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Full Length Research Paper

Determination of critical period for weed control in the second crop corn under Mediterranean conditions

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Weeds are a major constraint in corn production. Understanding the critical period for weed control (CPWC) can be a tool for effective weed control and reducing the impacts of weeds. Three experiments were conducted to determine CPWC in the second corn crop from 1996 to 1998. The critical period for weed control in the second crop corn in the mediterranean region was determined to be from 131 to 927 growing degree days (GDD) after sowing in 1996, from 337 to 731 GDD in 1997 and from 266 to 551 GDD in 1998 for 10% yield loss; for 2.5 - 5% yield loss, the critical period starts with germination and lasts longer. Preemergence (PRE) or presowing (PPI) herbicides would be preferred to avoid higher yield losses. If a farmer can tolerate 10% yield loss, a postemergence (POST) herbicide can be applied in the second week after crop sowing, and the field should be kept weed free for 4 or 5 weeks. The duration of weed competition and time of weed removal also affect tasseling, silking, plant height, stem diameter, first ear's height and number of kernels in an ear, all of which correlate with corn yield.

Key words: Weeds, weed competition, weed management, corn.

INTRODUCTION

Integrated pest management (IPM) is a system that, in the context of the associated environment and population dynamics of pest species, utilizes all suitable techniques and methods to maintain pest populations below the economic injury level (Labrada and Parker, 1994). The critical period of weed competition is an important part of developing IPM strategies (Swanton and Weise, 1991). Also, critical period studies can be used in a general way to determine weed control strategies and to explore the nature of weed-crop interactions (Weaver and Tan, 1987).

The critical period for weed control (CPWC) is the length of time that the crop must be kept weed-free to prevent yield losses at a certain level (Weaver and Tan, 1983). CPWC studies have been conducted in many crops in varying environments since the first reports were published in 1960's (Zimdahl, 2004).

Corn production is of increasing importance as both are the main crop, for which corn is sown after spring frosts in April and May and as a second crop, for which corn is sown after winter cereal harvest in June and July, taking advantage of the mediterranean climatic conditions. Second crop corn, which is sown generally just after wheat harvesting, provides extra benefit to the farmers.

CPWC for corn has been determined under different conditions with varying results being obtained. Benson (1982) summarized papers presented in a conference and did not reach a conclusive critical period because results varied country to country. Zimdahl (2004) suggested that CPWC for corn is from 3 to 6 weeks after seeding although he expressed concern about varying results being obtained. Gleason (1956) and Bunting and Ludwig (1964) reported that there was a very short competition period of up to 4 weeks. Nieto et al. (1968) determined CPWC in Mexico as from 10 -12th days to 30th day after crop emergence (ACE). Aleman and Nieto et al. (1968) found a longer duration of up 60 to 70 days ACE in high valleys of Mexico. Hall et al. (1992) reported that the beginning of CPWC varied from 3 to 14 leaf stages of corn and the end of CPWC was less variable with an average of the 14 leaf stage in Ontario. On the contrary,

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Halford et al. (2001) reported that the beginning of CPWC in no-till corn in Canada was relatively stable (6 leaf stage of corn) and the end of CPWC varied from 9 to 13 leaf stages. In another location, there were year to year variations. CPWC for corn in a no-till system started and ended earlier compared to traditional production systems. In the USA, CPWC was found as short as 4 days (from 21 to 25 days ACE) in one location where leaf stage was 1 to 2 leafs, to 8 to 10 leaf stage in another location (Norsworthy and Oliveria, 2004). Ferrero et al. (1996) calculated CPWC from 68 to 182 GDD ACE in 1992 and from 201 to 345 GDD in 1993, at the arbitrary 5% yield loss level in Italy. In another study in Italy, Del Pino and Covarelli (1999) found beginning of CPWC 189 GDD ACE in both years, but the end of the CPWC was 379 in 1990 and 481 in 1991 using 2.5 % yield loss level.

CPWC also may affect corn yield components. Evans et al. (2003) reported that ear number per plant and 100 seed weight of grains decreased linearly with increasing duration of weed interference. In addition, they found that seed number per ear was the most sensitive yield component to weed interference and nitrogen rate and its response was similar to relative yield. Sibuga and Bandeen (1978) found that delayed removal of weeds caused an increase in the days to flowering and maturity and a decrease in crop yield. Moolani and Slife (1960) found that the highest proportional crop yield loss occurred when weeds were allowed to compete until the silk emergence stage.

