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Phelipanche ramosa (L. - Pomel) Control in Field Tomato Crop

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***Abstract*—**The tomato is a very important crop, whose cultivation in the Mediterranean basin is severely affected by the phytoparasitic weed *Phelipanche ramosa*. The semiarid regions of the world are considered the main areas where this parasitic weed is established causing heavy infestation as it is able to produce high numbers of seeds (up to 500,000 per plant), which remain viable for extended period (more than 20 years). In this paper the results obtained from eleven treatments in order to control this parasitic weed including chemical, agronomic, biological and biotechnological methods compared with the untreated test under two plowing depths (30 and 50 cm) are reported. The split-plot design with 3 replicates was adopted. In 2014 a trial was performed in Foggia province (southern Italy) on processing tomato (cv Docet) grown in the field infested by *Phelipanche ramosa.* Tomato seedlings were transplant on May 5, on a clay-loam soil. During the growing cycle of the tomato crop, at 56-78 and 92 days after transplantation, the number of parasitic shoots emerged in each plot was detected. At tomato harvesting, on August 18, the major quantity-quality yield parameters were determined (marketable yield, mean weight, dry matter, pH, soluble solids and color of fruits). All data were subjected to analysis of variance (ANOVA) and the means were compared by Tukey's test. Each treatment studied did not provide complete control against *Phelipanche ramosa*. However, among the different methods tested, some of them which *Fusarium*, gliphosate, radicon biostimulant and *Red Setter* tomato cv (improved genotypes obtained by Tilling technology) under deeper plowing (50 cm depth) proved to mitigate the virulence of the *Phelipanche ramose* attacks. It is assumed that these effects can be improved combining some of these treatments each other, especially for a gradual and continuing reduction of the "seed bank" of the parasite in the soil.

***Keywords*—**Control methods, *Phelipanche ramosa,* tomato crop.

I. Introduction

PHELIPANCHE ramosa, also known as *Orobanche ramosa* L., is the crhrolopyll-lacking root parasite of many dicotyledonous species. It cause severe damage to vegetable and field especially in the semiarid regions of the world [1].

In the Apulia region (southern Italy) this devastating weed there is particularly in the field of processing tomato, where endangering the future existence of this crop [2], [3]. The heavy infestation are due to the ability of the *Phelipanche* to produce high number of seeds (up to 500,000 per plant) [4] with very small dimensions (about 0,2-0,3 mm), which remain viable for extend period (up to 20) years in the soil [5], [6].

As their small size, the seeds are easily spread by wind, water, animals, human means equipment and machinery for agriculture and especially through the mechanical harvesting of tomatoes that is cutting the plants at the level of soil where there are also shoot of *Phelipanche* [7], [8].

Seeds of parasitic plant germinate only if stimulated by host strigolactone root exudates and start producing a tubercle only if they are near enough to the host roots. The germinating seed produces a germ tube and haustorium that attacks the roots of the host plant, producing a connection with the plant's vascular system and subsequently withdraws nutrients and water from the host. This specie attacks tomato roots early in the growing season at 14 to 28 days after planting (DAP) depending on temperature conditions, and the shoot emerges 35 to 56 DAP [9]. After germination the parasite has a long underground phase and by the time it emerges on soil surface when the damage to tomato plants has already been produced. The tomato plants parasitized initially manifest a more or less stunted growth and subsequently a decrease-quantity production, in consequence of the reduction of the capacity utilization of the nutrients and the absorption of water. The quantitative decrease is very variable as it is dependent on the duration of the parasitization: if it takes place starting from the early stages of growth of the tomato is obviously greater, coming to wander up to 40% and in some cases even up to 75% compared to the production obtainable in the absence of infestation [10].

Given the particular biology of *Phelipanche,* the control of this weed is far from easy. To eliminate completely the parasite seed bank in the soil is practically impossible [11], [12]. The measures are expected to lead to successful containment of the parasitic weeds problem should be targeted at (1) reducting of existing seed banks, (2) preventing of further seed production and (3) avoiding seed dissemination. These objectives are mutually dependent. The seed bank can only be reduced when new seed inputs are smaller than the output caused by un successful germination, pathogens, seed predation or natural death of the seed [13]-[16].

