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The efficiency of organic herbicide Segador in controlling growth and regrowth of Curly Dock (*Rumex crispus* L.) in non-cropped areas

Plamen Marinov-Serafimov* and Irena Golubinova
Institute of Forage Crops, 89 „Gen. Vladimir Vazov" Str., Pleven 5800, Bulgaria

Abstract

Rumex crispus L. is an invasive weed species, widespread in Republic of Bulgaria. Owing to its great reproductive potential and high biological and ecological plasticity, the weed has been assigned to the list of economically most important weeds in the country. With the purpose of studying the possibility of weed control in non-cropped areas with heavy natural background infestation with *R. crispus* a field trials were carried out. Organic herbicide trade product Segador was tested at two doses 5.0 and 8.0% with the addition of the surfactant Silwet L-77 at a dose 0.1 l/ha. It was found that: (1) The degree of infestation with *R. crispus* in non-cropped areas can be successfully reduced by treatment with Segador (organic fertilizer with a contact herbicide against weeds effect); (2) treatment of *R. crispus* with trade product Segador must be carried with a 8.0% solution at early growth stages (BBCH 12-14) by the development of weeds; (3) twenty-one days after application with Segador (applicated as 8.0% solution) efficacy of the product ranges from 97.5 to 100% and there was only 7.8 – 9.1% regeneration of *R. crispus* The addition of a surfactant Silwet L-77 at a dose of 0.1 l/ha increases the efficiency of trade product Segador.

Key-Words: *Rumex crispus* L., Organic herbicide, Segador, Non-cropped areas

Introduction

Rumex crispus L. is an invasive weed species, widespread in Republic of Bulgaria (Dimitrova and Serafimov, 2008; Raycheva, 2006 and 2009). Tonev (2000) it is listed in a group of one hundred most economically important weeds characterized by high biological and ecological plasticity. *Rumex obtusifolius* L. classified as one of the most problematic weeds in the pasture, and colonize perennial plants where they can grow for ten years or more (Carmona, 1993; Brant et al., 2006; Pye, 2008; Martinkova et al., 2009a; 2009b; Hejcman et al., 2012**;** Hujerová et al., 2015). It was found that in the rotation of lucerne and winter grain cereal crops, 64% of the weed survive after each plowing (Pino, 1995). According to studies of a number of authors (Humpreys et al., 1999; Benvenuti, et al, 2001; Hopkins and Johnson 2002; Van Eekeren and Jansonius 2005; Van Eekeren et al., 2006; Dimitrova and Marinov-Serafimov, 2008; DiTomaso et al., 2013) in traditionally managed grasslands and in non-cropped areas, species of the genus *Rumex* can be controlled by selective herbicides.

*** Corresponding Author**
E.mail: plserafimov@abv.bg

At organic farming, however, the use of herbicides for weed control against species of the genus *Rumex* been banned and the may be used only biological or mechanical methods for weed control (Foster, 1989; Freese, 1995; Hatcher et al., 2007; Strnad et al., 2010; Latsch and Sauter, 2014; Zaller, 2004). The importance of the successful control of the species of the genus *Rumex* with the use of herbicides has attracted the attention of many researchers (Knezevic et al., 2003; Rurac et al., 2013; Khan, 2003; Boutin et al., 2012), but there are no data on the use of organic herbicides with the contact action, which can be used for weed control in farms in the period of conversion to biological (organic) agriculture production.

Many methods were being developed to reduce the use of herbicides and notably organic herbicides were developed to have the same herbicidal effect but without the side effects from the organic herbicides (Cheng, 2014).

According to manufacture label (SEGADOR, ETIQUETA, 2010) Segador is organic fertilizer with a non-selective contact herbicide effect against weeds. Segador is a complex natural hydroxyphosphate, in the form of an emulsion, and natural surfactant depressor of water activity that and thus causing desiccation of the plant cell. Contains phosphorus (P_2O_5) 25.5% water-soluble and zinc (Zn) water-soluble 0.20%. The action of the product depends on the dosage of administration.

The objective of this study was to test organic herbicide Segador (organic fertilizer with a contact herbicide effect against weeds) as a means of control on the growth and regrowth of *Rumex crispus* L. in noncropped areas.

