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SELECTIVITY AND EFFICACY OF HERBICIDE GF-3488, CONTAINING SYNTHETIC AUXINS HALAUXIFEN-METHYL AND CLOPYRALID, IN WINTER OILSEED RAPE CROPS IN UKRAINE

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Halauxifen-methyl is a new synthetic auxin, which in combination with another auxin-like herbicide clopyralid is the active ingredient of complex herbicide GF-3488, that is used for dicotyledonous weeds control in winter oilseed rape crops. The reason of this study was a necessity to test crop selectivity and efficacy of GF-3488 to control dicotyledonous weeds in winter oilseed rape crops in Ukraine and also the possibility of GF-3488 application in the tank mixture with graminicide or/and insecticide to control monocotyledonous weeds and insects. A randomized block experiment was conducted in 2015—2017 in 4 locations. It was found that under spring applying, the GF-3488 is not inferior to another widely used herbicide Galera Super on selectivity to the crop. Herbicide GF-3488 at the rate 1.0 l/ha was significantly better than Galera Super at the rate 0.3 l/ha in controlling of annual dicotyledonous weeds *Papaver rhoeas* L., *Galium aparine* L., *Consolida regalis* S.F. Gray and was effective to control of certain types of cruciferous weeds, which are resistant to Galera Super. Adding graminicide Fusilade Forte and insecticide Nurelle D did not affect the GF-3488 selectivity to the crop and had no negative impact on dicotyledonous weeds control. Efficacy of monocotyledonous weeds control by graminicide did not change in the mixture with GF-3488. It was concluded that herbicide GF-3488 is effective on winter oilseed rape against dicotyledonous weed species. Therefore for the simultaneous control of dicotyledonous and monocotyledonous weeds in winter oilseed rape in the spring after the renewal of the crop vegetation herbicide GF-3488 is advisable to be used in a tank mixture with graminicides, and for simultaneous protection against weeds and pests it can be mixed with insecticides.

Key words: *Brassica napus* L. var. *oleifera*, winter oilseed rape, herbicides, insecticides, halauxifen-methyl, clopyralid, fluazifop-*p*-butyl, weed control.

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Halauxifen-methyl is a new herbicide to the control of dicotyledonous weeds in cereals [1]. By chemical structure halauxifen-methyl belongs to the new class of active substances with auxinic activity — arylpicolinates, which by its characteristics exceeds all existing synthetic auxins [1, 2]. It has been characterized as a renaissance of synthetic auxin herbicides [3]. The use of halauxifen-methyl in winter oilseed rape, which is sensitive to this herbicide, is possible due to the antidote effect caused by other synthetic auxins, in particular the clopyralid, when use in combination with halauxifen-methyl [4]. Due of this effect, it has been developed herbicide GF-3488 (halauxifen-methyl 5 g/l + clopyralid 120 g/l) to control dicotyledonous weeds in winter oilseed rape crops.

For the herbicide registration in Ukraine it was required to carry out trials in the different climatic zones to test efficacy of GF-3488 in controlling dicotyledonous weeds in winter oilseed rape and herbicide selectivity to the crop. As a result of the trials conducted in 2015 and 2017 registration of herbicide GF-3488 in Ukraine has been obtained in 2019 under the trade name Slash, EC [5].

In addition to controlling of dicotyledonous weeds in oilseed rape there is a necessity to protect crop from monocotyledonous weeds including winter wheat carrion, since in many cases winter wheat is a predecessor to winter rape. Acetyl-CoA-carboxylase inhibitors (graminicides) are widely used to control monocotyledonous weeds in winter oilseed rape, and they are selective for dicotyledonous plant species and affect only cereal plants [6]. It has been found that in tank mixtures with graminicide halaxyfop-methyl, phytotoxic effect of Galera 334 SL (clopyralid, 267 g/l + picloram, 67 g/l) increased synergistically [7]. Therefore, the question arises whether the tank mixture with graminicides will lead to decreasing in the selectivity of halauxifen-methyl (accordingly the herbicide GF-3488) to the crop. On the other hand, it is known that herbicides effective against dicotyledonous weed species can antagonistically reduce efficacy of graminicides on monocotyledonous weeds [8]. It has been observed the strongest antagonism, when graminicides were applied in mixture with synthetic auxins [9, 10]. Such antagonism may be due to changes in graminicide translocation and metabolism caused by synthetic auxins [11]. Although when combined with clopyralid or Galera 334 SL, the effectiveness of graminicide against monocotyledonous weeds in winter oilseed rape did not decrease [7], it is unknown what can be the interaction between graminicides and halauxifen-methyl. Therefore, one of the aimes of this study was to define efficacy of GF-3488 applied in tank mixture with graminicide Fusilade Forte 150 EC (fluazifop-*p*-buthyl, 150 g/l) in winter oilseed rape to control dicotyledonous and monocotyledonous weeds and to test selectivity to the crop.

