UDC 635.21:631.53.01:631.67 (477.72)

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GROWING OF IMPROVED POTATO SOURCE MATERIAL IN PRIMARY SEEDING NURSERIES UNDER IRRIGATION IN SOUTHERN UKRAINE

Наведено результати досліджень з визначення технологічних прийомів, що впливають на збільшення коефіцієнта розмноження вихідного оздоровленого матеріалу картоплі, одержаного в культурі меристем *in vitro* за вирощування в первинних ланках насінницького процесу.

Використано польовий, лабораторний, математично-статистичний, розрахунково-порівняльний методи та системний аналіз у двофакторному досліді.

У середньому за роки досліджень, максимальну продуктивність посадки при поєднанні факторів одержано за садіння мікробульб на глибину 6 см з площею живлення 70 х 10 см – 31,2 ц/га, коефіцієнт розмноження становить 2,1. Збільшення глибини садіння мікробульб з 2 і 4 до 6 см підвищує їхню врожайність в середньому по кожному фактору на 48,7 і 45,6 % за рахунок збільшення на 36,7 і 22,2 % відповідно продуктивності однієї рослини та сприяє зростанню загальної кількості мінібульб на 23,6 і 25,7 %. У разі зменшення площі живлення до 70 х 5 см зростає внутрішньовидова конкуренція, внаслідок чого знижується продуктивність однієї рослини, тобто кількість мінібульб, що призводить до зменшення коефіцієнта розмноження.

Доведено, що для підвищення коефіцієнта розмноження вихідного оздоровленого матеріалу картоплі, одержаного в культурі in vitro, економічно доцільним є садіння мікробульб у весняній посадці на глибину 6 см з площею живлення 70 х 10 см: рентабельність при цьому становить 262 %, собівартість – 229 грн/кг мінібульб, чистий прибуток – 1155 тис. грн/га.

Ключові слова: картопля, південь України, первинне насінництво, площа живлення, глибина садіння, *in vitro*.

Introduction. The degeneration of potato source material is an extremely urgent problem in the south of Ukraine due to severe climatic conditions of this region. Thus, the traditional method of farming potatoes in spring while propagating seed material is accompanied with the decrease in plant productivity as early as on the second year – by 30-35 %, and over 50 % – on the third year. The intensity of potato degeneration mainly depends on the combination of external agents, the damage of plants with viral, viroid, mycoplasma diseases and the variety resistance both to unfavorable cultivation conditions and the diseases. The accumulation of the viral infection in the seed material and the manifestation of disease signs are relevant reasons of potato degeneration which get worse with the increase in vegetative propagation. It reflects the inhibition of plant development, the decrease in productivity and the decline in production quality [1, 2]. The application of the improved source material, obtained in meristem culture *in vitro*, to elaborate the selected varieties in the combination with the method of two-yield variety with its further propagation allow developing the efficient seeding system even in the conditions, non-typical for potatoes, in particular, in the South [2, 3].

The main constituents of the crop production system are primary, pre-basic and basic crop production. Obtaining the seed potatoes of higher categories in the South at the current stage of the biological science development is possible only in case of combining the biotechnological methods of enhancing source material (thermo- and chemotherapy, apical meristem) and the method of two-yield culture for its further field propagation. In the southern region the only producer of pre-basic and basic seed potatoes, using the unique combination of these methods to propagate the selected varieties, is the Irrigated Farming Research Institute, NAAS of Ukraine.

The studies were used to prove the actual possibility and economic efficiency of growing potato source material in the region and to elaborate the three-year-scheme of the crop production process, which was introduced into the Provisions on Potato Production [6]. By their productive and qualitative characteristics the seed potatoes of higher propagation, obtained in the southern conditions, are not inferior to the corresponding category of microtubers, grown in the regions of traditional potato production. High indices of productivity and quality of the selected varieties are preserved for 6-8 propagations, i.e. for 3-4 years [5, 6].

However, further research is required for the issues of scientific justification and elaboration of the optimization measures for the process of obtaining seed potatoes of higher categories, in particular, the technology and basic principles of propagating potato source material in the primary links of crop production to enhance the propagation coefficient of the improved source material.

