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ORIGINAL PAPER

Efficiency and selectivity of herbicides in common dry bean (*Phaseolus vulgaris* L.)

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Abstract

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The investigations were carried out during 2016–2017 at Dobrudzha Agricultural Institute – General Toshevo (DAI). The aim of this investigation was to determine the efficiency and selectivity of herbicides in varieties common dry bean. The following herbicides combinations were used: 1 variant: petoxamide (200 ml)+linuron (300 ml)+cikloksidim (200 ml); 2 variant: petoxamide (200 ml)+bentazon (200 ml)+cikloksidim (200 ml); 3 variant: petoxamide (200 ml)+bentazon (200 ml)+ cikloksidim (200 ml); 4 variant: dimetenamid-P+pendimetalin (400 ml)+linuron (300 ml)+ cikloksidim (200 ml); 5 variant: dimetenamid-P+pendimetalin (400 ml)+bentazon (200 ml)+cikloksadim (200 ml); 6 variant: dimetenamid-P+pendimetalin (400 ml)+bentazon (200 ml)+cikloksidim (200 ml). The vegetation herbicides were applied separate at variant 2 and 5 but at variant 3 and 6 – combined. The herbicides were applied at stage 01 (BBCH), and bentazon (200 ml) and cikloksidim (200 ml) at stage 12 (BBCH) on three varieties common dry bean "GTB-Usrtem", "GTB-Blijan" and "GTB-Elixir". The herbicide effect was determined by the quantitative weight method and evaluated by the EWRS scale. Regardless of the used cultivar, the herbicide combination 1 variant: petoxamide (200 ml)+linuron (300 ml)+cikloksidim (200 ml); 2 variant: petoxamide (200 ml)+bentazon (200 ml)+cikloksidim (200 ml); 5 variant: dimetenamid-P+pendimetalin (400 ml)+ bentazon (200 ml)+cikloksidim (200 ml) had highest efficiency (100%) on the annual grassy (green hides - *Setatia*

viridis L. and cockspur - *Echinochloa crus-galli* L.) and broadleaved weeds (wild mustard - *Sinapis arvensis* L., common amaranth - *Amaranths retroflexus* L., thorn-apple - *Datura stramonium* L., rough cocklebur - *Xanthium strumarium* L., fat-hen - *Chenopodium album* L. After application of the tested set of herbicides, no symptoms of phytotoxity were observed at the investigated varieties from 7 to 56 days after their use.

Key words: Common dry bean, Herbicides, Weeds, Efficiency, Selectivity

Introduction

The common, dry field bean (*Phaseolus vulgaris* L.) is the most widely grown of the cultivated species of *Phaseolus*. It is extremely important as food, is widely traded and is an important source of protein and calories in human diets in the tropical and sub-tropical developing countries, particularly in the Americas (Martin, 1984). Worldwide, an estimated 23.1 million tons of common beans is produced annually on about 8.7 million hectares (FAO, 2014).

Duration of weed competition and weed control depend on the crop species (Thakral et al., 1989), crop density (Radosevich, 1987), weed species (Cerna and Valdez, 1987) weed density (Aldrich, 1987) and environmental conditions (Radosevich, 1987). The dominant species in weed infestation of common bean crop were common galinsoga - *Galinsoga parviflora* L., cockspur - *Echinochloa crus-galli* L., fat-hen - *Chenopodium album* L. and common amaranth – *Amarantrhus retroflexus* L. These species are also mentioned by Chmielowiec and Borowy (2004) as those occurring most frequently in bean crops in Lubin region. In the segetal community of the common bean, 21species were noted, of which 16 were ephemeral and 5 perennial. The ephemeral species of common galinsoga - *Galinsoga parviflora* L., cockspur - *Echinochloa crus-galli* L., fat-hen - *Chenopodium album* L. and common amaranth – *Amarantrhus retroflexus* L. were dominant weeds. Perennial species occurred sporadically (Glowacka, 2010). Increasing crop uniformity had a negative effect on weed biomass (Oslen, 2012; Dusabumuremyi, 2014). Weeds emerging 4 weeks after planting are suppressed by crop growth (Karimi, 1998). Growth and development of weeds can be suppressed by plant spacing, planting pattern of crop plants and weeding frequencies. (Page and Willenborg, 2013).

