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Determining critical period for weeds control in sage (Salvia officinalis L.)

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Abstract. The critical period for weeds control in sage was determined in an experiment based on a Randomized Complete Block Design with three replications and five treatments in Ardabil in 2010-2011. The treatments included weeds interference and weeds control with the intervals of 20 days (0, 20, 40, 60, and 80 days after sowing). It was found that among weeds interference treatments, the highest weeds population was observed in the treatment of weeds interference until 40 days and among weeds control treatments, the highest weeds population was in the treatment of weeds control until 20 days as the duration of weeds interference was increased, their density was decreased because of self-thinning. Critical period for weeds control in sage was found to be 76, 60 and 53 days for acceptable yield losses of 5, 10 and 15%, respectively.

Keywords: critical period, sage, weeds, yield loss

1. INTRODUCTION

Human being is created on the basis of nature and his needs are met by his Creator. In addition to helping human beings' growth and development, these divine gifts help them in diseases (Hashemi, 2007.[1]). Medicinal herbs are one example of these gifts whose history of use is as long as the presence of mankind on the Earth (Kiani, 2009.[2]). Sage (*Salvia officinalis* L.) is the most invaluable medicinal herb of Salvia genus with important medicinal characteristics. Its leaves contain essential oil and strong tannin and they are traditionally used for healing digestion disorders, diuretic, convulsion, fever, and infections and for reducing blood sugar. It is also period-provoker in women (Silva Brum *et al*., 2001.[3]). Sage improves memory inasmuch as it is known as 'smart tea' (Mindell, 1992.[4]). It is used for relieving nervousness, shaking, depression and vertigo (Lust, 1986.[5]) and heals dyspepsia (Evans, 1989.[6]). It belongs to the family Labiatae with the scientific name of *Salvia officinalis* L. (Mirheidar, 2001.[7]). So given its numerous properties, its high yield is important. However, the weeds in agroecosystems are an important biological stress that reduces the yield of plants considerably and their management can play a vital role in increasing plant production (Mohammadoust Chamanabad, 2011.[8]). The frequency of herbicide application needs to be reduced considering the associated problems and the growing emphasis on sustained agriculture and environment conservation. Therefore, sound management of weeds in farms plays an important role in avoiding the loss of yield and crop quality and minimizing yield losses (Rashed Mohhasel *et al*., 2006.[9]). Integrated weeds management is the application of

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different, effective methods for controlling weeds aimed at reducing their interference with crops (Blackshaw, 1991.[10]). One main component of integrated management is suppressing weeds in critical period (Swanton & Weise, 1991.[11]). Evidence shows that crops are particularly susceptible to weeds in a certain period of their growth during which weeds management has the highest influence on crops yield. This period is known as critical period for weeds control (Mohammadoust Chamanabad, 2011.[8]). Hall *et al*. (1992.[12]) stated that critical period for weeds control is a period of time in crop life that should be kept free of weeds for reducing yield loss. This period is when the weeds most severely compete with crop and inflict the heaviest damage (Jackson *et al*., 1985.[13]).

This critical period varies with crop and time (Knezevic *et al*., 2002.[14]). It was found to be 24-38 days after emergence in cumin in its 80-day growth period (Hosseini *et al*., 2006.[15]). The critical period for weeds control in psyllium for 10 and 5% loss of yield was found to be 21-52 and 26-38 days after sowing (DAS), respectively (Sharifi Nouri, 2005.[16]). In a study on critical period for weeds control in *Nigella sativa* with 2.5, 5 and 10% acceptable loss of yield, Seyedi *et al*. (2011.[17]) found that they started 10.5, 13 and 17.3 days after emergence and lasted 76.8, 74.8 and 71.1 days after emergence which constituted 79, 74 and 64% of whole plant growing season, respectively.

A great number of studies have focused on determining critical period of weeds control in crops throughout the world, but they have rarely looked at medicinal herbs. Therefore, given the importance of sage as a medicinal herb, the present study was carried out to determine the critical period for weeds control in this plant.