Apart of weeds control, the oilseed rape requires insect protection that can be realized by using insecticides, for example Nurelle D (chlorpyrifos, 500 g/l + cypermethrin, 50 g/l). It is known about inhibition of herbicide metabolic detoxication caused by organophosphate insecticides, which can result in reducing herbicide selectivity to the crop [12–14]. It is likely that the treatment of winter rape by herbicide GF-3488 can be in the same time when it is necessary to insecticide treatment. To reduce the number of

applications it would be advisable to use insecticide Nurelle D in tank mixture with herbicide GF-3488 EC, however, to determine the possibility of such combination it is necessary to check whether insecticide has a negative effect on the selectivity of herbicide GF-3488 to the crop.

Materials and methods

Field experiments were conducted in 2015 and 2017 in Kyiv and Ivano-Frankivsk regions of Ukraine. In the Kyiv region in 2015, trials were allocated on the fields of agricultural companies in the village Movchanivka of the Skvyra district (49°36' N, 29°30' E) (location 1) and in the village Hermanivka of the Obukhov district (49°57' N, 30°34' E) (location 2), in the Ivano-Frankivsk region trials were allocated in the field of SE «Peremoga» of Pidpechery village, Tysmenytsia district (48°55' N, 24°32' E) (location 3a). In 2017 experiments were also allocated on the field of SE «Peremoga» of the Precarpathian State Agricultural Research Station (location 3b) and on the research field of the Institute of Plant Physiology and Genetics, village Glevakha, Vasylkiv district, Kyiv region (50°16' N, 30°18' E) (location 4).

The experiments were based on the following winter oilseed rape varieties: location 1 — NK Technic, location 2 — Votan, location 3 — Cheremosh, location 4 — Chornyi Veleten. In all trials the previous crop was winter wheat. Crop treatment was carried out in the spring after restart of vegetation at the following growth stages of the winter oilseed rape: location 1 — stem elongation (BBCH 39), location 2 — appearance of the flower buds (BBCH 50), location 3a — formation of the flower buds (BBCH 53), location 3b — formation of the flower buds (BBCH 51); location 4 — appearance and formation of the flower buds (BBCH 50—51). The experimental plot area was 12.5 m2 (2.5 m × 5 m), each plot was placed in four replications, trials were designed as randomized complete block.

Selectivity of herbicide GF-3488 to the winter rape was evaluated at 7, 14 and 28 days after application. Previous studies have shown that despite the antidote effect of clopyralid, the phytotoxic effect of halauxifen-methyl on winter oilseed rape plants can be manifested in morphological changes of leaves: the appearance of lanceolate leaves, changes in the formation of leaf vessels, deformation of leaf edges. Therefore, the selectivity of the herbicide GF-3488 was also assessed by calculating the percentage of plants with morphological changes in the leaves at each plot, including untreated.

Weeds were evaluated before application, then 14 and 28 days after application. Herbicide efficacy was assessed visually and expressed as a percentage: 0 % — no effect on weed, 100 % — complete weed control. The determined values of visual assessment were verified by the weight method and calculated by the formula:

$$E_i\ (\%) = 100\ (M_k - M_i)/M_k,$$

where E_i (%) — is efficacy, M_i — is the fresh weight of the aboveground part of certain weed plants in the experimental plot, M_k — is the fresh

weight of the aboveground part of this weed species plants in the untreated plot. Using weight method, the weed plants were cut off (when invasion was more than 3 pcs/m^2 — from four areas of 1.0 m^2 of each experimental plot; but under the lower level of invasion — all weed plants of this species from each areas of experiment). Yield of winter oilseed rape was evaluated by mowing and threshing plants from each experimental plot. A cleaned and dried seeds from each plot were weighted and the data were statistically analysed.

Statistical analysis of all the received data was performed using the computer program ARM 8, and the differences between the means were evaluated using Tukey's HSD test.