Aim. The study has been aimed at the development of technological methods that would help increase the propagation coefficient of improved source material of potatoes, obtained in meristem culture *in vitro*, grown in the primary seed production process.

Materials and methods. The studies were based on the complex application of the field, laboratory [7], mathematical and statistical, computationally-comparative method and systems analysis. In 2011-2013 a two-factor experiment was performed to determine the most efficient technological methods of cultivating the improved source material in the primary links of the seed production process. The influence of different depth and density of planting early maturing potato variety Kobza on the productivity of microtubers spring planting was studied. The experiment was accompanied with phenological observations, the registration of biometric indices of plants, the damage of microtubers from phytophthora rot, potato scab, etc., the registration of yield with the determination of the fraction composition of microtubers, the content of dry substances and starch in them. The experiment was planned according to the Methodological recommendations for conducting the research on potatoes – Nemishaeve [8]. It was performed on the irrigated land of the Irrigated Farming Research Institute (IFRI). The soil is dark-chestnut, slightly alkalized, medium clay loam. The farming technology of the experiment corresponded to the technology of cultivating potatoes in spring planting in the South in the irrigated conditions, developed at IFRI [9]. The years of studies were considerably different in the weather conditions of the vegetation periods. For instance, in 2011 they were favorable for the growth of spring potato plants, and in 2012-2013 they were severe and inconvenient for the growth of plants at the primary stages of development and formation of the early yield of potatoes.

Results and discussion. During the years of studies on the field germinability of microtubers of early-maturing potato variety Kobza, the dependence was observed between the nutrition area of plants and the number of sprouts with more spaced planting there are 14.6-32.5 % more germinated microtubers compared to the planting scheme of 70 x 5 cm, which may be explained by the increase in intraspecific competition for denser planting (Fig. 1). We observed average correlation dependence of the number of plants, formed by microtubers, on the interaction of the investigated factors (R = 0.608); here the nutrition area and the depth of planting have medium influence on the germination of microtubers (even correlation coefficients are $r = 0.408 \pm 0.228$ and 0.450 ± 0.223, respectively) (Table 1). The increase in the depth of microtuber planting from 2 to 4 and 6 cm on average by the factor resulted in the increase in the number of plants by 4.8 and 13.0 % respectively.

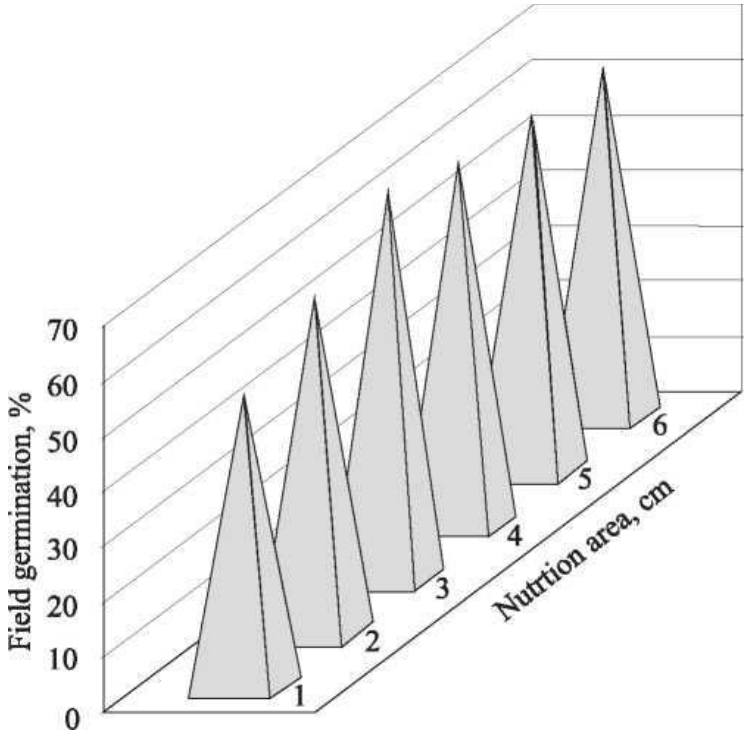

Fig. 1. **The dependence of the field germination of microtubers on the nutrition area** (2011-2013): 1–70 x 5; 2–70 * 10; 3–70 x 15; 4–70 x 20; 5–70 x 25 (checked in the graph); 6–70 x 30.

