Management measures for *Veronica persica* (*Plantaginaceae*), an invasive alien species and a weed in rapeseed crops in Southeast Romania

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Abstract. In Romania, new invasive plant species have been reported in the last decade. Such an invasive plant is the species *V. persica,* often found in winter rapeseed crops. Its germination period coincides with those of rapeseed and cause significant yield losses, especially on soils well supplied with nitrogen. The success of this weed is ensured by the large number of seeds and by the fact that it survives over the winter season, being immune to frost, especially in the context of milder growing winters. An increasing number of farmers now grow winter rape (*Brassica napus* L.) in Romania, because it is an economically profitable crop. One of the basic technological links is weed control, as the rape plants are susceptible to weed infestation, especially during their early stages of vegetation. Early control of the invasive species *V. persica* is absolutely necessary, because this allows rapeseed to develop vigorously throughout the growing season and because the plant has a great natural capacity to control weeds that occur later. Our assessments of rapeseed crops during 2017 and 2018 in Southeast Romania have shown that this weed may form associations with other species of the *Veronica* genus, so that they become dominant and can totally compromise the winter rape crop. The aim of this research was to develop measures so as to eradicate and limit the spread of the invasive species *V. persica* in winter rape crops by integrating agrotechnical measures with products for plant protection.

Key words: agrotechnical measures, herbicides, invasive species, weeds, winter rape

Introduction

Invasive plant species are a tangible threat to biodiversity, because, after once occurring in a habitat, they may suppress the native species. One such invasive species is *V. persica* Poiret, a small-sized plant, pretty, blue-flowered, which does not impress by its vigor and proliferation as other invasive species do (*Sorghum halepense, Xanthium italicum*) and also has no allergenic properties like *Ambrosia* species.

V. persica has been reported as a weed for 27 crops in 45 countries (Holm & al. 1997) and, according to Holm & al. (1991), is a serious or principal weed in 10 countries. In a survey of 2359 fields growing either winter wheat or winter barley in the UK, *V. persica* was one of the four most common broad-leaved weeds (Whitehead & Wright 1989). *V. persica* has been reported as an alternative host for a range of crop pests and pathogens: *Alternaria linicola,* (Vloutoglou & al. 1995), beet western yellow luteovirus (Stevens & al. 1994), clover yellow vein potyvirus (Okuda & al. 1992), *Verticillium dahliae* (Mesturino 1990), and the melon aphid, *Aphis gossypii*. The roots of *V. persica* may be colonized by the fungus *Fusarium oxysporum* f.sp. lini and *Myzus ascalonicus* may overwinter on the weed in strawberry fields (Karl 1983).

The ability of *V. persica* to root at the nodes makes it difficult to control mechanically (Herrmann & al. 1986), because disturbed plants are able to reroot after surface cultivation (Roberts & Stokes 1966). Emergence and density of seedlings may be affected by the timing and nature of cultivation practices.

V. persica is a decumbent winter to summer annual weed. A native of SW Asia, it was first recorded in Europe around 1800 (Clapham & al. 1987, Stace 1997). Within 50 years of being recorded, it became the commonest speedwell and one of the commonest annual weeds (Salisbury 1962a). It has also become a common garden weed (Roberts & Chancellor 1986, Copson & Roberts 1991). Common field speedwell prefers nutrient-rich loams (Hanf 1970). It is most frequent on soils with pH 6.0 to 8.0 (Boutin & Harper 1991, Grime & al. 1988, Tsuruuchi 1994).

In Romania, new invasive plant species have been reported in the last decade, especially in segetal and ruderal habitats (Niculescu & Cismaru 2013). Such an invasive plant is the species *V. persica,* frequently found in winter rapeseed crops. Its germination period coincides with that of rapeseed and causes significant yield losses, especially on soils well supplied with nitrogen. In Romania, this species is found in the steppe area, up to the beech wood level (Chirilă & al. 2002).

Considering that weed control is a major technological issue, because the rape plants are susceptible to weed infestation, especially during their early stages of vegetation, attention was focused on the control of that species.

