



## Production Systems

# Efficacy of herbicides, herbicide combinations and herbicide tank mixtures on lentil (*Lens culinaris* Medik.)

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**Abstract.** The research was conducted during 2019 - 2022 on pellic vertisol soil type. Under investigation was lentil cultivar *Ilina* (*Lens culinaris* Medik.). A total of 23 variants were investigated: untreated control, 8 herbicides – Pendistar 40 SC (pendimethalin), Dual gold 960 EC (S-metolachlor), Lentagran VP (pyridate), Challenge 600 SC (aclonifen), Zencor 600 SC (metribuzin), Wish top (quizalofop-P-ethyl), Zetrola (propaquizafop) and Passat 40 (imazamox), as well as combinations and tank mixtures between them. Soil-applied herbicides were used during the period after sowing before emergence. Foliar-applied herbicides were used during 2-3, 4-5 or 6-7 real leaf stage of the lentil. All of the herbicides, herbicide combinations and herbicide tank-mixtures were applied in a working solution of 300 l/ha. Mixing of foliar-applied herbicides was done in the tank on the sprayer. The combinations of herbicide Lentagran with soil-applied herbicides Pendistar and Dual gold, as well as herbicides Challenge with foliar-applied herbicides Wish top and Zetrola had an additive effect on herbicide efficacy. The herbicides Lentagran and Zencor, as well as their combinations, successfully controlled Clearfield and ExpressSun sunflower self-sown plants in lentil crops. The foliar-applied herbicide Passat controlled all annual and perennial broadleaved and graminaceous weeds and self-sown plants. The use of foliar-applied herbicide Passat and soil-applied herbicide Zencor at a dose of 900 g/ha led to high phytotoxicity in lentil plants – rate 3 according to the scale of EWRS. Double use of Zencor at doses of 600 + 300 g/ha and the combined use of the herbicides Challenge and Zetrola led to low phytotoxicity in lentil – rate 2 according to the scale of EWRS. The highest yields of lentil seeds were obtained by use of herbicide combinations Pendistar 5 l/ha + Lentagran 500 + 500 ml/ha and Pendistar 5 l/ha + Lentagran 1 l/ha. High yields were also obtained when combining Challenge 3 + 1 l/ha with Wish top 1.25 l/ha, as well as by the herbicide combination Challenge 4 l/ha + Wish top 1.25 l/ha.

**Keywords:** lentil, herbicides, herbicide combinations, efficacy, selectivity, seed yield

## Introduction

The use of herbicides provides producers with simple, easy and efficient weed control and leads to improved yields (Ali et al., 2014; Ahmadi et al., 2016; Jaswal and Menon, 2020). Although herbicides have many advantages, there are disadvantages to their increased use. Repeated use of the same herbicidal mode of action leads to the creation of a weed population that is no longer controlled by this herbicidal mode of action (Chaudhary et al., 2011; Dhuppar and Sarveshwara, 2013; Delchev, 2018).

Weather conditions often affect the efficacy and selectivity of herbicides (Sarker and Erskine, 2006; Jain, 2007; Reddy and Rebbly, 2010; Singh et al., 2014; Delchev, 2021). For example, when metribuzin is applied at the

recommended doses, it provides efficacy weed control, but can cause crop damage under stressful conditions such as cold weather and low humidity. Also, although imazethapyr has excellent control of broadleaved weeds even in systems without tillage or minimal tillage, in cold and humid conditions occurring within one week of application, it can seriously damage the crop.

Lentil producers have a number of herbicide options for controlling graminaceous weeds, but the same cannot be said for controlling broadleaved weeds. The number of registered antibroadleaved herbicides for use in lentil is very limited (Yadav et al., 2013; Kumar et al., 2018). The introduction in 2006 of Clearfield lentil, which uses imidazolinone-resistant cultivars – to herbicides imazamox and imazethapyr, is a major

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step forward in controlling broadleaved weeds in lentil (Beckie and Reboud 2009; Fedoruk et al., 2011; Fedoruk and Shirliffe, 2011). In most countries around the world, lentil is already grown using Clearfield technology. The application of herbicides on Clearfield lentil during the 5-6-leaves stage provides the best weed control and the highest yield. There are still no registered lentil cultivars for this technology in Bulgaria. On the other hand, herbicides based on imazethapyr – Pivot, Speed – were banned for use in Bulgaria.