Material and Methods

The experimental work was conducted during the period 2014 - 2015 in non-cropped area with natural background infestation with *Rumex crispus* L. in village Gorna Lipnitsa, area Veliko Tarnovo, Bulgaria (43^0 17' 56.31" N, 25^0 23' 35.96" E, 145 m.a.s.l.) (Fig.1).

The trial was laid out in a block design with four replications and plot size of 10 m^2. The study was conducted with organic herbicide Segador and Silwet L-77 as surfactant. In the trial Reglone Forte was used as a standard. Trial treatments and product characteristics are shown in Table 1.

The applied products and standard rates were as recommended by their manufacturers and were applied with a working solution quantity of 400 l/ha.

Treatments were conducted with a knapsack sprayer "ptp 18" with conic nozzle, pressure P max 3 bar, V max 1.68 l, and Q max 0.65 l/min.

All parameters were defined of 7, 14 and 21 days after application (DAA) for all treatments in the trial.

Efficacy was reported in eight permanent 1 m^2 for each replication according to a 9 score scale of EWRS (0-100% weed control = score 9-1) (Puntener, 1981);

Vigor of the weed was determined according to a 10 score scale, where 0 = completely dead plants and 10 = very healthy growing plants (Shinggu et al., 2009).

Ground cover of the weeds was determined visually and was recorded on a scale of 0-100% (0- no plants, 100% very healthy plants - covering the entire surface area) (Malthus et al., 2013, Fontenot et al., 2015).

For the characterization of the arid/humid characteristic during the study period was used index De Martonne's (I_{DM}). To determine arid/humid characteristic of a specific month, was calculated by Equation (1) (Coscarelli et al., 2004).

$$I_{DM} = \frac{12 P_i}{T_{ai} + 10} \quad (1)$$

where P_i is the monthly amount of precipitation (in millimeters) and T_{ai} is the mean monthly air temperature (in degree Celsius) recorded in the considered month, 12 and 10 are constants.

For seasonal aridity, the index was calculated by Equation (2) (Croitoru et al., 2013).

$$I_{DM} = \frac{3 P_s}{T_{as} + 10} \quad (2)$$

where P_s is the seasonal amount of precipitation (in millimeters) and T_{as} is the mean seasonal air temperature (in degree Celsius) for the analyzed season, 3 and 10 are constants.

All data were analyzed using Statistica version 10 software. Means separated using Fisher's protected least significant difference when F tests were significant at α=0.05.

Results and Discussion

During the study period the average monthly air temperatures are characterized by higher values of 0.4 to 3.0 ^{0}C (Table 2). The monthly sums of precipitation had strong variability - with increased values from 38.6 to 82.3% and decreased from 1.6 to – 65.5% in comparison with multi-annual period - 1961-2011.

There is a trend with small changes in temperature and stronger variability in rainfall in comparison with the multi-annual period 1961-2011.

According to De Martonne's (1920) global classification the I_{DM} (adapted after Baltas, 2007) the study period during the growing season of *R. crispus* can be classified: 2014 is very humid ($35.0 \leq I_{DM} \leq 55.0$) ($I_{DM\ 2014}$ = 37.0) and 2015 is mediterranean ($20.0 \leq I_{DM} < 24.0$) ($I_{DM\ 2015}$ = 21.4).

The degree of weed infestation of *Rumex crispus* L. in the trial area is relatively high - 34.5 to 44.5 plants/m^2, which is a prerequisite for a realistic assessment to determine the efficacy of organic herbicide Segador (Table 3 and Table 4).

There is a high initial effect seven days after application (7 DAA) with organic herbicide Segador in at both growth stage and development of *R. crispus* - BBCH 12-14 and BBCH 15-16. The herbicide effect of the trade product Segador expressed rapid initiation effect of desiccation and defoliation on plants of *R. crispus*.

