Studies on the Control of Broomrape (*Orobanche ramosa* L.) in Virginia Tobacco (*Nicotiana tabacum* L.)*

by

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SUMMARY

During 1997 and 1998, in the province of Perugia (Umbria, central Italy), four field experimental trials were carried out to study the control of broomrape (*Orobanche ramosa* L.) in Virginia tobacco. In 1997, maleic hydrazide (2040 mL ha⁻¹), flumetralin (1200 mL ha⁻¹), *n*-decanol (10720 mL ha⁻¹), glyphosate (180–324 mL ha⁻¹) and rimsulfuron (12.5–25 g ha⁻¹) were tested on the variety K 394. In the second year, maleic hydrazide (2040 mL ha⁻¹), *n*-decanol (10720 mL ha⁻¹) and butralin (2160 mL ha⁻¹) were utilised in the same variety. Furthermore, a field experiment was performed to assess the susceptibility of different untopped Virginia tobacco varieties to broomrape. The presence of the weed was recorded as the number of the aboveground broomrape plants per m² and after harvest dry weight was determined.

Maleic hydrazide proved to be highly effective against the parasitic weed when used at the early flowering stage of the crop, reducing by 95% and 73%, on average, the number of broomrape plants with respect to the untreated control, respectively in 1997 and 1998. Rimsulfuron, used 55 days after transplanting, had a satisfactory activity against broomrape (reduction of 50–70%). A double treatment with glyphosate caused a reduction of 100% of broomrape but it significantly depressed tobacco yield. Flumetralin, *n*-decanol and butralin did not show any control of broomrape. The variety BC 60 FB was found to be highly resistant to the weed with an average of 85% reduction in broomrape plants compared to the other varieties in the experiment. [Beitr. Tabakforsch. Int. 20 (2002) 77–81]

ZUSAMMENFASSUNG

In der Provinz von Perugia (Umbrien, Mittelitalien) wurden 1997 und 1998 vier Feldversuche zur Bekämpfung von *Orobanche ramosa* L. in Virginia Tabak durchgeführt. 1997 wurden Maleinsäurehydrazid (2040 mL ha⁻¹), Flume-

tralin (1200 mL ha⁻¹), *n*-Decanol (10720 mL ha⁻¹), Glyphosate (180–324 mL ha⁻¹) und Rimsulfuron (12.5–25 g ha⁻¹) bei der Sorte K 394 getestet. Im zweiten Jahr wurden Maleinsäurehydrazid (2040 mL ha⁻¹), *n*-Decanol (10720 mL ha⁻¹) und Butralin (2160 mL ha⁻¹) auf derselben Sorte eingesetzt. Außerdem wurde ein Feldexperiment zur Anfälligkeit verschiedener nichtgeköpfter Virginia-Tabaksorten gegen *Orobanche* durchgeführt. Die Befallstärke wurde aufgrund der vorhandenen *Orobanche*-Pflanzen pro m² ermittelt und nach der Ernte wurde ihr Trockengewicht bestimmt.

Maleinsäurehydrazid erwies sich als hoch wirksam gegen das parasitäre Unkraut, wenn es im frühen Blühstadium des Tabaks eingesetzt wurde; der Befall verringerte sich durchschnittlich um 95% (1997) und 75% (1998) im Vergleich zur unbehandelten Kontrollgruppe. Rimsulfuron, 55 Tage nach dem Auspflanzen angewandt, ergab zufriedenstellende Ergebnisse (50–70% Verringerung des Befalls). Die zweimalige Anwendung von Glyphosate führte zu einer 100%igen Verringerung, war allerdings mit einer beträchtlichen Abnahme des Tabakertrags verbunden. Flumetralin, *n*-Decanol und Butralin zeigten keinerlei Einfluss auf den *Orobanche*-Befall. Die Sorte BC 60 FB erwies sich als *Orobanche*-resistent mit einer mittleren Verringerung der *Orobanche*-Pflanzen um 85% im Vergleich zu den anderen untersuchten Sorten. [Beitr. Tabakforsch. Int. 20 (2002) 77–81]