2. MATERIALS AND METHODS

The present study was conducted in a farm with approximate area of 600 m^2 (Lat. 38°01' N., Long. 47°59' E.) located 35 km away from Ardabil with very cold winters and moderate springs and summers in 2010-2011. The altitude is 1778 m and the mean annual precipitation amounts to about 400 mm. The farm soil had loam-sandy texture with the pH of 6.1.

During plowing, 7 t manure was applied to the soil and the study was conducted on the basis of a Randomized Complete Block Design in two groups with five treatments and three replications. The treatments included weeds interference and weeds-free periods at 20-day intervals (0, 20, 40, 60 and 80).

Interference treatments included two levels: control (W1) in which weeds were not controlled in whole growing season and W2 in which weeds were not controlled until 20 DAS and then, the plots were weeded until the end of growing season. Treatments W3, W4 and W5 were left infested by weeds until 40, 60 and 80 DAS and then they were manually controlled until the end of growth period. Weeds-free treatments included control (W'1) with no weeds interference in whole growing season and W'2 which was the exact opposite of W2 in which weeds were controlled until 20 DAS and they were left uncontrolled until the end of the growing season. In treatments W'3, W'4 and W'5, the weeds were controlled until 40, 60 and 80 DAS and they were left uncontrolled until the end of the growing season.

The weeds were sampled during growing season according to the intervals selected for the plots. At each sampling, a 1-m^2 quadrat was randomly thrown inside the plot and the weeds inside it were counted. Then, they were oven-dried at 70°C for 48 hours and were weighed. At the end of growing season, sage plants were harvested and oven-dried at 70°C for 48 hours. Then, their dry weight was measured. The critical periods of weeds interference and weeds control were determined by logistic and Gompertz equations, respectively. The yield of the plots was determined as the percentage of that of weeds-free plots. The initiation of critical period at three levels of 5, 10 and 15% yield loss was determined by logistic equation (Knezevic *et al.*, 2002.[14]).

$$Y = \left[\frac{1}{\exp\left(c \times (T - d)\right) + f} + \frac{f - 1}{f} \right] \times 100$$

where, Y is the relative yield of sage as the percentage of control, T is independent variable of the time of interference start (interference period measured from the sowing time), d is the inflection point of curve in terms of DAS, *exp* is exponential function, and f and c are constants. The end of critical period at three levels of 5, 10 and 15% yield loss was calculated by Gompertz model (Knezevic *et al.*, 2002.[14]):

$$Y = a \exp\left(-b \exp(-kT)\right)$$

where, Y is the relative yield of sage as the percentage of control, T is independent variable of the time of starting control (weeds control period measured from the sowing time), a is the asymptote of yield percentage which is the maximum yield or the yield of weeds-free control, and b and k are constants. In the present study, the fitting was done with the least squares mean and the highest coefficient of determination (R^2).

3. RESULTS AND DISCUSSION

3.1. Weeds density

Analysis of variance (Table 1) showed that the effect of different weeds interference treatments was significant on total number of weeds at the 1% probability level. In addition, different weeds-free treatments significantly influenced total weeds density at the 5% probability level. Among interference treatments, the highest weeds density (129.67 plants m^{-2}) was observed in the treatment of infestation until 40 DAS and the lowest one (51.67 plants m^{-2}) in the treatment of infestation until 60 DAS which was ranked in the same statistical group with other treatments. Furthermore, the total weeds densities of different weeds-free treatments were ranked in the same statistical group and the number of weeds was decreased over the time as the weeding operations were increased (Fig. 1).

Table 1. Analysis of variance of the effect of different weeds interference and control periods on some traits.

