Effect of *Amaranthus quitensis* on parsley for dehydration yield

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SUMMARY

Weeds are a severe problem in many horticultural crops but information about weed competition on parsley (*Petroselinum crispus* (Mill.) Nym) yield is lacking. The objectives of this study were to determine the critical period for *Amaranthus quitensis* Kunth control in parsley and to quantify the influence of *A. quitensis* density on parsley yield. The critical period was variable between years and weed densities and ranged between 3 and 44 days in duration. In both years, *A. quitensis* densities of more than 30 plants/m^2 can account for up to 70 % of yield loss. The results indicate that *A. quitensis* can significantly reduce parsley yields even at low densities if the weed is not controlled in the appropriate period.

Key words: critical periods, parsley yield, density *Amaranthus quitensis*

RESUMEN

Las malezas son un problema en la producción de perejil (*Petroselinum crispus* (Mill.) Nym) para deshidratado, y existe poca información acerca del efecto de las malezas sobre el rendimiento de este cultivo. Los objetivos de este estudio fueron determinar el período crítico para el control de *Amaranhus quitensis* Kunth en perejil y cuantificar la influencia de la densidad de *A. quitensis* sobre el rendimiento del perejil. El período crítico fue variable entre años y densidad de la maleza y tuvo una duración de entre 3 y 44 días. En 2006 y 2007 una densidad de *A. quitensis* de más de 30 plantas/m^2 determina un 70 % de la reducción de rendimiento. Los resultados sugieren que bajas densidades de *A. quitensis* pueden reducir el rendimiento de perejil si no son controladas en el período adecuado.

Palabras clave: período crítico, rendimiento de perejil, densidad de *Amaranthus quitensis*

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INTRODUCTION

Parsley (*Petroselinum crispum* (Mill.) Nymen ex A.W. Hill) is a biennial herb of the Apiacea (Umbelliferae) family which is a popular vegetable crop in Argentina and is planted in spring when annual broad-leaved weeds begin to emerge. One of the main problems that affect yield and quality of crops is weed competition (Hager *et al.*, 2002). Horticultural crops are very sensitive to weed competition (Weaver, 1984). No reports of parsley–weed competition are available, but parsley is probably highly susceptible to weed competition due to its low height and reduced biomass as occurs with other horticultural crops such as onion (Williams *et al.*, 2004). Dehydrated parsley production has shown a recent increase in hectares in Argentina and as it is planted in larger areas than parsley production for fresh market, manual weed control may be labor intensive and time consuming.

In Argentina, traditional production areas for parsley for dehydratation are Villa Dolores, Córdoba (120 ha); Pergamino, Buenos Aires (300 ha); Mar del Plata, Buenos Aires (80ha), and 120 ha in the rest of the country (Arizio & Curioni, 2003). Parsley biomass production is 600 T per year (Curioni & Arizio, 2003). In the region where the present study was performed parsley production has increased in the last years (Longo & Ferrato, 2006). The demand of dehydrated parsley, estimated in about 800 T, is also increasing, particularly in mixtures with dehydrated garlic (Arizio & Curioni, 2003).

A very common broad-leaved weed widespread in the region under study is *Amaranthus quitensis* Kunth. Leguizamón *et al.* (1994) determined a yield loss function of *A. quitensis* in soybeans showing that the weed is highly competitive. Another species of *Amaranthus*, *A. hybridus*, is among the most noxious weeds in leafy vegetable production (Santos *et al.*, 2004)

Determining the appropriate timing of weed control tactics is valuable in developing integrated weed management systems (Rajcan & Swanton, 2001, Knezevic *et al.*, 2002). Critical period of weed competition is a period in the crop growth cycle during which weeds must be controlled to prevent yield losses (Knezevic *et al.*, 2002). This information is essential in determining the need for and timing of weed control and for achieving efficient use of herbicides, mechanical control and hand hoeing. However, the outcome of crop–weed competition is dependent on weed species composition (Rajcan & Swanton, 2001). Weed density also influences the critical period of weed control (Seem *et al.*, 2003). Studies of critical period have been done in many crops. Critical periods can be based on phenological growth stages and heat units (Williams, 2006) or on periods of time (Everman *et al.*, 2008). For parsley, the use of periods of time was preferred because information on crop phenological growth stages was not available. Understanding of the critical period of weed control during parsley growth will allow growers to manage weeds in production fields effectively. There are reports on studies about competition between species of the genus *Amaranthus* spp. and vegetable crops (Terry & Stall, 1992) but no information is available about parsley-weed competition, so understanding of the interaction between the effects of *A. quitensis* density and parsley yield is needed.