A wide variety of parasitic weed control methods (physical, chemical, agronomic, biological and biotechnological) has been tried. However, the main concern is that, up to date, no single cheap method of control proved to be effective, economical and complete in protection against the parasite because of pedoclimatic condition variability of the several environments [17]-[21].

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For that reason field studies in southern Italy are needed in which a variety of such techniques are combined, in order to maintain parasite populations below threshold levels of damage.

This paper deals with results of different methods to control the root-parasitic *Phelipanche ramosa* in field tomato crop.

II. Material and Methods

The experiment was carried out in open field heavily infested by *Phelipanche ramosa* during the spring-summer season of 2014, at Foggia (Apulia Region, southern Italy), which is an agricultural area that is characterized by numerous cultivated areas of processing tomato.

In the field, at the private farm of "Ortuso" property, the effect of 11 treatments of parasitic weed control, including chemical, agronomic, biological and biotechnological methods, compared with the untreated test have been carried out, which experimental details are reported in Table I.

Moreover, each above mentioned thesis was tested on two plowing depth (30 and 50 cm). Therefore, the experimental trial was arranged in the field according to a split-plot design, with three replicated, using the plowing depth as main plots and the 12 compared treatments as subplots of 6 m^2.

The crop was transplanted into the experimental field on May 5, 2014, in double rows that were 200 cm apart, with 40 cm spacing between the paired rows and 30 cm spacing in each row, resulting in a theoretical plant density of 3.3 plants m^{-2}. The soil was clay-loam (USDA) having the following characteristics: sand = 34.68%, silt = 31.54%; clay = 33.78%; total N (Kieldahl) = 1.3‰; assimilable P_2O_5 (Olsen) = 47 ppm; exchangeable K_2O (Schollemberger) = 1430 ppm; pH (in water) = 8.7; organic matter (Walkley and Black) = 1.30%.

A drip irrigation method was used, with the drip lines placed between each pair of rows. The water volume at each irrigation varied from 100 m^3 ha^{-1} to 300 m^3 ha^{-1}, depending on the crop growth stage, with a watering interval of about 3 days.

The agricultural management practices applied to the tomato crop during the experimental trial were those commonly adopted by local farmers, such as for fertilizing and for weed and pest control.

During the tomato cycle at 66, 78 and 92 day after transplanting (DAT) *Phelipanche* emerged shoots from soil were counted on the sampling area of 0.5 m^2.

At harvesting, on August 18, the major quantity-quality yield parameters (marketable yield, mean weight, dry matter, pH, soluble solids and color of fruits) were determined. All data were subjected to analysis of variance (ANOVA) and the means were compared by Tukey's test.