The purpose of this investigation was to establish the efficacy and selectivity of some herbicides, herbicide combinations and herbicide tank mixtures on the lentil by influence of different meteorological conditions.

## Material and methods

The research was conducted during 2019 - 2021 in Chirpan region, on pellic vertisol soil type. Under investigation was lentil cultivar Ilna (*Lens culinaris* Medik.). A field experiment was carried out under the block method, in 4 repetitions; the size of the crop plot being 15 m<sup>2</sup>. A total of 23 variants were investigated: untreated control, 8 herbicides – Pendistar 40 SC, Dual gold 960 EC, Lentagran VP, Challenge 600 SC, Zencor 600 SC, Wish top, Zetrola and Passat 40, as well as combinations and tank mixtures between them. Active substances of herbicides, their doses and treatment periods are shown in Table 1.

**Table 1.** Investigated experimental variants

No	Variants	Active substance	Doses	Treatment periods
1	Control	-	-	-
2	Pendistar 40 SC	pendimethalin	5 l/ha	ASBE
3	Dual gold 960 EC	S-metolachlor	1.2 l/ha	ASBE
4	Lentagran VP	pyridate	1 l/ha + 1 l/ha	3-4 leaf + 6-7 leaf
5	Lentagran VP	pyridate	750 ml/ha + 500 ml/ha + 500 ml/ha	2-3 leaf + 4-5 leaf + 6-7 leaf
6	Pendistar 40 SC + Lentagran VP	pendimethalin + pyridate	5 l/ha + 1 l/ha	ASBE + 6-7 leaf
7	Dual gold 960 EC + Lentagran VP	S-metolachlor + pyridate	1.2 l/ha + 1 l/ha	ASBE + 6-7 leaf
8	Pendistar 40 SC + Lentagran VP	pendimethalin + pyridate + pyridate	5 l/ha + 500 ml/ha + 500 ml/ha	ASBE + 4-5 leaf + 6-7 leaf
9	Dual gold 960 EC + Lentagran VP	S-metolachlor + pyridate + pyridate	1.2 l/ha + 500 ml/ha + 500 ml/ha	ASBE + 4-5 leaf + 6-7 leaf
10	Wish top	quizalofop-P-ethyl	1.25 l/ha	3-7 leaf
11	Zetrola	propaquizafop	1.6 l/ha	3-7 leaf
12	Challenge 600 SC	aclonifen	4 l/ha	ASBE
13	Challenge 600 SC	aclonifen	3 l/ha + 1 l/ha	ASBE + 3-7 leaf
14	Challenge 600 SC + Wish top	aclonifen + quizalofop-P-ethyl	4 l/ha + 1.25 l/ha	ASBE + 3-7 leaf
15	Challenge 600 SC + Zetrola	aclonifen + propaquizafop	4 l/ha + 1.6 l/ha	ASBE + 3-7 leaf
16	Challenge 600 SC + Wish top	aclonifen + aclonifen + quizalofop-P-ethyl	3 l/ha + 1 l/ha + 1.25 l/ha	ASBE + 3-7 leaf + 3-7 leaf
17	Challenge 600 SC + Zetrola	aclonifen + aclonifen + propaquizafop	3 l/ha + 1 l/ha + 1.6 l/ha	ASBE + 3-7 leaf + 3-7 leaf
18	Zencor 600 SC	metribuzin	900 ml/ha	ASBE
19	Zencor 600 SC	metribuzin	600 ml/ha + 300 ml/ha	ASBE + 3-7 leaf
20	Zencor 600 SC	metribuzin	350 ml/ha	ASBE
21	Zencor 600 SC + Wish top	metribuzin + quizalofop-P-ethyl	350 ml/ha + 1.25 l/ha	ASBE + 3-7 leaf
22	Zencor 600 SC + Zetrola	metribuzin + propaquizafop	350 ml/ha + 1.6 l/ha	ASBE + 3-7 leaf
23	Passat 40	imazamox	1.2 l/ha	3-7 leaf

Herbicide Passat 40 was used in addition with adjuvant Dash HC – 1 l/ha.

Soil-applied herbicides were used during the period after sowing before emergence. Foliar-applied herbicides were used during 2-3, 4-5 or 6-7 real leaf stage of the lentil. All of the herbicides, herbicide combinations and herbicide tank-mixtures were applied in a working solution of 300 l/ha. Mixing of foliar-applied herbicides was done in the tank on the sprayer. Due to low adhesion of the herbicide Passat 40 it was used in addition with adjuvant Dash HC – 1 l/ha.