Potential crop yield loss resulting from a given weed population is an important component of weed management and has been predicted using several

approaches. The simplest approach involves relating yield loss empirically to weed density. When yield loss is plotted as a function of weed density, it typically increases linearly with increased weed density at low to moderate densities and reaches an asymptotic maximum at high weed densities. This type of sigmoidal curve is usually described mathematically as an exponential or hyperbolic function (Cousens, 1985). Knowledge of crop yield loss of *A. quitensis* in parsley will help producers make adequate weed management decisions based on economic costs and environmental benefits. Therefore, the objective of this study was to determine the critical period for *A. quitensis* control in parsley and to quantify the influence of *A. quitensis* density on parsley yield.

MATERIALS AND METHODS

Field experiments were conducted in 2006 and 2007 at INTA San Pedro Experimental Station, Lat. 33° 41' S, Long. 59° 41' W., Buenos Aires, Argentina. The soil was a vertic argiudol with 2.5% organic matter and pH 6.5. The experimental area was harrow-disked in the spring, mouldboard ploughed and a field cultivated before planting. Parsley var. Liso común was planted 2 cm deep with the use of a seeder equipped with one shoe and rows were spaced 20 cm apart at 10 kg/ha in September 2006 and October 2007. The previous crop was sweet corn in 2006 and no crop in 2007. No fertilization was done. Within 5 days of parsley emergence, *A. quitensis* plants were thinned and spaced equidistantly within parsley rows. The experimental design was a factorial randomized complete block with three replications per treatment. *Amaranthus quitensis* natural populations were thinned at crop emergence to establish two *A. quitensis* densities (2 and 8 plants/m²) in 2006 and 6 plants/m² in 2007. A quantitative series of treatments of both the weedy and weed-free duration studies was arranged as factorial design within each planting-date main plot. Plots measured 1.6 m x 5 m (7 rows wide). The increasing duration of competition was established by delaying weed control from the time of crop planting until 0, 10, 20, 30, 50, and 80 days after planting. At each time, *A. quitensis* plants were removed, and plots were weeded throughout the rest of the season. The increasing length of *A. quitensis*-free period was established by maintaining *A. quitensis* weed control from the time of planting until the above-presented times before allowing subsequent emerging weeds to remain for the rest of the season.

Field experiments were also conducted to determine the effect of season-long competition of *A. quitensis* at varying densities on parsley biomass

yield. *A quitensis* density was 0, 2, 8, 16 and 32 plants/m² of in 2006 and 0, 8, 16, 32 and 64 plants/m² in 2007.

In both experiments, the only weed species present was *A. quitensis*. The other weeds were removed by hand-weeding of annual broad-leaved weeds different from *A. quitensis* and haloxifop-methyl was used to eliminate grassy annuals.

Parsley was harvested on November 29, 2006 and January 3, 2008. Biomass of parsley and weeds was collected from a 1 x 1 m quadrat per plot crop. Parsley and weed plants were clipped at the soil surface, counted, and weighed after oven-drying at 65 °C.

Statistical analysis. Critical period each year was analyzed separately using Gompertz and logistic equations fitted to the yield data, expressed as a percent of the weed-free yield.

The Gompertz equation used to describe the weed free period study is defined as:

$$y = Ae^{-Be^{-kt}}$$

where y is the relative yield, A is the yield asymptote, B and k are constants and t is the time of weed free period from emergence (days).

The log logistic equation used to describe the weed removal period study is defined as:

$$y = C + D/(1+e^{-(a+bt)})$$

where y is the relative yield, C is the yield asymptote, D is difference between higher and lower asymptote, a and b are constants and t is the time in days weeds competed from emergence so that $t_0 = a/b$ is the point of inflection. Parameter estimates of nonlinear equations were obtained employing the method of least squares. For each nonlinear model to be analyzed, we specified the model (using a single dependent variable) and the names and starting values of the parameters to be estimated. As iterative method, Newton method was used (because it is more robust than others). The coefficient of determination (R^2) was calculated for each fit as:

$$R^2 = 1 - SSE/SSTC$$

where SSE are the residual sums of squares and SSTC are the corrected total sums of squares.

