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Productivity and Plant Protection from Diseases and Pests of Milk Thistle (Variety Amulet) In Chernozems in the Steppe Zone of the Volga Region

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Abstract

Results of long-term double-factor investigations of the study of mineral fertilizers' optimal doses, seeding rates and crop protection products are given. Depending on the doses of fertilizers and seeding rates biological features of the formation of the photosynthetic apparatus of milk thistle are revealed. Highly productive mid-ripening variety Amulet with a growing season period of 96-105 days provides seeds in amount of 0.98-1.26 t / ha. The maximum leaf area (54.5 thousand m^2/ha), photosynthetic potential (2180 thousand. m^2/ha·days), dry above-ground biomass (7-12 t/ha) and roots (4.55 t / ha) were after $N_{80}P_{80}K_{60}$ kg application and at seed rate of 500 thousand germinating seeds / ha. The maximum seed yield (1.26 t / ha) was after $N_{80}P_{80}K_{60}$ application and at seed rate of 500 thousand germinating seeds / ha. It was found out that after escalation of the dose of fertilizers up to $N_{80}P_{80}K_{60}$ the oil content increases to 32.1% compared with the control variant (29.9%). The largest number of biologically active substances flavolignans (3.0-3.5%) was after $N_{80}P_{80}K_{60}$ application and at a seed rate of 500 thousand pcs. / ha. After treatment with tank mixture konfidor (50 ml/ha) + detcis (70 ml/ha), and Rex duo (0.6 l/ha) yields of milk thistle seeds increased to a significant degree.

Keywords: milk thistle; Amulet; productivity; leaf area; plant protection**;** minor plant nutrient; mineral nutrition; seed rate.

INTRODUCTION.

In the early 20th century medicinal plants accounted for 80% of all used therapeutic agents, but then synthetic, antibiotic and hormone medicines significantly pushed them out. In Russia, herbal medicines accounted for approximately 30% [1]. Today herbal medicines are popular all over the world [2, 3]. Milk thistle is a valuable medicinal raw material [4, 5] that is why it is necessary to cultivate its highly productive varieties [6]. It can be cultivated in areas where the frosty period does not exceed 150 days. Milk thistle is a drought-resistant plant and is a new culture in the steppe zone of the Volga region. The technology of its cultivation needs to be adjusted [16, 22], so it is necessary to cultivate more productive and drought-resistant varieties with high content of flavolignans.

The purpose of the work is to study the effect of the optimal combination of doses of mineral fertilizers, seed rate and methods of pests and diseases control on the formation of productivity of mid ripening and tall-growing variety Amulet in the steppe zone of the Volga region.

RESEARCH METHODS

Field experiments were carried out in 2012-2015 in the experimental field of "Rossorgo". The scheme of long-term three-factor field experiment included study of mineral nutrition regime (Factor A): 1) control - without fertilizer; 2) $N_{40}P_{40}K_{40}$; 3) $N_{60}P_{60}K_{60}$; 4) $N_{80}P_{40}K_{40}$; 5) $N_{80}P_{80}K_{60}$ kg of *active material / ha*; different seed rates (factor B): 500, 600 and 700 thousand germinating seeds per one ha; varieties (factor C): Start and Amulet (produced and release by the authors) (Patent No. 6346. No. 8954188, pending 30.11.2010, published 17.02.2012, Bulletin No. 22).

The climate of the region is extremely continental and rigorous. Hydrothermic coefficient in wet years is 1.20-1.45; in middle ones is 0.70-0.95 and in dry years it is 0.60-0.68. The average annual precipitation amount is 360-455 mm.

Soil of the trial field is southern chernozem, with low humus content, heavy loamy. In the arable layer humus content (according to Tyurin) is 3.80-4.60%; total nitrogen content is 0.17-0.22%, total phosphorus – 0.11-0.14%, potassium – 1.10-1.38%, labile phosphorus (according to

Machigin) - 18,0-22,0 mg / kg, exchange potassium (according to Machigin) - 28,0-32,0 mg / 100 g of soil; pH is almost neutral (pN_{salt} 6.1; $pN_{neutral}$ 7.0); total absorbed bases - 38,0-41,0 mg- equivalent / 100 g of soil. Soil density is 1.20 - 1.32 g / cm^3. Field capacity (FC) of 0-30 cm layer is 101.1 mm, 0-100 cm layer - 295.6 mm.

Field randomized experiments were carried out in a four-time replication. The area of the registration plot is 100-125 m^2, that of the sowing plot is 125-210 m^2. On the experimental plots, all farming practices were carried out in accordance with common recommendations adopted for the conditions of the region. Harvest accounting was carried out by direct combining with the harvester "Terrion".