Valor (flumioxazin) is a new herbicide that has recently been registred for use in dry beans and has both soil and foliar activity of many broadleaved weeds (Hartzler, 2004; Price et al., 2004). Herbicide application is the main method used in weed control. In recent years there has been a trend to decrease the quantity of applied herbicides, and to minimize their negative influence on the environment. One of the ways to achieve this goal is intercropping that has been used for fodder and food production of many years in various parts of the world (Carruthers et al., 1998).

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In the present time weeds in field beans are controlled by selective herbicides (Burnside et al., 1998). Cloransulam-methyl is a triazolopyrimidine sulfonamide herbicide that inhibits acetolactate synthase (ALS), an important enzyme responsible for the synthesis of branced-chain amino acids isoleucine, leucine and valine in plants (Senseman, 2007). In Ontario, cloransulam-methyl is used to control troublesome broadleaved weeds, including velvetleaf - *Abutilon theophrasti* Medic., rough cocklebur - *Xanthium strumarium* L., and common ragweed - *Ambrosia artemisifolia* L. (Senseman, 2007). Bentazon is a selective benzothiadiazole herbicide that controls broadleaved weeds such as fat-hen - *Chenopodium album* L., velvetleaf - *Abutilon theophrasti* Medic., purslane - *Portulaca oleracea* L., wild radish - *Raphanus raphanistrum* L., hairygalinsoga - *Galinsoga ciliate* L., common groundsel - *Senecio vulgaris* L., thorn-apple - *Datura stramonium* L., shepherd`s purse - *Capsella bursa-pastoris* (L.) Medic, wild mustard - *Sinapis arvensis* L., rough cocklebur - *Xanthium strumarium* L. and common chickweed *Stellaria media* (L.) Vill. (Senseman, 2007).

Tankmixes of cloransulam-methyl and halosulfuron with bentazon and fomesafen can reduce injury and provide control of broadleaved weeds in white bean. There is not adequate margin of crop safety or efficacy to control broadleaved weeds with other herbicide treatments evaluated in white bean under Ontario environmental conditions (Soltani et al., 2013).

ALS inhibiting herbicides such as imazethapyr and imazamix provide 76 to 100% control of different genotypes dry bean –*Amaranthus retroflexus* L., *Ambrosia artemisifolia* L., *Chenopodium album* L.. In other studies fomesafen plus imazamox provided 97% control of *Amaranthus retroflexus* L. and 87% control of *Chenopodium album* L. in dry bean (Wilson, 2005). Limited information exists on the tolerance and weed control efficacy of cloransulam-methyl, halosulfuron, bentazon, fomesafen and their tankmixes in white bean in Ontario. These herbicides, if used in a diversified, integrated weed management program, could reduce the selection intensity for herbicide-resistant weeds (Soltani et al., 2013). Dry bean have shown crop injury with cloransulam-methyl and halosulfuron-methyl applied post-emergence in some market classes dry bean (Soltani et al., 2010).

Bentazon has been shown to reduce crop injury in dry bean and other crops when tank mixed with injurious herbicides such as tritosulfuron, thifensulfuron, saflufenacil and imazethapyr (Moran et al., 2011). Fomesafen and fomesafen plus bentazon have been reported to provide 90% of greater control of *Chenopodium album* L.in dry bean (Bailey et al., 2003). The only herbicide treatment that reduced population density greater than 90% was halosulfuron plus fomesafen (Soltani et al., 2013). In other studies fomesafen plus imazamox provided 97% control of *Amaranthus retroflexus* L. in dry bean. In other studies , fomesafen alone provided

only 63% control of *Chenopodium album* L. in dry bean, but in tankmixure with imazamox or bentazon provided 77 and 87% control of *Chenopodium album* L. in dry bean, respectively (Wilson, 2005). Clorasulam-mithyl did not reduce biomass of *Amaranthus retroflexus* L. but bentazon reduced biomass of *Amaranthus retroflexus* L. 71% compared with the untreated control. Other herbicide treatments evaluated provided 89 to 97% reduction in *Amaranthus retroflexus* L. biomass compared with the untreated control (Soltani et al., 2013). Cloransulam-methyl, fomesafen and halosulfuron plus bentazon reduced biomass of *Ambrosia artemisifolia* L. 84 to 91%; however, all other herbicide treatments evaluated reduced above – ground biomass 100%, compared with the untreated control (Soltani et al., 2013).