The length of the weed-free period required to

prevent more than an arbitrary accepted level of yield loss (5%) was determined.

The relationships between *A. quitensis* density and parsley yield loss (%) was determined using regression analyses using a rectangular hyperbolic model.

Cousens (1985) reported that crop yield loss could be related to weed density using a rectangular hyperbola equation:

$$Y = I\ D/[1+(I\ D/A)]$$

where Y is percent yield loss, D is weed density (expressed as pl/m^2), I is percentage yield loss as weed density approaches zero, and A is the upper asymptote or maximum yield loss. The equation was fit to parsley yield loss for each year, and parameter estimates were determined using nonlinear regression.

RESULTS AND DISCUSSION

Studying weed competition is valuable in developing integrated weed managements systems (Knezevic *et al*., 2002). The length of the critical period of *A. quitensis* competition in parsley varied for the different years at the accepted level of yield loss chosen (Figure 1). Parsley yield reduction showed significant interactions between year and *A. quitensis* densities. In 2006, the critical period with 2 plants/m² of *A. quitensis* was 3 days and with 8 plants/m² of *A. quitensis*, 19 days. In 2007, with 6 plants/m² of *A. quitensis*, the critical period was 44 days. The long critical periods of competition are indicative of strong weed competition or little competitiveness of the crop (Weaver *et al*., 1992). In our studies, the critical period with 6 plants/m² in 2007 was longer than with 8 plants/m² in 2006, probably due to the later planting date. Planting date also influenced the length of the critical period of sweet corn (Williams II, 2006). Furthermore, the delay in planting date in 2007 favoured *A. quitensis* which has a spring-summer growing season (Faccini & Vitta, 2007).

Additionally, drought conditions occurred in 2007 and bad growth conditions for parsley in the presence of a high *A. quitensis* population (6 plants/m²) probably reduced the crop competitiveness. In other studies, adverse climatic conditions during sorghum development were reflected in low yield, which propitiated a greater damage by *A. retroflexus* (Knezevic *et al*., 1997) and *Helianthus annus* (Rosales Robles *et al*., 2005). Determining the critical
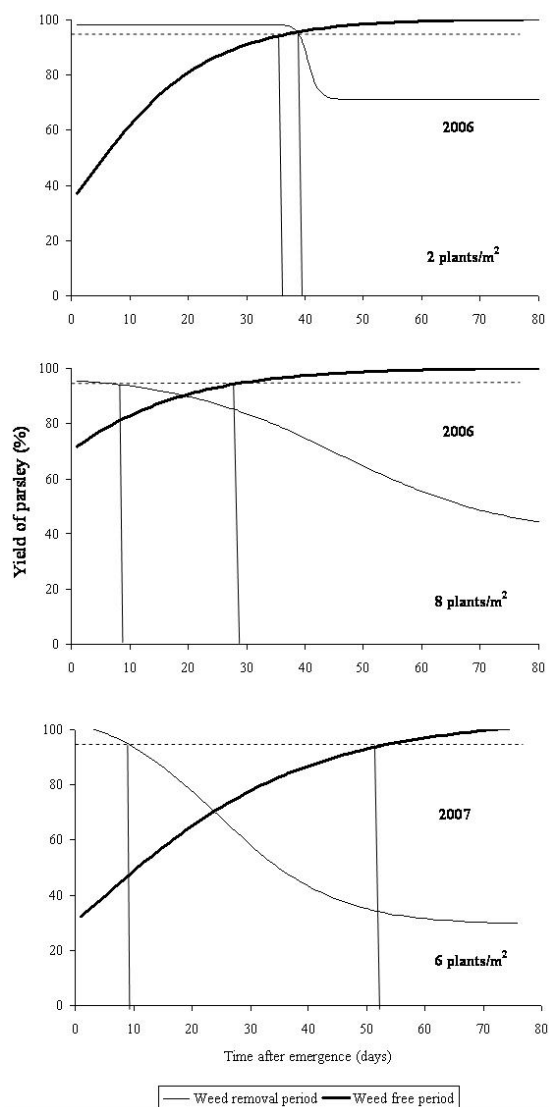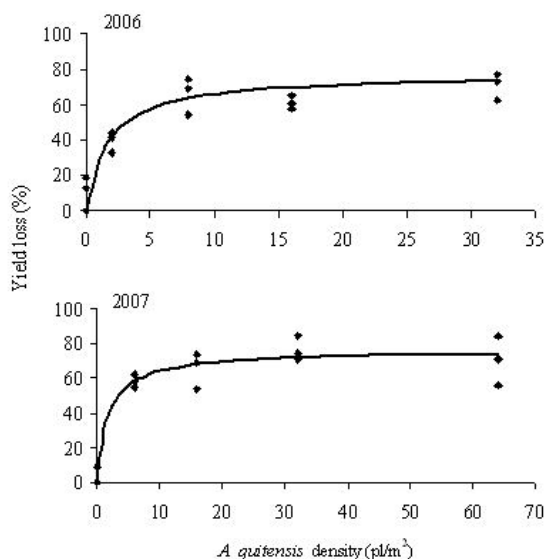