The efficacy and selectivity of herbicides, herbicide combinations and herbicide tank mixtures was investigated. Their influence on seed yield was established. Efficacy of herbicides against weeds and self-sown durum wheat was determined according to the 100% scale of EWRS (European Weed Research Society). Selectivity of herbicides to lentil plants was followed according to the 9-rate scale of EWRS (rating 1 - without damages, rating 9 - crop is completely destroyed). The mathematical processing was done by analysis of the variance method.

## Results and discussion

Annual broadleaved weeds in the experiment were represented by *Anthemis arvensis* L., *Chamomilla recutita* Rauchert, *Galium aparine* L., *Amaranthus retroflexus* L., *Falopia convolvulus* Leve, *Papaver rhoes* L., *Consolida regalis* Gray, *Lamium purpureum* L., *Veronica hederifolia* L.

Annual graminaceous weeds were *Avena fatua* L., *Alopecurus myosuroides* L., *Lolium multiflorum* L., *Bromus arvensis* L.

Perennial broadleaved weeds were *Cirsium arvense* Scop. and *Convolvulus arvensis* L. Perennial graminaceous weeds are *Sorghum halepense* Pers. and *Cynodon dactylon* Pers.

Cereal self-sown plants were represented by durum wheat (*Triticum durum* Desf.), which was grown as a predecessor.

Broadleaved self-sown plants were Clearfield and ExpressSun sunflower hybrids (*Helianthus annuus* L.), grown two years ago as a predecessor of wheat.

Soil-applied herbicide Pendister controlled 100% of annual broadleaved weeds such as *Galium aparine* L., *Amaranthus retroflexus* L., *Chenopodium album* L., *Anthemis arvensis* L. and *Veronica hederifolia* L. (Table 2). It controlled 85% of *Galium aparine* L. and *Papaver rhoes* L. This herbicide had low efficacy of 35 – 40% against *Falopia convolvulus* Leve and *Lamium purpureum* L.

Soil-applied herbicide Dual gold controlled 100% of *Galium aparine* L., *Anthemis arvensis* L., *Lamium*

*purpureum* L., *Amaranthus retroflexus* L., *Chenopodium album* L. It controlled 85 - 95% of weeds such as *Galium aparine* L. and *Papaver rhoes* L. This herbicide had low efficacy of 30% against *Falopia convolvulus* Leve and *Veronica hederifolia* L. and was inefficient against *Consolida regalis* Gray.

Herbicide Lentagran applied twice in doses of 1 l/ha during 3-4 leaf stage + 1 l/ha during 6-7 leaf stage had 100% efficacy against *Galium aparine* L., *Anthemis arvensis* L., *Chamomilla recutita* Rauchert, *Consolida regalis* Gray. This herbicide controlled 90-95% of weeds such as *Papaver rhoes* L., *Amaranthus retroflexus* L., *Falopia convolvulus* Leve, *Veronica hederifolia* L., *Lamium purpureum* L. Triple foliar treatment with Lentagran at doses of 750 ml/ha during 2-3 leaf stage + 500 ml/ha during 4-5 leaf stage + 500 ml/ha during 6-7 leaf stage increased the efficacy of the herbicide against *Papaver rhoes* L., *Falopia convolvulus* Leve, and *Veronica hederifolia* L., and controlled 100% of *Amaranthus retroflexus* L and *Lamium purpureum* L.

The combinations of foliar-applied herbicide Lentagran with the soil-applied herbicides Pendistar and Dual gold had additive effect in terms of their efficacy against annual broadleaved weeds.

Herbicide Challenge applied at a dose of 4 l/ha during the period after sowing before the emergence of the lentil, successfully controlled almost all annual broadleaved weeds. This herbicide controlled 90 – 98% of weeds such as *Papaver rhoes* L., *Chamomilla recutita* Rauchert, *Falopia convolvulus* Leve, *Veronica hederifolia* L. Double application of Challenge in doses 3 l/ha during the period after sowing before emergence period + 1 l/ha during 3-7 leaf stage increased herbicide efficacy against *Papaver rhoes* L. and *Veronica hederifolia* L.

