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STUDY ON THE ACTION OF FOLIAR HERBICIDES AND HERBICIDE COMBINATIONS FOR CONTROL OF WHEAT (*Triticum aestivum* L.) WEEDS

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ABSTRACT

The action of some foliar herbicides and herbicide combinations for control of common wheat (*Triticum aestivum* L.) weeds was studied. To that end against the background of soil applied Stomp 330EK New at a dose of 5 l/ha the herbicides Axial 050EK, Granstar 75DF, Derby Super WG, Sekator OD, Lintur 70WG, and the tank mixtures of Axial with the other herbicides applied in the tillering phenophase of the crop were studied. The species composition and density of weeds was assessed using the quantitative method prior to treatment and after herbicide treatment on days 5, 15 and 30, by constant metering. The herbicide Lintur 70WG and its combination with Axial 050EK had the fastest initial effect. The highest herbicidal effect (99.5%) against annual monocotyledon and dicotyledon weeds showed the combination of Derby Super WG 33 g/ha + Axial 050EK - 900 ml/ha. Very good was the effect of the other herbicidal mixtures between anti-broadleaf herbicides and the graminaceous herbicide Axial 050. All applied herbicides and herbicide mixtures showed a very good after-action on weeds.

Keywords: common wheat, weeds, herbicides, herbicide effect.

INTRODUCTION

The use of herbicides to kill weeds in the production of wheat and barley in modern agriculture is of particular importance. Getting high yields is unthinkable without their use. The large number of herbicides registered in grain crops with a different spectrum of action requires a study on their efficacy, the sensitivity of crops to them, to offer the most effective scheme for chemical control of weeds under certain climatic conditions.

Against the wild oat species, imazamethabenz, diclofop-methyl, tralkoxydim, fenoxaprop-P-ethyl and clodinafop-propargyl was the most effective in wheat (Tiebas et al., 1999). Increased efficacy of herbicides fenoxaprop-P-ethyl and clodinafop-propargyl has been reported with the addition of adherents (Callens et al., 1996). The herbicide pinoxaden showed higher herbicidal effect on annual monocotyledon weeds compared to clodinafop and fenoxaprop-P-ethyl (Hoffer et al., 2006).

In wheat and barley, pinoxaden can successfully control crop weeds (Dhawan et al., 2010; Dixit et al., 2011). This herbicide had high efficacy against graminaceous weeds and good selectivity against common wheat, durum wheat and barley (Campagna and Rueegg, 2006).

Some forms of wintering *Avena ludoviciana* L. (Uludag et al., 2008; Sasanfar et al., 2009) and of *Alopecurus myosuroides* Huds. (Petit et al., 2010; Delye, 2011) were reported to be resistant to pinoxaden. In a study of *Alopecurus myosuroides* Huds., resistance was reported to fenoxaprop-P-ethyl 99%, to clodinafop - 68% and to pinoxaden - 64%, respectively (Petit et al., 2010).

The propoxycarbazone-sodium herbicide, besides annual graminaceous cereal weeds meadow foxtail, windgrass and bromes, destroyed the conch-grass roots as well as a consequence of its systemic action (Ammon et al., 2000).

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The herbicides aminopyralid + florasulam and tribenuron-methyl had good efficacy against annual and perennial broadleaf weeds (Dalla Valle et al., 2006; Pasquini et al., 2006).

The mecoprop + diflufenican herbicide destroyed all broadleaf weeds resistant to hormone herbicides 2.4-D and 2M-4X (Soroka et al., 1999). In autumn weed control the herbicide pendimethalin + isoproturon showed better effect than the herbicides isoproturon + diflufenican and iodosulfuron + mefenpyr (Tsyuganov and Potarenko, 2011).

The tank herbicide mixture of carfentrazone-ethyl + tribenuron-methyl increased the effect against dicotyledone weeds (Bassi et al., 2002). Amidosulfuron, cafentriazone-ethyl, fluroxypyr, florasulam and cyclosulfuron had high efficacy against the catchweed (Covarelli and Stagnari, 2002).

