followed by the same letter do not differ significantly according to a Duncan test performed at $p < 0.05$, $p < 0.01$

***Table 7.** Potato cultivar competition indices in 2015 and 2016*

Cultivar	CI		WITI	
	2015	2016	2015	2016
Caesar	0.31^{g}	1.12 ^{abc}	0.36 ^{d}	0.91
Kennebek	0.62 ^{efg}	1.48 ^{abc}	0.60 ^{d}	0.83
Banba	1.29 ^{bcd}	1.00 ^{def}	0.95 ^{bc}	1.03
Markies	0.62 ^{efg}	1.38^{abc}	0.79 ^{c}	0.88
Hermes	0.44 ^{fg}	0.54 ^{f}	0.52 ^{d}	0.66
Marfona	0.91 ^{bcd}	0.83 ^{ef}	0.49 ^{d}	0.85
397097-14	1.59 ^{b}	1.67 ^{ab}	2.16 ^{a}	1.21
Difla	1.40 ^{bcd}	0.68 ^{ef}	1.13^{bc}	0.62
Satina	3.15 ^{a}	1.88 ^{a}	1.70 ^{ab}	1.43
Natascha	1.54^{bc}	1.12 ^{abc}	0.66^{c}	0.93

In each column, means followed by the same letter do not differ significantly according to a Duncan test performed at $p < 0.05$, $p < 0.01$

To aid in the interpretation of results, potato cultivars were categorized as highly, poorly, and intermediately competitive. Since the lowest weed density, weed biomass, yield loss, and the highest competitive index were recorded in satina in both years (*Tables*

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6 and 7) this may be considered highly competitive. Casear and Hermes had the highest weed characteristics and yield loss and the lowest competitive index in both years (*Tables 4, 6 and 7*) thus these may be considered poorly competitive. The rest were not classed as poorly or highly and were considered intermediately competitive (*Figures 1 and 2*).

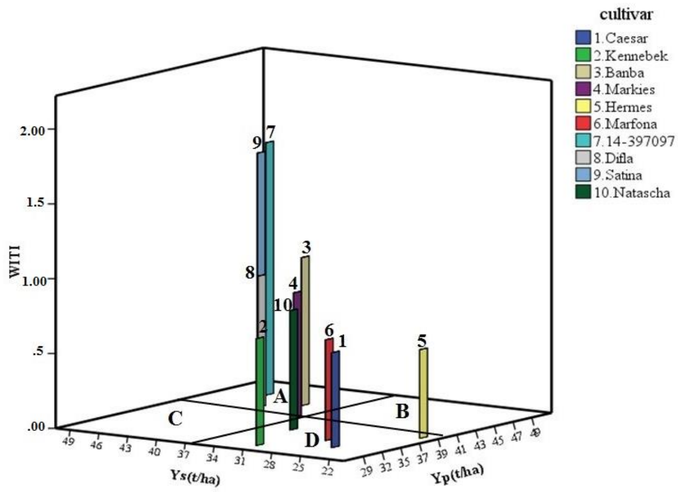

***Figure 1.** Three dimensional diagram of WITI index for 10 Potato genotypes based on Potato yield (t ha^{-1}) with weed (Y_s) and without presence of weed (Y_p)*

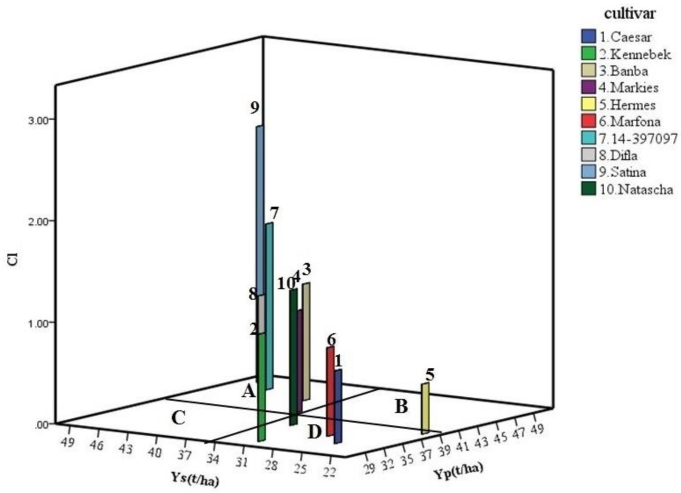

***Figure 2.** Three dimensional diagram of CI index for 10 Potato genotypes based on Potato yield (t ha^{-1}) with weed (Y_s) and without presence of weed (Y_p)*

Discussion

Cultivar competitiveness can be expressed as the ability of a cultivar to maintain yield when grown in the presence of weed and can be measured by weed interference tolerance index (WITI) or as one that is able to suppress weed growth, which is measured by competitive index (CI) (Watson et al., 2006). These are important in different production systems. For example, WITI is more suitable for conventional production systems, where

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herbicides are used. While in organic systems, CI is important to minimize seed return. However, the relationship between these aspects has not been addressed in potato. In this study, the potato cultivars differed significantly in the suppression weed growth. High CI in Satina caused to reduced weed density and weed biomass and allowed minimizing yield loss. This is in agreement with Watson et al. (2006) who reported barley yield loss and reduced weed seed return when high competitiveness barley cultivars were grown. It has been reported that weed biomass differ through potato cultivars (Nelson and Thoreson, 1981; Love et al., 1995; Khalegi et al., 2007; Hutchinson et al., 2011). Although, Conley et al. (2001) and Colquhoun et al. (2009) reported no differences in weed biomass with six potato cultivars.

Our results showed that Satina cultivar had high CI and, while 397097-14 cultivar had high WITI. Jordan (1993) and Lemerle et al. (2001) stated that CI and WITI might not necessarily be present in the same variety. WITI and CI are traits that differ both genetically and agronomically. CI is often associated with traits including vigorous growth, allelopathic potential, large seedling ground cover, height, canopy structure and overall leaf area (Hansen et al., 2008). 397097-14 is a new cultivar and Satina is an old (released 1971) cultivar. Murphy et al. (2008) reported that modern wheat cultivars were competitiveness than older cultivars. In other words, there is no trade-off among yield and competitive ability.

Potato yield and weed biomass for all cultivars was relatively greater in 2015 than in 2016, this difference between years in weed biomass as well as yield could have been caused by a relatively early rainfall in the seasonal growing conditions in 2015 than in 2016. According to various studies, potato responds to improved moisture conditions (Mazurczyk et al., 2009; Rolbiecki et al., 2009; Zaski, 2011; Karanja et al., 2014).

Conclusion

Potato cultivar competitive ability has a substantial range and can be an important IWM tool or it can be used in conjunction with other IWM tools such as yield loss thresholds and reduction of herbicide hazards. Satina and 397097-14 had highly competitive abilities and can be used in sustainable systems.

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