Herbicide Zencor applied at dose 900 ml/ha during the period after sowing before the emergence of the lentil, controlled 100% of weeds such as *Galium aparine* L., *Chamomilla recutita* Rauchert, *Anthemis arvensis* L., 98% - *Papaver rhoes* L. and *Veronica hederifolia* L., 92% - *Falopia convolvulus* Leve, 88% - *Amaranthus retroflexus* L. Zencor was not efficient against *Consolida regalis* Gray. Double application of Zencor at doses 600 ml/ha during the period after sowing before emergence of the lentil + 300 ml/ha during 3-7 leaf stage reduced the efficacy of the herbicide against early spring weeds and winter-spring ephemerals, and increased its efficacy against late spring weeds. The minimum use of Zencor at dose 350 ml/ha during after sowing before emergence reduced the efficacy of the herbicide against all annual broadleaved weeds.

**Table 2.** Efficacy of some herbicides, herbicide combinations and herbicide tank mixtures against annual broadleaved weeds and self-sown plants in lentil according to the 100 % visual scale of EWRS (mean 2019 - 2021)

Variants	Weeds									
	<i>Galium aparine</i>	<i>Chamomilla recutita</i>	<i>Papaver rhoeas</i>	<i>Consolida regalis</i>	<i>Amaranthus retroflexus</i>	<i>Anthemis arvensis</i>	<i>Falopia convolvulus</i>	<i>Veronica hederifolia</i>	<i>Lamium purpureum</i>	<i>Helianthus annuus</i> *
Control	0	0	0	0	0	0	0	0	0	0
Pendistar 5 l/ha	85	100	85	30	100	100	40	100	35	0
Dual gold 1.2 l/ha	85	100	90	0	100	100	30	30	100	0
Lentagran 1+1 l/ha	100	100	95	100	95	100	90	93	95	100
Lentagran 750+500+500 ml/ha	100	100	98	100	100	100	94	95	100	100
Pendistar 5 l/ha + Lentagran 1 l/ha	100	100	95	100	100	100	90	100	95	100
Dual gold 1.2 l/ha + Lentagran 1 l/ha	100	100	95	100	100	100	90	93	100	100
Pendistar 5 l/ha + Lentagran 500+500 ml/ha	100	100	98	100	100	100	94	100	100	100
Dual gold 1.2 l/ha + Lentagran 500+500 ml/ha	100	100	98	100	100	100	94	100	100	100
Wish top 1.25 l/ha	0	0	0	0	0	0	0	0	0	0
Zetrola 1.6 l/ha	0	0	0	0	0	0	0	0	0	0
Challenge 4 l/ha	100	100	95	98	100	100	90	95	100	0
Challenge 3+1 l/ha	100	100	98	98	100	100	90	100	100	0
Challenge 4 l/ha + Wish top 1.25 l/ha	100	100	95	98	100	100	90	95	100	0
Challenge 4 l/ha + Zetrola 1.6 l/ha	100	100	95	98	100	100	90	95	100	0
Challenge 3+1 l/ha + Wish top 1.25 l/ha	100	100	98	98	100	100	90	100	100	0
Challenge 3+1 l/ha + Zetrola 1.6 l/ha	100	100	98	98	100	100	90	100	100	0
Zencor 900 ml/ha	100	100	98	0	88	100	92	98	100	100
Zencor 600+300 ml/ha	90	90	92	0	98	90	100	94	92	100
Zencor 350 ml/ha	75	70	68	0	65	70	82	80	80	100
Zencor 350 ml/ha + Wish top 1.25 l/ha	75	70	68	0	65	70	82	80	80	100
Zencor 350 ml/ha + Zetrola 1.6 l/ha	75	70	68	0	65	70	82	80	80	100
Passat 1.2 l/ha	100	100	100	100	100	100	100	100	100	0

\* - self-sown plants of ClearField and ExpressSun sunflower

The combination of herbicides Lentagran and Zencor with the antigraminaceous herbicides Wish top and Zetrola did not affect their efficacy against annual broadleaved weeds.

Foliar-applied herbicide Passat completely controlled all annual broadleaved weeds available in the experiment.

The seed coat of sunflower hybrids has a thick armored layer consisting of several rows of carbon cells to protect from *Homoeosoma nebulella* D. & S. For this reason, some of these seeds do not germinate next year

in cereal crops but in the year later in lentil crops, and become a major problem during the lentil vegetation and the lentil harvest. Herbicides Lentagran and Zencor as well as their combinations, were the only ones that successfully controlled Clearfield and ExpressSun sunflower self-sown plants in lentil crops.