Against the graminaceous and deciduous weeds, good results were achieved with the application of the herbicide iodosulfuron + mesosulfuron (Ceconi et al. 2000; Cittar et al., 2002). It has been found that iodosulfuron + mesosulfuron was more effective than metribuzin, 2.4 D + metosulam, metosulam and the herbicide mixture clodinafop-propargyl + tribenuron-methyl (Montemurro et al., 2006).

Against wild oats, ryegrass, meadow foxtail and bromes some authors recommended the use of pyroxsulam. (Tityanov et al., 2009). Efficacy did not change when Pallas was added as a mixture with florasulam + aminopyralid potassium. Poor antagonism was reported in the tank mixture of florasulam + 2,4-D ester and strong antagonism in the tank mixture Pallas + Herboxone (2,4-D amine salt). The addition of adherents to the herbicides propoxycarbazone-sodium and sulfosulfuron had a positive influence on the herbicidal effect and resulted in an in wheat grain yield. (Adamczewski and Paradowski, 2004).

Weeds and volunteer rapeseed grown by Clearfield technology in durum wheat crops were controlled successfully by the foliar: florasulam + flumetsulam, florasulam + 2,4-D, metosulam + 2,4-D and Dicamba + 2,4-D and soil herbicides: pendimethalin + isoproturon, isoproturon + diflufenican and pendimethalin (Delchev, 2013).

The herbicide mixture fenoxaprop-P-ethyl + amidosulfuron + iodosulfuron also had high efficacy against graminaceous and broadleaf weeds (Gorbacheva et al., 2011). In the tank mixtures of fenoxaprop-P-ethyl and clodinafop with isoproturon there was synergism with regard to cereal weeds (Khan et al., 2002 and 2003).

The objective of the study was to investigate the effects of some herbicides and herbicide combinations to control weeds in common wheat.

MATERIAL AND METHODS

A field trial was conducted with common wheat (*Triticum aestivum* L.) on meadow-cinnamon soil type in non-irrigated conditions, with a preceding crop - sunflower.

The trial was set by block design in 4 replications with size of the plot 20 m^2. Against the background of soil applied Stomp 330EK. New at a dose of 5 l/ha, a total of 5 herbicides and 4 herbicide combinations were tested in the following variants:

Variant 1 – unweeded control;
Variant 2 – hand weeded control;
Variant 3 – Axial 050EK - 900 ml/ha;
Variant 4 – Granstar 75DF – 20 g/ha;
Variant 5 – Derby Super WG - 33 g/ha;
Variant 6 – Sekator OD - 100 ml/ha;
Variant 7 – Lintur 70WG - 150 g/ha;
Variant 8 – Granstar 75DF - 20 g/ha + Axial 050EK - 900 ml/ha;
Variant 9 – Derby Super WG - 33 g/ha + Axial 050EK - 900 ml/ha;
Variant 10 – Sekator OD - 100 ml/ha + Axial 050EK - 900 ml/ha;
Variant 11 – Lintur 70WG - 150 g/ha + Axial 050EK - 900 ml/ha.

The four herbicide combinations were introduced as herbicidal mixtures, the mixing being done in the spray tank.

The treatment with the foliar herbicides Axial 050EK, Granstar 75DF, Derby Super WG, Sekator OD and Lintur 70WG was carried out in the tillering phenophase of wheat. The introduction of the soil herbicide

Stomp 330EK. New was carried out in the post-sowing period prior to germination of the crop.

The species composition and density of the weeds was assessed by the quantitative method before treatment and after herbicide treatment on days 5, 15 and 30, by constant 0.25 m^2 measurements. The herbicidal effect on the number of weeds was calculated as the number of weeds in the treated plots in percentage from the number of weeds in the control.