Sources of variations	df	Means of squares (MS)		
		Total weeds density	Total dry biomass of weeds	Shoot yield
Weeds interference				
Replication	2	4564.46^{**}	0.01^{ns}	204797.86^{ns}
Treatment	4	2852.56^{**}	0.29^{**}	997170.82^{**}
Error	8	390.96	0.02	96533.01
Coefficient of correlation (%)		26.03	6.25	30.81
Weeds-free period				
Replication	2	0.01^{ns}	0.07^{ns}	93566.09^{**}
Treatment	4	0.11^{*}	0.36^{*}	1160391.40^{**}
Error	8	0.03	0.10	8865.83
Coefficient of correlation (%)		19.16	25.17	6.61

ns, * and ** show non-significance and significance at the 5 and 1% probability level.

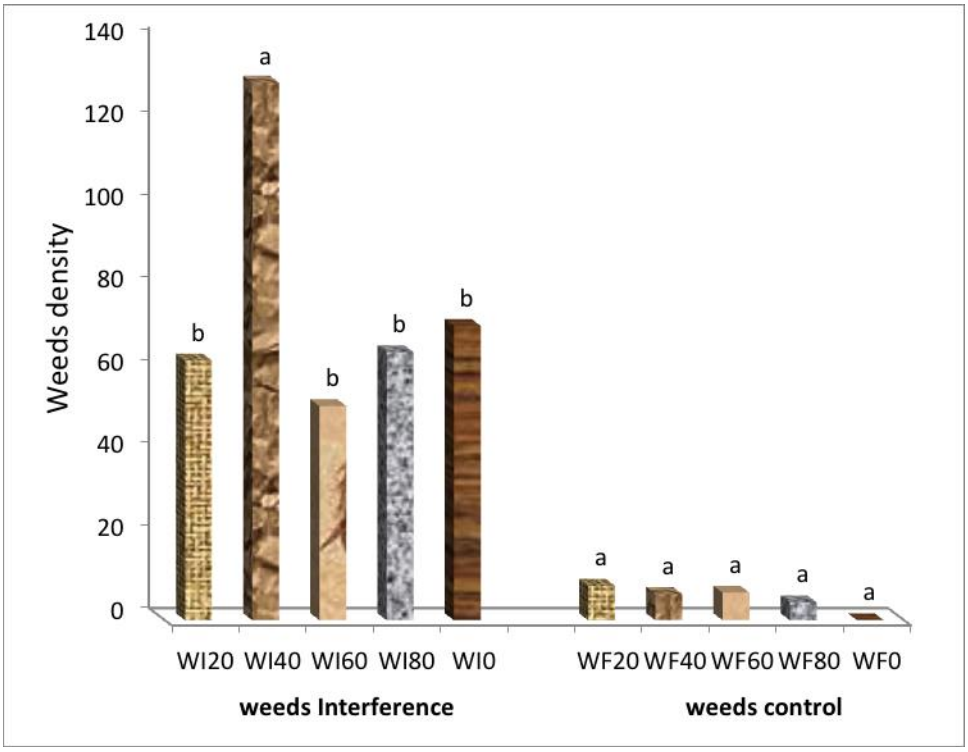

Figure 1. Effect of different weeds interference and weeds control treatments on weeds density

(in all figures - WF20: weeds free until 20 DAS; WF40: weeds free until 40 DAS; WF60: weeds free until 60 DAS; WF80: weeds free until 80 DAS; WF0: control, weeds free in whole growing season; WI20: weeds interference until 20 DAS; WI40: weeds interference until 40 DAS; WI60: weeds interference until 60 DAS; WI80: weeds interference until 80 DAS; WI0: control, weeds interference in whole growing season)

The high density of weeds in the treatment of infestation until 40 DAS can be related to the low competitiveness of crops in their early growth stages which results in the minimum competition between weeds and crops. Then, more number of weeds grow successfully. The decrease in the weeds population over the time and in the treatments of infestation until 60 and 80 DAS can be associated with higher growth of weeds and more severe inter-species and intra-species competition of weeds over nutrients which, in turn, results in the loss of weaker plants, a phenomenon known as 'self-thinning' (Koucheki *et al*., 1994.[18]). In a study on common beans, Lak *et al*. (2005.[19]) reported a similar trend of the decrease in weeds population with the increase in the duration of weeds control.