While planting microtubers using 70 x 5 cm scheme the density of plants, on average by the factor, was 151.9 thousand items/ha. The increase in the nutrition area resulted in its decrease by 64.7 (70 x 10 cm); 85.5 (70 x 15 cm); 106.0 (70 x 20 cm); 115.0 (70 x 25 cm); 122.5 (70 x 30 cm) thousand items/ha, or by 42.6; 56.3; 69.8; 75.7; 80.6 % on average for the years of studies. The increase in the depth of planting to 6 cm results in the germination of 13.0 and 15.6 % more microtubers compared to the planting at the depth of 4 and 2 cm respectively.

There is a strong correlative dependence between the productivity of microtubers, the total number of microtubers in the yield, the weight of the average microtuber, the number of microtubers under the plant and the investigated factors. The index of multiple correlation (R) is 0.876; 0.897; 0.847; 0.863 respectively. Here this dependence is mainly characterized by the inverse and direct correlation between the nutrition area and the productivity indices: r = -0.819 ± 0.143; -0.875 ± ± 0.121; -0.847 ± 0.133; 0.861 ± 0.127 respectively.

On average by the factor the maximal productivity of the planting was obtained while cultivating plants with the nutrition area of 70 x 5 cm (286 thousand microtubers per 1 ha): 24.2 c/ha, here the propagation coefficient is 1.1 (Table 2). This density of planting results in the increase in the intraspecific competition, due to which the productivity of one plant decreases, i.e. there are less microtubers which leads to the decrease in the propagation coefficient.

The increase in the nutrition area led to the decrease in the productivity by 21.5-75.7 % due to the reduction in the weight of obtained microtubers (from 11.3 to 4.2 g), but the propagation coefficient increased to 1.62.3 on average by the factor.

With the average correlation dependence on the investigated factors (R = 0.502) the yield of microtubers per one plant is dependent on the depth of planting (r = 0.492) more than on the nutrition area (r = -0.1). The increase in the depth of planting from 2 and 4 cm to 6 cm leads to the average increase in the productivity of one plant by the factor by 36.7 and 22.2 %, respectively. The nutrition area and the depth of planting microtubers have similar influence on the germination coefficient (r = 0.542 and 0.408, respectively). The multiple correlation index (R) is 0.678.

Table 1 – **The coefficients (r) of correlation dependence of the field germination, indices of economic efficiency and productivity of early maturing potato variety Kobza during early harvesting on the nutrition area and depth of planting microtubers** (2011-2013)

Index	Nutrition area, cm	Depth of planting, cm
Field germination, %	0.408 ± 0.228	0.450 ± 0.223
Yield of microtubers, items/ha	-0.819 ± 0.143	0.313 ± 0.237
Total number of microtubers in the yield, thousand items/ha	-0.875 ± 0.121	0.200 ± 0.245
Yield of microtubers per one plant, g	-0.100 ± 0.249	0.492 ± 0.218
Weight of average microtuber, g	-0.847 ± 0.133	-0.029 ± 0.250
Number of microtubers under the plant, items	0.861 ± 0.127	0.065 ± 0.249
Propagation coefficient	0.542 ± 0.210	0.408 ± 0.228
Prime cost, hryvna/microtuber	-0.545 ± 0.210	-0.485 ± 0.219
Profitability, %	0.262 ± 0.241	0.531 ± 0.212

On average during the years of studies the maximal productivity of planting for the interaction of factors was obtained while planting microtubers at the depth of 6 cm with the nutrition area of 70 x 10 cm – 31.2 c/ha, the propagation coefficient is 2.1. The increase in the depth of planting microtubers from 2 and 4 cm to 6 cm increases their productivity on average by the factor by 48.7 and 45.6 % due to the increase in the productivity of one plant by 36.7 and 22.2 % respectively, and promotes the increase in the total number of microtubers by 23.6 and 25.7 %.