The aim of this investigation was to determine the efficiency and selectivity of herbicides in varieties common dry bean.

Material and methods

The investigations were carried out during 2016 – 2017 at Dobrudzha Agricultural Institute – General Toshevo (DAI). The field trial was designed according to the block method in three replications, the size of the trial area being 10.5 m^2 and crop density 35 g.s. /m^2. One control is included: K_2 - weeded control until the end of the crop's vegetation (Table 1).

The herbicides were applied at stage 01 (BBCH) (Meier, 2001), and bentazon (200 ml) and cikloksidim (200 ml) at stage 12 (BBCH) (stage 1^{st} -2^{nd} shamrock) on three varieties common dry bean, "GTB-Usrtem", "GTB-Blijan" and "GTB-Elixir". Relying on natural weed infestation from grassy weeds: green hides - *Setaria viridis* L. and cockspur - *Echinochloa crus-galli* L. and broadleaved weeds: wild mustard - *Sinapis arvensis* L., thorn-apple - *Datura stramonium* L., rough cocklebur - *Xanthium strumarium* L., common amaranth - *Amaranths retroflexus* L., black-bindweed - *Polygonum convolvulus* L., fat-hen - *Chenopodium album* L., water papper - *Polygonum hydropiper*, field bindweed - *Convolvulus arvensis* L., creeping thistle - *Cirsium arvense* (*L.*) Scop and hemp - *Canabis sativa* L. Weed density was measured quantitatively per unit area by species using ¼ frame in four replications prior to introduction of herbicides.

The herbicide efficiency was estimated 25-30 days after the use of the preparations according to species, by amount and weight, using ¼ frame in four replications, measuring the weight of the weeds in fresh and dry condition. The effect was evaluated according to the 9-degree scale of EWRS for reading of the herbicide activity and selectivity, 1 corresponding to 100 % efficiency of the preparation, without symptoms of phytotoxicity on the cultural plants; and 9 corresponding to 29.9 % - 0 % effect of the preparation and complete perishing of the plants (Table 2).

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Table 1. Variants

Variants	Active substance	Doses (ml/da)
1.Sucssesor 600EK+ Kalin Flo+Stratus Ultra	petoxamide+linuron +cikloksidim	200+300+200
2.Sucssesor 600EK+ Basagran 400SL+Stratus Ultra-separated application at vegetation herbicides	petoxamide+bentazon +cikloksidim	200+200+200
3.Sucssesor 600EK+ Basagran 400SL+Stratus Ultra-combined at vegetation herbicides	petoxamide+bentazon +cikloksidim	200+200+200
4.Uing P+Kalin Flo+ Stratus Ultra	dimetenamid-P +pendimetalin + linuron+cikloksidim	400+300+200
5.Uing P+Basagran 400SL+Stratus Ultra- separated application at vegetation herbicides	dimetenamid-P +pendimetalin + bentazon+cikloksidim	400+200+200
6.Uing P+Basagran 400SL+Stratus Ultra- combined at vegetation herbicides	dimetenamid-P +pendimetalin + bentazon+cikloksidim	400+200+200
7.Weeded check	-	-

Table 2. Herbicide activity and selectivity according to 9-degree scale of EWRS

Rank	Herbicide effect, %	Damage symptoms	General evaluation
1	100	No symptoms – healthy plants	Excellent
2	99.9-98	Very weak symptoms – slight stunt effect	Very good
3	97.9-95	Weak but discernable symptoms	Good
4	94.9-90	Better expressed symptoms (eg. chlorosis) which do not affect yield	Satisfactory
5	89.9-82	Thinning of the crop, strong chlorosis or stunt. Lower yield expected	Indefinitely
6	81.9-70	Heavy damage or perishing of plants	Unsatisfactory
7	69.9-55		Poor
8	54.9-30		Very poor
9	29.9-0		Extremely poor

In 2016 the highest average monthly temperature in July is established (22.8 ^{0}C) (Table 3). The vast amount of precipitation (117.1 mm) during the month of May were good for intensive growth and development of the hybrid in the initial stages. The months July and August are dry compared to the multi-annual period. 2017 is characterized also with favorable weather conditions. Monthly temperature is highest during the month of August (22.8 ^{0}C). In June recorded the greatest amount of precipitation (87.7 mm) compared to multi-annual data.

