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Influence of the Seeding Rate, Sowing Methods and Disease and Pest Control Measures on the Yield and Quality of Seeds for Different Varieties of Milk Thistle

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Abstract.

The paper provides the data of long-term studies of milk thistle yield by selecting the most productive varieties, taking into account soil and climatic conditions, methods of sowing, seeding rates and plant protection products. The highest yield (1.25 t/ha) is characteristic of the Amulet milk thistle with a straight seeding method and a seeding rate of 500,000 seeds per hectare compared to the Samaryanka (1.01 t/ha) variety. Both the reduction and increase in the seeding rate lead to a decrease in yield: in the Amulet variety, it is 1.8 to 1.3-fold, in the Samaryanka variety, 1.6 to 1.2-fold.

The features of the leaf surface and biomass formation depending on the methods of sowing, the rate of seeding and cultivar characteristics are outlined. The maximum formation parameters of the leaf surface (54.1 thousand m^2) and dry biomass (4.51 t/ha) are reached for the Amulet variety at the beginning phase of fruit formation with the row method of sowing and the seeding rate of 500 thousand pieces per 1 hectare. The tall-growing medium-ripened varieties Panacea and Amulet with a vegetation period of 95-102 days ensure the production of 0.92-1.11 t/ha of seeds. It is 18-24% higher compared to the low-growing early-ripening varieties, Debut, Samaryanka and Nadezhda.

The treatment of the thistle sowings in the phase of 5-6 leaves against Phyllotreta Vittula and Scotia Segetum with Decis Expert and Confidor insecticide tank mixture increased the yield of seeds to 1.07 t/ha vs. 0.83 t/ha at the control plot.

Keywords: thistle; yield; yield structure; photosynthesis; flavolignans; seeding rates; seeding methods; insecticides.

INTRODUCTION.

In the world practice, preparations of plant origin are widely used at the present time. Milk thistle is a valuable medicinal raw material [1-2]. It should be noted that drugs beneficial to the liver (hypoprotectors) are based on the milk thistle. These are used for acute and chronic hepatitis, liver damage, diseases of the biliary tract, etc. Flavolignans contribute to successful withdrawal of toxins from the liver, as well as salts and slags [3].

In Russia, milk thistle does not form natural thickets [4], so it is necessary to expand planting of high-yielding varieties. It can be cultivated in those areas where the frost period is not more than 150 days. Milk thistle is classified among drought-resistant plants. It is a new culture for the steppe zone of the Volga Region; thus, the technology for its cultivation needs to be adjusted. The selection and comparative evaluation of the productivity of various milk thistle varieties were not conducted in the conditions of the steppe Volga Region.

The purpose is to study the techniques for milk thistle cultivation, aimed at expanding the areas of its sowing by selecting the most productive varieties, the optimal seeding rate and the method of sowing, the nutrition mode and plant protection products, and to obtain sustainable yields of high-quality and environmentally friendly seeds.

METHODS.

Field experiments were conducted in 2012-2015 on the experimental field of the FGBSI Rossorgo. The early-ripening varieties Debut, Samaryanka, Nadezhda and the late-maturing varieties Panacea and Amulet were included in the experiment.

The climate of the region is characterized as sharply continental and severe. Selyaninov's hydrothermal coefficient (SHC) in wet years is 1.20-1.45, in average – 0.70-0.95 and arid – 0.60-0.68. The average annual precipitation is 360-455 mm.

The experimental site soil is southern chernozem. The humus content in the top soil (according to Tyurin) was 3.80-4.60%, total nitrogen – 0.17-0.22%, total phosphorus – 0.11-0.14%, potassium – 1.10–1.38%, labile phosphorus (according to Machigin) – 30.1-40.5 mg/kg, exchange potassium (according to Machigin) – 260-310 mg/kg of soil; the value of pH is close to neutral. The density of the southern black soil is 1.20-1.32 g/cm^3. The minimum water capacity (MWC) of the 0-100 cm layer is 295.6 mm; the permanent wilting point (PWP) for the plants is 151.4 mm.

The filed experiments were set with 4-fold repeatability by the randomized method. The record plot area is 100-125 m^2, the sowing area is 125-210 m^2. The agrotechnical measures were carried out in accordance with recommendations of FSBSI "South-Eastern SRIAC" [5]. The account of yield was carried out by complete harvesting by direct combining using the Sampo 500 combine.