Laboratory and field studies were carried out by common methods [8, 9, 10, 16]. Statistical processing of the experimental data was performed by methods of variance, correlation and regression analysis [11].

RESULTS

In the process of observation and research growth characteristics and plants development of different varieties of milk thistle have been studied, depending on plants' dietary regime, seed rate and plant protection product under the conditions of a steppe zone of the Volga region. Decisive factors in increasing milk thistle productivity are moisture and soil nutrient regime.

Analysis of nutrients in the soil evidenced that the content of nitrate nitrogen before field experiment was low (12.2 mg / kg of soil). Content of nutrients in arable soil layer increased to 26.0-32.0 mg / kg after application of the average dose of fertilizer (N40P40K40).

In dry conditions, the lack of moisture reduces the yield by inhibiting the growth processes, by reducing the size of the plant and its reproductive organs. Study of the plant growth and development have established the duration of interphase and vegetation periods of milk thistle in the steppe zone of the Volga region. Duration of vegetation period ranged from 82 to 97 days. Milk thistle is characterized by high laboratory germination (91.5 to 96.0%). Similar results were obtained in the conditions of forest-steppe zone in the Volga region [1, 12].

DISCUSSION

Dietary regime and seed rate mode had little effect on germination (Table 1). All studied factors had a significant effect on shoot formation (Table 2).

Photosynthetic activity of plants effects on yield [13, 14]. Maximum size of sheet surface (59.7 thousand m^2/ha) was after application of N80P80K60 and seed rate of 500 thousand pcs. / ha.

Maximum photosynthetic potential (2,270 thousand m^2 / ha·day) was after application of N80P80K60 and seed rate of 500 thousand pcs. / ha. Net photosynthesis productivity was maximum on the same variant in the same variant. The most aboveground dry biomass (7.12 t / ha) and roots' weight (4.55 t / ha) was after N80P80K60 and seed rates of 500 thousand pcs. /ha.

According to domestic and foreign scholars, fertilizers have a significant impact on the structure of field crops harvest, optimizing its parameters, that has a positive effect on their productivity [15, 17, 18, 22].Mineral fertilizers had the most significant impact on seeds productivity. After application of N80P80K60 the highest increase of yield (0.35 t / ha) was in wet 2013 and 2014. For 4 years the best average dose was N80P80K60 and seed rate of 500 thousand pcs./ha. It provided 1.26 t/ha (an increase by 0.40 t / ha or 46.5% compared to the control variant) (Table 3).

Table 1. Effect of seed rate and the regime of mineral nutrition on stalks formation and yield structure of different varieties of milk thistle, average for 2012-2015

Fertilizer dose	Seed rate, thousand germinating seeds per 1 ha	Yield, pcs./m^2	Field germination rate, %	Plant safety, %	The number of shoots per plant, pcs.	The number of anthodium from 1 plant, pcs.	Seeds weight from 1 plant, g	Weight of 1000 seeds, g	The number of seeds from 1 anthodium, pcs.
Control	500	47,0	95,8	95,1	3,8	3,6	3,1	26,0	141
	600	58,0	94,3	94,0	3,5	3,2	3,0	25,1	130
	700	66,8	93,7	93,2	3,3	3,0	2,7	25,0	122
$N_{40}P_{40}K_{40}$	500	46,9	96,0	95,5	4,0	3,7	3,2	26,5	155
	600	56,2	95,7	93,0	3,8	3,5	3,1	25,2	141
	700	65,9	94,1	93,0	3,6	3,3	3,0	25,0	128
$N_{60}P_{60}K_{60}$	500	47,6	95,2	96,4	4,6	4,2	3,4	27,2	160
	600	56,0	93,3	95,2	4,3	4,0	3,1	26,6	149
	700	64,1	91,6	94,0	4,0	3,8	3,0	26,0	140
$N_{80}P_{80}K_{40}$	500	47,1	94,2	95,9	4,8	4,4	3,8	27,5	165
	600	56,9	94,8	93,8	4,5	4,1	3,5	26,8	157
	700	65,2	93,1	92,8	4,2	3,7	3,1	26,0	150
$N_{80}P_{80}K_{60}$	500	47,9	95,8	97,0	5,2	4,8	4,1	27,7	169
	600	56,0	93,3	96,8	5,0	4,5	3,8	27,0	158
	700	66,4	92,8	94,6	4,5	4,2	3,5	26,1	138

Table 2. Influence of fertilizers' doses and seed rates on photometric performance of milk thistle (average for 2012-2015)

