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INFLUENCE OF HERBICIDES ON SEED PRODUCTIVITY AND SOWING QUALITIES OF WHITE MELILOT IN THE STEPPE ZONE OF UKRAINE

Raisa VOZHEHOVA, Serhii KOKOVIKHIN, Oleksandr MISIEVYCH, Anatolii VLASHCHUK, Mykola PRYSHCHEPO, Liudmyla SHAPAR, Pavlo LYKHOVYD, Olesia DROBIT, Olena KONASHCHUK, Viktor NAIDIONOV

Institute of Irrigated Agriculture, Naddniprianske, Kherson, Ukraine, 73483, Phone: 0552361196, Email: izz.ua@ukr.net

Corresponding author email: pavel.likhovid@gmail.com

Abstract

Crop yields are mostly dependent on the climatic conditions and structural indexes where perennial and annual herbs have special value as previous crops. White melilot is an important annual herb that should be introduced into the crop rotations of the Steppe zone. Seed productivity of white melilot depends on a number of factors including the growth conditions and features of the cultivated variety. The best results in the increase of seed productivity of the crop could be achieved by the optimal agrotechnological and chemical measures of weed management herewith the application of herbicides is characterized with the highest efficiency. The three-year study was conducted in the conditions of the Steppe zone of Ukraine on the dark-chestnut soil to determine the best option for chemical weed management in the crops of white melilot. It was determined that the highest seed productivity of the crop with the average seed yield of 840.0 kg/ha and best sowing qualities of the obtained seeds (the energy of sprouting of 81%, seedling rate of 85%, 1000 seeds weight of 2.06 g) were achieved on the variant with application of herbicide Pulsar 40 (active substance imazamox, 40 g/l) in the dose of 1.0 l/ha. Therefore, we recommend the utilization of imazamox-based herbicide for weed management in the crops of white melilot under its cultivation in the conditions of the Steppe zone.

Key words*: herbicide, seed productivity, sowing qualities, white melilot.*

INTRODUCTION

White melilot (*Melilotus albus* Desr.) is a valuable annual or biennial legume herb, which is an important component of crop rotations. However, there is only a few scientific studies dedicated to the peculiarities of the crop's growth and development, and some of them were conducted for the biennial species of the plant (Martin, 1934). Besides, some studies even report about the crop as a weed, which is common in the cotton crops (Rajput et al., 2008). We do not agree with such an opinion on white melilot, especially, taking into account the long-term benefits provided by the crop introduction on the lands of the Steppe zone. The crop is a valuable source of high-qualitative forage for cattle (Yisehak, 2008), and an important source of organic matter for the degraded and deteriorated soils (Maynard, 1917).

Cultivation technology of white melilot is studied insufficiently. We lack scientific knowledge on a number of important technological questions of the crop cultivation. Furthermore, we know very little about the peculiarities of weed management in the crops of white melilot.

Taking into account insufficient efficiency of mechanical measures of weed control, most high-developed countries use pre-plant, pre-emergence and post-emergence herbicides to control weeds. Active substances of these products penetrate into the weeds' tissues through their roots and stomata that cause poisoning and death without any harm to the cultivated crop (Tsykov et al., 2012).

Weeds in the white melilot crops can dominate that will cause a negative effect on the seed productivity and sowing qualities of the seeds in the future.

Sowing qualities characterize the seed material as a mean of production and its suitability for usage in production conditions to obtain a high yield of the crop. They include the energy of sprouting, seedling rate, varietal pureness, seed moisture, 1000 seeds weight, contamination with insects, quarantine weeds and infestation

by diseases (Havryliuk et al., 2002; Harker et al., 2012).

Therefore, the necessity in the determination of the efficiency of herbicides Treflan 480 (trifluralin, 480 g/l of the active substance) and Pulsar 40 (imazamox, 40 g/l of the active substance) in different doses of application has been considered. Besides, their influence on the seed productivity and sowing qualities of white melilot seeds of Pivdennyi variety were studied in the conditions of Southern Steppe of Ukraine.