The mathematical processing of the results was done by hierarchical cluster analysis. The method of intergroup linking was used (Ward, 1963; Dyuran and Odelly, 1977). The Euclidean intergroup distance was used as a measure of similarity:

$$D(x\backslash,y) = \sqrt{\sum_{i\backslash=1}^{n} (x_i - y_i)^2}$$

A dendrogram was constructed to graphically represent the formed clusters. The dotted horizontal dendrogram line shows the rescaled distance at which the clusters are formed. Data were processed with the SPSS statistical software.

RESULTS AND DISCUSSION

At the moment of treatment all variants were uniformly weeded by an average of 139 to 220 pcs./m^2 (Table 1).

Table 1. Weed and species diversity of the weeds before treatment n/m^2

Weed species	Control	Hand rowing	Axial	Granstar	Derby Super	Secator	Lintur	Granstar + Axial	Derby Super + Axial	Secator + Axial	Lintur + Axial
Veronica hederifolia	59.5	75.7	50.0	82.3	50.7	62.7	58.0	60.0	55.0	58.0	50.7
Lamium amplexicaule	12.5	19.3	16.3	23.7	17.3	31.0	15.0	15.3	22.0	12.7	29.7
Stelaria media	6.8	16.7	1.7	5.0	3.0	0.7	0.0	0.0	1.3	1.3	0.3
Lithospermum arvense	3.0	1.0	0.0	0.7	4.0	2.7	3.5	3.0	1.3	3.3	0.7
Anthemis arvensis	6.5	44.3	10.0	11.0	6.7	2.7	4.5	6.3	5.0	5.7	4.3
Avena fatua	6.3	20.0	17.3	14.0	26.7	9.7	17.5	21.3	21.3	14.0	24.3
Galium aparine	15.0	24.0	5.7	14.0	8.7	19.0	26.5	15.7	7.0	17.7	11.7
Alopecurus myosuroides	5.0	6.0	4.0	1.3	1.7	3.0	4.0	7.3	2.0	6.0	7.0
Bromus arvensys	2.7	0.0	1.5	0.0	1.3	1.0	0.0	2.7	0.7	1.7	1.7
Papaver rhoeas	0.3	0.0	1.5	0.5	1.0	0.7	0.5	0.0	1.0	0.3	0.3
Consolida regalis	0.7	5.0	9.0	4.5	6.3	8.7	10.0	4.3	6.7	8.0	7.0
Polygonum convolvulus	9.0	4.0	32.5	12.0	9.0	32.0	0.0	32.0	13.7	30.7	22.3
Cirsium arvense	10.3	0.0	0.0	4.0	3.0	1.0	0.0	1.0	0.3	0.3	0.7
Cardaria draba	2.0	4.0	2.5	1.5	1.7	1.5	6.5	2.0	2.0	1.0	0.7
Summary	139.5	220.0	152.0	174.5	141.0	176.2	146.0	171.0	139.3	160.7	161.3

The species composition of weeds varied, the dominating species being mainly the winter-spring ephemerals: *Veronica hederifolia* L. and *Lamium amplexicaule* L. Of the early spring species, the greatest was the density of *Avena fatua* L.*, Galium aparine* L. and *Polygonum convolvulus* L. Of the winter-spring species the most common in the crop were *Consolida regalis* L. Gray., *Anthemis arvensis* L., *Alopecurus myosuroides* L. and *Papaver rhoeas* L. had lower levels of multiplying. In all variants of the trial single plants of *Bromus arvensis* L. were found. The perennial species were represented by *Cardaria draba* L. and *Cirsium arvense* L. Scop.

The results from the second reporting of the weeding of the experimental plots (Table 2) showed that the herbicide Lintur 70WG and its combination with Axial 050EK had the fastest initiating effect, the weeds destroyed being from the group of ephemeral and early spring species. The herbicidal effect was 24.6% -35.5%, while in the other variants it was within the range of 1.3%-5.5%, the dynamics of weeding being especially weak in the variant treated with Axial alone.