RESUME

En 1997 et 1998, quatre essais en champ ont été menés dans la province de Pérouse (Ombrie, Italie Centrale), pour évaluer l'efficacité de certains pesticides dans la lutte contre l'orobanche (*Orobanche ramosa* L.) affectant le tabac Virginie. En 1997, l'hydrazide maléique (2040 mL ha⁻¹), la flumétraline (1200 mL ha⁻¹), le *n*-décanol (10720 mL ha⁻¹), le glyphosate (180–324 mL ha⁻¹) et le rimsulfuron (12.5–25 g ha⁻¹) ont été utilisés sur la variété K 394. La deuxième année, l'hydrazide maléique (2040 mL ha⁻¹),

le *n*-décanol (10720 mL ha⁻¹) et la butraline (2160 mL ha⁻¹) ont été utilisés sur la même variété. De plus, un essai en champ a été conduit pour évaluer la sensibilité à l'orobanche des différentes variétés de tabac Virginie non écimée. La présence des mauvaises herbes a été évaluée sur la base du nombre de plantes sortant du sol par m² et après la récolte, leur poids sec a été déterminé.

L'hydrazide maléique a montré une grande efficacité contre le parasite dans le cas d'une application en début de floraison du tabac. Une réduction du nombre d'orobanches, de 95% et 73% en moyenne, est observée par rapport aux témoins non traités obtenu respectivement en 1997 et 1998. Le rimsulfuron, utilisé 55 jours après la transplantation, s'est avéré relativement efficace contre le parasite (réduction de 50–70%). Un double traitement au glyphosate a réduit l'infestation par l'orobanche de 100%, mais a toutefois sensiblement diminué le rendement en tabac. La flumétraline, le *n*-décanol et la butraline n'ont pas eu le moindre effet sur l'orobanche. La variété BC 60 FB se révèle résistante au parasite avec une réduction moyenne de 85% du nombre d'orobanches par rapport aux autres variétés de l'essai. [Beitr. Tabakforsch. Int. 20 (2002) 77–81]

INTRODUCTION

Control of broomrape (*Orobanche* spp.) represents one of the most studied subjects in tobacco disease research. Strategies to control broomrape can be based on physical methods (weeding, solarization, soil tillage, flaming, flooding, irrigation), chemical methods (soil fumigation, herbicides, germination stimulants) and biological methods (use of resistant varieties, biological control with insects and fungi, cropping systems). However, physical methods are too expensive or not feasible and biological methods still need more research (3). Among the chemical methods, soil fumigation and the use of herbicides seem to be the most effective approaches but most of the herbicides are not usually selective for the host crop and soil fumigation with methyl bromide or ethylene dibromide is too expensive and it is partly banned due to environmental risks (5).

ZAZZERINI *et al.* (12) found *O. ramosa* in central Italy and, less frequently, *O. crenata*, demonstrating the positive effect of diphenamide, which is no longer deployed, against the parasitic weed. DIMESKA *et al.* (4) indicated the possibility of controlling broomrape in tobacco by the herbicide oxyfluorfen but the phytotoxicity to the crop after rainfalls or irrigation in the first growth stages is well documented. Herbicides such as glyphosate have been shown to be effective against *O. crenata* in faba bean fields (11), in broad bean and field bean (7). LOLAS (9) also reported that glyphosate gave excellent control of *O. ramosa* in tobacco but it was phytotoxic to the crop when the 9% formulation was used.

Maleic hydrazide, a plant growth regulator commonly used for preventing lateral sucker growth in tobacco, also showed a positive effect in controlling *O. ramosa* in tobacco (8,9) and *O. aegyptiaca* in tobacco and watermelon (2).

AMSELLEM *et al.* (1) indicate the possibility of biologically controlling broomrape with the insect *Phytomyza oro-*

bachia. They also reported the positive effect of microbial bioherbicides such as the pathogen *Fusarium oxysporum* f. sp. *orthoceras* in controlling *O. cumana* in sunflower and the possibility of applying some fungal toxins as biocontrol agents of broomrape.

Despite all these studies, we can certainly state that satisfactory physical, chemical, biological and cultural control methods have not yet been developed. The most effective prevention of broomrape would be obtained by using a combination of methods, especially the integration of cultural and chemical approaches. However, the most interesting option of improving the control of broomrape would be the creation of resistant varieties (3).

The objectives of the field experiments reported in this paper are to 1) investigate the control of *O. ramosa* in a typical tobacco cultivation area of central Italy by using plant growth regulators and herbicides on topped Virginia tobacco and 2) to evaluate the resistance of a number of untopped Virginia tobacco varieties to this parasitic weed.