MATERIALS AND METHODS

The study was carried out at the experimental field of the Institute of Irrigated Agriculture NAAS (46°44′33″N, 32°42′28″E, 60 m above the sea level) in 2015-2017 with accordance with the generally accepted methodology of experimental work of the Scientific Program No. 22 "Scientific bases of production, storage and usage of forage for obtaining competitive products of stockbreeding («Forage and forage protein»)" (Dospekhov, 1985; Yeshchenko et al., 2005; Ushkarenko et al., 2008; Vozhehova et al., 2014). The soil of the experimental plot was dark-chestnut, middle-loamy, which is typical for the irrigated lands of Southern Steppe of Ukraine. Humus layer was 47-52 cm and it was characterized with high looseness, adhesion, and tendency to overcrusting that is connected to its natural salinity and narrow Ca^{2+} and Mg^{2+} ratio of 2.5-2.8. Besides, the soil is characterized with high bulk density after drying, and low water permeability. The total porosity in the soil layer of 0-40 cm was 47%. The water-holding capacity of the 0-70 cm soil layer was 22.0%, and the wilting point was fixed at 9.54% of moisture content to the dry mass. The bulk density of the soil was 1.41 g/cm^3. Humus content in the arable soil layer was 2.2%. The average content of nitrate nitrogen in the soil layer of 0-50 cm was 18 mg/1 kg of soil; the content of mobile phosphorus was 37, the content of exchangeable potassium was 332 mg/1 kg of soil, respectively.

Climate of the zone is characterized as semi-arid, moderately continental, comparatively dry and hot, with a strong tendency to warming (Lykhovyd, 2018). Weather conditions in the years of the field trials are presented in Table 1.

Winter of 2014-2015 was characterized by frequent precipitations. At the end of December the amount of precipitation was 124.5 mm that caused oversaturation of the soil with water. This led to ice crusting of the soil on some experimental plots in the first decade of January 2015. The soil was frosted to the depth of 40 cm. The weather of 2015 was unstable. It was characterized by high daily fluctuations of air temperature (within 15-20ºC) and high amount of precipitations. In March 55.7 mm of precipitations were recorded. Stable warming of the weather was observed from the third decade of April, which had the average month air temperature of 9.3ºC. Important precipitations were recorded in April (68.8 mm), while the average norm for this month is just 33.0 mm. May was warm (average air temperature of 19.6ºC) and humid (precipitation amount of 86.9 mm). The summer period of 2015 was moderately hot, with unstable precipitation distribution by showers. The total rainfall amount was 155.0 mm, average air temperature of the summer was 22.5-22.9ºC with several days with increase of the index up to 38.6ºC. August was dry and hot. September was warm and very dry (just 4.6 mm of rainfall). The autumn period of white melilot vegetation was warm and comparatively dry.

The winter of 2015-2016 was cold and wet. However, the third decade of February was abnormally warm (air temperature increased to 13ºC) and dry. March of 2016 was warm but dry (with rainfall of 19.5 mm). There was a steep increase of air temperatures up to 15-25ºC in April accompanied by the rainfall of 56.8 mm. The average air temperature in May was 16.1ºC, precipitation amounts reached 71.7 mm. The summer of 2016 was very hot and dry, with periods of air temperature increase to 38ºC. This caused an oppression to the plants of white melilot. September was comparatively warm (air temperature of 18.7-22.0ºC) and dry.

The winter of 2016-2017 was comparatively warm (average air temperature of 2.9ºC) with precipitation amounts of 74.3 mm. March of 2017 was dry, with only 5.1 mm of rainfall. April was characterized by the average air temperature of 9.3ºC and sufficient rainfall.

May was quite typical in the weather conditions for the zone, with 25.6 mm of rainfall. The summer was very hot and dry, with average air temperatures of 26-29ºC, with short periods with temperature increases up to 36.8-40.0ºC. Total precipitation amounts of the period averaged 54.9 mm.