3.2. Weeds dry biomass

Analysis of variance of weeds dry biomass (Table 1) indicated that total dry weight (TDW) of weeds was significant in the treatment group of infestation to weeds at the 1% probability level. The highest TDW of weeds (800.8 g m-2) was observed in the treatment of infestation until 80 DAS which was ranked in the same statistical group with the treatment of infestation in whole growing season (Fig. 2). It can be related to small, if any, control of weeds in these treatments. In the treatment of full infestation, weeds dry biomass was lower than that under the treatment of infestation until 80 days after planting because of the termination of the growing season of some weeds and their removal.

According to the analysis of variance for dry biomass under weeds-free treatments (Table 1), TDW of weeds was significant at the 5% probability level. The highest TDW of weeds (153.38 g m-2) was observed in the treatment of weeds control until 20 DAS (Fig. 2). Rasoulzadeh et al. (2011.[20]) concluded that the lowest weeds dry weight at the end of season was related to frequent weeding in whole growing season and the treatment of weeds control until 100 days which was zero. They revealed that there was an indirect relationship between the duration of weeds-free period from the initiation of emergence and their dry weight at harvest time, that the removal of weeds resulted in the loss of dry matter accumulation of weeds, and that the closer the weeding time to season termination, the lower the weeds dry weight. Bukun (2004.[21]) found that TDW of weeds increased as the weeds infestation period was increased and that TDW of weeds in all growing seasons decreased as the duration of weeds-free period was increased.

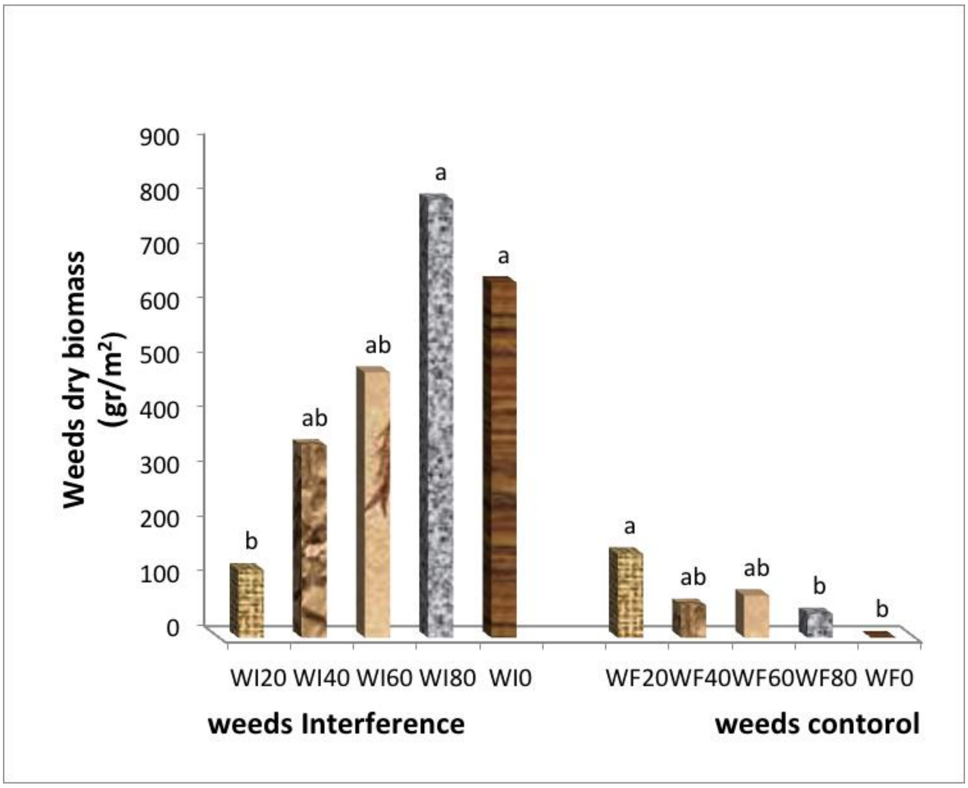

Figure 2. Effect of different weeds interference and weeds control treatments on weeds dry biomass