The studies were carried out according to generally accepted techniques and methodical developments of B. M. Smirnov and A. A. Nichiporovich [5, 6, 7]. The NPK content in soil was determined by sampling mixed soil samples from the 0 to 40 cm layer: nitrate nitrogen – according to Grandeval-Lagu, labile phosphorus and exchange potassium – according to Machigin in the TsIANAO modification. The qualitative seed parameters were determined according to the corresponding standards: seed humidity (drying method) – according to GOST 12041-66, the weight of 1000 seeds according to GOST 10802-76. The statistical treatment of the experimental material was carried out by the dispersion, correlation and regressive analysis methods.

RESULTS OF INVESTIGATIONS.

During the studies, we have studied the growth and development features of milk thistle plants depending on the seeding method, seeding rate, nutrition mode and protection means under the Volga Region steppe region conditions. A lot of attention was given to the issue of the seed germination ability that has been insufficiently studied, depending on their storage duration and cultivation conditions [4]. We have established that freshly harvested seeds in one month germinate in insignificant amounts (26 to 20%) under laboratory conditions, and only in April their laboratory germination achieved 90 to 96%, i.e. the after-harvesting after-ripening process in the seeds was almost complete.

The highest germination is in the seeds after the second storage year. The difference between seeds harvested in the gold ripe and full ripe phase is 5 to 6% in absolute values; therefore, milk thistle seeds should be harvested in the full ripe stage.

On average, in the years of the studies the maximum average daily gain was 2.08 cm.

The milk thistle yield is affected by the photosynthetic activity of the plants that depends on the leaf surface (LS). Apart from that, the important parameters are the photosynthetic potential (PP), above-land biomass and pure photosynthetic productivity (PPP) [6-7, 14]. The analysis of the obtained data on average in 2006-2011 has shown that the leaf surface at starting stages of the development is low and changes over the years at the 3-4 leave phase from 1.14 to 2.01 thousand m^2/ha, achieving the maximum value of 57.40 thousand m^2/ha at the full blossom phase. Also, PP was at maximum at the blossom phase (1390 thousand m^3·ha^{-1}·day^{-1}).

Selection and comparative assessment of the yield of various milk thistle varieties. The investigation of the growth and development features in various milk thistle varieties has shown that in the early ripening Debut, Samaryanka and Nadezhda varieties the vegetation duration was 9 to 12 days less than in the averagely ripening Panacea and Amulet varieties. The field germination rate and the duration of the period from sowing to sprout was the same in all studied varieties and depended on the conditions of moisture supply in the 0 to 10 cm soil layer. The correlation analysis has shown a close relationship between the duration of the sowing-sprout period and the moisture of the soil sowing layer. The dependence between these parameters is expressed by the high correlation coefficient ($r = 0.87$). The field germination rate in all studied varieties was high and varied over the years from 81 to 88%, and no significant differences in the varieties have been established. The plant survivability of all studied varieties was about the same – from 85 to 96%.

The moisture supply conditions significantly affected the survivability of the milk thistle plants. Thus, in moist 2013 and in average-arid 2014, the survivability of the plants in all varieties was higher (94.0-96.5%) than in the arid 2012 and 2015 (88.6-90.5%).

The Panacea (4.8 units) and Amulet (5.3 units) varieties formed more tendrils on one plant than the Debut (5.3 units) and Samaryanka (4.6 units) varieties. A close correlation relationship (r = 0.88) was established between the number of tendrils and seed yield. The Panacea and Amulet varieties are taller; their height at the harvest moment was 140 and 148 cm, correspondingly, whereas in the short Debut, Start and Samaryanka varieties it was 120, 123 and 135 cm.

The photosynthetic parameters in all studied varieties were similar.

More significant differences in the varieties were in such parameters as LS and PP. Thus, the LS in the Debut variety was 26.80 thousand m^2/ha, and PP was 1289 thousand m^3·ha^{-1}·day^{-1}. These parameters were 14 and 18% higher in the Panacea and Amulet varieties. The analogous results were obtained in harvesting of the dry above-ground biomass as well: Debut – 3.8 t/ha, Samaryanka – 4.03 t/ha, Panacea – 4.22 and Amulet – 4.51 t/ha. High results of the above-ground biomass, tendril and fruit formation in the Panacea and Amulet varieties provided for the maximum seed yield as well – 0.92 and 1.11 t/ha, correspondingly (Table 1). The increase in the productivity of the Panacea and Amulet varieties was achieved due to the higher seed weight from 1 plant – 3.0 and 3.1 correspondingly, a higher amount of capitula – 3.8 and 4.0 units and seeds from capitulum – 146.1-161.2 units, which is 12 to 15% higher as compared to other varieties. The milk thistle seeds of the Panacea and Amulet varieties are characterized in high oil contents (28.01 and 30.5%) and that of flavolignans (3.2 and 3.5%), and these parameters are lower in other varieties – 28.0-29.5% and 2.9-3.0%.