Fertilizer dose	Seed rate, thousand germinating seeds per 1 ha	plant height, cm	maximum leaf area, thousand m^2/ha	Photosynthetic potential, thousand m^2/g· day	Net photosynthesis productivity, g/ m^2· day	Overground biomass, t/ha	Dry weight of roots in 0–100 cm layer, t/ha
Control	500	162	38,0	1560	2,8	3,98	3,20
	600	146	33,2	1420	2,9	3,11	3,10
	700	127	30,1	1310	2,6	3,00	2,90
$N_{40}P_{40}K_{40}$	500	181	42,1	1800	3,4	4,71	3,68
	600	170	37,2	1660	3,2	4,62	3,45
	700	142	32,1	1590	3,0	4,40	3,21
$N_{60}P_{60}K_{60}$	500	182	49,5	1900	3,7	6,00	4,21
	600	164	40,5	1801	3,5	5,61	4,00
	700	147	36,0	1680	3,2	5,00	3,90
$N_{80}P_{80}K_{40}$	500	184	54,5	2180	3,7	6,60	4,41
	600	169	47,1	2000	3,4	6,12	4,00
	700	154	44,0	1904	3,3	5,95	3,75
$N_{80}P_{80}K_{60}$	500	186	59,7	2270	3,8	7,12	4,55
	600	173	52,1	2168	3,6	6,95	4,12
	700	160	46,0	2051	3,5	6,29	3,95

Table 3 .Influence of doses of fertilizers and seed rates on yield and flavolignans content in milk thistle

Fertilizer dose (Factor A)	Seed rate thousand germinating seeds per 1 ha (Factor B)	2012	2013	2014	2015	Average for 2012-2015	
						seed, t/ha	flavolignans, %
Control	500	0,76	0,99	0,97	0,71	0,86	3,1
	600	0,68	0,90	0,86	0,64	0,77	3,0
	700	0,61	0,80	0,80	0,57	0,69	3,0
$N_{40}P_{40}K_{40}$	500	0,97	1,11	1,03	0,89	1,00	3,2
	600	0,90	1,00	1,15	0,80	0,96	3,2
	700	0,90	0,81	0,91	0,71	0,83	3,0
$N_{60}P_{60}K_{60}$	500	0,77	1,25	1,38	0,86	1,06	3,3
	600	0,74	1,06	1,24	0,79	0,96	3,1
	700	0,70	1,01	1,26	0,73	0,92	3,1
$N_{80}P_{80}K_{40}$	500	0,81	1,25	1,48	0,73	1,07	3,4
	600	0,76	1,13	1,35	0,68	0,98	3,3
	700	0,70	0,98	1,22	0,62	0,88	3,2
$N_{80}P_{80}K_{60}$	500	1,01	1,39	1,69	0,67	1,26	3,5
	600	0,82	1,11	1,38	0,76	1,02	3,4
	700	0,73	0,98	1,28	0,71	0,92	3,2
Factor A		0,036	0,041	0,042	0,038	0,02	0,122
Factor B		0,024	0,022	0,020	0,013	0,02	0,109
Factor AB		0,021	0,022	0,023	0,020	0,03	0,101

Fertilizers had a positive impact on the yield structure. On average for four years, in well fertilized variant the number of anthodium on one plant was 3.5-4.2 pcs, in semi-fertilized – 3.3-3.5 pcs, and in the control variant- 3.0-3.3 pcs. The number of anthodium is decreased by 12.0-16.0% after seed rate of 500-700 thousand germinating seeds per 1 ha. There is a positive correlation (correlation coefficient r = 0.83) between the number of anthodium on 1 plant and yield (Figure 1).

The number of seeds and weight of seeds from one plant increased with increasing doses of fertilizer to N80P80K60 and decreasing seed rate up to 500 thousand pcs./ha. There is a robust correlation (r = 0.92) between weight of seeds from one plant and their productivity, Figure. 2.

Mineral fertilizers influence not only seed yield, but also their quality. Average for four years the oil content was 28.4% in the control variant, in the fertilized variants it was 29.0-32.1%. Effect of seed rate on the oil content was negligible.

Average for 2012-2015 the protein content after application of the maximum dose (N80P80K60) increased to 24.5% compared with the control variant (21.0%), while after raising seed rate from 500 to 700 thousand pcs./ha reduced it from 4.5 to 22.9%.

The content of biologically active substances flavolignans increased after increasing doses of mineral fertilizers. Their maximum number (3.3-3.5%) was after application of N80P80K60 and at seed rate of 500 thousand germinating seeds per one ha.