TABLE I
THE DESCRIPTION OF TREATMENTS USED IN THE EXPERIMENT

Treatment	
T1	***FUSARIUM* spp.** isolated from diseased *Orobanche* tubercles and grown on Potato Dextrose Agar (PDA). It was used to prepare a suspension of $1.5x10^4$ mL^{-1} of water and applied by foliar treatment on tomato crop, at 3-30 and 52 days after transplanting (DAT).
T2	**GLYPHOSATE.** The herbicide applied by foliar treatment to the tomato crop at the microdose of 36 g 100 L^{-1} of water at 30 and 52 DAT.
T3	**RADICON BIOSTIMULANT.** A suspension–solution containing humic and fulvic acids, obtained from compost of worm (night crawled) and applied at transplanting by soaking the tomato seedling roots into the concentrated solution of 1.5%.
T4	**TAYLOR TOMATO CULTIVAR INOCULATED WITH ARBUSCULAR MYCORRHIZAL FUNGI** (*Glomus intraradices*), performed by the nursery seedlings.
T5	**VIORMON PLUS BIOSTIMULANT.** A solution of nicotinic acid (0.1%), vitamin B1 (0.1%) and boron (2%). It was applied by foliar treatment at dose of at 50 ml L^{-1} at 30 and 52 DAT
T6	***RED SETTER* TILLINNG TOMATO CULTIVAR,** mutant created from *Red Setter* tomato cultivar by tilling technology (targeting induced local lesions in genomes).
T7	**SIAPTON 10 L BIOSTIMULANT.** A formulation based on amino acids and peptides obtained by chemical hydrolysis of animal epithelium. It was applied by foliar treatment at the dose of 300 mL 100 $^{-1}$ L of water, at 30 and 52 DAT.
T8	***FUSARIUM* spp.** isolated from diseased *Orobanche* tubercles and grown on kernels of grain, incorporated into the soil along each double rows of tomato crop, at dose of 0.2 t ha^{-1}, 20 days prior to tomato seedlings transplant.
T9	**SUMUS,** organic fertilizer comported manure mixture of cattle, poultry and domestic stallatic, incorporated into the soil at dose of 3.3 t ha^{-1}, 30 days prior the seedling transplant.
T10	**OLIVE-MILL WASTEWATER,** incorporated into the soil at dose of 80 m^3 ha^{-1} (amount permitted by italian law No 574, 1996), 60 days prior to seedling transplant.
T11	***RED SETTER* TOMATO CULTIVAR,** a processing round fruit.
T12	**CONTROL**

The processing tomato cultivar used in experiment was Docet, the elongated-fruit for peeled tomatoes, unless T4, T6 and T11 theses when the cultivars are different as indicated in the table.

A. Climate

The climate at the location where the trial were carried out is generally of the "thermomediterranean accentuated" type according to FAO Climesco Maps, with temperatures that can drop below 0° in winter and exceed peaks of 40 °C in summer. Rainfall is unevenly distributed over the year (540 mm $year^{-1}$) and predominantly concentrated in the period from November to February.

III. Results and Discussion

In Table II the number of *Phelipanche* emerged shoots from 0.5 m^2 of soil surface, detected during the growing tomato crop, at 66, 78 and 92 days after transplanting (DAT), are reported.

Among the different treatments the increase in the number of *Phelipanche* emerged shoots from the soil, during the growing tomato crop, occurred particularly between 66 and 78

DAT.

At 92 DAT, the average number of shoots per plot (0.5 m^2) varied, in general, between 5.0 and 30.3, whose values were lower in the plowing deeper (50 cm) than the most superficial one (30 cm), corresponding, on average, respectively to 8.82±3.02 and 13.6±3.14.

As regard the different methods of parasitic weed control compared, significantly lower values were determined in both plowing depth for T1 – T2 – T3 -T6 and T10 treatments, corresponding respectively to *Fusarium* (8.3±1.1 and 5.0±1.8), glyphosate (0.0±0.0 and 1.4±10.3),

Radicon biostimulant (1.0±0.6 and 3.6±2.7), genotype tomato resistant with improved technology TILLING (12.3±2.1 and 9.2±1.4) and olive-mill wastewater (10.3±4.3 and 5.3±0.9). In the other treatments the values of emerged shoots were higher, similar to that of the control (Table II).

TABLE II
AVERAGE NUMBER OF EMERGED SHOOT OF *PHELIPANCHE* ON 0.5 m^2 OF SOIL SURFACE, AT 66 – 78 AND 92 DAYS AFTER TRANSPLANTING (DAT), IN EACH TREATMENT OF PARASITIC WEED CONTROL. SEE IN MATERIAL AND METHODS FOR THE EXPERIMENTAL DETAILS