3.3. Sage shoot yield

Analysis of variance for weeds interference and weeds-free treatments (Table 1) revealed that total shoot yield of sage was significant at the 1% probability level. Among the treatments of weeds interference, the treatment of infestation until 20 DAS and among the treatment of weeds control, full weeds-free treatment had the highest yield (Fig. 3). In the treatment of infestation until 20 DAS, since the plants were exposed to weeds infestation for shorter time concurrent with the initial growth stages of weeds, weeds were not competitive enough to compete with sage. Also in full weeds-free treatment, the weeds were wholly controlled and so sage had the highest yield. The second highest yield was observed in the treatment of weeds control for 80 DAS owing to longer weeds-free period. The lowest yield was related to the treatment of weeds control until 20 DAS which had the shortest controlling period. Many studies show that the infestation of farms to weeds results in yield loss. Nezami and Bagheri

(1996.[22]) concluded that weeding significantly increased grain yield, that weeds control in the first five weeks after emergence of pea resulted in the highest grain yield, and that the lowest grain yield was observed in control. It seems that higher yield under weeding treatments than under no-weeding treatments is caused by the loss of weeds competitiveness.

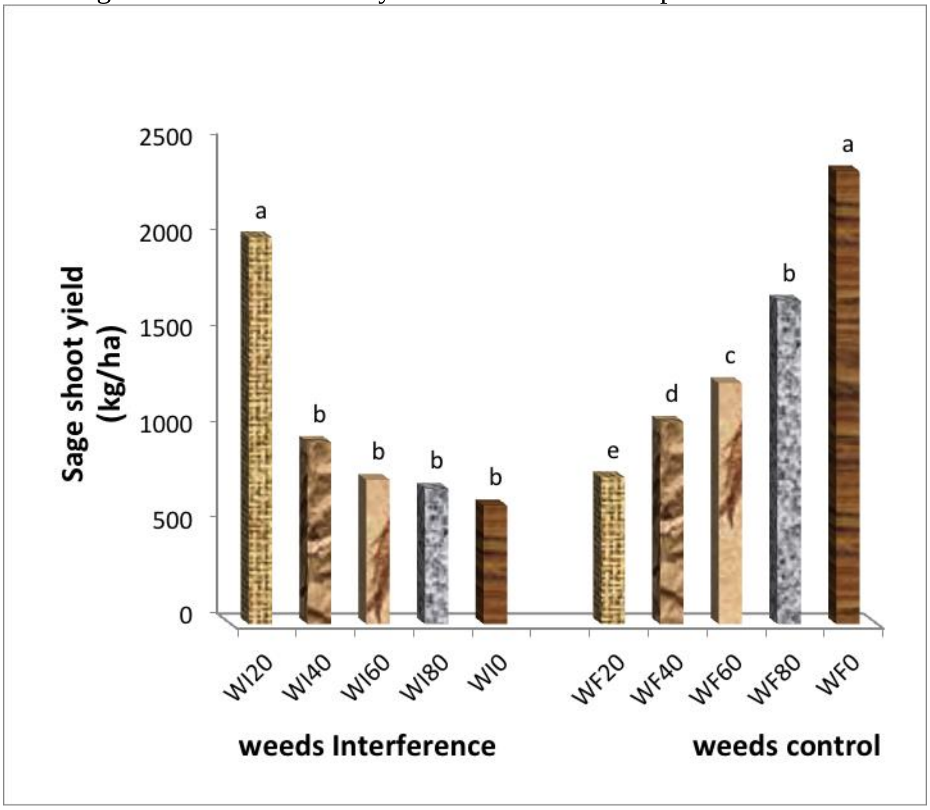

Figure 3. Effect of different weeds interference and weeds control treatments on sage total shoot yield.