Canola (*Brassica napus* L.) is a worthwhile crop for the Romanian farmers, so the area sown under rapeseed was over 460 000 hectares (ISN, 2017). Effective weed control is the major factor in achieving high rapeseed yields, because no maximum yields could be obtained without controlling the weeds (Hamzei & al. 2007). Early weed elimination ensures for rapeseed crops essential conditions for securing the necessary water, nutrients and sufficient space for growth and development.

Thus, management proves to be a key factor in the technology of oilseed rape growing. Integrated weed management in oilseed canola is a combination of preventive, mechanical and chemical methods, in order to reduce environmental pollution (Pourazar & Habibias 2003, Delchev 2014, Delchev & Georgiev 2018, Grădilă & al. 2020). The critical period of weed control is a key component of an integrated weed management program. Weed competition with oilseed rape in the early growth stages is critical (Chirilă 2001, Knezevic & al. 2002, Khan & al. 2003, Berca 2004).

Duration of the critical period of weed control depends on several factors, including weather conditions, weed population density and dominant weeds in the region, crop planting date, etc. (Seem & al. 2003). Knowledge of critical periods may be used in bioeconomic models, in order to improve the timing of herbicide application for integrated weed management (Eyherabide & Cendoya 2002).

A slowly growing crop, rapeseed is subject to severe competition from weeds. Weed suppression by shading begins only after the canopy of rapeseed leaves has grown over the rows and has covered the field early. By such light deprivation, less energy is available to crop plants for metabolic production and, hence, growth, yield and quality of the rapeseed plants will be reduced. Furthermore, weed development with rapeseed plants causes severe nutrition deprivation (Roshdi & al. 2008). Crop competitiveness is often determined by the absolute grain yield under weed-free conditions indicating the yielding ability of the crop, relative grain yield in the presence of weeds indicating crop competitive ability, and weed biomass indicating weed suppression ability (Mortensen & al. 2000, Zare & al. 2012). Canola yield loss exceeds 10%, if weed-free conditions are not maintained between crop emergence and the four- to six-leaf stage of canola (17–41 days after crop emergence) (Martin & al. 2001). In order to develop effective measures for protecting oilseed rape from weeds, it is necessary to find out the species composition and to ensure monitoring (Mikhailova & al. 2015). The spectrum of weeds in rape crops has a specific characteristic and is in constant evolution. A present problem with the common field speedwell (*V. persica*) is an example of the "weed species shift," in which a previously insignificant weed has evolved into a serious problem, because it was not controlled by commonly used herbicides. Research has shown that *Veronica* species are among a number of small-seeded broadleaf weed species whose germination is markedly inhibited by tillage after dark. Post-harvest practices of field disking only two inches deep, or non-tillage, favor the emergence of these species requiring light for germination. In recent years, the authors have noticed in their research some changes in the floristic composition of the segetal flora, namely, that some species such as *V. persica*, have become ever more damaging especially to rape crops (Mennan & Isik 2003, Grădilă 2017). Considering the fact that Persian speedwell germinates mostly in the fall and early winter, at the same time as rapeseed does, this invasive weed causes both direct losses by decreasing production per hectare and indirect losses by the cost of control. In the course of this study, the authors have developed measures in order to eradicate and limit the spread of the invasive species *V. persica* in winter rape crops by integrating agrotechnical measures with products for plant protection, which will be presented here.

Material and methods

The experiments were carried out at the Didactic Farm Moara Domneasca in Ilfov County, with the University of Agronomic Sciences and Veterinary Medicine of Bucharest, in the southeastern part of Romania (Fig. 1).

During the 2017-2018 field experiment with winter oilseed rape, DK Exprit hybrid was used. Planting density was 450 000 plants per hectare. Sowing was performed on August 25th. The previous crop was wheat. The following agrotechnical measures have been applied: systematic crop rotation, rational choice of the preceding plants, deep plowing up to 30 cm in summer, seedbed tillage by two passes with a disc harrow, followed by milling and high-quality hybrids. Along with this, 200 kg/ha of complex fertilizer was applied. The following herbicide products were evaluated: Sultan Top SC - suspension concentrate (375 g/L Metazachlor + 125 g/L Quinmerac), Butisan Avant

Fig. 1. Location of the Didactic farm Moara Domnească.