MATERIALS AND METHODS

The experimental field studies were carried out in 1997 and 1998 at the Experimental Station of the Department of Agro-environmental and Crop Sciences of the University of Perugia (Central Italy, 42°57' latitude, 165 m a.s.l.) in a typical Virginia tobacco cultivation area. The trials were executed in a silty-clay-loam soil with 1.5% organic matter, 200 mg kg⁻¹ available K₂O, 22.5 mg kg⁻¹ soluble P, on fields usually highly infested with broomrape when tobacco is cultivated. Seedlings of the flue-cured variety K 394 were transplanted the 15th of May, at a density of 2 plants m⁻² (1 m between rows, 0.5 m within the row). Plots were arranged in a randomised block design with four replicates and had a surface of 35 m². Soil was fertilised with 100 kg P₂O₅ ha⁻¹, 100 kg K₂O ha⁻¹ and, 15 days after transplanting, with 50 kg N ha⁻¹. A proper chemical weed control suppressed weed growth during the entire crop cycle. Irrigation was carried out using the trickle method to good maintain evapo-transpiration during the entire cycle. Anti peronosporic treatment with metalaxyl and mancozeb and insecticide treatments with methomyl and cypermethrin were carried out. Tobacco was manually topped at the early flowering stage, above the 18th leaf. Subsequently, all the growth regulators and herbicides were distributed directly on tobacco leaves by utilising a three-nozzle bar: one spraying the products vertically, the others spraying towards the two sides of the row.

Rainfall and temperatures during the experiments were near the average of the last 20 years. During tobacco cycle, the rainfall recorded was 251 mm in 1997 and 322 mm in 1998. In particular, in August, when treatments were carried out, rainfall was 25 mm and 21 mm in 1997 and 1998, respectively.

a) Experiments with plant growth regulators

Active ingredients, utilised rates, and solutions are reported in Table 1, while application times of all the experimented products are reported in Tables 2 and 3 for 1997 and 1998,

Table 1. Active ingredients, rates and solutions in the two years

Active ingredient	Commercial product	Active ingredient in commercial product (%)	Volume of water applied (L ha ⁻¹)	Active ingredient (mL ha ⁻¹)	1997	1998
<i>n</i> -Decanol	Royaltac	67	400	10720	+	+
Maleic hydrazide	Royal MH	17	600	2040	+	+
Flumetralin	Prime Plus	25	400	1200	+	—
Butralin	Tamex	34	400	2160	—	+
Glyphosate	Roundup	36	400	108 + 216 or 180	+	—
Rimsulfuron	Titus	25	400	12.5 or 25 g	+	—

Table 2. Efficacy of plant growth regulators in 1997

Active ingredients	Application time (DAFS ^a)	Broomrape plants (no. m ⁻²)	Broomrape dry weight (g m ⁻²)
<i>n</i> -Decanol + maleic hydrazide	0 + 10	0.3	0.4
<i>n</i> -Decanol + maleic hydrazide	7	0.1	0.1
<i>n</i> -Decanol + flumetralin	0 + 7	5.0	29.5
<i>n</i> -Decanol + (<i>n</i> -decanol + flumetralin)	0 + 7	5.3	27.0
<i>n</i> -Decanol + (maleic hydrazide + flumetralin)	0 + 10	0.4	0.6
Untreated control	—	4.6	23.0
L.S.D.^b (<i>P</i> < 0.05)	—	2.8	13

^aDAFS = days after flowering started.

^bL.S.D. = least significant difference.

respectively. Maleic hydrazide was used at the rate commonly utilised to prevent lateral sucker growth in tobacco. About three weeks after treatments the number of broomrape plants per m² was recorded and after harvest all the aboveground broomrape plants per plot and dry weight was determined and expressed as g m⁻². Visual observations of tobacco roots were carried out at the end of the crop cycle order to check the possible initial growth of the parasitic weed, which might have been inhibited by the experimented chemicals.

b) Experiments with herbicides

Active ingredients, utilised rates, and solutions are reported in Table 1. The experiment was carried out in 1997 (Tab. 4) on tobacco transplanted on the 31st of May and that was grown under the same agronomic practices as described above.

The herbicides glyphosate (one or two treatments 55 or 55 and 70 days after transplanting, respectively) and rimsulfuron (at the standard rate of 12.5 g ha⁻¹ and at the double rate of 25 g ha⁻¹) were tested. The control was maleic hydrazide sprayed at the early flowering stage and after 20 days. About three weeks after treatments the number of broomrape plants per m² was recorded.