The analysis of the fraction composition of microtubers of the yield testifies to the fact that with the nutrition area of 70 x 5 cm plants form the highest number of microtubers in the yield – 300.8 thousand items/ha, which is related to a high number of small microtubers in the yield (Table 3). Other planting schemes yielded the following indices: 221.9; 216.6; 142.0; 109.1; 93.6 thousand items/ha successively by the scheme of the experiment. Thus, the increase in the distance between planted microtubers up to 10, 15, 20, 25, and 30 cm decreases the total number of microtubers in the yield 1.4; 1.4; 2.1; 2.8 and 3.2-fold respectively.

Table 2 – **The productivity of potato microtubers for early harvesting depending on the nutrition area and the depth of planting microtubers** (2011-2013)

Nutrition area, cm (factor A)	Depth of planting, cm (factor B)	Total number of microtubers in the yield, thousand items/ha	Productivity of microtubers, c/ha				Yield of microtubers per one plant, g	Weight of average microtuber, g	Number of microtubers under the plant, items	Propagation coefficient
			In 2011	In 2012	In 2013	Average				
70 x 5	2	352.1	16.2	42.9	17.2	25.4	17.8	14.1	1.9	1.2
	4	227.3	13.9	21.3	19.2	18.1	10.7	8.3	1.8	0.8
	6	323.0	14.1	51.9	21.0	29.0	17.2	11.5	1.5	1.1
70 x 10	2	183.4	8.3	19.8	13.0	13.7	15.4	13.5	1.3	1.3
	4	181.9	7.8	17.3	11.3	12.1	15.1	9.1	1.7	1.3
	6	300.5	46.8	35.5	11.2	31.2	29.8	9.6	3.2	2.1
70 x 15	2	171.9	19.1	8.6	4.3	10.7	16.4	5.0	3.5	1.8
	4	247.5	22.1	17.3	14.3	17.9	27.8	7.7	3.7	2.6
	6	230.5	18.9	26.2	8.9	18.0	24.7	8.9	2.9	2.4
70 x 20	2	131.0	22.3	4.2	4.8	10.4	18.7	6.4	3.5	1.8
	4	136.5	28.1	3.7	4.1	12.0	21.1	5.4	5.0	1.9
	6	158.7	19.4	8.0	6.1	11.2	19.6	5.8	3.8	2.2
70 x 25	2	93.0	14.9	2.6	1.9	6.5	13.4	4.8	3.7	1.6
	4	97.7	18.0	1.2	2.0	7.1	15.0	4.6	4.5	1.7
	6	136.4	21.2	10.8	1.2	11.1	21.4	6.3	3.6	2.4
70 x 30	2	78.9	12.4	2.1	0.9	5.1	13.5	3.8	4.4	1.7
	4	102.3	13.5	3.4	1.5	6.1	16.8	4.6	4.8	2.1
	6	99.5	13.8	4.2	1.1	6.4	17.6	4.2	4.4	2.1
Multiple correlation index		0.897	-			0.876	0.502	0.847	0.863	0.678

Note. HIP_{05}, c/ha – 2011: A – 3.5; B – 11.2; 2012: A – 9.7; B – 5.2. 2013: A – 2.6; B – 1.9

While planted at the depth of 6 cm the microtubers formed 208.1 thousand items/ha microtubers, which is and 23.6 % more than while planting for 4 and 2 cm respectively.

The regression analysis of the data allowed obtaining the mathematical models of the dependence of the plant productivity of early-maturing variety Kobza for early harvesting on the nutrition area and the depth of planting microtubers (Table 4). The models obtained are linear regarding the investigated parameters.

The economic estimation of the efficiency of cultivating microtubers depending on the technological methods was performed, based on the price of 5 hryvna per one microtuber, technological expenses of cultivation, norms and prices for potato cultivation in IFRI, prices for resources (combustible and lubrication materials, spareparts, irrigation systems, fertilizers, pesticides and chemicals, irrigation water) in accordance with the technological charts (Table 5).