Treatment	Depth of plowing (cm)	66 DAT	78 DAT	92 DAT
T1	30	2.0±0.6	8.3±1.2	8.3±1.1
	50	4.7±2.7	5.0±1.4	5.0±1.8
T2	30	0.3±0.2	0.0±0.0	0.0±0.0
	50	2.0±0.6	1.7±0.9	1.4±0.3
T3	30	0.0±0.0	0.7±0.7	1.0±0.6
	50	3.0±2.4	2.3±1.4	3.6±2.7
T4	30	0.3±0.3	9.0±3.4	13.6±2.0
	50	0.0±0.0	4.0±1.1	6.6±1.9
T5	30	0.0±0.0	5.0±1.5	12.6±1.2
	50	0.0±0.0	1.7±0.3	4.0±1.0
T6	30	2.5±1.2	8.3±1.2	12.3±2.1
	50	1.7±0.7	8.3±1.2	9.2±1.4
T7	30	1.0±0.6	12.7±0.9	13.9±0.6
	50	0.7±0.7	5.0±1.7	11.3±4.6
T8	30	1.7±0.7	24.0±9.9	27.6±11.3
	50	4.7±1.2	16.0±6.0	15.7±5.0
T9	30	4.7±1.8	29.3±12.1	30.3±2.5
	50	2.3±1.3	24.6±6.2	24.6±7.8
T10	30	0.3±0.3	9.3±4.7	10.3±4.3
	50	0.0±0.0	3.0±2.1	5.3±0.9
T11	30	1.8±1.3	12.3±5.4	15.7±5.5
	50	4.7±1.4	4.7±4.3	10.4±5.0
T12 Control	30	0.7±0.6	14.3±5.1	16.8±5.5
	50	0.7±0.6	8.5±4.0	8.8±3.8
Mean	**30**	**1.28±0.65**	**11.1±3.81**	**13.6±3.14**
	50	**2.06±0.97**	**7.06±2.55**	**8.82±3.02**

Data are means ± standard errors determined on 3 samples for each treatments, plowing depth and sampling dates

Regard the effect of different treatments on the productive traits of the tomato crop results are shown in Table III.

Between the two compared plowing depths the thesis at 50 cm depth provided higher marketable yield (68.8 t ha^{-1}) than that at 30 cm depth (54.9 t ha^{-1}).

Among treatments to control *Phelipanche*, generally, the data did not show any significant effect probably due to interference of others factors dependent to different genotypes and organic nutritional products (biostimulants) used in the experiment.

Anyway, among the same Docet tomato cultivar treatments, the marketable yield was tends to by higher in T1, T2, T3 and T10 corresponding to the treatments where a smaller number of emerged shoots than the others compared thesis were noted. Moreover, the transformed Red setter tomato cv gave a higher yield than that original one, in agreement with lower parasitic attach of the plant.

The higher marketable yield appears to be mainly due to the high mean weight of fruits. Regarding the other fruit characteristics no significant differences were observed.