In the milk thistle sowings, close relationships were established between yield and such parameters of the yield structure as the number of capitula: $y = 1.533x + 1.6867$ ($r = 0.86$) and the weight of seeds from one capitulum. The analogous results were found by foreign authors [15-16].$y = 3.086x + 7.1499$ ($r = 0.90$).

Table 1 – Yield of seeds in various varieties of holy thistle and oil contents in the black soils of the Volga Region steppe zone

Variety	Yield per hectare (metric tons)					Content, % (average over 2012-2015)	
	2012	2013	2014	2015	Average	Vegetable oil	Flavolignans
Debut	0.51	0.68	0.81	0.64	0.66	28.0	2.9
Start	0.62	0.71	0.90	0.70	0.73	28.5	2.9
Samaryanka	0.68	0.79	0.85	0.75	0.77	29.5	3.0
Panacea	0.77	1.07	0.88	0.96	0.92	30.0	3.2
Amulet	0.88	1.19	1.30	1.06	1.11	30.5	3.5
F_{fact}	43.99*	338.74*	211.09*	68.29*	53.94*	21.0*	128.09*
LSD_{05}	0.036	0.031	0.034	0.037	0.034	2.11	0.13

Effect of seeds seeding rate and seeding methods on yield of various varieties of milk thistle. The decisive condition of increasing the yield of crops are seeding rates and seeding methods [8-9]. There is no single opinion among various scholars with respects to this issue [10-13]. In the studied varieties, with an increase in the seeding rate, the field germination rate decreased from 87.5 to 81.0%. Plant survivability with an increase of the seeding rate from 100 to 700 thousand germinable seeds per 1 ha at the straight seeding method decreased from 97.5 to 92.0%. This trend maintained at all seeding methods in both varieties. The minimal duration of vegetation period was noted at the seeding rate of 700 thousand units/ha – from 91 to 94 days, and the maximum one at the seeding rate of 100 thousand units/ha – 100 to 105 days.

Yield and quality of milk thistle seeds. At an increase in the seeding rate from 100 to 500 thousand units/ha at the straight seeding method, the yield of green mass increased to the fertility phase from 31.51 to 35.80 t/ha, and at the seeding rate of 700 thousand units/ha it decreased to 32.1 t/ha. The analogous regularity was established in other seeding methods as well. The maximum dry matter content (4.51 t/ha) was noted in the Amulet variety at the straight seeding method up to the ripe phase at the seeding rate of 500 thousand units/ha.

The Amulet and Samaryanka varieties at simple straight seeding and the seeding rate of 500 thousand germinable seeds per 1 ha are characterized by the maximum yield – 1.25 and 1.01 t/ha (Table 2). Both an increase and a decrease in the seeding rate lead to a decrease in yield. There is a close correlation relationship established between the seeding rate and yield, $r = 0.84$ (Fig. 1).

The protein and vegetable oil contents were not observably affected by the seeding rates and seeding methods. An increase in the seeding rate facilitated an increase in flavolignans. Their maximum content was noted in the Amulet variety – 3.2 to 3.5%, and in the Samaryanka variety – 2.9 to 3.2%.