Table 3. Air temperature and rainfalls during the period 1960-2017

Period	Period of vegetation				Average for V – VIII. t^0 C
	The average monthly temperature of the air. t^0C				
	V	VI	VII	VIII	
2016	14.7	20.9	22.8	22.2	20.2
Deviation ^0C	-0.4	-1.5	1.6	1.4	0.3
2017	15.2	20.2	21.8	22.5	19.9
Deviation ^0C	0.1	-2.2	0.6	1.7	0.1
Average 50 years (1960 – 2010)	15.1	22.4	21.2	20.8	19.9
Period	Monthly rainfall. *mm*				Amount for V – VIII. *mm*
	V	VI	VII	VIII	
2016	117.1	55.7	2.8	5.0	180.6
Deviation.%	233.7	98.6	5.2	11.9	349.5
2017	29.0	87.7	66.3	12.4	195.4
Deviation.%	57.9	155.2	124.2	29.6	366.9
Average 50 years (1960 – 2010)	50.1	56.5	53.4	41.9	201.9

Variety ”GTB-Ustrem” is suitable for direct harvesting. The main stem and branches of the cultivar end with vegetative bud. The plant is without tendril and lodging (II a type). The plant height depending on environmental conditions is within 40-60 cm. The pods are located in the upper 4/5 of the plant. The seeds are white, with medium veining and weak glossines. Longitudinal shape is elliptic, and cross shape – wide elliptic. The weight of 1000 seeds is 320 g. The protein content is 19.0%.

Variety ”GTB-Blijan” is suitable for direct harvesting. The main stem and branches of the cultivar end with vegetative bud. The plant is without tendril and lodging (II a type). The plant height depending on environmental conditions is

within 40-50 cm. The pods are located in the upper 4/5 of the plant. The seeds are white, with medium veining and weak glossines. Longitudinal shape is elliptic, and cross shape – wide elliptic. The weight of 1000 seeds is 330 g. The protein content is 20.9%.

Variety ”GTB-Elixir” is suitable for two-phase harvesting. The main stem and branches of the cultivar end with vegetative bud. The plant is lodging and climbing (III b type). The plant height depending on environmental conditions is within 100-160 cm. The pods are located in the lower 1/3 of the plant. The seeds are white, with medium veining and glossines. The seeds are kidney-shaped. The weight of 1000 seeds is 410 g. The protein content is 21.5%.

Results and discussion

The combination of variant 1, petoxamide+linuron+ciclosidim, shows very good efficacy (100%) for all annual grassy (green hides - *Setaria viridis* L. and cockspur - *Echinochloa crus-galli* L.) and broadleaved weeds (wild mustard - *Sinapis arvensis* L., common amaranth - *Amaranths retroflexus* L., thorn-apple - *Datura stramonium* L., rough cocklebur - *Xanthium strumarium* L., fat-hen - *Chenopodium album* L.,). Creeping thistle - *Cirsium arvense* (*L.*) Scop. has been retained in its development but has not died. Newly emerged species of creeping thistle have been reported (Tables 4, 5, 6).

The active substances of variant 2, petoxamide+bentazon+cikloksidim-separate application of the vegetative herbicides have excellent herbicidal effect (100%) against annual grassy (green hides - *Setaria viridis* L. and cockspur - *Echinochloa crus-galli* L.) and broadleaved weeds (wild mustard - *Sinapis arvensis* L., common amaranth - *Amaranths retroflexus* L., thorn-apple - *Datura stramonium* L., rough cocklebur - *Xanthium strumarium* L., fat-hen - *Chenopodium album* L..

The active substances of variant 3, petoxamide+bentazon+cikloksidim-combined application of the vegetative herbicides have a very good effect (100%) on the weeds of green hides - *Setaria viridis* L. and cockspur - *Echinochloa crus-galli* L., common amaranth - *Amaranths retroflexus* L., thorn-apple - *Datura stramonium* L.. Single unaffected weeds were identified: wild mustard - *Sinapis arvensis* L., rough cocklebur - *Xanthium strumarium* L., fat-hen - *Chenopodium album* L., which do not reduce the activity of herbicides.