Table 2. Weed and species diversity of weeds 5 days after treatment

Weed species	Control	Hand rowing	Axial	Granstar	Derby Super	Secator	Lintur	Granstar + Axial	Derby Super + Axial	Secator + Axial	Lintur + Axial
Veronica hederifolia	55.7	0.0	50.0	76.7	49.0	58.7	35.5	57.7	54.0	55.0	26.3
Lamium amplexicaule	9.3	0.0	16.3	22.0	16.3	29.3	7.5	13.3	20.7	11.0	16.0
Stelaria media	9.0	0.0	1.7	4.5	2.7	0.7	0.0	0.0	1.3	1.0	0.0
Lithospermum arvense	8.7	0.0	0.0	1.7	4.0	2.7	2.0	3.0	1.3	3.3	0.3
Anthemis arvensis	7.0	0.0	10.0	5.7	6.7	2.7	3.5	6.3	5.0	5.3	2.7
Avena fatua	14.0	0.0	17.3	17.3	26.7	9.7	17.5	21.3	21.3	14.0	24.3
Galium aparine	5.7	0.0	5.7	15.0	8.7	18.3	24.0	15.7	6.7	17.7	9.0
Alopecurus myosuroides	3.0	0.0	2.0	1.3	1.7	3.0	4.0	7.3	2.0	6.0	7.0
Bromus arvensys	0.5	0.0	1.5	1.0	1.3	1.0	0.0	2.7	0.7	1.7	1.7
Papaver rhoeas	1.0	0.0	1.5	0.5	1.0	0.7	0.5	0.0	1.0	0.3	0.3
Consolida regalis	11.0	0.0	9.0	4.0	6.3	8.3	9.5	4.0	6.7	8.0	5.7
Polygonum convolvulus	15.5	0.0	32.5	11.5	9.0	29.0	0.0	31.5	13.7	30.7	10.0
Cirsium arvense	0.0	0.0	0.0	4.0	3.0	1.0	0.0	1.0	0.3	0.3	0.3
Cardaria draba	3.0	0.0	2.5	1.5	1.7	1.5	6.0	2.0	2.0	1.0	0.3
Summary	143.3	0.0	150.0	166.7	138.0	166.5	110.0	165.8	136.7	155.3	104.0

The third reporting of weed density gives a more realistic picture of the effectiveness of the applied herbicides and combinations thereof (Table 3). The highest herbicidal effect (99%) was achieved with the introduction of the herbicide mixture Derby+Axial. Similar were the results obtained after application of Axial in a mixture with one of the following herbicides Sekator, Lintur or Granstar. The effect was within the range of 96.9%-98.8%. When herbicides were used alone, the degree of

weeding was the lowest after spraying with Sekator - herbicidal effect 91.8%. The effect of the herbicide Axial was unsatisfactory, due to the fact that dicotyledon weeds, on which it does not act, predominated in the crop. In the other variants the herbicidal effect was 77.8% -85.5%.

Table 3. Weed and species diversity of weeds 15 days after treatment

Weed species	Control	Hand rowing	Axial 050EC	Granstar 75DF	Derby Super WG	Secator OD	Lintur 70WG	Granstar 75DF + Axial 050EC	Derby Super WG + Axial 050EC	Secator OD + Axial 050EC	Lintur 70WG + Axial 050EC
Veronica hederifolia	22.5	0.0	39.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lamium amplexicaule	5.0	0.0	14.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stelaria media	6.8	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lithospermum arvense	5.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anthemis arvensis	4.0	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avena fatua	5.5	0.0	0.0	17.3	26.7	9.7	17.5	0.3	0.0	0.0	0.0
Galium aparine	6.8	0.0	4.3	3.0	0.0	0.0	1.0	0.7	0.3	0.0	0.0
Alopecurus myosuroides	0.7	0.0	0.0	1.3	1.7	3.0	4.0	0.0	0.0	0.0	0.0
Bromus arvensys	0.3	0.0	1.5	0.0	1.3	1.0	0.0	2.7	0.7	1.7	1.7
Papaver rhoeas	1.0	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Consolida regalis	4.3	0.0	9.0	0.0	0.0	0.3	4.0	0.0	0.0	0.0	3.3
Polygonum convolvulus	10.3	0.0	32.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cirsium arvense	0.0	0.0	0.0	3.0	1.0	0.0	0.0	0.5	0.0	0.0	0.0
Cardaria draba	1.0	0.0	2.5	0.5	0.7	0.5	0.5	0.0	0.3	0.3	0.0
Summary	73.9	0.0	114.7	25.2	31.3	14.5	27.0	4.2	1.3	2.0	5.0

