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Impact of some herbicides, herbicide combinations and herbicide tank mixtures on sowing characteristics of winter forage pea (*Pisum sativum* L.)

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Abstract

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The research was conducted during 2015 - 2017 on pellic vertisol soil type. Under investigation was Bulgarian winter forage pea cultivar Mir (*Pisum sativum var. arvense*). Factor A included 3 rates: untreated control and 2 soil-applied herbicides – Dual gold 960 EC (S-metolachlor) - 1.5 $l.ha^{-1}$, Stomp aqua (pendimethalin) - 5 $l.ha^{-1}$. Factor B included 8 rates: untreated control, 5 foliar-applied herbicides – Basagran 480 CL (bentazone) - 2 $l.ha^{-1}$, Pulsar 40 (imazamox) - 1.2 $l.ha^{-1}$, Korum (bentazone + imazamox) - 1.25 $l.ha^{-1}$, Zencor 70 WG (metribuzine) - 500 $g.ha^{-1}$, Maton 600 EK (2.4-D ethylhexyl ester) – 1 $l.ha^{-1}$ and 2 herbicide tank mixtures – Zencor 70 WG (metribuzine) – 500 $g.ha^{-1}$ + Targa super 5 EC (quizalofop-P-ethyl) - 2 $l.ha^{-1}$, Maton 600 EK (2.4-D ethylhexyl ester) – 1 $l.ha^{-1}$ + Targa super 5 EC (quizalofop-P-ethyl) – 1 $l.ha^{-1}$. Soil-applied herbicides were applied during the period after sowing before emergence. Foliar-applied herbicides were applied during 2 - 3 real leaf stage of the pea. All of herbicides, herbicide combinations and herbicide tank-mixtures were applied in a working solution of 200 $l.ha^{-1}$. Mixing of foliar-applied herbicides was done in the tank on the sprayer. Foliar-applied herbicides Zencor and Maton and herbicide tank mixtures Zencor + Targa super and Maton + Targa super were proven to decrease germination energy of the winter forage pea seeds. Laboratory seed germination was proven to decrease by herbicide Maton and herbicide tank mixture Maton + Targa super only. Lengths of primary germ and primary root are decreased by herbicides Zencor and Maton and herbicide tank mixtures Zencor + Targa super and Maton + Targa super. Foliar-applied herbicides Basagran, Pulsar and Korum as well as their combinations with soil-applied herbicides Dual gold and Stomp aqua, were proven to decrease waste grain quantities. The highest yields of winter forage pea seeds were obtained by treatment with foliar-applied herbicide Korum after soil-applied herbicides Stomp aqua and Dual gold. High yields were obtained also by treatment with foliar-applied herbicide Pulsar after soil-applied herbicides Stomp aqua and Dual gold, as well as by foliar treatment with herbicide tank-mixture Zencor + Targa super after soil-applied herbicides Stomp aqua and Dual gold.

Keywords: winter forage pea; herbicides; herbicide combinations; seed yield; sowing characteristics

Introduction

Pea (*Pisum sativum* L.) is one of the oldest and most important legumes crops, grown widely in the world under different ecological conditions. Like all legumes it has an important role in stabilizing soil fertility, microbiological processes and plant health conditions and desired predecessor for all crops, except for itself and other legumes (Drew et al., 2007).

Weeds are one of the main factors that cause low yields and inferior production. Chemical control in pea is carried out with selective herbicides - soil-applied and foliar-applied. Herbicides must be selected depending on the composition of the weed associations accompanying pea culture (Bakht et al., 2009). In the pre-sowing period with incorporation against annual graminaceous and broadleaved weeds a soil-applied herbicide can be used, but because of the early sowing time when the soil humidity is high, this is most often not technically feasible. The chemical control of weeds in peas can be successfully accomplished by alone use or combined use of soil-applied herbicides against annual broadleaved and annual graminaceous weeds in the period after sowing before emergence (Dann et al., 1987; Sondhia, 2013; Delchev, 2018). Sowing a suitable depth is an important condition for protecting crops from soil-applied herbicides (Munakamwe et al., 2012; Yu et al., 2015).