Table 1. Meteorological parameters during the years of the study (2015-2017)

2015			2016			2017			Months
AT, ºC	AH, %	PA, mm	AT, ˚ ºC	AH, %	PA, mm	AT, ˚ ºC	AH, %	PA, mm	
-0.4	92	39.8	-3.6	89	67.3	-4.7	85	27.5	January
0.8	85	47.4	4.0	85	30.9	-0.8	84	20.3	February
5.2	78	55.7	6.3	78	19.5	7.0	73	5.1	March
9.3	75	68.8	12.6	71	56.8	9.3	72	87.9	April
17.0	69	86.9	16.1	76	71.7	16.3	64	25.6	May
20.0	73	38.3	22.1	68	43.0	22.0	61	10.3	June
23.4	69	104.6	24.4	58	46.3	23.4	60	39.8	July
24.2	49	12.1	24.7	59	26.7	25.4	51	4.8	August
20.9	60	4.6	18.0	63	33.2	19.9	61	0.7	September
9.4	70	18.6	8.4	80	74.4	11.3	76	12.0	October
7.3	86	44.2	4.0	87	34.2	5.4	87	40.6	November
2.3	86	2.1	-1.2	86	26.5	5.9	87	35.4	December
12.2	72.0	364.2	11.3	75.0	530.3	11.7	71.8	310.0	Annual

Note: AT - air temperature, AH - air humidity, PA - precipitation amounts.

We carried out a double-factor field trial in four replicates using the randomized plot design method. The total area of the experiment was 900 m^2, and the area of the single plot was 24 m^2.

We used an annual variety of white melilot (*Melilotus albus* Desr.) Pivdennyi, which was created by the Institute of Irrigated Agriculture NAAS. The design of the study foresaw the application of preemergence herbicide Treflan 480 in doses of 1.5, 2.5, 3.0, and 4.0 l/ha, and postemergence herbicide Pulsar 40 in doses of 0.50, 0.75, 1.00, and 1.50 l/ha.

Cultivation technology of the crop was based on the common recommendations for white melilot cultivation in the conditions of the South of Ukraine. The previous crop was winter rape. Primary tillage in the autumn period included deep plowing at the depth of 25-27 cm. Dragging of the soil was conducted in the early spring period. Herbicide Treflan 480 was applied under the soil cultivator tillage on the depth of 6-8 cm. The crop was sown by the means of a seed tractor-towed drill with the rate of 2.5 million seeds/ha on the depth of 2-3 cm in the first decade of April. The inter-row spacing was 15 cm. Sowing of the crop was followed by rolling. Herbicide Pulsar 40 was applied at the stage of 1-3 triple leaves of the crop. Weeds reached 1-3 (gramineous weeds) and 2-4 (dicotyledonous weeds) leaves stage at the moment of the herbicide application. Complete death of the weeds was recorded in 4-6 weeks after the herbicide application. This term depended on the dose of the herbicide application and weather conditions. White melilot seeds were harvested in the first decade of September by using a self-propelled combine harvester “Sampo-250” at the stage of the seeds ripeness and 12-13% moisture content. Harvesting was followed by purification on the Petkus-3 machine.

Modification and phenotypical variabilities of the seeds were determined by the generally accepted methodology (Brewbaker, 1964; Rokitskii, 1967; Litun et al., 2004). 1000 seeds weight, energy of sprouting and seedling rate were determined in laboratory according to the methodology of DSTU 4138-2002 (Derzhspozhyvstandart Ukrainy, 2003) before and after scarification.

Statistical processing of the experimental data was performed by using the standard procedures of the double-factor analysis of variance (ANOVA) with calculation of the least significant difference (LSD_{05}) at the probability level of 95% (Ushkarenko et al., 2008).

RESULTS AND DISCUSSIONS

In average, for the 2015-2017 period, the dynamic of the increase in the yield of white melilot variety - Pivdennyi was observed for all the variants of the experiment compared to the control ones. At the application of Treflan 480 herbicide, the maximum yield of 740.0 kg/ha was obtained at the dose of 3.0 l/ha, and the increase of the yield was 273.3 kg/ha. It was established that the variant of application of Pulsar 40 with the dose of 1.0 l/ha provided the

highest biological efficiency (by seed yield of the crop) in all the years of the study, as follows: 2015-1120 kg/ha, 2016-920 kg/ha, 2017-480 kg/ha (Table 2). At the application of Pulsar 40 herbicide, the maximum yield was 840.0 kg/ha in the variant with the dose of 1.0 l/ha, and the increase of the yield was 373.3 kg/ha, respectively.