The critical period for weed control in corn greatly vary and weed removal time and duration of weed interference effect yield and yield components. The purpose of this study was to identify the critical period for weed control in the second crop corn under Mediterranean conditions and to understand the relationship of corn yield to yield components. The goal is for farmers to use the results to maximize crop yield by eliminating weed competition and/ or minimizing herbicide usage by applying the chemical in a timely manner.

MATERIALS AND METHODS

Experiments were conducted on the experimental farm of the field crop Department, Cukurova University, Adana-Turkey from 1996 to 1998. Soil type was sandy loam with pH 7.3 and 1.66% organic matter. The field was tilled twice with a cultivator and disk harrow in 1996 and 1998, ploughed and tilled with a rototiller in 1997 following wheat harvest in all years. The corn varieties, TTM-815, XL.72.AA, and P.3394 were sown in 28 m^2 (2.8 m by 10.0 m) plots at a rate of 71400 plants ha^{-1}, after leveling the field on June 26, 1996, June 26, 1997 and July 4, 1998, respectively. At the time of sowing, 80 kg N ha^{-1} and 80 kg P_2O_5 ha^{-1} were applied as a 20 - 20 fertilizer. When corn plants reached 80 cm in height, 170 kg N ha^{-1} was applied as urea nitrogen. Fields were irrigated 6, 4 and 5 times in 1996, 1997 and 1998, respectively. Lambda-cyhalothrin applications of 1 lha^{-1} were sprayed twice to control insect pests each year.

Natural weed populations were used in the experiments. Plots were covered generally with 6 or 7 weed species. The most common species were redroot pigweed (*Amaranthus retroflexus* L.), common cocklebur (*Xanthium strumarium* L.), common purslane (*Portulaca oleracea* L.), junglerice (*Echinochloa colonum* (L.) Link.), purple nutsedge (*Cyperus rotundus* L.), field bindweed (*Convolvulus arvensis* L.), bristly foxtail (*Setaria verticillata* (L.) P.Beauv.), and johnsongrass (*Sorghum halepense* (L.) Pers.) in all plots every year. After germination of corn, experiments were set up in a randomized complete block design with 3 replications. In weedy treatments, weeds were allowed to interfere with corn from emergence until a certain week, after which weeds were removed and plots maintained weed-free for the duration of the experiment. In weed-free treatments, plots were maintained weed free from emergence until a certain week, after which weeds were allowed to remain for the duration of the season. Also, season-long weedy and season-long weed-free plots were maintained. Weeds were removed by hand and hand hoeing in all plots weekly.

Observations and measurements made according to Ulger (1986), except yield. For quantification of yield, plants in the 2 central rows in each plot were harvested by hand on 18 November 1996, 12 November 1997 and 7 November 1998. Corn yields were adjusted using number of plants harvested, number of plants sown modified from Ulger (1986) and 15% moisture. Adjusted yield data and the other data were subjected to ANOVA. Furthermore, the relative yield (RY), which were calculated as a percentage of corresponding weed-free yield, were subjected to ANOVA. Due to differences in growing degree days (GDD), which was used as an explanatory variable in regression analyses, at weeks plots weeded, statistical analysis was done separately for each year. GDD was calculated using following equation:

$$GDD = [(T_{max} + T_{min})/ 2] - T_b \qquad [1]$$

Where T_{max} is maximum temperature of a day (°C), T_{min} is minimum temperature of a day (°C), T_b is base temperature. For T_{max}, over 30°C values were assumed as 30°C and T_{min}, under 10°C values were taken as 10°C. Base temperature was 10°C (Kirtok, 1998).