During the vegetation against broadleaved weeds in their early stages can be used foliar-applied antibroadleaved herbicides (Wágner, 2015). It should be noted that crops are not treated at high air temperature and humidity (Dimitrova, 2005). With antigraminaceous herbicides, all annual and perennial graminaceous weeds are treated (Blažinkov et al., 2015).

The use of a large number of herbicides with a diverse chemical composition, mechanism and spectrum of action, changes in weed associations under the influence of various factors, necessitates a constant study of the problem of the efficacy of the herbicides and the sensitivity of the cultivars to them (Dimitrova, 1994; 2008).

The aim of this investigation was to establish the influence of some herbicides, herbicide combinations and herbicide tank mixtures on sowing characteristics of the winter forage pea seeds and the quantity of waste grain.

Materials and Methods

The research was conducted during 2015 - 2017 on pellic vertisol soil type. Under investigation was Bulgarian winter forage pea cultivar Mir (*Pisum sativum var. arvense*). Two factors experiment was conducted under the block method, in 4 repetitions, the size of the crop plot was 15 m^2. Factor A included 3 rates: untreated control and 2 soil-applied herbicides – Dual gold 960 EC and Stomp aqua. Factor B included 8 rates: untreated control, 5 foliar-applied herbicides – Basagran 480 CL, Pulsar 40, Korum, Zencor 70 WG, Maton 600 EK and 2 herbicide tank mixtures – Zencor 70 WG + Targa super 5 EC, Maton 600 EK + Targa super 5 EC. Active substances of herbicides and their doses are shown in Table 1.

Table 1. Investigated variants

No	Variants	Active substance	Doses
After sowing, before emergence			
1	Control	-	-
2	Dual gold 960 EC	S-metolachlor	1.5 $l.ha^{-1}$
3	Stomp aqua	pendimethalin	5 $l.ha^{-1}$
2 – 3 real leaf stage			
1	Control	-	-
2	Basagran 480 CL	bentazone	2 $l.ha^{-1}$
3	Pulsar 40	imazamox	1.2 $l.ha^{-1}$
4	Korum	bentazone + imazamox	1.25 $l.ha^{-1}$
5	Zencor 70 WG	metribuzine	500 $g.ha^{-1}$
6	Zencor 70 WG + Targa super 5 EC	metribuzine + quizalofop-P-ethyl	500 $g.ha^{-1}$ + 2 $l.ha^{-1}$
7	Maton 600 EK	2.4-D ethylhexyl ester	1 $l.ha^{-1}$
8	Maton 600 EK + Targa super 5 EC	2.4-D ethylhexyl ester + quizalofop-P-ethyl	1 $l.ha^{-1}$ + 2 $l.ha^{-1}$
Herbicides Pulsar 40 and Korum were used in addition with adjuvant Dash HC – 1 $l.ha^{-1}$			

Soil-applied herbicides were treated during the period after sowing before emergence. Foliar-applied herbicides were treated during 2 - 3 real leaf stage of the pea. All of herbicides, herbicide combinations and herbicide tank-mixtures were applied in a working solution of 200 l/ha. Mixing of foliar-applied herbicides was done in the tank on the sprayer. Herbicides Pulsar 40 and Korum were used in addition with adjuvant Dash HC – 1 l/ha.

The grain gained after every variant was cleaned through sieves and the quantity of the waste grain was defined (siftings). All version seeds for sowing were defined for their germination energy and lab seed germination. It was investigated intensity of early growth of seeds, expressed by the lengths of primary germ and primary root definite on the eighth day after setting the samples. Each index was determined in two repetitions of the year. Averages in each of the years of experience were used as repetitions in mathematical data processing were evaluated according to the method of analysis of variance.