Results and discussion

After herbicides application there were not established changes in the rate of growth and development of winter oilseed rape plants in locations 1, 3a, 3b and 4 (Table 1). But slight growth inhibition of winter rape variety Votan was observed in location 2 after 7 days after treatment with herbicides GF-3488 and Galera Super, as well as mixtures of herbicide GF-3488 with graminicide and insecticide. The suppression of the Votan oilseed rape plants growth was short-term, and on 14 and 28 days after treatment, the plants in the experimental plots did not differ from the untreated ones. At the same time, after 14 days after application of herbicides GF-3488 and Galera Super, as well as mixtures of herbicide GF-3488 with graminicide Fusilade Forte and insecticide Nurelle D, in winter rape Votan variety crop significantly increased the percentage of plants with deformed leaves in the upper tier compared to plants in untreated plots and on treatment with herbicide Fusilade Forte.

In location 4 in 14 days after herbicides application on winter oilseed rape Chornyi Veleten variety, there was also observed a slight, but significant increase in the percentage of plants with deformed leaves in treatments with herbicides GF-3488 and Galera Super, as well as mixtures of herbicide GF-3488 with graminicide and insecticide. The phytotoxic effect of herbicides on crop was short-term and at 28 day after application the percentage of deformed leaves in the upper tier in the evaluated areas did not differ from untreated plots, where single plants also had leaf deformations. In both cases, in 2015 at location 2 and in 2017 at location 4, the negative effect of the herbicide GF-3488 on winter oilseed rape did not exceed the phytotoxic effect of the herbicide Galera Super, which is confirming that selectivity to the winter oilseed rape of herbicide GF-3488 is not inferior to the herbicide Galera Super. Adding graminicide Fusilade Forte or insecticide Nurelle D to the herbicide GF-3488 did not increase the percentage of deformed leaves in winter rape plants compared to the treatments where herbicide GF-3488 was used alone (see Table 1). It follows from these observations that graminicide Fusilade Forte or insecticide Nurelle D addition does not negatively affect the selectivity of herbicide GF-3488 to the winter oilseed rape.

Efficacy assessments showed that herbicide GF-3488 was superior to Galera Super in controlling particularly harmful to the rape annual weed

TABLE 1. Phytotoxic effect on winter oilseed rape (percentage of plants with deformed upper tier leaves) at 7 (1), 14 (2) and 28 (3) days after treatment by herbicides

Treatment	Location 1 (2015)			Location 2 (2015)			Location 3a (2015)			Location 3b (2017)			Location 4 (2017)		
	1	2	3	1	2	3	1	2	3	1	2	3	1	2	3
GF-3488 (1.0 l/ha)	0.2	0.5	0	0.5	3.2[a]	0.5	0	0.2	0	0	0.3	0	0	0.8[a]	0
GF-3488 (1.0 l/ha) + + Nurelle D (0.6 l/ha)	0.3	0.5	0	0.7	3.5[a]	0.5	0	0.2	0	0	0.3	0	0	1.1[a]	0
GF-3488 (1.0 l/ha) + + Fusilade Forte (1.0 l/ha)	0.2	0.3	0	0.5	3.0[a]	0.2	0	0.2	0	0	0.2	0	0	0.8[a]	0
Galera Super (0.3 l/ha)	0.5	0.5	0	0.7	3.8[a]	0.5	0	0.2	0	0	0.4	0	0	0.9[a]	0
Fusilade Forte (1.0 l/ha)	0.3	0.5	0	0.5	0.7[b]	0.5	0	0.2	0	0	0.2	0	0	0.2[b]	0
Untreated control	0.3	0.5	0	0.5	0.5[b]	0.3	0	0.2	0	0	0.2	0	0	0.2[b]	0
Tukey's HSD $P = 0.05$	0.2	0.3	–	0.2	1.2	0.2	–	0.2	0	0	0.2	–	–	0.3	–

Note. Here and in Table 2 – there is no significant difference between the mean values when they are marked with identical letters.

TABLE 2. Efficacy of dicotyledonous weed control (%) at 14 and 28 days after treatment of winter oilseed rape by herbicide GF-3488 and its mixtures with graminicide Fusilade Forte and insecticide Nurelle D