Soil-applied herbicides Pendister and Dual gold applied during the period after sowing before emergence (ASBE) of lentil, were inefficient against perennial broadleaved weeds *Cirsium arvense* Scop. and *Convolvulus arvensis* L. (Table 3).

**Table 3.** Efficacy of some herbicides, herbicide combinations and herbicide tank mixtures against perennial weeds, annual graminaceous weeds and self-sown plants in lentil according to the 100% visual scale of EWRS and selectivity according to the 9-rate scale of EWRS (mean 2019 - 2021)

Variants	Weeds									
	<i>Cirsium arvense</i>	<i>Convolvulus arvensis</i>	<i>Sorghum helepense</i>	<i>Cynodon dactylon</i>	<i>Avena fatua</i>	<i>Lolium multiflorum</i>	<i>Alopecurus myosuroides</i>	<i>Bromus arvensis</i>	<i>Triticum durum*</i>	Selectivity
Control	0	0	0	0	0	0	0	0	0	1
Pendistar 5 l/ha	0	0	0	0	95	100	100	0	0	1
Dual gold 1.2 l/ha	0	0	0	0	0	100	100	0	40	1
Lentagran 1+1 l/ha	90	90	0	0	0	0	0	0	0	1
Lentagran 750+500+500 ml/ha	100	100	0	0	0	0	0	0	0	1
Pendistar 5 l/ha + Lentagran 1 l/ha	90	90	0	0	95	100	100	0	0	1
Dual gold 1.2 l/ha + Lentagran 1 l/ha	90	90	0	0	0	100	100	0	40	1
Pendistar 5 l/ha + Lentagran 500+500 ml/ha	100	100	0	0	95	100	100	0	0	1
Dual gold 1.2 l/ha + Lentagran 500+500 ml/ha	100	100	0	0	0	100	100	0	40	1
Wish top 1.25 l/ha	0	0	100	100	100	100	100	100	100	1
Zetrola 1.6 l/ha	0	0	100	100	100	92	100	90	100	1
Challenge 4 l/ha	0	0	0	0	40	65	80	0	70	1
Challenge 3+1 l/ha	0	0	0	0	44	70	85	0	75	1
Challenge 4 l/ha + Wish top 1.25 l/ha	0	0	100	100	100	100	100	100	100	1
Challenge 4 l/ha + Zetrola 1.6 l/ha	0	0	100	100	100	92	100	90	100	2
Challenge 3+1 l/ha + Wish top 1.25 l/ha	0	0	100	100	100	100	100	100	100	1
Challenge 3+1 l/ha + Zetrola 1.6 l/ha	0	0	100	100	100	92	100	90	100	2
Zencor 900 ml/ha	0	0	0	0	0	98	98	0	70	3
Zencor 600+300 ml/ha	0	0	0	0	0	90	90	0	70	2
Zencor 350 ml/ha	0	0	0	0	0	65	65	0	55	1
Zencor 350 ml/ha + Wish top 1.25 l/ha	0	0	100	100	100	100	100	100	100	1
Zencor 350 ml/ha + Zetrola 1.6 l/ha	0	0	100	100	100	92	100	90	100	1
Passat 1.2 l/ha	100	100	97	100	100	100	100	100	100	3

\* - self-sown plants of durum wheat

Lentagran is a selective contact herbicide without systemic action. It destroys only the aboveground parts of perennial antibroadleaved weeds. Lentagran controlled these weeds 90% with two treatments and 100% with three treatments.

Foliar-applied herbicide Passat completely controlled all annual broadleaved weeds.

Herbicides Challenge and Zencor were inefficient against perennial broadleaved weeds *Cirsium arvense* Scop. and *Convolvulus arvensis* L.

Foliar-applied herbicides Passat, Wish top and Zetrola successfully controlled perennial graminaceous weeds. The efficiency of Passat only against *Sorghum halepense* Pers. was lower - 97%.

Herbicides Pendistar, Dual gold, Lentagran, Challenge and Zencor were inefficient against perennial graminaceous weeds.

Soil-applied herbicide Pendistar was efficient against all annual graminaceous weeds, except for *Bromus arvensis* L. The herbicide was inefficient against self-sown plants of *Triticum durum* Desf.