Results and Discussion

One of the important conditions for obtaining a normal crop and a good harvest is the use of quality seeds. Apart from the high-yield cultivar which is resistance to diseases and pests, it must have the necessary sowing properties, the main of which are high germination energy and seed germination. Germination energy is one of the most important characteristics of the sowing properties of the seed. The low germination energy is the reason for slower development of primary germ and primary root after seed germination and is associated with later germination in field conditions, less tempering of plants and a higher risk of frost in the winter. It leads to lower seed yields. The obtained results show that the treatment of the winter forage pea with herbicides Zencor and Maton and herbicide tank mixtures Zencor + Targa super and Maton + Targa super lead to the decrease in the germination energy (Table 2). Analysis of variance, in which the years have taken for replications, shows that these decreases are mathematically proven.

Table 2. Influence of some herbicides, herbicide combinations and herbicide tank mixtures on sowing characteristics of the pea seeds (mean 2015 - 2017)

Herbicides		Germinative energy, %	Germination, %	Length, cm		Waste grain, %
Soil-applied	Foliar-applied			Primary germ	Primary root	
-	-	62.8	71.7	3.8	5.0	18.8
	Basagran	70.1	78.5	4.1	6.1	15.1
	Pulsar	71.0	78.5	5.4	6.5	15.4
	Korum	70.3	79.0	5.1	6.1	16.0
	Zencor	59.3	77.3	3.6	4.9	18.5
	Zencor + Targa super	60.1	77.0	3.3	4.7	18.0
	Maton	58.5	70.7	3.7	4.8	19.4
	Maton + Targa super	57.2	70.5	3.4	4.5	19.9
Dual gold	-	64.8	72.5	4.0	5.6	18.6
	Basagran	71.3	79.2	4.2	6.3	14.7
	Pulsar	73.2	81.7	5.3	6.9	14.9
	Korum	72.4	80.8	4.2	6.7	15.1
	Zencor	61.3	78.2	5.2	4.5	18.3
	Zencor + Targa super	61.8	79.0	4.2	4.4	18.0
	Maton	59.0	71.5	3.8	4.8	19.1
	Maton + Targa super	58.8	71.1	4.0	4.8	19.4
Stomp aqua	-	65.4	73.8	4.3	5.3	18.3
	Basagran	72.0	80.3	4.4	6.0	14.8
	Pulsar	74.1	82.3	5.5	6.8	15.0
	Korum	73.3	74.2	5.3	6.5	15.6
	Zencor	61.1	78.5	4.1	4.3	18.1
	Zencor + Targa super	61.5	79.2	4.3	4.6	17.9
	Maton	59.2	72.2	3.9	5.3	18.9
	Maton + Targa super	59.0	71.8	4.3	5.0	19.1
LSD 5 %		2.5	3.1	1.2	1.5	2.3
LSD 1 %		3.4	4.1	2.0	2.3	3.5
LSD 0.1 %		4.6	5.3	3.1	3.4	5.1

Germination is the most important index which characterizing the sowing properties of the seeds. At low laboratory germination sowing should be done with higher sowing rate, which increases the cost production. Laboratory germination of the seeds at all variant during the three years of study is above the requirements of the standard, although in different years account for some variation of its values. This is the positive effect of their use, because it is not necessary to increase the sowing rate (in kg/ha) and the cost of necessary seeds. At herbicide Maton and herbicide tank mixture Maton + Targa super seed germination is lower than untreated control. The pea seeds germinate normally under influence of the herbicide Zencor and herbicide tank mixture Zencor + Targa super, although the initial rate of development is lower due to lower germination energy. Other soil-applied herbicides, foliar-applied herbicides and their combinations increase the indexes germination energy and seed germination. This means that they help for joint and fast germination of the winter forage pea sowing-seeds.

