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SELECTIVITY AND STABILITY OF SOME HERBICIDES FOR ANNUAL GRAMINACEOUS WEED CONTROL APPLIED DURING STEM ELONGATION STAGE OF DURUM WHEAT (*Triticum durum* Desf.)

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Abstract

The experiment was carried out during 2018-2020 in the experimental field of Field Crops Institute - Chirpan with durum wheat cultivar Progress (Triticum durum Desf.). The influence of 6 antigraminaceous herbicides was tested - Palace 75 WG (piroxulam) - 250 g/ha; Axial 050 EC (pinoxaden) - 900 ml/ha; Traxos 045 EC (pinoxaden + clodinafop) – 1.3 ml/ha; Topic 080 EC (clodinafop) - 450 ml/ha; Puma super 7.5 EB (phenoxyprop-ethyl) - 1 ml/ha; Hussar max WG (mesosulfuron + iodosulfuron) - 250 g/ha. Herbicides were applied at the beginning of stem elongation stage - during 1st, 2nd and 3rd stem node stage of durum wheat. The highest grain yield was obtained by treatment of herbicide Topic during 1st stem node stage of durum wheat, followed by herbicides Puma super, Axial and Hussar max. During 2nd stem node stage of durum wheat, the highest grain yield was obtained by treatment of herbicide Puma super, followed by herbicides Traxos, Axial and Topic. During 3rd stem node stage of durum wheat, the highest grain yield was obtained by treatment of herbicide Puma super, followed by herbicides Topic and Traxos. Technologically, the most valuable are herbicides Puma super, Hussar max, Traxos and Palace, applied during 1st stem node stage; herbicides Hussar max, Topic and Puma super applied during 2nd stem node stage and herbicides Hussar max, Puma super, Topic and Traxos applied during 3rd stem node stage.

Key words*: durum wheat, herbicides, selectivity, stability, grain yield.*

INTRODUCTION

Durum wheat (*Triticum durum* Desf.) is a traditional material for pasta production and is indispensable in this respect compared to common wheat (*Triticum aestivum* L.).

An important factor that significantly affects the quantity and quality of durum wheat yield is weeds (Delchev, 2016; 2016a; 2017; 2018; 2018a; 2020). If they are not combated, the decrease in crop yields due to weed infestation is on average between 10% and 50%. A decisive role in this regard is done by the chemical method of weed control (Buczek et al., 2007; Nakayama et al., 2010; Gupta et al., 2011; Lobkov et al., 2012; Delchev, 2019; 2019a; 2021; 2022). This method has established itself as an important and fundamental unit in this control.

Chemical weed control in durum wheat is mainly carried out through tillering stage. Many studies have been conducted with herbicides, herbicide combinations and herbicide tank mixtures during this stage of crop development (Callens et al., 1996; Imanat, 2002; Campagna and Rueegg, 2006; Tityanov, 2009; Petit et al., 2010; Zhelyazkova et al., 2016). Some of them have been found to exhibit a phytotoxic effect on durum wheat grain yield (Kumar et al., 1997; Korres et al., 1999; Holm et al., 2000; Cacak-Pietrzak et al., 2008; Delchev and Georgiev, 2015; 2015a; Georgiev and Delchev, 2016).

Due to various reasons (meteorological, financial, organizational), chemical weed control may be delayed and it may be necessary to conduct it during stem elongation stage of durum wheat (Delchev, 2006). In the presence of secondary weed infestation, especially in seed crops, it is necessary to apply herbicides also during this later stage. There is insufficient data regarding the impact of herbicides applied late in the growing season of durum wheat on its productivity. Their influence on grain yield requires further investigation. This will lead to improvements in weed control in durum wheat, particularly secondary weed infestation in this crop.

The aim of the present study is to investigate the selectivity and stability of the actions of some antigraminaceous herbicides applied during the stem elongation stage of durum wheat.

MATERIALS AND METHODS

The experimental work was carried out during 2018-2020 under non-irrigated conditions of the leached vertisol soil type on the experimental field of Field Crops Institute - Chirpan. The experiment was carried out with durum wheat cultivar Progress (*Triticum durum* Desf.). It was carried out according to the block method (Dimova et al., 1999), in 4 repetitions with a harvest plot size of 15 m^2.

