USE OF SUNFLOWER CULTIVARS WITH RESISTANCE TO IMIDAZOLINONE HERBICIDES TO CONTROL BROOMRAPE (*OROBANCHE CUMANA*) INFECTION

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Abstract

Broomrape (*Orobanche cumana* Wallr.) is an important constraint for sunflower cropping in large areas of Spain. Genetically resistant cultivars have been used for some years, but the continuous appearance of new, more virulent races of the parasite hinders the effort of the breeders to develop new germplasm catching up with the newest races. The use of sunflower cultivars resistant to some herbicides of the imidazolinone group is being currently considered as an alternative tool to control broomrape infection in sunflower. The performance of four experimental sunflower hybrids, resistant to some herbicides of the imidazolinone family (IMI sunflowers), treated with two doses of Imazamox in three moments of application, was studied in four locations of southwestern Andalusia in 2003. Herbicide treatments significantly reduced broomrape infection across locations, raising seed yield accordingly by 15%; this increase being much higher in locations with heavier broomrape infections. The stage of sunflower growth selected for herbicide application did not seem to be of relevance.

Introduction

Orobanche cumana Wallr. is an obligate, specific parasitic weed in the root system of the sunflower (*Helianthus annuus* L.), that may cause heavy yield reduction in sunflower in Southern and Southeastern Europe (Musselman, 1994; Parker and Riches, 1993). Parasitism alters physiological and biochemical processes in the host plant such as photosynthesis, respiration, water absorption, and amino acid and sugar biosynthesis (Graves, 1995). These effects, together with competition for nutrients and water by *O. cumana*, cause yield losses, depending on the intensity of infestation, the host growth stage, and the environmental conditions (Garcia-Torres et al., 1995).

There have been different strategies for the management of broomrape infection in sunflower crops, but as of yet there is no means of eradication that is both effective and practical. In Spain, the most successful so far has been genetic resistance, so, sunflower varieties which are broomrape resistant have been developed and released during the last decade, however, *O. cumana* remains a problem for sunflower cropping because resistance continues to be overcome by new, more virulent, races of the parasite (Dominguez, 1999).

Among other alternative methods for controlling broomrape in sunflower, the use of herbicides has been the most employed. Preemergence application, at very low doses (10– 40 g/ha), of herbicides of the imidazolinone, sulfonylurea and substituted amide families on the sunflower crop, as studied by Garcia-Torres et al. (1994); although at these low rates, these herbicides are selective for sunflower and active against broomrape, and environmental conditions, particularly rainfall and soil type, play an important role in the effectiveness of the treatments. Higher doses than those referred, have been shown to be sunflower phytotoxic.

The discovery of a wild sunflower population resistant to the imidazolinone and sulfonylurea classes of herbicides applied to the crop postemergence (Al-Khatib et al., 1998) did mean a very interesting possibility of broomrape control in sunflower through the use of cultivars resistant to these herbicides (Alonso et al., 1998).

After the discovery of the wild sunflower resistant to imidazolinone herbicides, several studies have been carried out to ascertain the gene action and the mode of inheritance involved in the resistance (Baumgartner et al., 1999; Malidza et al., 2000).

As a consequence of the early development of sunflower germplasm resistant to imidazolinone herbicides (Miller and Al-Khatib, 2000), several sunflower breeding companies have bred experimental sunflower hybrid cultivars resistant to both imazethapyr and imazamox herbicides.

The main objective of this study was to assess the performance of some of those experimental sunflower cultivars when seeded in broomrape-infected fields and treated with imazamox at different doses, applied at different growth stages (times of application).

Materials and Methods

Four different experimental sunflower hybrids, designated H1 through H4, provided by Monsanto, Syngenta, Advanta and Nickerson seed companies, were seeded in four different locations in the province of Seville (Andalusia, Southwestern Spain).

Locations were typical of the large rainfed areas of mainly Vertisol soils of southwestern Andalusia, and had previous records of broomrape infections, where race F or higher of *O. cumana* had been detected.

Two different doses of imazamox (Pulsar 40 ®): D1 = 0 and D2 = 40 g/ha were applied at three different stages of the crop growth (times of application): M1 = 3 pair of leaves, M2= 9 pair of leaves, and M3= both. Herbicide spraying was carried out with a Maruyama sprayer model MS073D. A split–split–plot design with four replications was set up, with hybrids as the main plot, times of application as subplots and herbicide doses as sub–sub plots.

Experimental plots consisted of four rows 8 m long, 70 cm apart, with plants 25 cm apart within the row. The main variables studied were: percentage of infected sunflower plants, number of broomrape stalks per sunflower plant and seed yield. All the visual observations and data taking were performed on the two central rows of the experimental plot.
Analysis of variance of individual and combined over locations was carried out for each of the variables studied in accordinance with to the experimental design.