To calculate CPWC, RY data were subjected to regression analysis under PROC NLMIXED procedure in SAS. Analyses were based on the models suggested by Knezevic et al. (2002). The Gompertz equation was used for describing the effect of increasing duration of weed control on corn yield and the logistic equation for describing the effect of increasing duration of weed interference on corn yield was used. The Gompertz equation is as follows:

$$Y = a * \exp[-b * \exp(-k * G)] \qquad [2]$$

Where Y is RY, a is the asymptote, G is cumulative GDD corresponding value of length of weed-free period (d°C) and b and k are constants. The logistic equation is as follows:

$$Y = [(1/\{\exp(c * (G-d)]+ f\}) + [(f-1)/f]]*100 \qquad [3]$$

Where Y is RY, G is cumulative GDD corresponding value of duration of weed interference (d°C), d is the inflection point (days) and c and f are constants. The critical period for weed control in corn using both equations was determined for yield loss levels of 2.5, 5 and 10%, chosen arbitrarily (Baziramakenga and Leroux, 1994). Yield and other plant parameters (Table 1) were compared using PROC CORR procedure in SAS.

RESULTS AND DISCUSSION

Corn yield changed year by year in both seasonlong weed-free and seasonlong weedy plots. Corn yield was 13.15, 12.56 and 10.81 t ha^{-1} in seasonlong weed-free plots in 1996, 1997 and 1998, respectively, and 6.77,

Table 1. Parameter estimations for the Gompertz and logistic equations for RY.

Year	Gompertz			Logistic		
	a	b	k	c	d	f
1996	91	0.45	0.004	0.006	160	2.51
1997	102	0.54	0.002	0.003	410	2.46
1998	100	0.55	0.003	0.003	330	2.49

Where: a is the asymptote; d is the inflection point (days); b, k, c and f are constants.

Table 2. Critical period calculated using equations for varying crop losses.

Crop losses (%)	Critical period (growing degree days)		
	1996	1997	1998
2.5	N/A*	0-1241	0-1026
5	N/A	55-1014	0-791
10	131-927	337-731	266-551

*N/A means not applicable.

Table 3. Relation between days and growing degree days starting form sowing time.

Days after sowing	Cumulative growing degree days		
	1996	1997	1998
7	113*	118	115
14	230	237*	231*
21	356	355	346
28	479	472	472
35	594	589	599**
42	715	708	729
49	834	821**	852
56	955**	935	970
63	1071	1046	1095
70	1190	1157	1215
77	1298	1252	1330
84	1423	1370	1460
91	1532	1468	1557
98	1634	1546	1655
105	1730	1629	1751
112	1804	1728	1845
119	1876	1791	1926
126	1917	1852	1995
133	1970	1906	2056***
140	2026	1956***	
141	2034***		

* CPWC starts after this time for crop loss 10%.
** CPWC ends before this time for crop loss 10%.
*** Crop was harvested.

7.36 and 6.68 t ha^{-1} in seasonlong weedy plots during the same period. Although weed species and more intense species varied year by year, the same species such as redroot pigweed, common cocklebur, common purslane, junglerice and purple nutsedge were dominant species in all 3 years. At the end of the season, seasonlong weedy treatments were covered entirely with weeds.

Nonlinear regression analysis was used to determine CPWC based on RY (Figure 1). Coefficients for the parameters used to fit Gompertz and logistic equations are presented in Table 1. The beginning of the CPWC in the second crop corn in the mediterranean region was determined to be from 131 to 337 GDD for 10% yield loss (Table 2), which lies between 1st and 3rd week after corn sowing (Table 3). Yet, it is around the second week after crop sowing in 3 years. The end of CPWC was 551 GDD in 1998 while it was longer in the other years, 731 in 1997 and 927 in 1996. Those GDDs corresponds 4 - 5 weeks to 7-8 weeks after corn sowing. These findings are in agreement with Halford et al. (2001), who reported that beginning of CPWC in no-till corn in Canada was relatively stable (6 leaf stage of corn) and the end of CPWC varied but findings of Hall et al. (1992). For 2.5 to 5% yield loss, the critical period starts with sowing (55 GDD for 5% crop loss in 1997 is considered as sowing also). It lasts 791-1014 GDD for 5% yield loss and over 1026-1241 GDD for 2.5% yield loss in 1998 and 1997, respectively. But the model was not able to calculate a CPWC for 1996.