The obtained results for germination energy and seed germination are a prerequisite to continue investigating the effect of herbicides, herbicide combinations and herbicide tank mixtures on initial intensity of the growth of seeds, expressed by the lengths of primary germs and roots. It was found that the lengths of the primary germ and primary root of winter forage pea are decreased by herbicides Zencor and Maton and herbicide tank mixtures Zencor + Targa super and Maton + Targa super. These decreases are proven by analysis of variants. These two herbicides and two herbicide tank mixtures done difficult young plants developments reduce their resistance to cold and increase risk of frost damages during winter months. Other combinations between soil-applied and foliar-applied herbicides led to increase of the lengths of primary germ and primary root of the pea and are recommended for use in seed production crops of winter forage pea.

During the evaluation of the sowing characteristics we have to consider not only the characteristics of the sowing seeds but also the quantity of the waste grain (siftings) which are gained at the preparation of these seeds. Bigger quantity screenings lead to higher cost of the seed and reduce the economic effect of seed production of winter forage pea. Alone use of foliar-applied herbicides Basagran, Pulsar and Korum, as well as their combined use with soil-applied herbicides Dual gold and Stomp aqua, lead to mathematically proven decrease in the quantity of waste grain. Other herbicides, herbicide combinations and herbicide tank mixtures do not influence on the quantity of waste grain. Differences between them and untreated control are not mathematically proven.

Decreases in the values of germination energy and laboratory seed germination, decreases in the intensity of the initial growth, expressed by the lengths of the primary root and primary germ at germination and changes in the quantity of waste grain under the influence of the relevant herbicides, herbicide combinations and herbicide tank mixtures are explained by the depressing effects on growth and development of the winter forage pea during its vegetative period.

To make a full evaluation of the sowing characteristics needed to establish not only the quality of seeds, but also the quantity of grain which will be received these seeds. Data for the influence of investigated herbicides, herbicide combinations and herbicide tank mixtures on seed yield of winter forage pea (Table 3) show that the lower yield is obtained by alone use of herbicide tank mixture Maton + Targa super – 97.2% compared to untreated control. Low yields are also obtained by alone use of herbicide Maton and by combined use of herbicide tank mixture Maton + Targa super with soil-applied herbicides Dual gold and Stomp aqua. Their use does not increase seed yield compared to untreated control, despite their very good herbicidal effect against both graminaceous and broadleaved weeds. The reason for this is their higher phytotoxicity against pea.

Alone use of soil-applied herbicides Dual gold and Stomp aqua does not increase proven seed yield compared to untreated control, because these herbicides cannot control the perennial weeds and a part of annual weeds.

Alone use of foliar-applied herbicides Pulsar and Korum increases seed yields because all of weeds and self-sown plants are destroyed by these herbicides. Seed yields of Korum are higher than those of Pulsar. The reason for this is the longer effect of Korum and its longer control over the secondary-emerged weeds. The differences in yields between the herbicides Korum and Pulsar are mathematically unproven, because after the herbicide treatment, the pea develops rapidly, covers the whole soil surface, competes with weeds and almost prevents secondary weed infestation.

Herbicide Basargan slightly increases yield because of its inefficacy against graminaceous weeds and part of annual broadleaved weeds. Herbicide Zencor slightly increases yield because of its inefficacy against perennial broadleaved weeds and its higher phytotoxicity to pea plants.

The highest seed yields are obtained by treatment with foliar-applied herbicide Korum after soil-applied herbicide Stomp aqua – 123.7% and by Korum after soil-applied herbicide Dual gold – 123.2% above the untreated control. High yields are obtained also by treatment with foliar-applied herbicide Pulsar after soil-applied herbicides Stomp aqua and Dual gold – 121.8% and 120.9% respectively, as well as by foliar treatment with herbicide tank-mixture Zencor + Targa super after soil-applied herbicides Stomp aqua and Dual gold 119.4% and 119.0% respectively.