In the untreated control and the variant which included Axial 050EK, the density of the ephemeral species - *Veronica hederifolia* L, *Lamium amplexicaule* L. and *Stellaria media* L. decreased. This is due to the biology of these species, which finish their vegetation, leaving a large stock of seeds in the soil.

With single application of Axial 050EK, complete destruction of graminaceous weeds was observed - wild oats and slender meadow foxtail tail. The reported individual plants of *Bromus arvensys* L. remained undamaged by the herbicide, which showed that it was not efficient against this species. In the variants with applied anti-broadleaf herbicides, almost complete destruction of broadleaf species of weeds was reported. A weaker effect against *Galium aparine* L. was observed in the variant treated with Granstar 75DF, as well as in its combination with Axial 050EK. In the variant with application of Lintur 70WG, as well as its combination with Axial 050EK, incomplete destruction of *Consolida regalis* L. Gray was observed.

The results obtained from the last weed counting (Table 4) showed that at the 30th

day after treatment, in the unweeded control and the variant with Axial 050EK applied on its own, strong decrease in the number of ephemeral species such as *Veronica hederifolia* L., *Lamium amplexicaule* L. and *Stellaria media* L. was reported, due to the natural completion of their vegetation.

Table 4. Weed and species diversity of weeds 30 days after treatment

Weed species	Control	Hand rowing	Axial 050EC	Granstar 75DF	Derby Super WG	Secator OD	Lintur 70WG	Granstar 75DF + Axial 050EC	Derby Super WG + Axial 050EC	Secator OD + Axial 050EC	Lintur 70WG + Axial 050EC
Veronica hederifolia	12.7	0.0	20.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lamium amplexicaule	2.0	0.0	7.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stelaria media	9.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Lithospermum arvense	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Anthemis arvensis	7.7	0.0	4.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Avena fatua	5.3	0.0	0.0	17.3	26.7	9.7	17.5	0.3	0.0	0.0	0.0
Galium aparine	7.3	0.0	4.3	0.7	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Alopecurus myosuroides	9.0	0.0	0.0	1.3	1.7	3.0	4.0	0.0	0.0	0.0	0.0
Bromus arvensys	1.0	0.0	1.5	0.0	1.3	1.0	0.0	2.7	0.7	1.7	1.7
Papaver rhoeas	0.5	0.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Consolida regalis	2.0	0.0	9.0	0.0	0.0	0.0	3.5	0.0	0.0	0.0	3.0
Polygonum convolvulus	9.5	0.0	32.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cirsium arvense	15.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Cardaria draba	3.0	0.0	2.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Summary	88.5	0.0	87.7	19.3	29.7	13.7	25.0	3.3	0.7	1.7	4.7

In the same variants, the number of early spring and winter-spring broadleaf species such as *Polygonum convolvuls* L., *Consolida regalis* L. Gray and *G. aparine* L. increased. The number of *P. rhoeas* L. stayed the same.

In the variants treated with anti-broadleaf herbicides alone, the number of graminaceous weeds was reduced to a minimum and weeding was entirely by graminaceous species. The highest efficacy against broadleaf weeds on the 30th day after applying herbicides was shown by Sekator OD and Granstar, where the herbicidal effect was 92.2% and 88.9%. In the variant treated with Granstar 75DF, individual plants of catchweed were recorded, and in the variant with applied Lintur 70WG - of field larkspur, which showed the lower efficacy of the two herbicides to these species. The combination with the best effect against weeds was Derby Super WG + Axial 050EK - herbicidal effect 99.5%. Close was the effect in the combinations of the other anti-broadleaf herbicides with Axial, as the only reported species of graminaceous weeds was *Br. arvensys* L., and of the broadleaf ones

Galium aparine L. and *Consolida regalis* L. Gray.