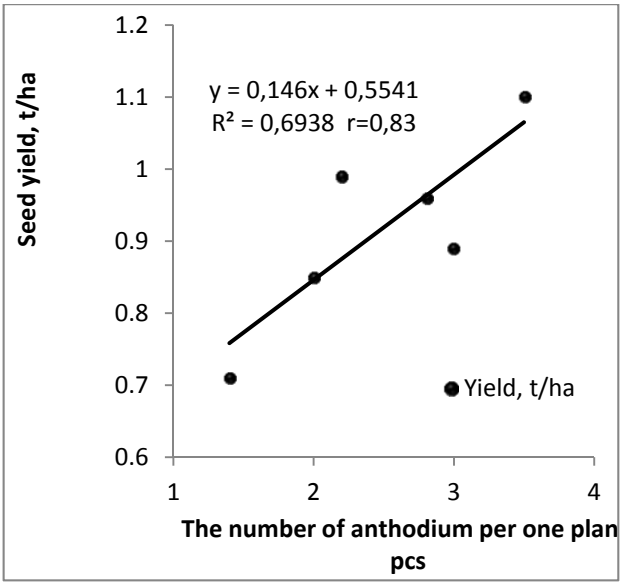

Figure 1. Dependence of milk thistle (Amulet variety) yield on the number of anthodium per one plant, average for 2012-2015

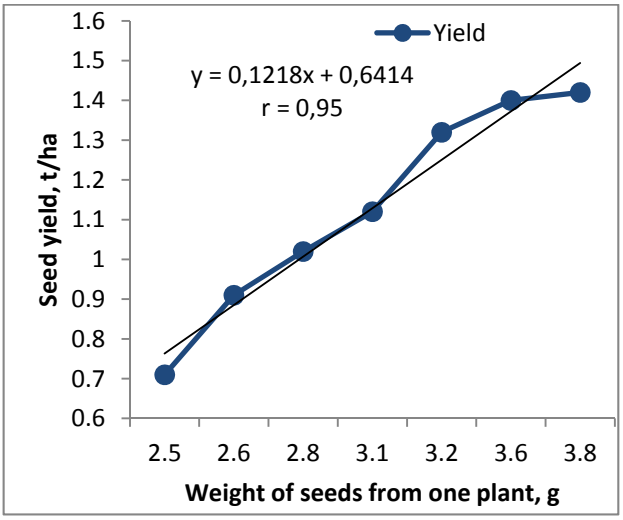

Figure 2. Dependence of milk thistle (Amulet variety) seed yield on the weight of seeds from one plant, average for 2012-2015

The influence of mineral nutrition level of milk thistle on nutritional utilization. Milk thistle being an oilseed utilizes nutrients more than cereal crops, and responds to the application of fertilizers [7, 19]. The maximum nitrogen content was in the seeds and inflorescences of milk thistle – 2.25-3.32%, in the leaves – 1.45-1.82%. The most number of phosphorus was in seeds and inflorescences – 0.48-0.60%. There is a close correlation between the phosphorus content and yield of seeds (r = 0.86) (Figure 3.)

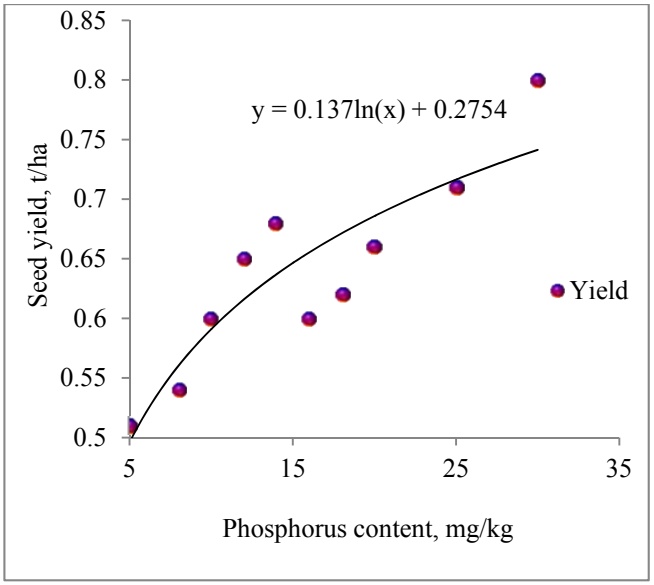

Figure 3. Influence of phosphorus content on the yield of milk thistle seeds, average for 2012-2015

At the beginning of the growing season milk thistle utilizes a small quantity of nitrogen. In the formation of seed nitrogen flow into the plant reaches its maximum. There is a close correlation between the nitrogen content and yield of seeds (r = 0.38) (Figure 4.)