This peculiarity is explained by the fact that under the application of Treflan 480 herbicide with the increased dose from 1.5 to 3.0 l/ha, and under the application of herbicide Pulsar 40 with the increased dose from 0.5 to 1.0 l/ha, there was a negative effect on the growth processes of weeds. Application of Treflan 480 herbicide at the dose of 3.0 l/ha, and Pulsar 40 herbicide at the dose of 1.0 l/ha showed a tendency in increasing of seed yield of white melilot variety Pivdennyi with the years of study. It was also determined that at the application of Treflan herbicide at the dose of 3.0 l/ha, and Pulsar 40 herbicide at the dose of 1.0 l/ha, there was a negative effect on the crop that might be proved by the observations of some changes in the processes of the crop plants' growth, development, and seed yield.

Table 2. Seed yield of white melilot variety Pivdennyi in dependence on application of the herbicides

Herbicide	Application dose, l/ha	Yield, kg/ha				Average yield by the factor, kg/ha	Raise of the yield in kg/ha, average for 2015-2017
		2015	2016	2017	2015-2017		
Treflan 480	control	700	580	120	466.67	636.67	0
	1.50	1020	740	140	633.33		166.67
	2.50	1040	780	210	676.76		210.00
	3.00	1090	820	310	740.00		273.33
	4.00	1010	720	270	666.67		200.00
Pulsar 40	control	700	580	120	466.67	705.330	0
	0.50	1050	780	210	680.00		213.33
	0.75	1070	860	330	753.33		286.67
	1.00	1120	920	480	840.00		373.33
	1.50	1090	890	380	786.67		320.00
Evaluation of the significance of the studied factors							
LSD_{05}, kg/ha	Treflan 480	20.04	27.77	32.77	17.38		
	Pulsar 40	21.92	25.00	29.90	16.56		
Share of the factors in the effect on the yield of the crop, %							
	Treflan 480	99	97	94	96		
	Pulsar 40	99	99	99	99		

Table 3. Yield of conditional seeds of white melilot variety Pivdennyi in dependence on application of the herbicides

Herbicide	Application dose, l/ha	Yield, kg/ha				Average yield by the factor, kg/ha	Raise of the yield in kg/ha, average for 2015-2017
		2015	2016	2017	2015-2017		
Treflan 480	control	611.18	500.25	104.40	405.28	566.50	0
	1.50	918.00	658.60	122.38	566.33		161.05
	2.50	931.50	689.75	186.90	602.72		197.44
	3.00	978.75	732.03	271.45	660.74		255.47
	4.00	909.00	640.80	242.53	597.44		192.17
Pulsar 40	control	611.18	500.25	104.40	405.28	631.76	0
	0.50	945.00	704.25	189.00	612.75		202.47
	0.75	958.50	774.00	294.75	675.75		270.47
	1.00	1016.93	830.90	436.80	761.54		356.27
	1.50	976.50	796.50	337.50	703.50		298.22
Evaluation of the significance of the studied factors							
LSD_{05}, kg/ha	Treflan 480	17.65	24.52	29.11	15.33		
	Pulsar 40	19.44	22.68	26.81	14.55		
Share of the factors in the effect on the yield of the crop, %							
	Treflan 480	100	97	95	97		
	Pulsar 40	100	100	100	100		

On the variants with application of Treflan 480 at the dose of 4.0 l/ha, and Pulsar at the dose of 1.5 l/ha, we established the decrease in the yielding indexes. The yield of the control plots was lower because of high weediness of the crops. The seed yield of white melilot variety Pivdennyi was mainly dependent on the efficiency of the herbicides. It was determined that on the variants with the maximum percentage of dead weeds the highest yield was obtained, which was accompanied by the highest output of the conditional seeds with the best sowing qualities. In the yield of conditional seeds, a high varietal reaction on the studied herbicides and their doses were determined (Table 3).

It is important to mention that the conditions of seed formation affect its quality and conditional seed yield. The obtained results proved that on the variants without the herbicides' application, the share of non-conditional seeds has increased. Independently on the year of the study, the percentage of non-conditional seeds fluctuated within 9.0-13.7%. Application of Pulsar 40 herbicide at the dose of 1.0 l/ha resulted in the increase of the yield of conditional seeds up to 1016.9 kg/ha. The yield of conditional seeds significantly increased due to the application of the herbicides compared to the control. We determined the influence of Pulsar 40 herbicide application on the yield of conditional seeds of white melilot Pivdennyi.