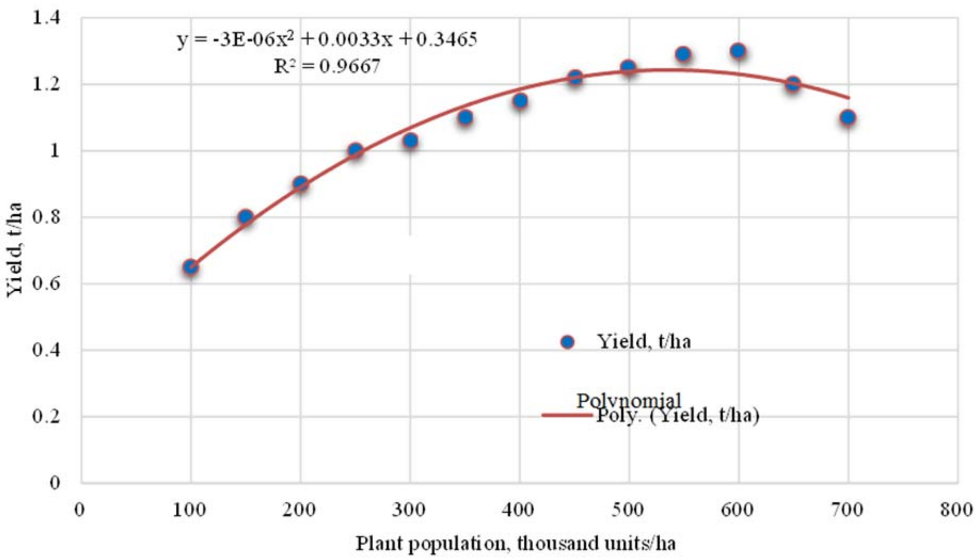

Fig. 1. Plot of thistle seeds yield on plant population, average for 2012-2015.

Table 2 – Effect of seeding methods and seeding rates in yield and quality of milk thistle seeds

Seeding method (Factor A)	Seeding rate, thousand germinable seeds/ha (Factor B)	Variety (Factor C)					Contents of (average over 2012-2015), %	
		2012	2013	2014	2015	average	protein	fat
		Amulet						
Simple straight, 15 cm	100	0.58	0.80	0.63	0.50	0.63	22.6	30.0
	300	0.87	1.30	0.90	0.88	0.99	22.1	29.8
	500	1.02	1.58	1.29	1.11	1.25	21.9	29.7
	700	0.78	1.15	0.83	0.74	0.88	22.0	29.7
Straight with widened inter-rows, 30 cm	100	0.64	0.73	0.74	0.63	0.69	21.6	30.1
	200	0.73	1.03	0.85	0.76	0.84	21.2	30.0
	300	0.77	1.14	0.97	0.84	0.93	21.3	29.8
	400	0.70	0.98	0.91	0.61	0.80	21.0	29.4
Wide row, 60 cm	100	0.50	0.51	0.49	0.43	0.48	21.7	30.4
	150	0.56	0.68	0.63	0.54	0.60	21.4	30.2
	200	0.43	0.31	0.30	0.37	0.35	21.3	30.1
	250	0.26	0.26	0.23	0.27	0.26	21.3	30.0
		Samaryanka						
Simple straight, 15 cm	100	0.47	0.64	0.61	0.43	0.54	21.8	29.5
	300	0.73	0.96	0.80	0.72	0.80	21.6	29.2
	500	0.79	1.17	1.21	0.87	1.01	21.7	29.0
	700	0.65	0.88	0.69	0.61	0.71	21.5	28.9
Straight with widened inter-rows, 30 cm	100	0.56	0.60	0.59	0.53	0.57	21.1	29.5
	200	0.58	0.82	0.72	0.63	0.69	20.8	29.4
	300	0.68	0.94	0.79	0.70	0.78	20.7	29.2
	400	0.59	0.76	0.60	0.64	0.65	20.4	29.0
Wide row, 60 cm	100	0.31	0.40	0.44	0.40	0.39	21.1	29.8
	150	0.35	0.54	0.50	0.46	0.46	20.9	29.4
	200	0.29	0.35	0.40	0.35	0.35	20.8	29.0
	250	0.26	0.28	0.28	0.23	0.26	20.6	29.0
F_{fact}		805.01*	155.8*	287.2*	102.7*	69.46*	456.12*	345.12*
LSD_{05} according to Factor A		0.02	0.1	0.1	0.1	0.2	0.7	0.8
F_{fact}		108.65*	141.4*	103.7*	37.91*	8.465*	16.78*	76.22*
LSD_{05} according to Factor B		0.12	0.16	0.2	0.1	0.2	0.8	0.9
F_{fact}		318.61*	778.4*	834.2*	468.6*	41.46*	367.12*	322.55*
LSD_{05} according to Factor AB		0.03	0.03	0.03	0.03	0.08	0.9	1.1

Table 3 – Efficiency of insecticide use on milk thistle plants

Experiment variant	Usage rate of insecticide, l/ha, kg/ha	Population, units/m^2		Biological efficiency, %	
		turnip moth	striped flea beetle	turnip moth	striped flea beetle
Control		3.0	9.0		
Taran	0.10	0.4	1.4	86.7	84.4
	0.15	0.2	0.6	93.3	93.3
Decis Expert + Confidor	50 + 30	0.2	0.4	93.3	95.6
Decis Expert + Confidor	70 + 50	0.1	0.2	96.7	97.8