Results and Discussion

The degree of significance of the main and interaction effects for yield and broomrape infection indices (% of sunflower plants infected and number of broomrape stalks by each sunflower plant) is presented in Table 1. Yields of the four hybrids, for the three times of application and for the two doses in the four locations are depicted in Figure 1. The percentages of infected sunflower plants, as well as the number of broomrape per sunflower plant in the four hybrids for the different times of application and doses of imazamox in the four locations are shown in Figure 2.

Table 1. Main and interaction effects for yield, % infected sunflower plants and number of broomrapes per sunflower plant, for the four hybrids tested in four locations at two doses of imazamox applied at three times.

SOURCE	YIELD (Kg/HA)	% INFECTED PLANTS	NUMBER BROOMRAPE STALKS/PLANT
Locations	*** (§)	***	***
Hybrids	***	***	**
Hyb. X Loc.	***	***	***
Times	n.s.	**	n.s.
Loc. X Time	**	n.s.	n.s.
Hyb. X Time	**	n.s.	n.s.
Loc. X Hyb. X Time	n.s.	n.s.	n.s.
Doses	***	***	***
Hyb. X Doses.	**	***	***
Time X Doses.	n.s.	n.s.	n.s.
Loc. X Doses.	***	***	***
Loc. X Time X Doses	**	n.s.	n.s.
Hyb. X Time X Doses	n.s.	n.s.	n.s.

(§) *** Significant P=0.001; ** Significant P=0.01

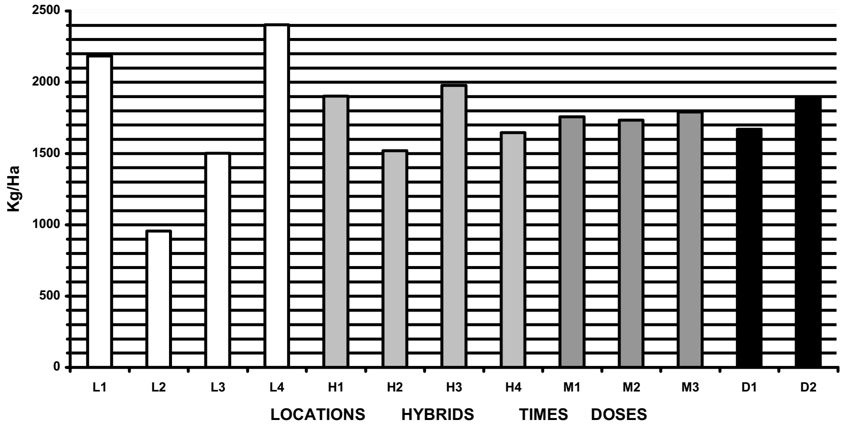

Figure 1. Yield of the four hybrids for the different times of application and doses of imazamox at the four locations.

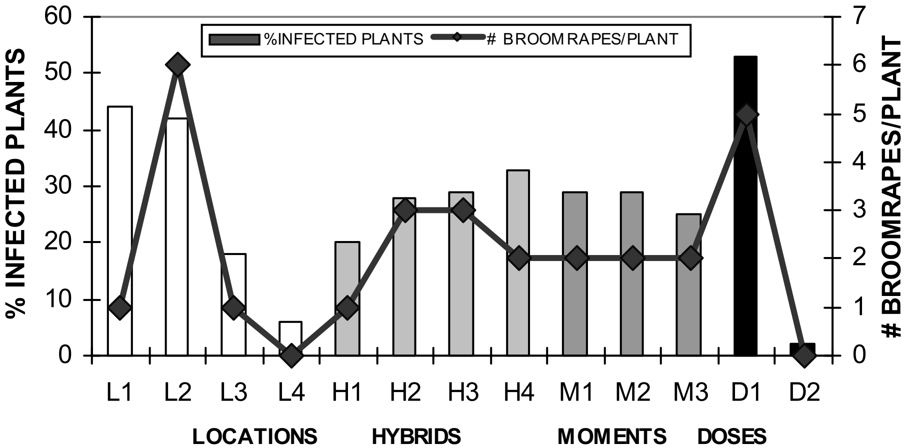

Figure 2. Percentage of infected plants and number of broomrapes per sunflower plant of the four hybrids for the different times of application and doses of imazamox at the four locations.

The effects of Locations, Hybrids and the interaction Hybrids x Locations were highly significant for the three variables studied, meaning important variation among locations and also among sunflower imidazolinone-resistant hybrids. This fact is very interesting since it means a broader than expected genetic background for the first hybrids bred with this special characteristic. The significant interaction Location x Hybrids was expected, as this is the standard feature for sunflower hybrids when tested in these locations.