The efficacy of the product Segador applied against *R. crispus* seven days after application (7 DAA) in dose 5.0% of a solution varies from to 85.0 to 86.6%, with increasing concentration (8.0%) efficiency increases to 94.4%. The addition of surfactant Silwet L-77 the efficiency of Segador increased at both concentrations of application, independently from growth stages of *R. crispus*. Seven days after application (7 DAA) herbicide efficacy of the trade product Segador is equalized on efficacy to standard - Reglone Forte, but only at the higher concentration (8.0%) of the application (Table 4).

High efficacy was observed in the recording fourteen and twenty-one days after application (14 and 21 DAA) of Segador at both growth stages (BBCH 12-14 and BBCH 15-16) at the development on *R. crispus*.

Completely killed plants reached 100% at the treatment - Segador applied in dose 8.0% with surfactant Silwet L-77 (in dose 0.1 l/ha) in growth stage BBCH 12-14 at the development on *R. crispus* and standard Reglone Forte.

Herbicide efficiency was relatively low in treatments - Segador applicated in dose 8.0% and - Segador applicated in dose 5.0% solution + Silwet L-77 in dose 0.1l/ha, killed the *R. crispus* from 96.3 to 96.9% at both growth stages (BBCH 12-14 and BBCH 15-16) at the development of the weeds.

Herbicide efficacy was the lowest from 88.1 to 91.3% in treatment - Segador applicated dose in 5.0% at both growth stage at the development of the *R. crispus*.

A characteristic biological feature of the *R. crispus* is its high regenerative ability (Pye, 2008; Zaller, 2004; Strnad et al., 2012; Hujerová et al., 2015).

Twenty-one days after application (21 DAA) regenerated plants range from 7.8 to 12.7% when treated in the growth stage BBCH 12-14, and 6.8% for standard (Reglone Forte). Regeneration was considerably higher from 38.7 to 48.0%, for treatment at the growth stage BBCH 15-16, as compared to standard - 20.0% (Table 4).

Therefore, control of *R. crispus* was more successful with the trade product Segador when weeds are treated in early growth stages (BBCH 12-14) with a higher dose (8.0%) of the product and/or a surfactant is added at a dose Silwet L-77 0.1 l/ha). Twenty-one days after application (21 DAA) of Segador (applicated at 8.0% solution) in growth stage (BBCH 12-14) of *R. crispus* efficacy of the product ranges from 96.9 to 100.0% and there was only 7.8 - 9.1% regeneration of the weed.

On the base on a complex evaluation of the efficacy data (under EWRS score and regrowing, % over *R. crispus* on fourteen and twenty-one days after application (14 and 21 DAA) organic herbicide applied in the grow stage BBCH 12-14 on the weeds) the most effective treatments were Segador (8.0% + Silwet L-77 - EWRS score 1.0 and 7.8% regrowing, followed by treatments Segador (8.0%) and Segador (5.0%) + Silwet L-77 - EWRS score 1.31 and regrowing from 9.1 to 9.8%.

High efficacy is fourteen and twenty-one days after application (14 and 21 DAA) (under EWRS score) and higher regrowing (in percentage) of *R. crispus* were treatments Segador (8.0%) + Silwet L-77 - EWRS score 1.0 and 38.7% regrowing followed by treatment Segador (8.0%) and Segador (5.0%) + Silwet L-77 - EWRS score from 1.31 to 1.38 and regrowing from 39.1 to 42.3%) in the application of organic herbicide in the grow stage BBCH 15-16 at the development of *R. crispus*.

Less effective and at a high rate of regrowing *R. crispus* was in the treatment Segador (5.0%), EWRS score from 1.88 to 2.19 and regrowing ranged from 12.7 to 48.0% depending on growth stage BBCH 12-14 and BBCH 15-16 of the weed.

Was established correlation between efficiency and vigor of the *R. crispus* twenty-one days after application (21 DAA) depending on the grow stage of application BBCH 12-14 - r = -0.910 and BBCH 12-14 - r = -0.921 and between efficacy of the product and ground cover of the *R. crispus* r = -0.914.

Population density of *R. crispus* in non-cropped areas can be successfully reduced by treatment with organic herbicide Segador (organic fertilizer with a contact herbicide against weeds effect) with a higher dose (8.0%) when *R. crispus* are treated in early growth stages (BBCH 12-14) and/or a surfactant is added Silwet L-77 at a dose 0.1 l/ha).