TABLE III
QUANTI-QUALITATIVE TRAITS OF PROCESSING TOMATO FRUIT UNDER DIFFERENT TREATMENTS

Treatment	Depth of plowing (cm)	Marketable yield (t ha^{-1})	Red fruit							
			Rotten fruits (kg)	Mean weight (g)	Dry matter (%)	Soluble solids °Brix	pH	Acidity (g ac.cit./100 ml of juice)	Color a/b
T1	30	79.9±5.9	0.08±0.08	65±2.9	6.51±0.40	5.90±0.15	4.19±0.04	0.29±0.01	1.09±0.01
	50	98.4±8.7	0.28±0.10	60±8.2	6.15±0.25	5.90±0.10	4.11±0.04	0.33±0.01	1.11±0.07
T2	30	53.5±5.4	0.10±0.08	50±4.1	7.49±0.25	5.90±0.00	4.21±0.02	0.34±0.01	1.13±0.04
	50	91.5±3.0	0.33±0.26	58.3±1.7	6.82±0.21	5.33±0.12	4.19±0.04	0.31±0.02	1.13±0.01
T3	30	58.3±7.9	0.23±0.16	65±2.9	6,32±0.02	6.53±0.20	4,11±0.03	0.40±0.00	1.08±0.02
	50	78.5±1.5	0.08±0.04	60±2.9	5.97±0.31	5.93±0.12	4.22±0.01	0.34±0.02	1.06±0.02
T4	30	67.3±1.4	0.85±0.15	65±5.0	6.37±0.20	5,27±0,07	4.13±0.04	0.36±0.01	1.12±0,03
	50	71.3±5.8	1.53±0.19	63.3±1.7	6.29±0.44	4,83±0,03	4.13±0.02	0.38±0.04	1.05±0.01
T5	30	43.5±4.7	0.25±0.13	51.7±4.4	7.13±0.27	6,60±0,15	4.10±0,02	0.38±0.02	1,08±0,05
	50	53.0±6.0	0.65±0.18	58.3±4.4	6.51±0.21	6.13±0.30	4.06±0.01	0.41±0.00	1.10±0.01
T6	30	48.2±9.3	0.53±0.12	46.7±3.3	6,65±0.19	4.97±0.03	4,00±0.02	0.39±0.00	1.16±0.02
	50	52.0±6.5	0.72±0.14	53.3±1.7	6.06±0.26	4.60±0.06	4.00±0.02	0.34±0.01	1.15±0.02
T7	30	32.3±3.0	0.52±0.29	51.7±1.7	6.33±0.10	4,93±0.15	4.12±0.04	0.36±0.01	1.19±0.01
	50	50.5±3.2	1.08±0.12	50.0±0.1	5.80±0.51	4.70±0.20	4.07±0.04	0.38±0.01	1.04±0.02
T8	30	40.7±2.1	0.10±0.06	46.7±4.4	6,72±0,09	5.50±0.23	4.11±0.05	0,41±0,01	1.10±0.05
	50	60.2±8.1	0.57±0.02	55.0±8.7	6.37±0.13	5.00±0.10	4.14±0.02	0.32±0.00	1.13±0.01
T9	30	43.6±4.2	0.50±0.23	46.7±3.3	7.31±0.13	5.20±0.10	4.21±0.05	0.34±0.02	1.18±0.03
	50	61.6±2.6	0.95±0.39	60.0±2.9	7.68±0.19	5.40±0.06	4.10±0.04	0.39±0.01	1.17±0.04
T10	30	67.7±0.6	0.67±0.12	48.3±3.3	7.32±0.13	5.00±0.10	4.13±0.07	0.35±0.02	1.13±0.03
	50	64.9±6.6	0.82±0.45	55.0±2.9	7.01±0.25	5.17±0.12	4.23±0.01	0.31±0.01	1.16±0.02
T11	30	68.9±11.9	0.92±0.15	61.7±1.7	6.81±0.23	5.23±0.07	4.05±0.02	0.34±0.02	1.05±0.03
	50	76.8±8.8	1.87±0.20	78.3±9.3	6.96±0.13	5.17±0.07	4.18±0.01	0.35±0.02	1.08±0.03
T12 Control	30	55.5±10.9	0.65±0.20	58.3±3.3	6.53±0.17	5.63±0.20	4.10±0.02	0.38±0.38	1.100.02
	50	66.9±9.0	0.70±0.15	56.7±1.7	6.45±0.17	5.47±0.17	4.18±0.03	0.33±0.01	1.18±0.01
Mean	**30**	**54.9±6.4**	**0.45±0.15**	**54.7±3.4**	**6.8±0.18**	**5.6±0.12**	**4.12±0.03**	**0.4±0.04**	**1.1±0.03**
	50	**68.8±5.8**	**0.80±0.19**	**59.0±3.9**	**6.5±0.26**	**5.3±0.12**	**4.13±0.02**	**0.35±0.01**	**1.1±0.02**

IV. CONCLUSION

In view of the importance of processing tomato as major cash crop for farmer and the heavy losses in the field mainly due to *P. ramosa* in Apulia region (southern Italy), very important is to select the best method to this harmful weed control.

The principal conclusion to be drawn from this study is to confirm that no single technique provides complete control of *Phelipanche*, and resorting to some of them is unavoidable.

Anyway, among the same Docet tomato cultivar treatments, the marketable yield was tends to by higher in some control methods such as soil applied of *Fusarium* spp., Glyphosate, Radicon biostimulant, olive mille wastewater and crop resistance approaches appear to be the most effective control in reducing the infestation of *Phelipanche* tomato crop.

It is assumed that these effects can be improved by combining some of these treatments each other, especially for a gradual and continuing reduction of the "seed bank" of the parasite in the soil.

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