The maximum yield of conditional seeds at the level of 91% (in average for the period of 2015-2017) was obtained at the application of Pulsar 40 herbicide at the dose of 1.0 l/ha with the reproduction coefficient of 168 (Table 4).

The obtained results showed that conditional seed yield and coefficient of reproduction of white melilot variety Pivdennyi changed with the level of the crop protection. By analyzing different application doses of the herbicides, we have to mention that under the different application doses of Pulsar 40 herbicide, we observed the increase of conditional seed yield and coefficient of reproduction compared to the indexes obtained under application of Treflan 480 herbicide and on the control. This is explained by considerable reduction of weeds' growth and higher formation of the productive stems of the white melilot plants at the moment of seed harvesting. It should be mentioned that the effect of the factors of environment and agrotechnology did not shift onto the seeds of the crop, but it is transformed through the plant as a complex of processes of energy and substance conversion in the organisms. The conditions of the seed formation had an important value because they influenced on the heredity of new plant organism (Berkutova, 1991; Bilyk et al., 2005).

Table 4. Conditional seed yield and coefficient of reproduction of white melilot variety Pivdennyi in dependence on application of the herbicides

Herbicide	Application dose, l/ha	Conditional seed yield, %		Coefficient of reproduction	
		Average for 2015-2017	V_m (modificatory variability), %	Average for 2015-2017	V_m (modificatory variability), %
Treflan 480	Control	86.9	7.33	93.3	20.14
	1.5	88.8	7.21	126.7	19.69
	2.5	89.0	7.03	135.3	19.33
	3.0	88.9	6.77	148.0	19.12
	4.0	89.6	6.95	133.3	19.24
	V_{pf} (phenotypical variability), %	2.89		8.08	
Pulsar 40	Control	86.9	7.33	93.3	20.14
	0.5	90.1	7.14	136.0	19.44
	0.75	89.6	7.00	150.7	19.19
	1.0	91.0	6.66	168.0	18.87
	1.5	89.3	6.88	157.3	19.11
	V_{pf} (phenotypical variability), %	3.11		9.91	

One of the most important indexes characterizing sowing quality of seeds is 1000 seeds weight, the energy of sprouting and seedling rate. Purified and calibrated seeds usually have a high index of sprouting energy that is important for obtaining strong and simultaneous sprouts on time.

The application of Treflan 480 and Pulsar 40 herbicides Treflan 480 and Pulsar 40 positively affected the seed productivity of white melilot. This found the reflection in the indexes of the sprouting energy, emergence rate and 1000 seeds weight at the different doses of its application (Table 5).

Application of the studied herbicides had a considerable positive effect on the energy of sprouting and seedling rate of the obtained seeds of white melilot variety Pivdennyi. On the control plots, where chemical protection was not used, the indexes of the sprouting energy and seedling rate did not exceed 71%. This is explained by the fact of high contamination of the control plots with weeds that had a negative effect on harvesting because of high quantity of unripe seeds and green mass of weeds, which was very difficult to separate and caused overheating of the seeds in the piles during their drying process. All these factors led to the decrease of the sprouting energy and seedling rate that led to a worse sowing quality of the obtained white melilot seeds.

The maximum average sprouting energy (81%) and seedling rate (85%) were obtained on the variants with the application of Pulsar 40herbicide at the dose of 1.0 l/ha.

The lowest sprouting energy (76%) and seedling rate (78%) were obtained on the variants with the application of Treflan 480 herbicide. Weeds dominated the crops of white melilot on the control plots that affected the seed productivity and 1000 seeds weight (Table 6).

The results of the study showed that Treflan 480 and Pulsar 40 herbicides at different application doses had positive effect on 1000 seeds weight compared to the control variant.

The maximum average of 1000 seeds weight (1.86-2.33 g) was obtained at the application of herbicide at the dose of 1.0 l/ha. On the control variants, 1000 seeds weight averaged to 1.76 g that is by 10-15% less than on the variants with the applied herbicides.