The influence of 6 antigraminaceous herbicides was tested. The active substances and doses of the studied herbicides are shown in Table 1. Due to their poor adhesion, the herbicides Palace and Hussar max were applied together with the adjuvants Dasoil - 500 ml/ha and Biopower - 250 ml/ha, respectively.

Table 1. Investigated variants

№	Herbicides	Active substances	Doses
1	Control	-	-
2	Palace 75 WG	piroxulam	250 g/ha
3	Axial 050 EC	pinoxaden	900 ml/ha
4	Traxos 045 EC	pinoxaden + clodinafop-propargyl	1.30 l/ha
5	Topic 080 EC	clodinafop-propargyl	450 ml/ha
6	Puma super 7.5 EB	fenoxaprop-ethyl	1 l/ha
7	Hussar max WG	mesosulfuron + iodosulfuron	250 g/ha

Herbicides were applied at the beginning of stem node stage - during 1st, 2nd and 3rd stem node stage of durum wheat.

The selectivity of herbicides has been established through their influence on grain yield. The math processing of the data was done according to the method of analyses of variance (Shanin, 1977; Barov, 1982; Lidanski, 1988). The stability of herbicides for grain yield with relation to years was estimated using the stability variances σ_i^2 and S_i^2 of Shukla (1972), the ecovalence W_i of Wricke (1962) and the stability criterion YS_i of Kang (1993).

RESULTS AND DISCUSSIONS

The grain yields are a result of the combined effect of weather conditions over the years and the selectivity of the studied herbicides (Table 2). The highest grain yield on mean for the period is obtained by treatment with herbicide Topic during 1st stem node stage of durum wheat - 4637 kg/ha, followed by herbicides Puma super - 4570 kg/ha, Axial - 4547 kg/ha and Hussar max - 4503 kg/ha. During 2nd stem node stage of durum wheat, the highest grain yield is obtained by treatment with herbicide Puma super - 4470 kg/ha, followed by herbicides Traxos - 4200 kg/ha, Axial - 4157 kg/ha and Topic - 4157 kg/ha. During 3rd stem node stage of durum wheat, the highest grain yield is obtained by treatment with herbicide Puma super - 4557 kg/ha, followed by the herbicides Topic - 4487 kg/ha and Traxos - 4353 kg/ha. The lowest grain yields are obtained with the herbicide Palace, especially by treatment during 3rd stem node stage - 3787 kg/ha.

When using the herbicides Palace, Axial, Traxos, Topic, Puma super and Hussar max during 1st stem node stage of durum wheat, the mean yield increase is 118.8% over the control. When using these herbicides during 2nd stem node stage of durum wheat, the mean increase in yield is 112.8% over the control. When using the six herbicides during 3rd stem node stage of durum wheat, the mean increase in yield was 114.7% over the control.

This means that by treatment during stem elongation stage, the selectivity of the herbicides in regard to durum wheat is highest during the 1st stem node stage, followed by the 3rd stem node stage. The selectivity is lowest by treatment during 2nd stem node stage. This fact is important when, in the presence of secondary weed infestation, it is necessary to done a late treatment with herbicides of durum wheat seed crops.

Table 2. Influence of some herbicides on grain yield of durum wheat during stem elongation stage (2018-2020)

Treatment stages	Herbicides	2018		2019		2020		Mean Factor B	
		kg/ha	%	kg/ha	%	kg/ha	%	kg/ha	%
Control		6140	100	3400	100	1570	100	3703	100.0
1st stem node stage	Palace	4740	77.2	4320	127.0	3480	221.7	4180	112.9
	Axial	6130	99.8	3710	109.0	3800	242.0	4547	122.8
	Traxos	5180	84.4	3290	96.8	3420	217.8	3963	107.0
	Topic	6120	99.7	4110	121.0	3680	234.4	4637	125.2
	Puma super	5330	86.8	4420	130.0	3960	252.2	4570	123.4
	Hussar max	5310	83.6	4390	129.0	3810	242.7	4503	121.6
2nd stem node stage	Palace	5220	85.0	4680	138.0	2450	156.1	4117	111.2
	Axial	5540	90.2	3260	95.9	3670	233.4	4157	112.3
	Traxos	5480	89.3	3930	116.0	3190	203.2	4200	113.4
	Topic	5470	89.1	4010	118.0	2990	190.4	4157	112.3
	Puma super	5350	87.1	4130	121.5	3930	250.3	4470	120.7
	Hussar max	5110	83.2	3700	108.8	3040	193.6	3950	106.7
3rd stem node stage	Palace	5650	92.0	4140	121.8	1570	100.0	3787	102.3
	Axial	5550	90.4	3610	106.2	3250	207.0	4137	111.7
	Traxos	6250	101.8	3710	109.1	3100	197.5	4353	117.6
	Topic	6180	100.7	4140	121.8	3140	200.0	4487	121.6
	Puma super	5450	88.8	3830	112.6	4390	279.6	4557	123.1
	Hussar max	5820	94.8	3690	108.5	2970	189.2	4160	112.3
Mean Factor A		5594	-	3906	-	3333	-		-