Table 3 – **The influence of the nutrition area and the depth of planting microtubers on the fractional composition of potato microtubers of early-maturing variety Kobza at early harvesting** (2011-2013)

Nutrition area, cm	Depth of planting, cm	Total number of microtubers in the yield, thousand items/ha	Number of microtubers with the diameter (cm), %			
			> 3	2-3	1-2	< 1
70 x 5	2	352.1	9.0	24.5	46.2	20.3
	4	227.3	7.4	19.1	35.4	38.0
	6	323.0	6.3	16.8	29.3	47.6
70 x 10	2	183.4	7.7	31.3	40.0	21.0
	4	181.9	7.9	17.6	42.9	31.6
	6	300.5	26.0	23.7	23.8	26.5
70 x 15	2	171.9	12.6	22.0	28.0	37.3
	4	247.5	12.7	18.3	34.0	35.0
	6	230.5	15.0	24.7	38.6	21.7
70 x 20	2	131.0	21.4	28.4	28.9	21.3
	4	136.5	28.6	22.5	33.0	15.9
	6	158.7	18.5	26.0	30.3	25.3
70 x 25	2	93.0	14.2	23.5	35.9	26.5
	4	97.7	17.4	35.2	25.7	21.8
	6	136.4	19.5	21.0	29.4	30.1
70 x 30	2	78.9	13.7	28.0	27.0	31.4
	4	102.3	21.2	23.6	22.1	33.2
	6	99.5	11.8	23.6	30.2	34.5

Table 4 – **The regression equations for the dependence of the indices of field germination and productivity of potato plants of early-maturing variety Kobza at early harvesting on the nutrition area *(X_1)* and the depth of planting microtubers *(X_2),*** (2011-2013)

Index	Type of equation
Field germination, %	$Y = 49.58 + 0.33Xj + 1.92X_2$
Productivity of microtubers, c/ha	$Y = 20.96 - 0.73Xj + 1.46X_2$
Total number of microtubers in the yield, thousand items/ha	$Y = 285.9 - 8.28Xj + 9.93X_2$
Yield of microtubers per one plant, g	$Y = 13.59 - 0.0571Xj + 1.46X_2$
Weight of average microtuber, g	$Y = 12.97 - 0.3Xj + 0.0542X_2$
Number of microtubers under the plant, items	$Y = 1.07 + 0.12Xj + 0.0458X_2$
Propagation coefficient	$Y = 0.76 + 0.0307Xj + 0.12X_2$

Table 5 – **The economic efficiency of cultivating microtubers depending on the technological methods** (2011-2013)

Nutrition area, cm	Depth of planting, cm	Yield of microtubers, c/ha	Expenses, thousand hryvna/ha	Prime cost, hryvna/kg	Net profit or loss, thousand hryvna/ha	Profitability, %
70 x 5	2	25.4	1430	562	96	107
	4	18.1	1430	789	-342	-76
	6	29.0	1430	493	310	122
70 x 10	2	13.7	715	522	107	115
	4	12.1	715	589	13	102
	6	31.2	715	229	1155	262
70 x 15	2	10.7	479	449	161	134
	4	17.9	479	268	595	224
	6	18.0	479	266	601	225
70 x 20	2	10.4	358	343	269	175
	4	12.0	358	299	361	201
	6	11.2	358	320	313	187
70 x 25	2	6.5	286	442	102	136
	4	7.1	286	405	138	148
	6	11.1	286	258	378	232
70 x 30	2	5.1	236	460	72	131
	4	6.1	236	385	132	156
	6	6.4	236	93	146	162

The estimates demonstrated that the production cost increased in inverse proportion to the density of planting microtubers: with the increase in the nutrition area the costs of their cultivation decrease 2, 3, 4, 5, and 6.1-fold compared to planting by the 70 x 5 cm scheme.

The profit of capital investment is maximal while using the 70 x 10 cm scheme of planting microtubers at the depth of 6 cm.