The share of the influence of the studied factor fluctuated within 94-99% within the years of the study that emphasizes the strong effect of the herbicides on the studied sowing qualities of white melilot seeds.

Besides, the significance of the herbicide application effect on seed yield and sowing qualities of the seeds was proved by the results of ANOVA (the differences between the studied variants of the experiment exceeded the LSD_{05} at the probability level of 95%).

Table 5. The energy of sprouting and seedling rate of the seeds of white melilot variety Pivdennyi after mechanical scarification in dependence on application of the herbicides

Herbicide	Application dose, l/ha	The energy of sprouting,%		Seedling rate, %	
		Average for 2015-2017	Average by the herbicide	Average for 2015-2017	Average by the herbicide
Treflan 480	control	71	76	71	78
	1.5	78		80	
	2.5	76		80	
	3.0	78		81	
	4.0	77		79	
Pulsar 40	control	71	78	71	81
	0.5	78		82	
	0.75	78		85	
	1.0	81		85	
	1.5	80		83	

Table 6. 1000 seeds weight of conditional seeds of white melilot variety Pivdennyi in dependence on application of the herbicides

Herbicide	Application dose, l/ha	1000 seeds weight, g				Average by the herbicide
		2015	2016	2017	2015-2017	
Treflan 480	Control	2.02	1.73	1.54	1.76	1.90
	1.5	2.33	1.79	1.67	1.93	
	2.5	2.40	1.89	1.56	1.95	
	3.0	2.27	1.76	1.77	1.93	
	4.0	2.37	1.73	1.68	1.93	
Pulsar 40	Control	2.02	1.73	1.54	1.76	1.91
	0.5	2.29	1.79	1.70	1.93	
	0.75	2.25	1.90	1.80	1.98	
	1.0	2.33	1.99	1.86	2.06	
	1.5	2.03	1.79	1.60	1.80	
Evaluation of the significance of the studied factors						
LSD_{05}, g	Treflan 480	0.030	0.034	0.031	0.010	
	Pulsar 40	0.024	0.025	0.017	0.010	
Share of the factors in the effect on the yield of the crop, %						
	Treflan 480	99	94	96	98	
	Pulsar 40	99	99	99	99	

CONCLUSIONS

From the analysis of the efficiency of Treflan 480 and Pulsar 40 herbicides at the different application doses, we have observed that Treflan 480 based on its physiological and biochemical effects demonstrated superior oppression of the white melilot plants compared to Pulsar 40. The results of such an influence modified the seed productivity of white melilot variety Pivdennyi and led to the decrease of the seed yield compared to Pulsar 40 herbicide. The variants without application of the herbicides had increased the share of non-conditional seeds. Independently on the year, the percentage of non-conditional seeds fluctuated within 9.0-13.7%.

In average, for the 2015-2017 period, the maximum total seed productivity (840.0 kg/ha) and conditional seed yield (761.54 kg/ha) of white melilot variety Pivdennyi was determined in the variant with application of Pulsar 40 herbicide at the dose of 1.0 l/ha. The maximum sprouting energy (81%) and seedling rate (85%) were achieved on the variant with treatment of the crops with h Pulsar 40 herbicide at the dose of 1.0 l/ha. The lowest sprouting energy (76%) and seedling rate (78%) were determined at application of Treflan 480 herbicide. The highest 1000 seeds weight of 2.06 g was also obtained in the variant with Pulsar 40 treatment. Therefore, we recommend the cultivation of white melilot in the conditions of the Steppe zone of Ukraine by using the chemical control of weeds with Pulsar 40 herbicide applied at the dose of 1.0 l/ha.

However, the study has a number of limitations. First, further investigations are required to determine the reactions of all available varieties of white melilot on the herbicides' application. Second, we need to find out whether other chemical products could be efficient in weed management of the crop. Furthermore, we have to pay special attention to the development of environmentally friendly and ecologically safe efficient agrotechnological measures of weed management in the crops of white melilot because chemical control of weeds is undesirable and must not be used if the crop is cultivated for livestock feeding. In addition, economic efficiency of weed management should be carefully studied in the future.

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