Trade product Segador can be used successfully to control *R. crispus* in non-cropped areas in farms in the period of conversion to biological (organic) agriculture production.

Conclusion

The degree of infestation with *Rumex crispus* L. in non-cropped areas can be successfully reduced by treatment with an organic herbicide Segador (organic fertilizer with a contact herbicide against weeds effect).

Treatment of *Rumex crispus* L. with Segador must be carried out with an 8.0% solution at early growth stages (BBCH 12-14) by the development of weed.

Twenty-one days after plication with Segador (applicated as 8.0% solution) efficacy of the product ranges from 97.5 to 100.0% and there was only 7.8 – 9.1% regeneration of *Rumex crispus* L. The addition of a surfactant Silwet L-77 at a dose of 0.1 l/ha increases the efficiency of trade product.

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Fig. 1. Location of the trial

Table 1: Trial treatments and product characteristics

Trial treatments		Active Ingredient (s)	Chemical family	Density, g/cm^3	Application	
					Dose of commercial product, l (%)/ ha	Growth stage, BBCH*
T$_1$	Control (untreated)	-	-	-	-	12-16
T$_2$	Reglone Forte (standard)	150 g/l diquat	bipyridylium	1.144	3.0 l/ha	12-16
T$_3$	Segador	phosphorus (P_2O_5) 25.5% water-soluble and zinc (Zn) water-soluble 0.20%	natural hydroxyphos-phate	1.109	5.0%	12-16
T$_4$	Segador				8.0%	12-16
T$_5$	Segador Silwet L-77	phosphorus (P_2O_5) 25.5% water-soluble and zinc (Zn) water- soluble 0.20% siloxane polyalkyleneoxide copolymer	natural hydroxyphos-phate trisiloxane ethoxylate	1.109 1.0070	5.0% 0.1 l/ha	12-16
T$_6$	Segador Silwet L-77	phosphorus (P_2O_5) 25.5% water-soluble and zinc (Zn) water- soluble 0.20% siloxane polyalkyleneoxide copolymer	natural hydroxyphos-phate trisiloxane ethoxylate	1.109 1.0070	8.0% 0.1 l/ha	12-16

**BBCH scale—general for the descriptions of the growth stages of mono; and dicotyledonous weed species,* Hess et al. (1997)

Table 2: Meteorological conditions during the study period

Period	Months				For the period IV – VII
	IV	V	VI	VII	
Mean monthly air temperature, t^0 *C*					t^0 *C*
2014	13.2	17.8	21.6	23.4	19.0
2015	12.4	19.8	21.0	25.6	19.7
1961-2011	12.0	16.9	20.5	22.6	18.0
Monthly amount of precipitation, *mm*					*mm*
2014	68.0	93.0	91.0	106.0	358.0
2015	40.0	66.0	86.0	20.0	212.0
1961-2011	48.7	67.1	58.1	58.0	231.9
De Martonne aridity index, I_{DM}					I_{DM}
2014	35.2	40.1	34.6	38.1	37.0
2015	21.4	26.6	33.3	6.7	21.4
1961-2011	26.6	29.9	22.9	21.3	24.8

Table 3: Weed infestation of Curly Dock (*Rumex crispus* L.) in the trial area, average for the period 2013-2014

Trial treatments**		T_1		T_2		T_3		T_4		T_5		T_6	
0 DBA	BBCH	12-14	15-16	12-14	15-16	12-14	15-16	12-14	15-16	12-14	15-16	12-14	15-16
	Number, m^2	23.5	14.0	22.0	12.5	27.5	12.5	33.0	11.5	25.5	13.0	25.5	15.5
	Total number for treatment. m^2	37.5		34.5		40.0		44.5		38.5		41.0	
	Vigor of the weed	10	10	10	10	10	10	10	10	10	10	10	10
	Ground cover of the weed	80		70		80		70		70		80	