Location	Weed species	Treatment				Tukey's HSD $P = 0.05$	Treatment				Tukey's HSD $P = 0.05$
		GF-3488 (1.0 l/ha)	GF-3488 (1.0 l/ha) + + Nurelle D (0.6 l/ha)	GF-3488 (1.0 l/ha) + Fusilade Forte (1.0 l/ha)	Galera Super (0.3 l/ha)		GF-3488 (1.0 l/ha)	GF-3488 (1.0 l/ha) + + Nurelle D (0.6 l/ha)	GF-3488 (1.0 l/ha) + + Fusilade Forte (1.0 l/ha)	Galera Super (0.3 l/ha)	
		14 days after treatment					28 days after treatment				
Location 1	*Papaver rhoeas*	93^{a}	88^{a}	87^{a}	68^{b}	12	99^{a}	99^{a}	99^{a}	75^{b}	2
	Consolida regalis	93^{a}	93^{a}	93^{a}	68^{b}	7	98^{a}	97^{a}	98^{a}	74^{b}	5
	Thlaspi arvense	68^{a}	48^{ab}	68^{a}	25^{b}	30	53^{a}	53^{a}	60^{a}	0^{b}	10
	Descurainia sophia	76^{a}	75^{a}	78^{a}	30^{b}	5	98^{a}	96^{a}	95^{a}	32^{b}	6
	Galium aparine	93^{a}	90^{a}	88^{a}	87^{a}	10	99^{a}	99^{a}	99^{a}	70^{b}	5
	Sonchus oleraceus	94^{a}	93^{a}	94^{a}	94^{a}	3	99^{a}	99^{a}	99^{a}	99^{a}	1
Location 2	*Thlaspi arvense*	42^{a}	32^{a}	34^{a}	15^{a}	30	59^{a}	45^{a}	52^{a}	12^{b}	30
	Capsella bursa-pastoris	79^{a}	76^{a}	75^{a}	10^{b}	8	96^{a}	94^{a}	99^{a}	0^{b}	9
	Descurainia sophia	66^{a}	63^{a}	65^{a}	0^{b}	12	65^{a}	63^{a}	63^{a}	0^{b}	11
	Papaver rhoeas	98^{a}	96^{a}	98^{a}	45^{b}	30	99^{a}	98^{a}	98^{a}	58^{b}	17
	Galium aparine	98^{a}	98^{a}	98^{a}	98^{a}	8	98^{a}	98^{a}	99^{a}	98^{a}	8
	Centaurea cyanus	96^{a}	93^{a}	95^{a}	98^{a}	9	99^{a}	95^{a}	98^{a}	98^{a}	8
Location 3a	*Matricaria inodora*	98^{a}	95^{a}	96^{a}	95^{a}	9	98^{a}	98^{a}	98^{a}	95^{a}	10
	Anthemis arvensis	93^{a}	98^{a}	95^{a}	95^{a}	13	98^{a}	95^{a}	98^{a}	95^{a}	10
	Cirsium arvense	95^{a}	95^{a}	93^{a}	95^{a}	10	98^{a}	98^{a}	95^{a}	95^{a}	10
	Sonchus arvensis	93^{a}	93^{a}	90^{a}	85^{a}	15	95^{a}	95^{a}	95^{a}	93^{a}	11
	Veronica persica	45^{a}	41^{a}	48^{a}	0^{b}	7	35^{a}	33^{a}	32^{a}	0^{b}	8