The CPWC in second crop corn starts earlier and lasts longer, as compared to studies with main crop corn. In no-till conditions, Halford et al. (2001) found that critical period for 2.5% yield loss started usually at 14 to 18 DAE and the end of the critical period was more varying at 16 to 46 DAE. Only in one site in a year, the critical period started as early as 7 DAE. In conventional corn, the beginning of critical period varied more compared to the no-till one, but, it did not start with germination (Hall et al., 1992) and lasted up to 40-50 DAE. A possible reason for starting earlier and lasting longer of CPWC at the second crop corn is sown in late June or early July in the mediterranean region, when conditions favor summer weeds. Higher temperatures provide good growth conditions for those weeds and they germinate at the same time with corn and compete more. For instance, optimum germination temperature for velvetleaf, pigweed, junglerice, venice mallow, common purslane, bristly foxtail, Johnsongrass and common cocklebur is about 30°C, while minimum temperature is as low as 10°C for mentioned species (Uremis and Uygur, 1999; Kadioglu, 1997). Soil temperatures in the region favoring those weeds start May and June. In main crop corn in the mediterranean region, the crop may have been at a later stage, and this crop can compete with weeds when summer weeds have germinated, unlike the second crop. This could cause higher infestation levels of weeds in the second crop

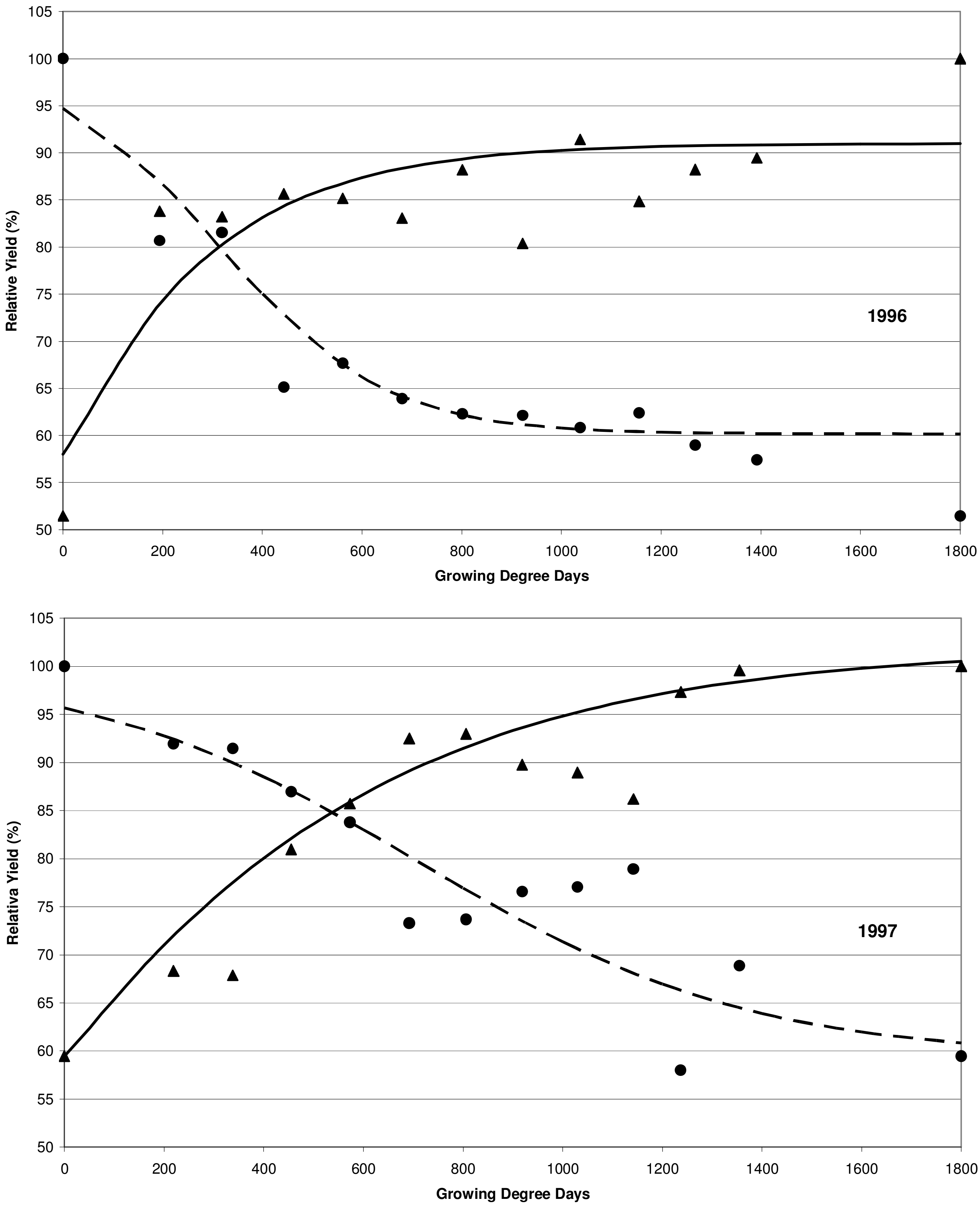

Figure 1. Estimated and observed values for the critical period of weed control in the Mediterranean Region in 1996-1998 (lines estimated, dots observed values).

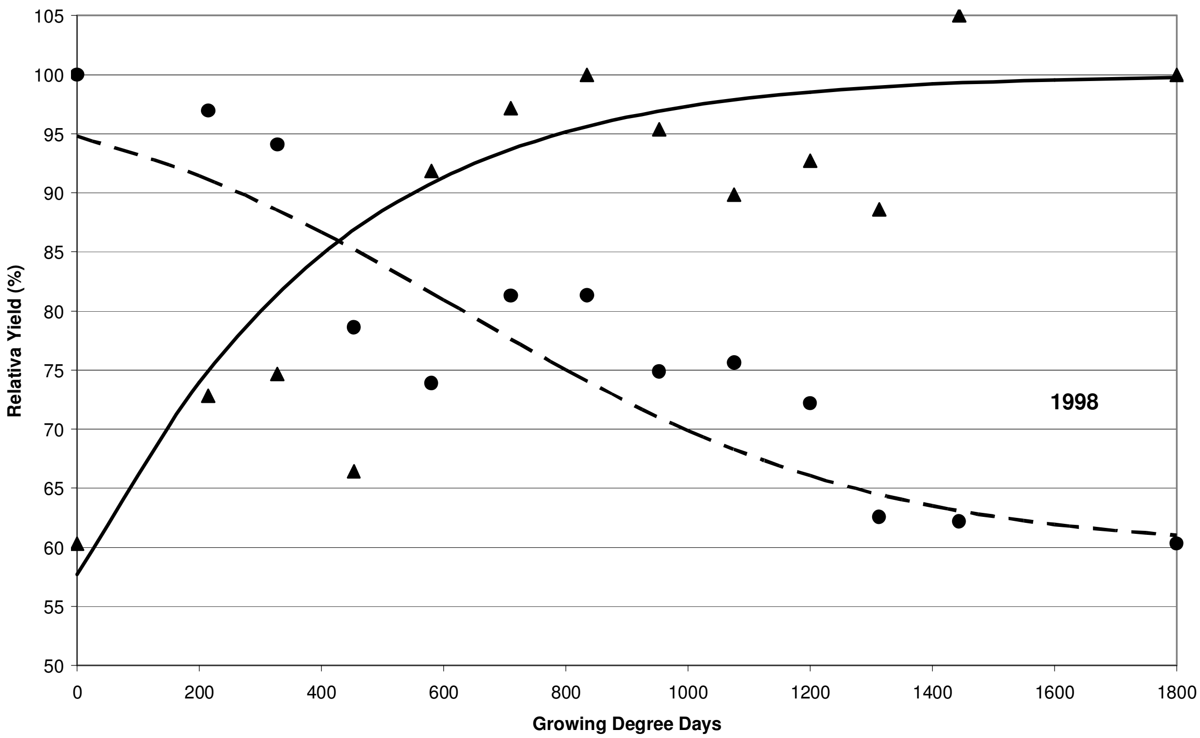

Figure 1. Continued

Table 4. Pearson correlation coefficients and relation between plant parameters and relative yield.

Parameter	Relative yields		
	1996	1997	1998
Tasseling time	-0.73***	-0.48***	-0.09
Silking time	-0.73***	-0.48***	-0.09
Plant height	0.65***	0.44***	0.25*
Stem diameter	0.80***	0.57***	0.18
First ear height	0.44***	0.41***	0.09
Ear length	0.50***	0.32**	0.43***
Ear diameter	0.49***	0.46***	0.27*
Relative kernel weight	0.50***	0.44**	0.60***

* There is a correlation at p=0.05 level.
** There is a correlation at p=0.01 level.
*** There is a correlation at p=0.001 level

corn. Emerging time of weeds affects weed-crop competition. Fall panicum (*Panicum dichotomiflorum*), giant foxtail and *Rottboellia exaltata* emerging at the same time with corn decreased corn yield while emerging later than corn did not affect corn yield (Vengris, 1975; Knake and Slife, 1965, 1969; Thomas and Allison, 1975).