Phytotoxicity caused by the herbicides was observed at 71 and 81 days after transplanting and recorded by utilising

Table 3. Efficacy of plant growth regulators in 1998

Active ingredients	Application time (DAFS)	Broomrape plants (no. m ⁻²)	Broomrape dry weight (g m ⁻²)
Butralin + maleic hydrazide	0 + 12	1.3	2.5
Butralin	0 + 12	6.5	28.9
Butralin + maleic hydrazide	0	2.0	7.8
<i>n</i> -Decanol + maleic hydrazide	0 + 12	1.4	2.0
<i>n</i> -Decanol + maleic hydrazide	0	2.2	6.2
Untreated control	—	6.3	22.5
L.S.D. (<i>P</i> < 0.05)	—	2.2	12.3

the European Weed Research Society (EWRS) scale 1–9, 1 corresponding to none and 9 to the maximum phytotoxicity.

As in the previous experiments, visual observations of tobacco roots were carried out at the end of tobacco cycle.

c) Experiments with untopped varieties

In 1997, six untopped Virginia tobacco varieties were compared in a randomised block experimental design (Tab. 5) with four replicates. They were transplanted on the 15th of May in a soil with the same characteristics as described in a) and, apart from topping, were grown under the same agronomic practices as already described.

The variety named BC 60 FB (Bright Cospaia Fiore Bianco), which in ordinary field crops showed none or low broomrape infestation, was compared to other untopped varieties, which in previous experiments proved to be of good yielding and quality characteristics for the production of mildly aromatic tobacco noted for its low nicotine content (COVARELLI G., unpublished data). They were Cospaia BH11, Cospaia BH23, G-9, Flue cured 0027 and Foglia oro 104. About three weeks after flowering started, the number of broomrape plants per m² and tobacco yield were recorded. As in the other experiments, visual observations of tobacco roots were carried out at the end of tobacco cycle.

Table 4. Efficacy of herbicides in 1997

Active ingredients	Application time	Broomrape plants (no. m ⁻²)	Phytotoxicity (1–9)	
			71 DAT ^a	81 DAT
Maleic hydrazide	0 DAFS (55 DAT)	0.0	1	1
Maleic hydrazide	20 DAFS (75 DAT)	1.9	—	1
Glyphosate (108 + 216)	55 + 70 DAT	0.0	4	5
Glyphosate (180)	55 DAT	1.1	3	4
Rimsulfuron	55 DAT	0.6	3	1
Rimsulfuron	55 DAT	0.9	4	2
Untreated control	—	1.8	—	—
L.S.D.^b (<i>P</i> < 0.05)	—	0.5	—	—

^aDAT = days after transplanting.^bL.S.D. = least significant difference.**Table 5. Susceptibility of different Virginia tobacco varieties to broomrape**

Varieties	Yield (kg ha ⁻¹)	Broomrape plants (no. m ⁻²)	Loss of yield per broomrape plant per m ² (kg ha ⁻¹)
BC 60 FB	2805	0.9	0
Cospaia BH 11	2604	5.2	46
Cospaia BH 23	2433	5.6	79
G-9	2399	8.1	56
Flue cured 0027	1930	6.2	165
Foglia oro 104	1870	4.5	260
L.S.D. (<i>P</i> < 0.05)	388	3.9	38

RESULTS AND DISCUSSION

a) Experiments with plant growth regulators

As expected, in both years, all the controls were highly infested by *O. ramosa*: 4.6 and 6.3 spikes m⁻² were detected in the untreated controls, respectively in 1997 and 1998 (Tab. 2 and 3). All maleic hydrazide treatments on caused a significant reduction of the occurrence of broomrape, expressed as the number and the dry weight of observed plants. In particular, in the first year, 0.1 and 0.3 and 0.4 plants m⁻² were recorded when maleic hydrazide was used at 7 days after flowering started (DAFS) in mixture with *n*-decanol, at 10 DAFS after a treatment with *n*-decanol and at 10 DAFS after a treatment with *n*-decanol in mixture with flumetralin, respectively. This occurrence level corresponded to a broomrape dry weight of 0.1, 0.4 and 0.6 g m⁻², respectively.