Continuation of Table 2

Location	Weed species	Treatment				Tukey's HSD $P = 0.05$	Treatment				Tukey's HSD $P = 0.05$
		GF-3488 (1.0 l/ha)	GF-3488 (1.0 l/ha) + + Nurelle D (0.6 l/ha)	GF-3488 (1.0 l/ha) + Fusilade Forte (1.0 l/ha)	Galera Super (0.3 l/ha)		GF-3488 (1.0 l/ha)	GF-3488 (1.0 l/ha) + + Nurelle D (0.6 l/ha)	GF-3488 (1.0 l/ha) + Fusilade Forte (1.0 l/ha)	Galera Super (0.3 l/ha)	
		14 days after treatment					28 days after treatment				
	Geranium dissectum	27^{b}	26^{b}	27^{b}	60^{a}	9	20^{b}	18^{b}	18^{b}	55^{a}	7
	Lamium purpureum	98^{a}	96^{a}	98^{a}	98^{a}	8	100^{a}	98^{a}	100^{a}	98^{a}	6
Location 3a	*Capsella bursa-pastoris*	19^{a}	17^{a}	16^{a}	0^{b}	12	15^{a}	15^{a}	15^{a}	0^{b}	10
	Stellaria media	0	0	0	0	–	0	0	0	0	–
	Myosotis arvensis	0^{b}	0^{b}	0^{b}	95^{a}	7	0^{b}	0^{b}	0^{b}	95^{a}	5
	Viola arvensis	33^{a}	30^{a}	33^{a}	0^{b}	6	20^{a}	20^{a}	20^{a}	0^{b}	5
	Papaver rhoeas	74^{a}	71^{a}	70^{a}	60^{b}	8	89^{a}	86^{a}	80^{a}	68^{b}	10
	Galium aparine	70^{a}	70^{a}	68^{a}	63^{a}	7	100^{a}	100^{a}	100^{a}	96^{a}	8
	Centaurea cyanus	84^{a}	84^{a}	83^{a}	78^{a}	6	99^{a}	98^{a}	96^{a}	96^{a}	6
	Matricaria inodora	57^{a}	56^{a}	52^{a}	54^{a}	8	88^{ab}	85^{ab}	80^{b}	93^{a}	8
	Anthemis arvensis	53^{a}	53^{a}	50^{a}	55^{a}	7	100^{a}	100^{a}	93^{a}	100^{a}	8
	Cirsium arvense	58^{a}	56^{b}	55^{b}	65^{a}	6	93^{ab}	91^{b}	93^{ab}	100^{a}	8
	Sonchus arvensis	61^{b}	61^{b}	60^{b}	70^{a}	5	95^{ab}	98^{ab}	93^{b}	100^{a}	6
Location 3b	*Veronica arvensis*	0	0	0	0	–	0	0	0	0	–
	Geranium dissectum	78^{a}	78^{a}	76^{a}	73^{a}	7	95^{a}	95^{a}	91^{ab}	89^{a}	5
	Lamium purpureum	85^{a}	85^{a}	83^{a}	85^{a}	6	100^{a}	100^{a}	100^{a}	100^{a}	2
	Lamium amplexicaule	80^{a}	80^{a}	80^{a}	80^{a}	6	100^{a}	100^{a}	100^{a}	100^{a}	2

End of Table 2

Location	Weed species	Treatment				Tukey's HSD $P = 0.05$	Treatment				Tukey's HSD $P = 0.05$
		GF-3488 (1.0 l/ha)	GF-3488 (1.0 l/ha) + + Nurelle D (0.6 l/ha)	GF-3488 (1.0 l/ha) + Fusilade Forte (1.0 l/ha)	Galera Super (0.3 l/ha)		GF-3488 (1.0 l/ha)	GF-3488 (1.0 l/ha) + + Nurelle D (0.6 l/ha)	GF-3488 (1.0 l/ha) + Fusilade Forte (1.0 l/ha)	Galera Super (0.3 l/ha)	
		14 days after treatment					28 days after treatment				
Location 3b	*Capsella bursa-pastoris*	23^{a}	2^{a}	20^{a}	0^{b}	3	28^{a}	26^{a}	23^{a}	0^{b}	4
	Thlaspi arvense	20^{a}	20^{a}	15^{a}	0^{b}	7	20^{a}	20^{a}	15^{a}	0^{b}	5
	Myosotis arvensis	26^{b}	26^{b}	19^{c}	64^{a}	6	28^{b}	26^{b}	20^{b}	70^{a}	9
	Viola arvensis	20^{a}	20^{a}	16^{ab}	13^{b}	6	23^{a}	23^{a}	18^{ab}	13^{b}	6
Location 4	*Centaurea cyanus*	91^{a}	91^{a}	93^{a}	90^{a}	5	97^{a}	99^{a}	98^{a}	97^{a}	5
	Matricaria inodora	99^{a}	99^{a}	99^{a}	99^{a}	2	99^{a}	99^{a}	99^{a}	99^{a}	2

Papaver rhoeas L. (Table 2). Another harmful dicotyledonous weed *Galium aparine* L. was effectively controlled by both herbicides, except location 2 in 2015, when at application timing the plants of this species reached significant size and in this case the performance of herbicide GF-3488 significantly exceeded the performance of herbicide Galera Super. Herbicide Galera Super practically had no effect on cruciferae weeds. The herbicide GF-3488 in most cases suppressed but did not effectively control the weeds of this family, however, when at timing of treatment the plants of *Descurainia sophia* (L.) Webb. (location 1, 2015) and *Capsella bursa-pastoris* (L.) Medicus (location 2, 2015) were in the early growth stages, then these weed species were effectively controlled by herbicide GF-3488. The control of annual dicotyledonous weed *Consolida regalis* S.F. Gray by herbicide GF-3488 was significantly better in comparison with Galera Super. Herbicide GF-3488 was also superior to herbicide Galera Super in its performance on annual dicotyledonous weeds *Veronica persica* Poiret and *Viola arvensis* Murr., although the control level of these weed species was insufficient. Herbicide GF-3488 was not inferior to herbicide Galera Super in controlling of annual and