Soil-applied herbicide Dual gold was inefficient against annual graminaceous weeds *Bromus arvensis* L. and *Avena fatua* L. It had low efficacy of 40% against self-sown plants of durum wheat (*Triticum durum* Desf.).

Foliar-applied herbicide Lentagran was inefficient against annual graminaceous weeds and against self-sown plants of durum wheat (*Triticum durum* Desf.). It is a typical broadleaved herbicide.

In vegetation treatment, herbicide Challenge was poorly efficient against annual graminaceous weeds. In soil application this herbicide provided good control of these weeds.

Herbicide Zencor was inefficient against *Bromus arvensis* L. Single application of Zencor at dose of 900 ml/ha controlled annual graminaceous weeds such as *Alopecurus myosuroides* L. and *Lolium multiflorum* L. at 98% and self-sown plants of durum wheat at 70%. Double application of Zencor at doses of 600 ml/ha during the period after sowing before the emergence of the lentil + 300 ml/ha during 3-7 leaf stage reduced efficacy of the herbicide against annual graminaceous weeds *Alopecurus myosuroides* L. and *Lolium multiflorum* L. to 90%. Control of self-sown plants of durum wheat was maintained at 70%. The minimum use of Zencor at a dose of 350 ml/ha during the period after sowing before the emergence of the lentil significantly reduced the efficacy of the herbicide against all annual graminaceous weeds and against self-sown plants of durum wheat.

Herbicides Passat and Wish top successfully controlled all annual graminaceous weeds and self-sown

plants of durum wheat.

Herbicide Zetrola controlled 90% of *Bromus arvensis* L. and 92% of *Lolium multiflorum* L. It was efficient against all other annual graminaceous weeds and self-sown plants of durum wheat.

The combinations of herbicides Wish top and Zetrola with herbicides Challenge and Zencor had additive effect in terms of their efficacy against annual graminaceous weeds and self-sown plants of durum wheat.

Soil-applied herbicides Pendistar and Dual gold, treated after sowing before emergence and also foliar-applied herbicides Lentagran, Wish top and Zetrola, treated during 3-7 real leaf stage of the lentil, had very high selectivity to lentil plants - rating 1 by scale of EWRS (Table 3).

The combinations of soil-applied herbicides Pendistar and Dual gold with foliar-applied herbicide Lentagran also had high selectivity to lentil plants - rating 1 by scale of EWRS.

Herbicide Challenge applied after sowing before emergence had excellent selectivity to lentil plants - rating 1 by scale of EWRS. Later phytotoxicity was possible with later foliar treatment with herbicide Challenge - bleaching and discoloration on the periphery of the lentil leaves. It was overcome quickly and had no effect on seed yield.

Herbicide combination of soil-applied Challenge with foliar-applied Wish top and herbicide tank mixture of foliar-applied Challenge and Wish top also had high selectivity to lentil plants - rating 1 by scale of EWRS.

In case of joint use of herbicides Challenge and Zetrola, there was low phytotoxicity - rating 2 by scale of EWRS. This phytotoxicity was manifested both in soil application of Challenge, followed by foliar application of Zetrola as herbicide combination, and also in joint foliar application of both herbicides as tank mixture. Phytotoxicity was overcome by lentil plants up to 15 - 20 days after treatment with Zetrola. If it is necessary to use Zetrola with an antibroadleaved herbicide, the interval between treatments with the antibroadleaved herbicide and Zetrola should be 7 days.

Early chlorosis on lentil leaves had been reported by use of the herbicide Zencor. At a dose of 350 g/ha the lentil plants recovered quickly - rating 1 by scale of EWRS. At a dose of 600 g/ha soil-applied + 300 g/ha foliar-applied, the lentil plants recovered more slowly - rating 2 by scale of EWRS. Chlorosis was the longest by Zencor at a dose of 900 g/ha - rating 3 by scale of EWRS.

Herbicide combinations of soil-applied herbicide Zencor at a dose of 350 g/ha with foliar-applied herbicides Wish top and Zetrola had good selectivity to lentil plants - rating 1 by scale of EWRS.

Foliar-applied herbicide Passat had phytotoxicity in lentil – rating 3 by scale of EWRS. Although there were no strong visible signs, it was overcome slowly, slowed down lentil growth and led to reduction in seed yield.