The combination of variant 4, dimethenamid-P + pendimeetalin+linuuron+ cikloksidim also had a very good effect against the above weeds (100%). Single intact plants of wild mustard - *Sinapis arvensis* L., and thorn-apple - *Datura stramonium* L. were found. The minimum number of weeds killed does not affect the effect of herbicides.

The herbicidal combination of variant 5, dimethenamid-P+pendimetalin+

bentazon+cikloksidim - separate application of vegetative herbicides is characterized by excellent herbicidal effect on all studied weeds (green hides - *Setaria viridis* L. and cockspur - *Echinochloa crus-galli* L., wild mustard - *Sinapis arvensis* L., common amaranth - *Amaranths retroflexus* L., thorn-apple - *Datura stramonium* L., rough cocklebur - *Xanthium strumarium* L., fat-hen - *Chenopodium album* L.. Single plants of creeping thistle - *Cirsium arvense* (*L.*) Scop. have been found to be suppressed, but new shoots have emerged.

The active substances of variant 6, dimethenamid-P+pendimetalin+bentazon+ci kloksidim-combined application of vegetative herbicides have very good herbicidal activity in the studied annual grassy and broadleaved weeds. Single plants thorn-apple - *Datura stramonium* L., rough cocklebur - *Xanthium strumarium* L. are unaffected by herbicides (90-94%).

After application of the tested set of herbicides, no symptoms of phytotoxity were observed at the investigated varieties from 7 to 56 days after their use.

Table 4. Efficiency of some herbicides against grassy and broadleaved weeds in common dry bean variety "GTB-Ustrem" according to 100 % visual scale of EWRS

Weeds	Variants						
	1.	2.	3.	4.	5.	6.	7.
S. viridis	100	100	100	100	100	100	0
E. crus-galli	100	100	100	100	100	100	0
S. arvensis	100	100	90	90	100	100	0
D. stramonium	100	100	100	90	100	90	0
X. strumarium	100	100	90	100	100	90	0
A. retroflexus	100	100	100	100	100	100	0
Ch. album	100	100	90	100	100	100	0
C. arvensis	90	100	90	90	90	100	0

Table 5. Efficiency of some herbicides against grassy and broadleaved weeds in common dry bean variety "GTB-Blyan" according to 100 % visual scale of EWRS

Weeds	Variants						
	1.	2.	3.	4.	5.	6.	7.
S. viridis	100	100	100	100	100	100	0
E. crus-galli	100	100	100	100	100	100	0
S. arvensis	100	100	90	90	100	100	0
D. stramonium	100	100	100	90	100	90	0
X. strumarium	100	100	90	100	100	90	0
A. retroflexus	100	100	100	100	100	100	0
Ch. album	100	100	90	100	100	100	0
C. arvensis	90	100	90	90	90	100	0

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Table 6. Efficiency of some herbicides against grassy and broadleaved weeds in common dry bean variety "GTB-Elixir" according to 100 % visual scale of EWRS

Weeds	Variants						
	1.	2.	3.	4.	5.	6.	7.
S. viridis	100	100	100	100	100	100	0
E. crus-galli	100	100	100	100	100	100	0
S. arvensis	100	100	90	90	100	100	0
D. stramonium	100	100	100	90	100	90	0
X. strumarium	100	100	90	100	100	90	0
A. retroflexus	100	100	100	100	100	100	0
Ch. album	100	100	90	100	100	100	0
C. arvensis	90	100	90	90	90	100	0

Conclusion

Regardless of the used cultivar, the herbicide combination 1 variant: petoxamide (200 ml)+linuron (300 ml)+cikloksidim (200 ml); 2 variant: petoxamide (200 ml)+bentazon (200 ml)+cikloksidim (200 ml); 5 variant: dimetenamid-P+pendimetalin (400 ml)+bentazon (200 ml)+cikloksidim (200 ml) had highest efficiency (100%).

These herbicide combinations had excellent herbicide effect (100%) on the annual grassy (green hides - *Setatia viridis* L. and cockspur -*Echinochloa crus-galli* L.) and broadleaved weeds (wild mustard - *Sinapis arvensis* L., common amaranth - *Amaranths retroflexus* L., thorn-apple - *Datura stramonium* L., rough cocklebur - *Xanthium strumarium* L., fat-hen - *Chenopodium album* L.

After application of the tested set of herbicides, no symptoms of phytotoxity were observed at the investigated varieties from 7 to 56 days after their use.

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