Combining the soil-applied herbicides Dual gold and Stomp aqua with the foliar-applied herbicides Basagrain, Pulsar, Korum, Zencor and Maton and with the herbicide tank mixtures Zencor + Targa super and Maton + Targa super always results in a higher yield increase compared to the alone use of the respective herbicides and herbicide tank mixtures during the three years of the investigation.

Table 3. Influence of some herbicides, herbicide combinations and herbicide tank mixtures on seed yield of pea (2015 - 2017)

Herbicides		2015		2016		2017		Mean	
Soil-applied	Foliar-applied	kg.ha^{-1}	%	kg.ha^{-1}	%	kg.ha^{-1}	%	kg.ha^{-1}	%
-	-	2314	100	2890	100	2580	100	2595	100
	Basagran	2586	111.8	3299	114.2	2842	110.2	2909	112.1
	Pulsar	2762	119.4	3390	117.3	2944	114.1	3032	116.8
	Korum	2841	122.8	3480	120.4	3003	116.4	3108	119.8
	Zencor	2511	108.5	3244	112.2	2755	106.8	2837	109.3
	Zencor + Targa super	2684	116.0	3355	116.1	2924	113.3	2988	115.1
	Maton	2377	102.7	2777	96.1	2691	104.3	2615	100.8
	Maton+ Targa super	2280	98.5	2688	93.0	2597	100.7	2522	97.2
Dual gold	-	2378	102.8	2992	103.5	2666	103.3	2679	103.2
	Basagran	2654	114.7	3413	118.1	2967	115.0	3011	116.0
	Pulsar	2841	122.8	3503	121.2	3068	118.9	3137	120.9
	Korum	2906	125.6	3589	124.2	3099	120.1	3198	123.2
	Zencor	2571	111.1	3355	116.1	2866	111.1	2931	112.9
	Zencor + Targa super	2754	119.0	3468	120.0	3044	118.0	3089	119.0
	Maton	2441	105.5	2890	100.0	2812	109.0	2714	104.6
	Maton + Targa super	2340	101.2	2803	97.0	2712	105.1	2618	100.9
Stomp aqua	-	2414	104.3	3030	104.8	2691	104.3	2712	104.5
	Basagran	2670	115.4	3439	119.0	2980	115.5	3030	116.8
	Pulsar	2867	123.9	3534	122.3	3081	119.4	3161	121.8
	Korum	2911	125.8	361.0	124.9	3106	120.4	3209	123.7
	Zencor	2596	112.2	3381	117.0	2879	111.6	2952	113.8
	Zencor + Targa super	2762	119.4	3480	120.4	3057	118.5	3100	119.4
	Maton	2462	106.4	2922	101.1	2825	109.5	2736	105.4
	Maton + Targa super	2356	101.8	2829	97.9	2712	105.1	2632	101.4
LSD 5 %		106	4.6	173	6.0	132	5.1		
LSD 1 %		139	6.0	220	7.6	170	6.6		
LSD 0.1 %		174	7.5	269	9.3	212	8.2		

Conclusion

Foliar-applied herbicides Zencor and Maton and herbicide tank mixtures Zencor + Targa super and Maton + Targa super were proven to decrease germination energy of the winter forage pea seeds. Laboratory seed germination was proven to decrease by herbicide Maton and herbicide tank mixture Maton + Targa super only. Lengths of primary germ and primary root are decreased by herbicides Zencor and Maton and herbicide tank mixtures Zencor + Targa super and Maton + Targa super. Foliar-applied herbicides Basagran, Pulsar and Korum as well as their combinations with soil-applied herbicides Dual gold and Stomp aqua, were proven to decrease waste grain quantities. The highest yields of winter forage pea seeds were obtained by treatment with foliar-applied herbicide Korum after soil-applied herbicides Stomp aqua and Dual gold. High yields were obtained also by treatment with foliar-applied herbicide Pulsar after soil-applied herbicides Stomp aqua and Dual gold, as well as by foliar treatment with herbicide tank-mixture Zencor + Targa super after soil-applied herbicides Stomp aqua and Dual gold.

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