Ear diameter and ear length were not affected by treatments, except ear length in 1998 (data not shown). All other measured components were significantly affected by treatments, except for stem diameter, silking time, tasseling time and plant height in 1998, kernel weight and the height of the first ear in 1996. Significant correlations were found between measured components and RY, except in tasseling time, silking time, stem diameter and first ear height 1998 (Table 4).

Number of kernels per ear is closely associated with grain yield of corn and greatly affected by stress period from 2 weeks before to 3 weeks after silking (Andrade et al., 2000). Kernel number increased with decreasing duration of weed competition while it decreased with delaying weeding. Silking time decreased with decreasing duration of weed competition and increased with delaying weeding. These findings are parallel with earlier studies. Evans et al. (2003) found a linear relationship between ear number per plant and increasing duration of weed interference. Sibuga and Bandeen (1978) reported that delaying weeding increased days to flowering and caused crop yield loss.

Three experiments in the same area in the successive 3 years with highly similar weed composition did not supply only one CPWC, which is either based on GDD or days after sowing. It might be the nature of CPWC studies because there are several factors which can affect CPWC such as weed species, weed density, environment and cultural practices (Knezevic et al., 2002). Similar results can be seen in all literature cited in this paper, such as Ferrero et al. (1996) who found CPWC from 68 to 182 GDD in 1992 while 201 to 345 in the following year. Furthermore, in Italy the results of 2 studies were different from each other on GDD base (Ferrero et al., 1996; Del Pino and Covarelli, 1999). However, our study shows that regarding acceptable yield loss of 10%, CPWC roughly starts around the second week after sowing. Although the end of the CPWC is highly variable, CPWC ends before silking time.

Conclusion

The critical period for weed control in the second crop corn in the mediterranean region differed depending on the year, the shortest was in 1998 and the longest was in 1996 for 10% yield loss; for 2.5-5% yield loss, the critical period starts with germination and lasts longer. Pre-emergence (PRE) or presowing (PPI) herbicides would be preferred to avoid higher yield losses. If a farmer can tolerate 10% yield loss, a postemergence (POST) herbicide can be applied in the second week after crop sowing and the field should be kept weed free for 4 or 5 weeks. Duration of weed competition and time of weed removal also affect the corn development and the size and number of plant organs, all of which correlate with corn yield.

Herbicides are available as preemergence and post-emergence for weed control in corn. Farmers tend to use postemergence herbicides and these are recommended by technicians in the context of IPM. However, our results show that preemergence or presowing herbicides would be preferred to avoid higher yield losses. If a farmer can tolerate 10% yield loss, a postemergence herbicide can be applied in the second week after crop sowing. Interrow tillage, which is a common practice in the region, could keep the field clean until the end of the critical period, 5-6 weeks after crop sowing. However, in heavy infestations, further weed control practices could be needed using a method appropriate for an individual farmer.

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REFERENCES

Aleman F, Nieto JH (1968). The critical periods of competition between weeds and corn in the High Valleys of Toluca, Mexico. Abstracts of Weed Science Society of America, p. 150.

Andrade FH, Cirilo AG, Echarte L (2000). Factors affecting kernel number in maize. In: Physiological Bases for Maize Improvement (eds. Otegui ME, Slafer GA), pp. 59-74. Food Products Press.

Baziramakenga R, Leroux GD (1994). Critical period of quackgrass (*Elytrigia repens*) removal in potatoes (*Solanum tuberosum*). Weed Sci. 42: 528-533.

Benson JM (1982). Weeds in tropical crops: review of abstracts on constraints in production caused by weeds in maize, rice, sorghum-millet, groundnuts, and casava, 1952-1980. FAO Plant Production and Protection Paper 32 Sup. 1. FAO, Rome.