3.4. Critical period for weed control in sage

Considering 5, 10 and 15% as the acceptable yield loss, the critical period for weed control initiates 22, 25 and 29 days after transplanting sage, respectively. The present of weeds before these times had no significant effect on sage. It can be explained by the fact that since sage is transplanted, it has the chance of establishment and canopy expansion before the germination of weeds. Therefore, sage does not need weeding until this time. The critical period terminates 98, 85 and 82 DAS for the acceptable yield losses of 5, 10 and 15%, respectively (Table 2, Diagram 1). That is, the farm should be kept weeds-free in these periods of time in order to avoid the yield losses of >5, 10 and 15%. In total, the critical period for weeds control was found to be 76, 60 and 53 DAS for the acceptable yield losses of 5, 10 and 15%, respectively. These periods are concurrent with the expansion of leaves and the increase in their number as well as the increase in the number of auxiliary branches of sage. In their study on critical period for weeds control in cumin, Hosseini et al. (2006.[15]) stated that the highest economical yield was obtained when the farm was kept weeds-free from 24 until 38 DAS. In their study on critical period for weeds control in psyllium, Sharifi Nouri et al. (2005.[16]) concluded that psyllium plants had lower capacity for competing with weeds in early growing season because of their slow rate of shoot growth and so they experienced a severe yield loss so that for 10% loss of yield, a weeds-free period of 26-38 DAS was required which should have been exactly before full canopy expansion of psylliums and their full establishment.

Table 2. Initiation and termination of critical period for weeds control in sage using logistic and Gompertz equations at different levels of yield loss.

Acceptable yield loss (%)	Initiation of critical period (DAS)	Termination of critical period (DAS)
5	22	98
10	25	85
15	29	82

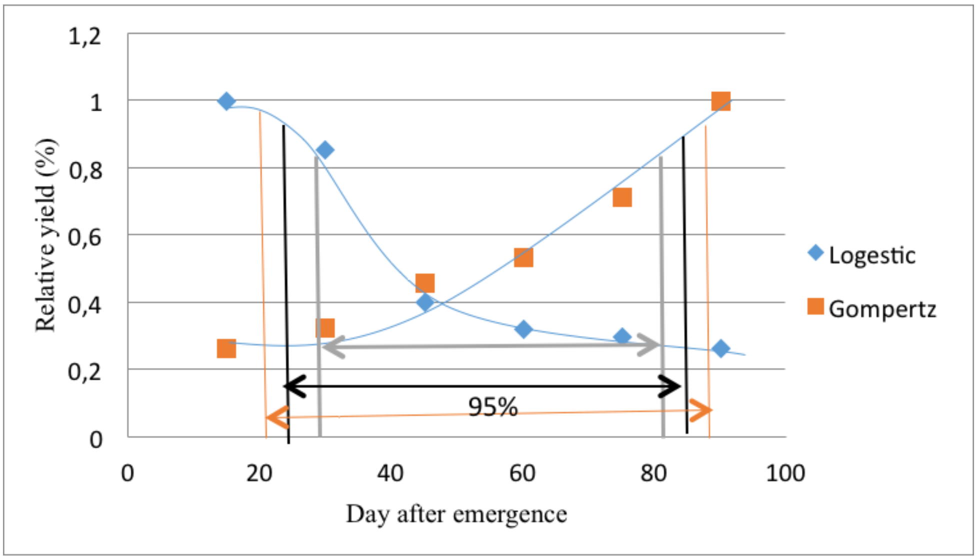

Diagram 1. Effect of weeds interference on total yield of sage. The increase in weeds interference period (♦) and its related curves by logistic equation; the increase in weeds-free period (■) and the related curves by Gompertz equation. Horizontal lines showing different levels of yield loss of 5, 10 and 15% used in determining critical period for weeds control.

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