*Legend: ** Treatments are the same as in Table 1; DBA - days before applications; BBCH scale—general for the descriptions of the growth stages of mono; and dicotyledonous weed specie, Hess et al. (1997); Vigor of the weed (0 = completely dead plants and 10 = Very healthy growing plants); Ground cover of the weed were recorded on a scale of 0-100% (0- no plants. 100% very healthy plants - covering the entire surface area)*

Table 4: The efficiency of organic herbicide Segador in controlling growth and regrowth of Curly Dock (*Rumex crispus* L.) in noncropped areas (average for the period 2013-2014)

Trial treatments**	Number, m^2	BBCH	Efficacy, %	EWRS *	Vigor of the weed	Ground cover of the weed	Regrowing,%	Number, m^2	BBCH	Efficacy, %	EWRS *	Vigor of the weed	Ground cover of the weed	Regrowing, %	Number, m^2	BBCH	Efficacy, %	EWRS *	Vigor of the weed	Ground cover of the weed	Regrowing,%
	7DAA							14DAA							21DAA						
T_1	23.5	12-14	0.0a	9.0d	10.0d	80	-	23.5	12-14	0.0a	9.0d	10.0e	80	-	26	12-14	0.0a	9.0d	10.0e	85	-
	14.0	15-16						14.0	15-16						15.5	15-16					
T_2	22.0	12-14	95.6d	1.44a	0.44a	5	0.0b	22.0	12-14	100.0d	1.00a	0.00a	1	4.5a	22.0	12-14	100.0d	1.00a	0.00a	1	6.8a
	12.5	15-16	95.0d	1.38a	0.50a		00.0b	12.5	15-16	100.0d	1.00a	0.00a		12.0d	12.5	15-16	100.0d	1.00a	0.00a		20.0d
T_3	27.5	12-14	85.0d	2.50c	1.50c	15	00.0b	27.5	12-14	91.3b	1.88c	0.88cd	10	9.1c	27.5	12-14	91.3b	1.88c	0.88cd	10	12.7c
	12.5	15-16	86.6d	2.44c	1.75c		12.0a	12.5	15-16	88.1b	2.19c	1.19d		36.0g	12.5	15-16	88.1b	2.19c	1.19d		48.0g
T_4	33.0	12-14	94.4cd	1.56ab	0.56a	6	00.0b	33.0	12-14	96.9cd	1.31ab	0.31ab	3	6.1ab	33.0	12-14	96.9cd	1.31ab	0.31ab	3	9.1ab
	11.5	15-16	93.8cd	1.63ab	0.63a		00.0b	11.5	15-16	96.9cd	1.31ab	0.31ab		21.7e	11.5	15-16	96.9cd	1.31ab	0.31ab		39.1e
T_5	25.5	12-14	91.9cd	1.81ab	0.81ab	8	00.0b	25.5	12-14	96.9cd	1.31ab	0.31ab	3	7.8bc	25.5	12-14	96.9cd	1.31ab	0.31ab	3	9.8b
	13.0	15-16	88.8bc	2.13bc	1.25bc		00.0b	13.0	15-16	96.3c	1.38b	0.50bc		26.9f	13.0	15-16	96.3c	1.38b	0.50bc		42.3f
T_6	25.5	12-14	95.0d	1.50a	0.50a	5	00.0b	25.5	12-14	100.0d	1.00a	0.00a	1	5.9ab	25.5	12-14	100.0d	1.00a	0.00a	1	7.8ab
	15.5	15-16	93.8cd	1.63ab	0.63a		00.0b	15.5	15-16	100.0d	1.00a	0.00a		19.4e	15.5	15-16	100.0d	1.00a	0.00a		38.7e

*Legend: ** Treatments are the same as in Table 1; DAA - days after applications; BBCH scale—general for the descriptions of the growth stages of mono; and dicotyledonous weed species, Hess et al. (1997); Means with different letters differ at P=0.05 level of probability by LSD test;* EWRS (European Weed Research System) scales for weed control efficacy (1 = total control, 9 = no effect on weeds); Vigor of the weed (0 = completely dead plants and 10 = Very healthy growing plants); Ground cover of the weed were recorded on a scale of 0-100% (0- no plants, 100% very healthy plants - covering the entire surface area).*

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