Conclusions. In order to obtain the maximal propagation coefficient for the improved potato source material, obtained in the culture *in vitro,* while cultivating in the primary seed production process in the irrigated conditions of the south of Ukraine, it is economically reasonable to conduct spring planting of microtubers at the depth of 6 cm with the nutrition area of 70 x 10 cm. Here the profitability is 262 %, and the net profit amounts to 1.155 thousand hryvna/ha.

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Выращивание оздоровленного исходного материала картофеля в питомниках первичного семеноводства в условиях орошения на юге Украины

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Приведены результаты исследований по определению технологических приемов, влияющих на увеличение коэффициента размножения исходного оздоровленного материала картофеля, полученного в культуре меристем *in vitro* при выращивании в первичных звеньях семеноводческого процесса.

Использовались полевой, лабораторный, математико-статистический, расчетно-сравнительный методы и системный анализ в двухфакторном опыте.

В среднем за годы исследований, максимальная продуктивность посадки при взаимодействии факторов получена при посадке микроклубней на глубину 6 см с площадью питания 70 х 10 см – 31,2 ц/га, коэффициент размножения составляет 2,1. Увеличение глубины посадки микроклубней с 2 и 4 до 6 см повышает их урожайность в среднем по фактору на 48,7 и 45,6 % соответственно за счет увеличения на 36,7 и 22,2 % производительности одного растения и способствует росту общего количества миниклубней на 23,6 и 25,7 %. При уменьшении площади питания до 70 х 5 см растет внутривидовая конкуренция, в результате чего снижается производительность одного растения, то есть количество минибульб, что приводит к уменьшению коэффициента размножения.

Доказано, что для повышения коэффициента размножения исходного оздоровленного материала картофеля, полученного в культуре *in vitro*, экономически целесообразным является высаживание микроклубней в весенней посадке на глубину 6 см с площадью питания 70 х 10 см: рентабельность при этом составляет 262 %, себестоимость – 229 грн/кг миниклубней, чистая прибыль – 1155 тыс. грн/га.

Ключевые слова: картофель, юг Украины, первичное семеноводство, площадь питания, глубина посадки, in vitro.

Growing of improved potato source material in primary seeding nurseries under irrigation in southern Ukraine

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The study has been aimed at the development of technological methods that would help increase the propagation coefficient of improved source material of potatoes, obtained in meristem culture in vitro, grown in the primary seed production process.

The research has been based on the integrated use of field, laboratory, mathematical and statistical, computationally-comparative methods and systems analysis. In order to determine the most effective technological methods for the cultivation of improved source material in the primary seed production process, a two-factor experiment has been performed. The effect of different depth and density of microtubers spring planting on the potato productivity has been studied on the Kobza early-maturing variety.

Proved the maximum productivity of 24.2 c/ha (on the average by the factor) has been achieved with the nutrition area of 70 x 5 cm, the propagation coefficient being 1.1. With higher planting density up to 286,000 microtubers per hectare, the intraspecific competition increases, causing the decrease in plant productivity, that is, the number of microtubers, conducive to the propagation coefficient decrease. On average, long-term experiment testifies to the fact that the maximum productivity of 31.2 c/ha with the interaction of factors can be achieved with microtubers planted to the depth of 6 cm, the nutrition area being 70 cm x 10 cm, the propagation coefficient being 2.1. Increasing the depth of microtubers planting from 2, 4 cm to 6 cm improves yields on the average by 48.7 % and 45.6 % by the factor due to plant productivity growth by 36.7 % and 22.2 %, the total amount of microtubers increasing by 23.6 % and 25.7 %, respectively.

In order to increase the propagation coefficient of improved potato source material obtained in vitro, microtubers spring planting to the depth of 6 cm and the nutrition area of 70 cm x 10 cm prove to be most economically efficient. In this case the profitability amounts to 262 %, the prime cost is 229 hryvna/kg of microtubers, net income comes to 1,155 thousand hryvna/hectare.

Key words: potatoes, southern Ukraine, primary seed production, nutrition area, the depth of planting, in vitro.

Надійшла 12.10.2015 р.