Figure 1. Critical period of *A. quitensis* in parsley. The weed free period study was described by the Gompertz regression model (---):
Y= 100,25 Exp [-0,38 Exp (-0,68t)], 2006 (2 pl/m²)
Y = 100,41 Exp [-1,02 Exp (-0,08 t)], 2006 (8 pl/m²)
Y = 104,04 Exp [-1,17 Exp (-0,04 t)], 2007 (6 pl/m²)
The weed removal period study was described by the log logistic regression model (—):
Y= 71,15+27,17/[1+Exp (-42,01+1,06t)], 2006 (2 pl/m²)
Y = 39,51+58,44/[1+Exp(-3,14+0,07t)], 2006 (8 pl/m²)
Y = 29,27+79,37/[1+Exp(-2,36+0,1t)], 2007 (6 pl/m²)
The horizontal dashed line represents 5% yield loss relative to the weed-free control, and the vertical line define the critical period of weed control.

period of *A. quitensis* in parsley has an applied aspect because parsley is a crop with a reliance on manual control or preemergence herbicides (Constantino *et al*., 2008) because no postemergence

herbicides are available. Variability in the extent of the critical period of *A. quitensis* for an accepted parsley yield loss may be attributed to the interaction of weed density and climate. Considering all the studies, the weed-free period indicates that duration of a preemergence residual herbicide in parsley need to be greater than 52 days after parsley emergence in order to prevent a yield loss greater than 5%. Some preemergence herbicides used in parsley to control *A. quitensis* such as flurochloridone (Constantino *et al.*, 2008) provide residual activity of more than 90 days and thus could be recommended to control this weed with only one herbicide application.

Plants in the genus *Amaranthus* have shown to reduce crop yields with an increase in weed density (Wulff, 1987). In our study, a rectangular hyperbolic model adequately represented the loss in parsley yield with increasing density of *A. quitensis* (Figure 2). The asymptotic yield loss (parameter A) indicates that *A. quitensis* density can account for up to 73 of yield loss in presence of more than 40 plants/m^2 in 2006 and 2007. Although these value indicate an important reduction in parsley yield, with other crops and weeds parameter A was even higher. Values of 100 were found in *Amaranthus palmeri* grown with peanut in other study (Burke *et al.*, 2007) and with volunteer potato as a weed in onion (Williams *et al.*, 2004).

Parameter I is a very good indicator of the effect of the weeds on crops. In studies considering different weed species in different arable crops, estimates of I were found ranging from 0.67 to 192.0 (Cowan *et al.*, 1998; Pester *et al.*; 2000; Lindquist, 2001; Askew & Wilcut, 2002). In *Amaranthus palmeri*, parameter I varied greatly. Grown with peanut, parameter I was 39.0 (Burke *et al.*, 2007) and with cotton 68.7 (Smith *et al.*, 2000) and 192.0 (Rowland *et al.,* 1999).

In this study, parameter I was 46.1 and 42.6. In studies with *Amaranthus retroflexus* - a species similar to *A. quitensis*- in cotton, parameters I were lower, ranging between 20.5 and 40.5, probably due to the higher plant height and competitiveness of cotton relative to parsley (Buchanan & Burns, 1971, Buchanan *et al.*, 1980, Street *et al.*, 1981).

The results indicate that for the same year, the higher is *A. quitensis* density the higher is the critical period. Control should always begin one week after planting and the critical period will be shorter in years with higher rainfall levels. The weed can significantly reduce parsley yields.

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