Table 4 – Effect of usage of different insecticides in the milk thistle sowings on seed yield, t/ha

Experiment variant	Usage rate of insecticide, l/ha	2012	2013	2014	2015	Average over 2012-2015
Control		0.70	0.96	0.93	0.73	0.83
Taran	0.10	0.79	1.11	1.08	0.82	0.95
	0.15	0.80	1.20	1.15	0.85	1.00
Decis Expert ++ Confidor	50 + 30	0.82	1.20	1.16	0.86	1.01
Decis Expert + Confidor	70 + 50	0.90	1.24	1.17	0.97	1.07
LSD_{05}		0.15	0.20	0.16	0.11	

Diseases and pests of milk thistle in the Volga Region zone are poorly studied. In our experiments, we were unable to identify any diseases of thistle plants [12-13, 17]. In earlier experiments, techniques of controlling pest organisms were studied [18-20]. In 2011-2015, we have found damage to thistle plants by phytophages: striped flea beetle (*Phyllotreta vittula* Redt.) and turnip moth (*Agrotis segetum*). In order to control them, we have developed control techniques (Table 3).

The usage rate of the working solution was 200 l/ha. The introduction of various dosages to the 5-6 leave phase of the crop has shown their high biological efficiency. Thus, the Taran dosage of 0.10 l/ha less affected the striped flea beetle (84.4%) and turnip moth (86.7%), than 0.15 l/ha – 93.3 and 93.3%, correspondingly. The efficiency of tank mixture of Decis Expert (50 g/ha) + Confidor (30 g/ha) was 95.6 and 93.3%, and from the usage rate of Decis Expert (70 g/ha) + Confidor (50 g/ha) it was 97.8 and 96.7%. In the control variant, the population of striped flea beetle was 9.0 units per 1 m^2, and that of turnip moth was 3 units per 1 m^2.

The treatment of the thistle sowings at the 5-6 leave phase with Taran in the 0.10 l/ha dosage increased the thistle seed yield (Table 4) up to 0.95 t/ha, and in the 0.15 l/ha dosage – up to 1.00 t/ha, and that with the tank mixture of Decis Expert of 50 g/ha + Confidor of 30 g/ha – up to 1.01 t/ha, that with Decis Expert of 70 g/ha + Confidor of 50 g/ha – up to 1.07 t/ha (control 0.83 t/ha), i.e. the increase was correspondingly 0.12; 0.17; 0.18 and 0.24 t/ha.

CONCLUSION

For milk thistle, high laboratory germination is characteristic – 90.0-96.0%. The appearance of even sprouts depends on the presence of moisture in the 0-10 cm layer; a close correlation relationship was established between the sowing-sprouts period and the presence of the moisture in the soil, r = 0.87. The field germination rate of the studied milk thistle varieties with an increase in the seeding rate decreased from 87.5 to 81.0%. The plant survivability increased from 92.0 to 97.5% with a decrease in the seeding rate from 700 to 100 thousand/units seeds per 1 ha.

The longest vegetation period of 100 and 105 days was in the Amulet and Samaryanka varieties at the norm of 100 thousand germinable seeds per 1 ha. The shortest period of 91 and 94 days was observed in these varieties at the straight seeding method and the seeding rate of 700 thousand germinable seeds per 1 ha.

Upon the interaction of seeding rates and seeding methods, the optimal conditions for yield formation of milk thistle were in the Amulet and Samaryanka varieties at the seeding rate of 500 thousand germinable seeds per 1 ha and the straight seeding method. Here, on average in 4 years 1.25 and 1.01 t/ha correspondingly was obtained, which is 38% higher compared to the seeding rate of 100 thousand units/ha and 26.0 and 62.1% higher compared to the same seeding rate at straight seeding with widened inter-rows (30 cm) and the wide-row method (60 cm). The flavolignan content was maximum in the Amulet variety – 3.5% correspondingly vs. 2.9; 2.9 and 3.0% in the Debut, Start, Samaryanka varieties.

The yield of milk thistle mainly depends on the moisture supply and mineral nutrition level. The treatment of thistle sowings at the 5-6 leave phase against the turnip moth and striped flea beetle with the tank mixture of Decis Expert + Confidor insecticides with a usage rate per 1 ha of: 50 g + 30 g and 70 g + 50g increased the yield correspondingly up to 1.01 and to 1.07 t/ha at the control yield of 0.83 t/ha; the increase was 0.18 and 0.24 t/ha.

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