Data about the influence of investigated herbicides, herbicide combinations and herbicide tank mixtures on seed yield of lentil (Table 4) showed that the lower yield was obtained by untreated weedy control due to the large number of weeds.

**Table 4.** Influence of some herbicides, herbicide combinations and herbicide tank mixtures on seed yield of lentil (2019 - 2021)

Variants	2019		2020		2021		Mean	
	kg/ha	%	kg/ha	%	kg/ha	%	kg/a	%
Control	1169	100	1411	100	1260	100	1280	100
Pendistar 5 l/ha	1309	112.0	1620	114.8	1414	112.2	1446	113.0
Dual gold 1.2 l/ha	1286	110.0	1594	113.0	1390	110.3	1422	111.1
Lentagran 1+1 l/ha	1336	114.3	1654	117.2	1445	114.7	1477	115.4
Lentagran 750+500+500 ml/ha	1350	115.5	1671	118.4	1460	115.9	1492	116.6
Pendistar 5 l/ha + Lentagran 1 l/ha	1486	127.1	1834	130.0	1607	127.5	1641	128.2
Dual gold 1.2 l/ha + Lentagran 1 l/ha	1404	120.1	1736	123.0	1518	120.5	1551	121.2
Pendistar 5 l/ha + Lentagran 500+500 ml/ha	1501	128.4	1857	131.3	1625	129.0	1658	129.5
Dual gold 1.2 l/ha + Lentagran 500+500 ml/ha	1416	121.1	1748	123.9	1528	121.3	1563	122.1
Wish top 1.25 l/ha	1225	104.8	1518	107.6	1323	105.0	1354	105.8
Zetrola 1.6 l/ha	1218	104.2	1507	106.8	1310	104.0	1344	105.0
Challenge 4 l/ha	1358	116.2	1681	119.1	1469	116.6	1501	117.3
Challenge 3+1 l/ha	1367	116.9	1690	119.8	1478	117.3	1510	118.0
Challenge 4 l/ha + Wish top 1.25 l/ha	1469	125.7	1815	128.6	1589	126.1	1623	126.8
Challenge 4 l/ha + Zetrola 1.6 l/ha	1443	123.4	1785	126.5	1565	124.2	1596	124.7
Challenge 3+1 l/ha + Wish top 1.25 l/ha	1475	126.2	1822	129.1	1595	126.6	1629	127.3
Challenge 3+1 l/ha + Zetrola 1.6 l/ha	1430	122.3	1767	125.2	1546	122.7	1580	123.4
Zencor 900 ml/ha	1243	106.3	1537	108.9	1337	106.1	1371	107.1
Zencor 600+300 ml/ha	1260	107.8	1562	110.7	1363	108.2	1394	108.9
Zencor 350 ml/ha	1267	108.4	1568	111.1	1370	108.7	1400	109.4
Zencor 350 ml/ha + Wish top 1.25 l/ha	1320	112.9	1634	115.8	1428	113.3	1459	114.0
Zencor 350 ml/ha + Zetrola 1.6 l/ha	1312	112.2	1624	115.1	1419	112.6	1450	113.3
Passat 1.2 l/ha	1232	105.4	1528	108.3	1333	105.8	1363	106.5
LSD 5 %	49	4.2	75	5.3	62	4.9		
LSD 1 %	68	5.8	96	6.8	79	6.3		
LSD 0.1 %	88	7.5	119	8.4	98	7.8		

The highest yields of lentil seeds on average for the period were obtained by herbicide combination Pendistar 5 l/ha + Lantagran 500 + 500 ml/ha - 129.5% compared to weed control, followed by herbicide combination Pendistar 5 l/ha + Lantagran 1 l/a - 128.2% compared to the control. These herbicide combinations controlled the largest number of weeds throughout the lentil growing season.

High yields were also obtained by combining Challenge 3 + 1 l/ha with Wish top 1.25 l/ha - 127.3% compared to weed control, as well as by herbicide combination Challenge 4 l/ha + Wish top 1.25 l/ha - 126.8% compared to the control. These variants also controlled the largest number of weeds during the lentil growing season.