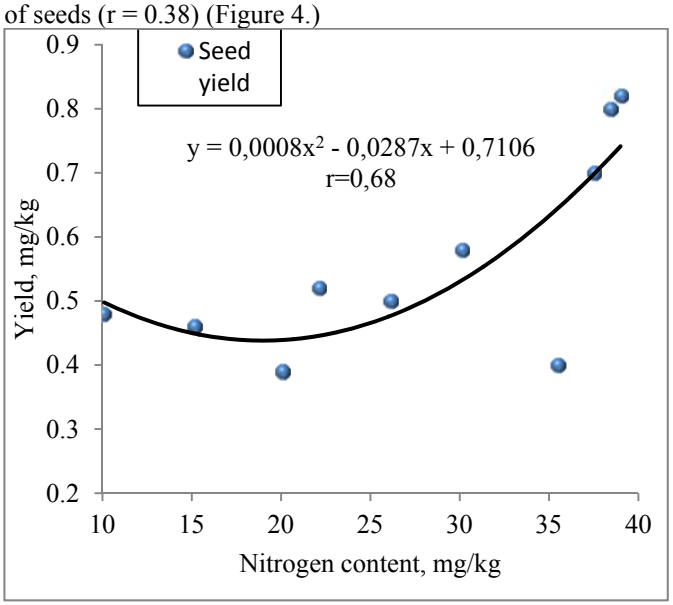

Figure 4. Influence of nitrogen content on the yield of milk thistle seeds, average for 2012-2015

Average for 2012-2015 in the control variant total nitrogen yield of Amulet variety was 68.5 kg / ha, after application of N80P80K60 it increased to 136.0 kg/ha, after phosphorus application it increased from 16.2 to34,0 kg/ha. Potassium yield was the highest - 260.2 kg/ha.

In order to determine the level of microfertilizers supply it is necessary to study their threshold concentrations [19]. A maximum accumulation in the seeds of milk thistle such elements as iron - 247-253; zinc - 10,3-12,6; copper - 1.59-1.70; manganese - 25,03-28,82; iodine - 0,29-0,36 mg/kg of dry basis was found.

Table 4. Effectiveness of insecticides against pests (average for 2012-2015)

Experiment variant	Consumption rate, ml/ha	Number of cutworms, pcs./m^2		Biological effect, %	Yield, t/ha
		before treatment	after treatment		
Control		10,8	12,7		1,12
Control + detsis expert	35 + 50	10,7	3,0	76,4	1,25
konfidor + detsis expert	40 + 60	10,9	2,0	84,3	1,30
konfidor + detsis expert	50 + 70	11,1	0,3	96,8	1,36

Thus, application of rational doses of fertilizers optimizes nutrient regime of the soil in crops of milk thistle and provides a high yield (1.30 t/ha) of environmentally friendly and high-quality seeds.

Plant protection against pests and diseases. Important factors of stable milk thistle seeds' yield are plant protection products [20–24]. It is interesting to note that some bacteria have plant-protecting effects [25]. In our experiments a stable defect of plants with winter cutworm has been determined. In this regard in the phase of 5-6 leaves crops were treated tank mixture of insecticides in the following doses: konfidor + detsis expert in various doses (35 +50, 40 + 60, 50 + 70 ml / ha). The most effective doses were 50 ml of konfidor and 70 ml of detsis expert / ha (Table 4).

High biological effectiveness was after treatment with Rex duo against brown rust. Research confirms that the best dose of Rex duo is 0.6 l / ha, because it will provide the seed yield of 1.32 t / ha. Treatment with shansil was less effective.

CONCLUSION

It is possible to get 0.75 - 1.56 t / ha of milk thistle seeds after adaptive technology of cultivation in soil and climatic conditions of a steppe zone of the Volga region

Increasing the seed rate from 500 to 700 thousand germinating seeds per 1 ha decreased the germination on 3.2-4.3%.

Milk thistle have the most favorable conditions for the formation of the photosynthetic after application of N80P80K60 doses of fertilizers and seed rate of 500 thousand pcs. / ha. It provided high seed yield (1.26 t / ha).

After increasing the dose of fertilizer to N80P80K60 oil and protein content increased significantly compared with the control, flavolignans content was also the highest - 3.3-3.5%.

Application of fungicide Rex duo (0.6 l / ha) against brown rust and the treatment of milk thistle crops in the phase of 5-6 leaves with insecticide mix (50 ml / ha of konfidor and 70 ml / ha of detsis expert) against winter cutworm reduces the amount of cutworms and provides maximum seed yield.

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