SE - suspoemulsion (100 g/L Dimethenamid-P + 300 g/L Metazachlor + 100 g/L Quinmerac), and Butisan SC - suspension concentrate (500g/L Metazachlor) as a standard reference.

Herbicide treatment was applied at two different application times: pre emergence and early postemergence.

Herbicide treatment was done with sprayer for plot trails. The expanse of spray solution was 300 L/ha. The herbicide efficacy was recorded on the 12th, 28th and 42th day after treatment on a 10-score scale for efficacy of EWRS (European Weed Research Society), with control in percentage compared to the untreated plots. Also, there were observations of the weeds found in the experimental plots before treatment, and selectivity - at each date of the efficacy assessments.

Selectivity of the studied herbicides was evaluated by the 9-score visual scale of EWRS (score 0 - no damage of the crop, score 9 – complete death of the crop). Determination of segetal flora was carried out on one square meter by a metric frame. Statistical data obtained from the assessments was calculated by ARM-9 software (P=.05, Student – Newman – Keuls).

Results and discussion

The experimental plots were dominated by the invasive species *V. persica*. Other weed species were also found, but with low density/m²: *V. hederifolia*, *Galium aparine*, *Setaria* spp., *Echinochloa crus-galli, Lamium* spp. *and Papaver rhoeas.*

When herbicides were applied at pre emergence (rape has not emerged), the percentage of coverage by *V. persica* was quite high: 18.75% after 14 days, 30.5% after 28 days, and over 37% after 42 days of treatment (Table 2 and 3).

When herbicides were applied in early postemergence (rape with 5-6 leaves), the percentage of coverage by *V. persica* was higher: 15.5% before treatment, 21.2% after 14 days, 35.7% after 28 days, and over 50% after 42 days of treatment (Fig. 2).

Assessment data for the growth stage of *B. napus* and *V. persica,* when the herbicide was applied in early postemergence, are presented in Table 1.

The applied agrotechnical measures have reduced the biological reserve of weed seeds, but have failed to stop the growth and development of invasive weeds

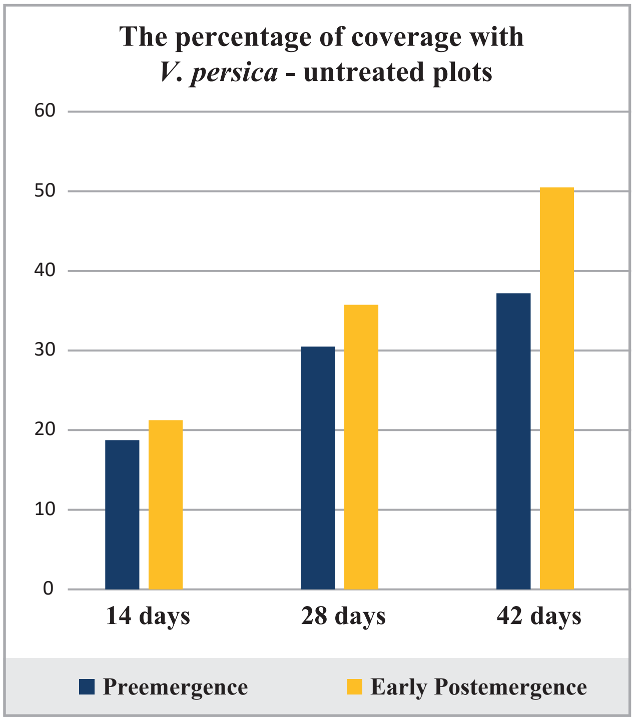

Fig. 2. Density of *V. persica* in untreated plots.

in the rape crop. Crop rotation is the best agrotechnical method for weed control, because it reduces weed density, reserves of weed seeds in the soil, and reduces or eliminates the specific weed infestation, avoiding any appearance of the resistance phenomena (Tonev & Mitkov 2015).