After the cluster analysis, it became clear that the effect of the herbicides and herbicide mixtures, subject of the present study, can be grouped into one basic cluster with two subclusters. The results are presented by a dendrogram (Figure 1).

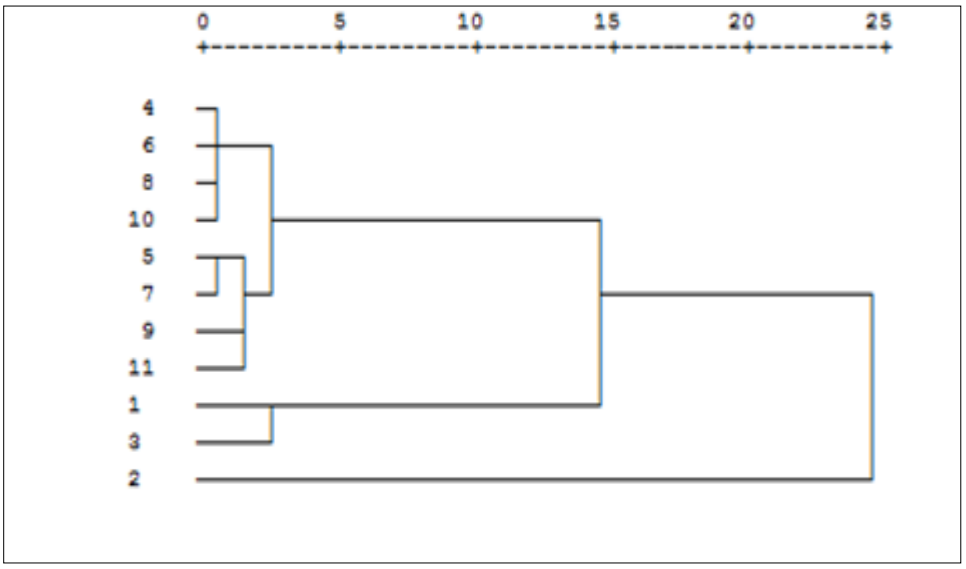

Figure 1. Dendrogram based on mean inter-group Euclidean distances

The first subcluster is more homogeneous and combines variants 4, 6, 8, and 10 and 9. These variants are the most similar to the surveyed indicators and with the least Euclidean distance between them.

The second subcluster includes variants 5, 7, 9 and 11 using herbicides Derby, Lintur and their herbicide mixtures with Axial and their effect is reported on the fifth day after treatment. They are the most similar in terms of the indicators studied and close results.

For the second subcluster, the Near-Euclidean distances combine variants 5 and 7 and variants 9 and 11 at the subsequent counting stages as well - on the fifteenth and the thirtieth day after treatment. Similarity is due to the effectiveness of the herbicides, which was more pronounced in their mixtures with Axial. The other variants differed by complex assessment of the previously considered ones.

Intergroup distances are the greatest in variant 1 (unweeded) and variant 2 (weeded control).

The hierarchical analysis grouping makes it possible to increase the objectivity of the evaluation of treatment variants with herbicides and herbicide mixtures applied in the study.

The hierarchical cluster analysis grouping allowed increasing the objectivity of the evaluation of the treatment variants with the herbicides and herbicide mixtures applied in the study.

CONCLUSIONS

Herbicides Lintur 70WG and its combination with Axial 050EK had the quickest initial effect, the destroyed weeds being from the group of ephemeral and early spring species.

The highest herbicidal effect (99.5%) to the annual monocotyledon and dicotyledonous weeds showed the combination Derby Super WG + Axial 050. Very good was the effect of the other herbicide mixtures between anti-broadleaf herbicides and the anti-graminaceous herbicide Axial 050.

In all variants with applied herbicides and herbicide mixtures there was no secondary weeding, which showed very good after-action.

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