Broomrape infections, as measured by the percentage of infected sunflower plants as well as by the mean number of broomrape stalks per sunflower plant, varied according to location.

Location 2 showed the biggest infection with the highest number of broomrapes per sunflower plant whereas Location 1 showed the highest percentage of infected sunflower plants and location 4 showed the lowest broomrape infection.

The effect of herbicide doses which were shown to be significant for the three variables as well as the interaction of Doses with Hybrids and Locations, imply the beneficial effect of the herbicide in the control of broomrape as it can be seen in Figures 1 and 2.

Yield of the different locations varied significantly according to the different environmental conditions and ranged among the standard yield values for sunflower cropped under the Mediterranean environmental conditions, typical of the area where the trials were carried out. Average yield across locations increased significantly, around 15 % (1,670 to 1,855 kg/ha), when hybrids were sprayed with imazamox which, as indicated by the good Orobanche control (Figure 2), supposed the expected effect on yield. This rise in yield was much more evident in those locations where broomrape infections were heavier (Location 1: 1,924 to 2,445 kg/ha; Location 2: 771 to 1,141 kg/ha).

Given that dose 1 means no application of herbicide, the interaction of Doses x Hybrids and Doses x Locations was mainly due to the different response of hybrids and locations when the herbicide was applied. Hybrid no. 1 presented milder infections that the other 3 hybrids when not sprayed with imazamox across all the locations, suggesting a certain genetic resistance to some of the broomrape races present.

It is noticeable that the time of application seems to be important only for the percentage of infected sunflower plants but neither for the number of broomrape stalks per sunflower plant nor for seed yield.

Conclusions

Imazamox treatments on imidazolinone-resistant sunflower hybrids efficiently control broomrape infections, significantly increasing the yield over nontreated plots of the same hybrids. This increase is much more relevant in those locations where infections are heavier. The stage of sunflower growth in which herbicide spraying is done does not seem to be important, since the control is quite efficient at any time of application.

References

Al-Khatib, K., J.R. Baumagartner, D.E. Peterson, and R.S. Curie. 1998. Imazethapir resistance in common sunflower (*Helianthus annuus*). Weed Science. 46:403-407.

Alonso, L.C., M.I. Rodríguez-Ojeda, J. Fernández-Escobar, and G. Lopez-Ruiz-Calvo. 1998. Chemical control of broomrape (*Orobanche cernua* Loefl.) in sunflower (*Helianthus annuus* L.) resistant to imazethapyr herbicide. Helia. 21(29):45-54

Baumgartner, J.R., K. Al-Khatib, and R.S. Currie. 1999. Cross–resistance of Imazethapyr–resistant sunflower (*Helianthus annuus*) to selected Imidazolinone, sulfonylureas and Triazollopyrimidine herbicides. Weed Technology. 13:489-493.

Dominguez, J. 1999. Inheritance of the resistance to Orobanche cumana Wallr. in sunflower: a review. *In*: Junta de Andalucia,. Consejeria de Agricultura y Pesca, eds. Resistance to Orobanche: the State of the Art, Congresos y Jornadas 51/99. p.115:120.

Garcia-Torres, L., M. Castejon-Munoz, M. Jurado-Exposito, and F. Lopez-Granados. 1996. Modelling the economics of controlling nodding broomrape (*Orobanche cernua*) in sunflower (*Helianthus annuus*). Weed Sci. 44: 591.

Garcıa-Torres, L. Lopez-Granados, F. and M. Castejon-Munoz. 1994. Preemergence herbicides for the control of broomrape (*Orobanche cernua*) in sunflower (*Helianthus annuus*). Weed Research. 34:395.

Graves, J.F. 1995. Host–plant responses to parasitism. *In*: M.C. Press, J.D. Graves (eds.). Parasitic Plants, Chapmann and Hall, London. p. 206–225.

Malidza, G., D. Skoric and S. Jocic. 2000. Imidazolinone–resistant sunflower (*Helianthus annuus*): Inheritance of resistance and response towards selected sulfonyrurea herbicides. Proceedings 15th International Sunflower Conference. Toulouse (France). Pp: O42-O47.

Miller, J. F. and K. Al–Khatib. 2000. Development of herbicide resistant germplasm in sunflower. Proceedings 15th International Sunflower Conference. Toulouse (France). Pp. O39-O41.

Musselman, L. 1994. Taxonomy and spread of *Orobanche*. *In*: A.H. Pieterse, J.A.C. Verkleij, S.J. ter Borg (Eds.), Biology and Management of Orobanche. Proc.3rd Int. Workshop on *Orobanche* and Related *Striga* Research, Amsterdam, The Netherlands. p. 27–35.

Parker, C. and C. R. Riches. 1993. *In*: Parasitic Weeds of the World: Biology and Control, CAB International, Wallingford, UK. p. 332.