Combining Challenge with antigraminaceous herbicide Zetrola led to lower seed yields than combining Challenge with antigraminaceous herbicide Wish top. This was due to the lower efficacy of Zetrola against some annual graminaceous weeds such as *Lolium multiflorum* L. and *Bromus arvensis* L., as well as the higher phytotoxicity of these herbicide combinations. It is important to note that the combination of Zetrola with Challenge had an initial phytotoxic effect on lentil, resulting in inhibition of plant growth for the first 15 - 20 days after foliar treatment. Subsequently, the lentil overcomes this negative effect and at the end of the growing season in these variants, high values of seed yield were reported, which is proved mathematically. This was due to the good chemical control of the herbicide combinations against the available weeds.

Combining foliar-applied herbicide Lantagran with soil-applied herbicide Dual gold led to lower seed yields than combining Lantagran with soil-applied herbicide Pendistar. The reason for this was the lower efficacy of Dual gold against some annual broadleaved weeds such as *Consolida regalis* Gray, *Falopia convolvulus* Leve, *Stellaria media* Cyr.

The single use of soil-applied herbicides Pendistar and Dual gold increased yields less than their herbicide combinations with foliar-applied herbicide Lantagran, as these herbicides cannot control perennial weeds and some annual weeds.

The single use of foliar-applied antigraminaceous herbicides Wish top and Zetrola slightly increased the yield of lentil seeds. The reason for this was their inefficacy against annual and perennial broadleaved weeds and Clearfield and ExpressSun sunflower self-sown plants.

The single use of herbicide Zencor at a dose of 350 ml/ha during the period after sowing before emergence of the lentil resulted in low seed yields due to the low herbicide efficacy of Zencor at this minimum dose. The

use of Zencor at doses of 600 ml/ha during the period after sowing before emergence + 300 ml/ha during 3-7 leaf stage reduced seed yield. The double use of Zencor, although it increased the efficacy of the herbicide against weeds, reduced its selectivity to lentil. The single use of Zencor as soil-applied herbicide at a dose 900 ml/a controled even more weeds, but had lower selectivity to lentil, resulting in even lower yields.

Combination of Zencor with foliar-applied herbicides Wish top and Zetrola always led to bigger increase in yield compared to single use of the respective herbicides during the three years of the study.

In treatments with herbicide Passat during the three years of the study, higher seed yields were reported compared to the weed control. Lentil lagged behind in their development, the ripening stage was delayed by 4-5 days, but nevertheless seed yields were not significantly reduced, as weed infestation was significantly lower compared to the untreated control. Passat was the only herbicide that destroyed all available weeds and self-sown plants. This herbicide will be most suitable for imidazolinone-resistant lentil cultivars by Clearfield technology.

## Conclusion

The combinations of herbicide Lantagran VP (pyridate) with soil-applied herbicides Pendistar 40 SC (pendimethalin) and Dual gold 960 EC (S-metolachlor), as well as herbicides Challenge 600 SC (aclonifen) with foliar-applied herbicides Wish top (quizalofop-P-ethyl) and Zetrola (propaquizafop) had an additive effect on herbicide efficacy. The herbicides Lantagran VP (pyridate) and Zencor 600 SC (metribuzin), as well as their combinations, successfully controlled Clearfield and ExpressSun sunflower self-sown plants in lentil crops. The foliar-applied herbicide Passat 40 (imazamox) controlled all annual and perennial broadleaved and graminaceous weeds and self-sown plants. The use of foliar-applied herbicide Passat 40 (imazamox) and soil-applied herbicide Zencor 600 SC (metribuzin) at a dose of 900 g/ha led to high phytotoxicity in lentil plants - rate 3 according to the scale of EWRS. Double use of Zencor 600 SC (metribuzin) at doses of 600 + 300 g/ha and the combined use of the herbicides Challenge 600 SC (aclonifen) and Zetrola (propaquizafop) led to low phytotoxicity in lentil - rate 2 according to the scale of EWRS. The highest yields of lentil seeds were obtained by use of herbicide combinations Pendistar 40 SC (pendimethalin) 5 l/ha + Lantagran VP (pyridate) 500 + 500 ml/ha and Pendistar 40 SC (pendimethalin) 5 l/ha + Lantagran VP (pyridate) 1 l/ha. High yields were also

obtained when combining Challenge 600 SC (aclonifen) 3 + 1 l/ha with Wish top (quizalofop-P-ethyl) 1.25 l/ha, as well as by the herbicide combination Challenge 600 SC (aclonifen) 4 l/ha + Wish top (quizalofop-P-ethyl) 1.25 l/ha.

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