Bunting S, Ludwig JW (1964). Plant competition and weed control in maize. Proceedings of Seventh British Weed Control Conference, 7: 385-388.

Del Pino A, Covarelli G (1999). Critical period of weed competition in maize. Proceedings of 11th EWRS (European Weed Research Society) Symposium, Switzerland. p. 68.

Evans SP, Knezevic SZ, Lindquist JL, Shapiro CA, Blankenship EE (2003). Nitrogen application influences the critical period for weed control in corn. Weed Sci. 51: 408-417.

Ferrero A, Scanzio M, Acutis M (1996). Critical period of weed interference in maize. Proceedings of the 2nd International Weed Control Congress, Denmark. pp. 171-176.

Gleason LS (1956). Weed control in the wet tropics. Proceedings of North Central Weed Control Conference, 13: p. 54.

Halford C, Hamil AS, Zhang J, Doucet C (2001). Critical period of weed control in no-till soybean (*Glycine max*) and Corn (*Zea mays*). Weed Technol. 15: 737-744.

Hall MR, Swanton CJ, Anderson GW (1992). The critical period of weed control in grain corn (*Zea mays*). Weed Sci. 40: 441-447.

Kadioglu I (1997). Akdeniz bolgesi pamuk ekim alanlarinda gorulen bazi yabanci ot tohumlarinin cimlenme biyolojileri ve cikis derinlikleri uzerinde arastirmalar. Proceedings of Turkish 2nd Weed Science Congress, Turkey. pp. 205-217.

Kirtok Y (1998). Misir uretimi ve kullanimi. Kocaoluk Press, Tarsus, p. 445.

Knake EL, Slife FW (1965). Giant foxtail seeded at various times in corn and soybeans. Weeds, 13: 331-334.

Knake EL, Slife FW (1969). Effect of time giant foxtail removal from corn and soybeans. Weed Sci. 17: 281-283.

Knezevic SZ, Evans SP, Blankenship EE, Van Acker RC, Lindquist JL (2002). Critical period for weed control: the concept and data analysis. Weed Sci. 50: 773-786.

Labrada R, Parker C (1994). Weed control in the context of integrated pest management. *In*: Labrada R, Caseley JC and Parker C (eds.). Weed Management for Developing Countries. FAO. Rome. pp. 3-8.

Moolani MK, Slife FW (1960). The competitive effects of various intensities of pigweed on the development of corn and soybeans. Proceedings of North Central Weed Control Conference, 17: 26-27.

Nieto JH, Brondo MA, Gonzalez JT (1968). Critical periods of the growth cycle for competition from weeds. Pans 14: 159-166.

Norsworthy JK, Oliveria MJ (2004). Comparison of the critical period for weed control in wide- and narrow-row corn. Weed Sci. 52: 802-807.

Sibuga KP, Bandeen JD (1978). An evaluation of green foxtail (*Setaria viridis* (L.) Beauv.) and common lambsquarters (*Chenopo-dium album* L.) competition in corn. Abstracts of Weed Science Society of America, p. 66.

Swanton CJ, Weise SF (1991). Integrated weed management: the rationale and approach. Weed Technol. 5: 657-663.

Thomas PEL, Allison JCS (1975). Competition between maize and *Rottboellia exaltata* Linn. J. Agric. Sci. 84: 305-312.

Ulger AC (1986). Reaktion verschieder mais inzuchlinien und- hybriden auf steigendes stickstoffengebot. Dissertation, University Hohenheim, Stuttgart, Germany.

Uremis I, Uygur FN (1999). Minimum, optimum and maximum germination temperatures of some important weed species in the Cukurova Region of Turkey. J. Turkish Weed Sci. 2(2): 1-12.

Vengris J (1975). Weedy grass competition in corn. Proceedings of Northeast Weed Science Society, 29: 141.

Weaver SE, Tan CS (1983). Critical period of weed interference in transplanted tomatoes (*Lycopersicon esculentum*): Growth analysis. Weed Sci. 31: 476-481.

Weaver SE, Tan CS (1987). Critical period of weed interference in field-seeded tomatoes and its relation to water stress and shading. Canadian J. Plant Sci. 67: 575-583.

Zimdahl RL (2004). Weed Crop Competition: A Review, 2nd ed. Blackwell Publishing. p. 220.