perennial dicotyledonous weeds of the Asteraceae family: *Sonchus oleraceus* L., *Matricaria inodora* L., *Anthemis arvensis* L., *Cirsium arvense* (L.) Scop., *Sonchus arvensis* L., as well as dicotyledonous weeds of the Labiatae family: *Lamium purpureum* L. and *Lamium amplexicaule* L. Annual dicotyledonous weeds *Stellaria media* (L.) Vill. and *Veronica arvensis* L. were resistant to both herbicides. Annual dicotyledonous weeds *Geranium dissectum* (L.) Jusl. and *Myosotis arvensis* (L.) Hill were resistant to herbicide GF-3488 but were effectively controlled by herbicide Galera Super. None of the trials did show efficacy reduction in the treatments with addition graminicide or insecticide (see Table 2). Based on the obtained data, it can be concluded that application GF-3488 in mixture with graminicide Fusilade Forte or insecticide Nurelle D does not affect on herbicide control of dicotyledonous weed species in winter oilseed rape crops.

In addition to dicotyledonous weeds, winter oilseed rape was infested by monocotyledonous weeds: in locations 1, 2 and 4 trials were infested by winter wheat carrion and in location 3 by annual monocotyledonous weed *Apera spica-venti* (L.) Pal. Beauv. (Table 3). As we can see from the table the use of graminicide Fusilade Forte in tank mixture with herbicide GF-3488 did not affect the efficacy on monocotyledonous weeds.

Effective control of dicotyledonous weeds with GF-3488 and Galera Super herbicides provided a significant increase in yield compared to control (Table 4). The highest yield increase was obtained in location 3 where dicotyledonous weeds infestation was the highest. Despite the more effective control of dicotyledonous weeds by herbicide GF-3488 in comparison with herbicide Galera Super, the trials accuracy did not allow to determine a significant difference in yield between treatments with these herbicides. Due to the relatively low level of monocotyledonous weeds infestation, there was no significant difference in yield observed in treatments by GF-3488 alone and in mixture with graminicide Fusilade Forte. Pest control in the area surrounding the experimental plots ensured that pests did not affect the yield formation of the winter oilseed rape. Therefore, no significant difference in yield was observed between treatments with herbicide GF-3488 alone and in mixture with insecticide Nurelle D.

Given the fact, that in recent decades no herbicides with new modes of action have been developed, the development halauxifen-methyl, which belongs to the new class of active substances with auxinic activity — arylpicolinates, is actually a significant achievement. First of all, it provides an opportunity to develop new effective mixtures of herbicides, which is now considered as the one of the way to prevent the occurrence of herbicide-resistant weed biotypes [15].

The combined data obtained from trials suggest that the herbicide GF-3488 is effective in protecting winter oilseed rape against dicotyledonous weeds. When applied in the spring after the renewal of winter oil seed rape vegetation, the herbicide GF-3488 is not inferior to herbicide Galera Super in terms of selectivity to the crop. At application rate 1.0 l/ha herbicide GF-3488 effectively controls annual and perennial dicotyledonous weeds of the Asteraceae and Labiatae families, not inferior to the herbicide Galera Super at rate 0.3 l/ha. GF-3488 is superior to Galera Super in controlling annual dicotyledonous weeds *P. rhoeas*, *G. aparine* and *C. regalis*

TABLE 3. Efficacy of monocotyledonous weed control (%) at 14 and 28 days after treatment of winter oilseed rape by graminicide Fusilade Forte and its mixtures with herbicide GF-3488

Location	Weed species	Treatment		Tukey's HSD $P = 0.05$	Treatment		Tukey's HSD $P = 0.05$
		GF-3488 (1.0 l/ha) + Fusilade Forte (1.0 l/ha)	Fusilade Forte (1.0 l/ha)		GF-3488 (1.0 l/ha) + Fusilade Forte (1.0 l/ha)	Fusilade Forte (1.0 l/ha)	
		14 days after treatment			28 days after treatment		
Location 1	*Triticum aestivum*	80	80	7	95	97	5
Location 2	*Triticum aestivum*	60	65	8	88	86	6
Location 3a	*Apera spica-venti*	65	65	6	87	90	5
Location 3b	*Apera spica-venti*	45	45	5	93	95	5
Location 4	*Triticum aestivum*	90	95	8	95	95	5