LSD, kg/ha:

F.A	p≤5%=81	p≤1%=107	p≤0.1%=138
F.B	p≤5%=204	p≤1%=204	p≤0.1%=348
AxB	p≤5%=353	p≤1%=486	p≤0.1%=603

Analysis of variance for grain yield (Table 3) shows that the years have the highest influence on grain yield - 80.5% on the variants. It is determined by the unequal reaction of the variants to the change in the environmental conditions. The reason is the large differences in the meteorological conditions during the three years of investigation. The strength of influence of herbicides is 3.9%. The influence of years and herbicides is very well proven at $p \leq 0.1\%$. There is an interaction between herbicides and meteorological conditions of years (A x B) - 12.5%. It is very well proven at $p \leq 0.1\%$. The influence of tract of land, i.e. of soil fertility is 0.3%. It is well proven at $p \leq 1\%$.

Table 3. Analysis of variance for grain yield

Source of variation	Degrees of freedom	Sum of squares	Influence of factor, %	Mean squares	Fisher's criterion	Level of significance
Total	170	1956478	100	-	-	-
Tract of land	2	6390	0.3	3195.0	6.6	**
Variants	56	1896644	96.9	33868.6	70.9	***
Factor A - Years	2	1575208	80.5	787604.0	1650.0	***
Factor B - Herbicides	18	77666	3.9	4314.8	9.0	***
A x B	36	343770	12.5	7471.4	14.2	***
Pooled error	112	53444	2.7	477.2	-	-

*p≤5%; **p≤1%; ***p≤0.1%.

Based on proven herbicide x year interaction, it was evaluated stability parameters for each herbicide for grain yield of durum wheat with relation to years (Table 4). It was calculated the stability variances σ_i^2 and S_i^2 of Shukla, the ecovalence W_i of Wricke and the stability criterion YS_i of Kang.

Table 4. Stability parameters of some herbicides for grain yield with relation to years

Treatment stages	Herbicides	$\bar{x}$	σ_i^2	S_i^2	W_i	YS_i
Control		3703	15067.7**	-118.5	27676.3	-7
1st stem node stage	Palace	4180	6091.1**	429.8	11613.1	8+
	Axial	4547	14181.6**	6179.8**	26806.6	1
	Traxos	3963	5026.1**	9202.7**	9707.2	10+
	Topic	4637	6060.0**	6617.9**	7942.6	-4
	Puma super	4570	2109.1*	2944.5*	4487.2	16+
	Hussar max	4503	7473.8**	-107.4	14087.4	13+
2nd stem node stage	Palace	4117	265.5	0.5	1286.3	-1
	Axial	4157	23808.4**	48010.5**	43317.6	-5
	Traxos	4200	7827.3**	15818.1**	14702.0	-1
	Topic	4157	-141.8	141.3	459.2	10+
	Puma super	4470	1288.5	2827.0	3018.9	6+
	Hussar max	3950	1478.6*	121.5	3359.1	13+
3rd stem node stage	Palace	3787	2740.1**	-368.2	5616.4	0
	Axial	4137	5176.5**	12625.7**	17134.0	-4
	Traxos	4353	236.4	674.0	1136.2	5+
	Topic	4487	8081.5**	368.7	15175.4	5+
	Puma super	4557	4711.2**	686.2	9143.7	7+
	Hussar max	4160	14865.0**	13922.3**	27313.5	11+
Mean		4278				4.2
LSD (p = 0.05)		171				