Under such conditions of weed infestation, the herbicides applied to the rape crop have proved efficacious in the control of *V. persica.* (Table 2 and 3). Metazachlor is a chloroacetamide herbicide, which inhibits the germination of annual broadleaf and grass weeds (Tomlin 2004). Metazachlor is a good start in the control of annual weeds (*V. persica*) and the dose depends on timing, soil type and expected weed species. Metazachlor could be used as a co-formulated product with quinmerac, or dimethenamid-p in enhancing the spectrum of controlled weeds, especially when used in early postemergence. If conditions are unsuitable at pre emergence timing, or if the preferences are for treatment during postemergence, then there are an increasing range of options in early postemergence. Metazachlor acts by root uptake; quinmerac or dimethenamid-p, which are available in co-formulation, have shoot or leaf uptake, which enhances the postemergence performance as compared to straight metazachlor (Martin 2019). Thus, the efficacy of pre emergence applied metazachlor has been 72.6% after 14 days of application and 81.8% after 28 days of application. After 42 days of treatment metazachlor has low efficacity in the control of *V. persica*. Due to the high degree of weed infestation with *V. persica* after 42 days of treatment, the efficacy was low both at pre emergence application (56.2%) and at early postemergence (40.7%). In pre emergence application, metazachlor herbicide is absorbed by germinating weed seeds and as a consequence, the new weed plants are destroyed immediately after emergence. Good seedbed preparation and sufficient soil moisture favours taking over the active substance and increases effectiveness. If the soil is dry, the effect is initiated after the first rain.

Herbicide with two active substances (375 g/L Metazachlor + 125 g/L Quinmerac) has a better efficacy in controlling *V. persica as* compared to Metazachlor, especially when applied at early postemergence: 74.7% after 14 days of application, 81.8% after 28 days and 50.5% after 42 days of treatments; the obtained results are similar to those in the published literature. Shimi & al. (2006) have reported that 2.5 L/ha of Butisan Top have been able to control annual broadleaf and grass weeds in the canola fields of Khuzestan,

Table 1. Growth stage of *B. napus* and *V. persica* (early postemergence)

Plants	BBCH[1]	Description
Brassica napus	1st assessment 15-16	5-6 leaves unfolded
	2nd assessment 21	Beginning of side shoot development, first side shoot detectable
	3rd assessment 36	Six visibly extended internodes
Veronica persica	1st assessment 12-13	2-3 leaves unfolded
	2nd assessment 16-18	6-8 leaves unfolded
	3rd assessment 22	Two side shoots visible

[1]BBCH scale is a scale used to identify the phenological stages of plant development.

Table 2. Efficacy of herbicides against *V. persica* after 14 and 28 days of treatment

Treatment with	Dose f.p.1 (l/ha)	Dose a.i.2 g/ha	After 14 days of treatment		After 28 days of treatment	
			Pre emergence	Early postemergence	Pre emergence	Early postemergence
			Efficacy (%) Ground coverage untreated (%)			
			18.75	21.25	30.50	35.75
Untreated	-	-	0.0c	0.0d	0.0c	0.0d
Dimethenamid-P + Metazachlor + Quinmerac	2.5	1250	96.13a	86.15a	96.68a	95.01a
Metazachlor + Quinmerac	2.0	1000	82.33b	74.77b	85.92b	85.64bc
Metazachlor	1.5	750	72.87b	61.44c	81.80b	79.31c
LSD (P=.05)			6.4-10.5	5.7-7.3	5.8-8.5	4.8-7.0
Standard deviation			4.775t	2.877t	4.638t	3.512t

[1]f.p. = Formulated product/ha; [2]a.i. = Active ingredient/ha

Mazandaran and Qazvin provinces in Iran. Krawczyk & Adamczewski (2002) have reported that that herbicides control the weeds very well in the canola fields, including *Galium* spp., *Veronica* spp., and *Stellaria* spp. Butisan Top has been recommended for use in the canola fields by Palmer (1994) at 1.5 L/ha; Montvilas (1997) Hallgren (1991) and Petzoldt & Muhling (1984) at 2 L/ha; Bernotas & Kalvaitiene (1997), Person (1996) at 2.5 L/ha and Roslin (1991), at 3 L/ha.