No statistically significant differences in the number of plants and dry weight, with respect to the untreated control were recorded when flumetralin was used at 7 DAFS following a treatment with *n*-decanol and at 7 DAFS in mixture with *n*-decanol and following a treatment with *n*-decanol. In the second year, 2.0 and 2.2 broomrape plants m⁻² were recorded when maleic hydrazide was used at 0 DAFS,

respectively in mixture with butralin and *n*-decanol, 1.3 and 1.4 plants m⁻² when maleic hydrazide was used at 12 DAFS, following a treatment with butralin and *n*-decanol, respectively.

Two treatments with butralin, at 0 and 12 DAFS, did not show any activity against broomrape (6.5 plants m⁻²).

Visual observations performed on the roots of tobacco plants which were apparently not infested by broomrape, showed a moderate growth of the parasitic weed, which was probably suppressed after the treatment with maleic hydrazide. This product, due to its systemic action, was probably absorbed by tobacco and translocated to broomrape plants suppressing their growth. Application time of the products, in fact, corresponded to the initial growth stages of broomrape.

b) Experiments with herbicides

Broomrape infestation in the control was of 1.8 plants m⁻² (Tab. 4). Results obtained confirmed the good control of broomrape when maleic hydrazide was used at early flowering (no broomrape plants were observed) while unsatisfactory results were obtained when used 20 days after transplanting (DAT) (1.9 plants m⁻²).

Glyphosate, used at 55 and 70 DAT, showed a good control of broomrape but caused a strong phytotoxicity to the crop which appeared less developed than the untreated and infested control (phytotoxicity values of 4 and 5 in the two observations, respectively). The same product used only at 55 DAT did not control completely *O. ramosa* (1.1 plants m⁻²) and caused a moderate phytotoxicity to the crop with phytotoxicity values of 3 and 4 in the two observations, respectively.

Conversely, rimsulfuron had a very good effect in controlling broomrape, even at the lowest rate of 12.5 g ha⁻¹. These results confirm findings of GOLDWASSER *et al.* (6) on *Orobanch* spp. and SIDAHMAD and HAIDAR (10) on *O. ramosa* in potato.

This is of particular interest because this herbicide has a good efficacy on some weeds otherwise difficult to control by the other herbicides commonly utilised for this crop. However, rimsulfuron caused a slight phytotoxicity to the crop that disappeared after a week, following abundant

irrigation. Phytotoxicity values, in fact, decreased from 3 to 1 when rimsulfuron was used at the rate of 12.5 g ha⁻¹, from 4 to 2 when used at the rate of 25 g ha⁻¹.

Because no aboveground broomrape plants were visible when treatment with rimsulfuron was carried out, this product was probably absorbed by tobacco and, due to its systemic action, subsequently translocated to broomrape plants inhibiting their growth.

c) Experiments with different untopped varieties

All the varieties utilised in the present experiments were strongly infested by *O. ramosa* with the exception of variety BC 60 FB (Tab. 5). This variety confirmed to have a very good resistance to broomrape (0.9 plants m⁻²) while all the others were highly infested, with no statistically significant differences among them. Furthermore, no additional germinated broomrape plants were detected on BC 60 FB during root observations. This could mean that the high resistance observed was probably due to root secretions of this variety, which did not stimulate broomrape seed germination. As a consequence of the presence of broomrape, the other varieties in the experiment showed a yield reduction which ranged, with respect to BC 60 FB, from 46 kg ha⁻¹ (Cospaia BH11) to 260 kg ha⁻¹ (Foglia oro 104) for each additional broomrape plant per m². BC 60 FB gave, in fact, the highest yield (2805 kg ha⁻¹) as compared to the other varieties, which, in previous experiments produced yields equal to BC 60 FB.

CONCLUSIONS

Maleic hydrazide, commonly utilised to prevent lateral sucker growth in tobacco, due to its systemic action, prevented the growth of broomrape in Virginia tobacco when used at the early flowering stage of the crop, corresponding to the initial growth stages of the parasitic weed. Rimsulfuron, though it caused a temporary phytotoxicity to the crop, gave a good control of *O. ramosa*. Glyphosate, at the experimented rates, gave a satisfactory control of broomrape but caused a strong phytotoxicity to the crop. Butralin, flumetralin and *n*-decanol did not show any efficacy against the parasitic weed.

The untopped tobacco variety BC 60 FB showed a very high resistance to *O. ramosa* and gave the highest yield. This is of particular interest because the variety BC 60 FB could yield a good source of resistance, with the potential identification and isolation of the responsible resistance genes and their transfer to other Virginia tobacco varieties or to other tobacco types.

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