TABLE 4. Yield of winter oilseed rape (t/ha) under the effect of herbicides

Location	Treatment						Tukey's HSD $P = 0.05$
	GF-3488 (1.0 l/ha)	GF-3488 (1.0 l/ha) + + Nurelle D (0.6 l/ha)	GF-3488 (1.0 l/ha) + + Fusilade Forte (1.0 l/ha)	Galera Super (0.3 l/ha)	Fusilade Forte (1.0 l/ha)	Untreated control	
Location 1	3.05	2.98	3.11	2.90	2.36	2.21	0.23
Location 2	2.54	2.56	2.69	2.44	2.18	2.11	0.18
Location 3a	2.20	2.24	2.23	2.04	1.10	1.05	0.07
Location 3b	2.03	2.06	2.10	2.00	0.75	0.69	0.21
Location 4	2.14	2.09	2.16	2.13	1.88	1.87	0.16

which are particularly harmful to winter oilseed rape. Herbicide GF-3488 is able to suppress cruciferae weeds resistant to Galera Super and can effectively control of *D. sophia* and *C. bursa-pastoris* when plants of these species are in the early growth stages at application.

Trials have shown that adding of graminicide Fusilade Forte or insecticide Nurelle D did not affect the selectivity of herbicide GF-3488 to the winter oilseed rape and its efficacy in controlling of dicotyledonous weeds. Despite the strong antagonism, observed when graminicides applied in mixture with synthetic auxins [9, 10], efficacy of Fusilade Forte in mixture with GF-3488 did not differ from that of graminicide alone. From another hand, our assumption that insecticide Nurelle D may reduce selectivity, because it is known that organophosphate insecticides can inhibit the cytochrome-P_{450}-monooxygenase, catalyzed hydroxylation of herbicides in crops [12, 13], was also not confirmed. It follows that for simultaneous control of dicotyledonous and monocotyledonous weeds in the spring after renewal of the winter rape vegetation herbicide GF-3488 can be recommended to use in a tank mixture with graminicides, and for simultaneous protection against weeds and pests in a mixture with insecticides.

REFERENCES

1. ArylexTM Active — Technical Bulletin. (2013). Retrieved from http://www.arylex.com/en
2. Schmitzer, P.R., Balko, T., Satchivi, N.M. & Weimer, M.R. (February 6-7, 2013). XDE-729 methyl a new post-emergent dicotyledonous herbicide for cereal grains. In: Proceedings of the Annual Meeting of the Weed Science Society of America and the Northeastern Weed Science Society (Abstract 259), Baltimor.
3. Kraehmer, H., Almsick, A., Beffa, R., Dietrich, H., Eckes, P., Hacker, E., Hain, R., Strek, H.J., Stuebler, H. & Willms, L. (2014). Herbicides as weed control agents: State of the art: II. Recent achievements. Plant Physiology, 166, No. 3, pp. 1132-1148. https://doi.org/10.1104/pp.114.241992
4. Pat. 8912120B2 US. Herbicidal compositions comprising 4-amino-3-chloro-5-fluoro-6-(4-chloro-2-fluoro-3-methoxyphenyl) pyridine-2-carboxylic acid or a derivative thereof and synthetic auxin herbicides. Yerkes, C.N., Mann, R.K., Satchivi, N.M., Schmitzer, P.R. Publ. 16.09.2014.
5. Rafalskyj, V.V., Vashchenko, V.M. Chajkovska, V.V. (Eds.) (2019). Addition to the list of pesticides and agrochemicals approved for use in Ukraine. Kyiv: Yunivest Media [in Ukrainian].
6. Focke, M., Gieringer, E., Schman, S., Jansch, L., Binder, S. & Braun, H. (2003). Fatty acid biosynthesis in mitochondria of monocotyledonouses: malonyl coenzyme A is generated by mitochondria-localized acethyl-CoA carboxylase. Plant Physiology, 133, No. 2, pp. 875-884. https://doi.org/10.1104/pp.103.027375
7. Morderer, Ye.Yu., Lukyanchenko, O.S. & Rodzevich, O.P. (2007). Efficacy and selectivity of the herbicide Galera 334 SL in crops of rape and mustard. Quarantine and plant protection, 53, pp. 198-209 [in Ukrainian].
8. Morderer, Ye.Yu. & Merezhynsky, Yu.G. (2009). Herbicides. Mechanisms of action and practice. Kyiv, Logos [in Ukrainian].
9. Mueller, T.C., Witt, W. & Barrett, M. (1989). Antagonism of johnsonmonocotyledonous control with fenoxaprop, haloxyfop and sethoxydim by 2,4-D. Weed Technology, 3, No. 1, pp. 86-89.
10. Dechamps, J.A. & Hsiao, W.A. (1990). Quick Antagonistic effect of MCPA on fenoxaprop activity. Weed Science, 38, No. 1, pp. 62-66. https://doi.org/10.1017/S0043174500056125