Stability variances (σ_i^2 and S_i^2) of Shukla, which recorded respectively linear and nonlinear interactions, unidirectional evaluate the stability of the variants. These variants which showed lower values are considered to be more stable because they interact less with the environmental conditions. Negative values of the indicators σ_i^2 and S_i^2 are considered 0. At high values of either of the two parameters - σ_i^2 and S_i^2, the variant are regarded as unstable. At the ecovalence W_i of Wricke, the higher are the values of the index, the more unstable is the variant.

On this basis, using the first three parameters of stability, it is found that by treatment during 1st stem node stage, the six tested herbicides exhibited high instability. Instability is mainly due to the significant differences in grain yields in these variants over the years of experience, as the weather conditions are most affected. In herbicides Axial, Traxos, Topic and Puma super there is instability of linear and non-linear type - proven values of σ_i^2 and S_i^2. At them, the values of stability variances σ_i^2 and S_i^2 according to Shukla and of equivalence of Wricke W_i are high and mathematically proven. In herbicides Palace and Hussar max there is only linear type instability - the value of σ_i^2 is proven and the values of S_i^2 are unproven.

By treatment during 2nd stem node stage high instability exhibits herbicides Axial, Traxos and Hussar max. In herbicides Axial and Traxos there is instability of linear and non-linear type - proven values of σ_i^2 and S_i^2. In herbicide Hussar max there is only linear type instability - the value of σ_i^2 is proven and the values of S_i^2 are unproven. Herbicides Palace, Topic and Puma super are stable by treatment during 2nd stem node stage of durum wheat.

By treatment during 3rd stem node stage high instability exhibits herbicides Palace, Axial, Topic, Puma super and Hussar max. In herbicides Axial and Hussar max there is instability of linear and non-linear type - proven values of σ_i^2 and S_i^2. In herbicide Palace, Topic and Puma super there is only linear type instability - the value of σ_i^2 is proven and the values of S_i^2 are unproven. Herbicide Traxos are stable by treatment during 3rd stem node stage of durum wheat.

To evaluate the complete efficacy of each herbicide should be considered as their effect on grain yield of durum wheat and their stability - the reaction of durum wheat to this herbicide during the years. Valuable information about the value of technologic value of the variant give the stability criterion YS_i of Kang for simultaneous assessment of yield and stability, based on the reliability of the differences in yield and variance of interaction with the environment. The value of this criterion is experienced that using nonparametric methods and warranted statistical differences we get a summary assessment aligning variants in descending order according to their economic value.

Generalized stability criterion YSi of Kang, taking into accounts both the stability and value of yields gives high assessments of herbicides Puma super, Hussar max, Traxos and Palace, applied during 1st stem node stage; of herbicides Hussar max, Topic and Puma super, applied during 2nd stem node stage and of herbicides Hussar max, Puma super, Topic and Traxos applied during 3rd stem node stage. These variants are the most valuable from the viewpoint of durum wheat cultivation technology. They combine high values of grain yield and relatively good stability of this indicator in different years.

Negative assessments are given to the control, herbicide Topic applied during 1st stem node stage; herbicides Palace, Axial and Traxos applied during 2nd stem node stage and herbicide Axial applied during 3rd stem node stage. These variants combine lower values of grain yield and low stability of this indicator in different years.

CONCLUSIONS

The highest grain yield was obtained by treatment of herbicide Topic during 1st stem node stage of durum wheat, followed by herbicides Puma super, Axial and Hussar max.

During 2nd stem node stage of durum wheat, the highest grain yield was obtained by treatment of herbicide Puma super, followed by herbicides Traxos, Axial and Topic.

During 3rd stem node stage of durum wheat, the highest grain yield was obtained by treatment of herbicide Puma super, followed by herbicides Topic and Traxos.

Technologically, the most valuable are herbicides Puma super, Hussar max, Traxos and Palace, applied during 1st stem node stage; herbicides Hussar max, Topic and Puma super applied during 2nd stem node stage and herbicides Hussar max, Puma super, Topic and Traxos applied during 3rd stem node stage.

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