Quinmerac is a quinolinecarboxilic acid herbicide, a systemic, synthetic auxin that controls broadleaf weeds, including *G. aparine* and *Veronica* spp. (Tomlin 2004). Studies on the mode of action of quinmerac indicate that it has auxin effect. This, in turn, stimulates the production of ethylene, which again is positively correlated with the susceptibility of the species to quinmerac. Visual symptoms are inhibition of root growth, stunting of the shoot, epinasty.

Fig. 3. *V. persica* in untreated plot after 42 days application at preemergence.

The best results have been obtained in the case of the herbicide Butisan Avant, with three active substances (Dimethenamid-P + Metazachlor + Quinmerac), both at pre emergence and at early postemergence application. An advantage of the suspoemulsion formulation of Butisan Avant is that under most conditions season-long control of weeds is obtained by just one application of the formulation. Dimethenamid-p (DMTA-p), a formulated active isomer of the herbicide dimethenamid (Courdechet & al. 1997), is a chloroacetamide which after 42 days of treatment controls the same range of broadleaf and grass weeds as metazachlor. DMTA-p products are less affected by drier conditions, a common occurrence in early autumn.

DMTA-p is taken up by both roots and young shoots of the weed; metazachlor is taken by the roots. (Tomlin 2004). DMTA-p is not so reliant on 'chasing'

Table 3. Efficacy of herbicides against *V. persica* after 42 days of treatment

Treatment name	Dose (l/ha)	Pre emergence	Early postemergence
		Efficacy (%) Ground coverage untreated (%)	
		37.20	50.50
Untreated	-	0.0d	0.0c
Butisan Avant	2.5	82.03a	66.16a
Sultan Top	2.0	61.07bc	50.55b
Butisan	1.5	56.27c	40.72b
LSD (P=.05)		4.8 – 5.8	12.4 – 12.7
Standard deviation		2.233t	4.755t

Fig. 4. *V. persica* in untreated plot after 42 days of treatment at early postemergence.

the roots deep down in the soil but waits for the shoots to reach it.

Herbicidal effect of Butisan Avant was manifested for a longer period so that even after 42 days of application the efficacy was 82% for pre emergency treatment and 66% for early postemergence treatment (Table 3).

No phytotoxicity symptoms have been found in the experimental plots. No symptoms have been observed, such as chlorosis, necrosis and deformation of leaves, as well as reduction of the plant height, or distortion and delay of anthesis.

Conclusions

Invasive species represent some of the main threats to agrobiodiversity, causing very high losses in agricultural production.

Increasing losses in the rapeseed crops are caused by *V. persica*, because the weed's germination period coincides with the germination period of rapeseed.

In the winter rape crop of this experiment, the degree of weed infestation with *V. persica* has been very high, because ground coverage in untreated plots after 42 days of treatment exceeded 50%.

The applied agrotechnical measures have reduced the biological reserve of weed seeds but failed to stop the growth and reproduction of the invasive weed species in the rape crop.

The applied herbicides in rape crop had a good efficacy in the control of *V. persica.* After 42 days of treatment metazachlor had low efficacity in the control of *V. persica.*

Herbicide with two active substances (375 g/L Metazachlor + 125 g/L Quinmerac) had better efficacy in controlling *V. persica,* as compared to metazachlor, especially in early postemergence.

The best results were obtained in the case of herbicide with 3 active substances.

The main advantage of the suspoemulsion formulation of herbicide Butisan Avant is that under most conditions season-long control of weeds is obtained by just one application of the formulation.

No phytotoxicity symptoms have been traced down in the experimental plot.

Control of invasive species in the rape crops is necessary, due to the high cost of production related to decreased productivity and because rape is grown in dense rows that do not allow mechanical processing.

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