11. Mueller, T.C., Barrett, M. & Witt, W. (1990). A basis for the antagonistic effect of 2,4-D on haloxyfop-methyl toxicity to johsonmonocotyledonous (Sorghum halepense). Weed Science, 38, No. 2, pp. 103-107.
12. Kreuz, K. & Fonne-Pfister, R. (1992). Herbicide-insecticide interaction in maize: malathion inhabits cytochrome P-450-dependent primisulfuron metabolism. Pesticide Biochemistry and Physiology, 43, No. 3, pp. 232-240.
13. Baerg, R., Barrett, M. & Polge, N. (1996). Insecticide and insecticide metabolite interactions with cytochrome P-450 mediated activities in maize. Pesticide Biochemistry and Physiology, 55, No. 1, pp. 10-20. https://doi.org/10.1006/pest.1996.0030
14. Altman, J. (2018). Pesticide Interactions in Crop Production: Beneficial and Deleterious Effects. Boca Raton, CRC Press. https://doi.org/10.1201/9781351075459
15. Norsworthy, J.K., Ward, S.M., Shaw, D.R., Llewellyn, R.S., Nichols, R.L., Webster, T.M., Bradley, K.W., Frisvold, G., Powles, S.T., Burgos, N.R., Witt, W.W. & Barrett, M. (2012). Reducing the risk of herbicide resistance: best management practices and recommendation. Weed Science, Special Issue, pp. 31-62. https://doi.org/10.1614/WS-D-11-00155.1

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СЕЛЕКТИВНІСТЬ ТА ЕФЕКТИВНІСТЬ ГЕРБІЦИДУ GF-3488, ЯКИЙ МІСТИТЬ СИНТЕТИЧНІ АУКСИНИ ГАЛАУКСИФЕН-МЕТИЛ ТА КЛОПІРАЛІД, У ПОСІВАХ РІПАКУ ОЗИМОГО В УКРАЇНІ

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Галауксифен-метил — це новий синтетичний ауксин, який у поєднанні з іншим ауксиноподібним гербіцидом клопіралідом є діючою речовиною комплексного гербіциду GF-3488, що використовується для контролювання дводольних бур'янів у посівах озимого ріпаку. Підставою цього дослідження була необхідність перевірити селективність щодо культури та ефективність GF-3488 для боротьби з дводольними бур'янами в посівах озимого ріпаку в Україні, а також можливість застосування GF-3488 у баковій суміші з граміцидом або (та) інсектицидом для боротьби з однодольними бур'янами та шкідниками. Рендомізований експеримент був проведений у 2015—2017 рр. у чотирьох локаціях. Було встановлено, що при весняному застосуванні GF-3488 не поступається іншому широко використовуваному гербіциду галера супер за селективністю до врожаю. Гербіцид GF-3488 із розрахунку 1,0 л/га був значно кращим за галера супер із розрахунку 0,3 л/га для боротьби з однорічними дводольними бур'янами *Papaver rhoeas* L., *Galium aparine* L., *Consolida regalis* S.F. Gray і

ефективний для боротьби з деякими видами бур'янів з родини хрестоцвітих, стійких до галера супер. Додавання граміциду фюзилад форте та інсектициду нурел Д не впливало на селективність GF-3488 до культури та не зменшувало ефективність контролювання дводольних бур'янів. Ефективність контролювання однодольних бур'янів граміцидом також не змінилася в суміші з GF-3488. Зроблено висновок, що гербіцид GF-3488 ефективний у посівах озимого ріпаку проти дводольних бур'янів. Для одночасного контролювання дводольних та однодольних бур'янів у посівах озимого ріпаку навесні після відновлення вегетації гербіцид GF-3488 доцільно використовувати в баковій суміші з граміцидами, а для одночасного захисту від бур'янів та шкідників його можна застосовувати з інсектицидами.

Ключові слова: *Brassica napus* L. var. *oleifera*, озимий ріпак, гербіциди, інсектициди, галауксифен-метил, клопіралід, флуазифоп-*p*-бутил, контролювання бур'янів.