Original Paper

Garden pea yield and its quality indicators depending on the technological methods of growing in conditions of Vinnytsia region

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This paper aims to study the growth and development of garden pea plants when liming the soil, applying mineral fertilizers, pre-sowing seed treatment with inoculants, micronutrients and foliar nutrition. Plants survival was higher in the trial variant when applying lime (1.0 norm of lime per ha), mineral fertilizers, pre-sowing seed treatment with Rhizobophyte and microfertilizer Wuxal Extra CoMo, foliar nutrition with microfertilizers Wuxal Microplant at the microstage BBCH 12–13 and Wuxal Calcium, Boron at the microstage BBCH 51–59 – 92.0% and 92.1% in Skinado and Somerwood garden pea varieties. In the same variant, maximum values of the use of photosynthetic active radiation (PAR) were observed in Skinado variety – 1.38 and Somerwood variety – 1.89%. This was 0.47 and 0.57% higher compared to the control. The longest period of symbiosis, both general and active, was 35.3 and 37.1, 25.4 and 26.7 days. This was 2.2, 4.6, and 1.6 days more compared to the control where liming was applied. The highest rates of symbiotic and active potentials were observed in Skinado and Somerwood varieties and amounted to 14.0 and 15.4, 7.8 and 8.6 thousand kg per day/ha, and the amount of symbiotically fixed nitrogen (SNF) was 148.2 kg/ha in Skinado and 172 kg/ha in Somerwood variety. Pea yield was 9.36 t/ha in Skinado and 11.09 t/ha in Somerwood varieties. This was 2.15 and 2.14 t/ha more compared to the control. Green pea output was 46.4% in Skinado and 50.3% in Somerwood varieties. This was higher compared to the control by 4.4 and 3.0%, respectively.

Keywords: garden pea, microfertilizers, variety, inoculation, active symbiosis, Rhizobophyte, fertilizers

1 Introduction

At the current stage of the agricultural production development, the issue of growing eco-friendly crop products with minimal accumulation of nutrients in the soil and, above all, nitrogen-containing compounds, is becoming extremely important (Hrushetskyi et al., 2021; Kovbasa et al., 2021). Recently, the deficiency of nitrogen of biological origin in the soils of Ukraine is primarily caused by a sharp decrease in the application of organic fertilizers due to significant reductions in livestock in the public sector, and, consequently, minimal use of manure as a traditional organic fertilizer (Didur and Shevchuk, 2020). Therefore, attempts to increase the number of nodule bacteria, intensification and productivity of nitrogen fixation are quite relevant (Mazur et al., 2021). One of the most common annual legume crops is garden pea, which is widely known in a canned form as "green peas" (Mostovenko and Didur, 2021; Mostovenko, 2020).

Garden pea is of great importance for proper nutrition due to the balanced content of protein and carbohydrates, biologically active and mineral substances (Paziuk et al., 2021). This botanical species belongs to plants with a high degree of utilization of crops and products of life activity. Unripe grain – green peas – is used as a highly nutritious product in fresh and canned form. Waste of canned production including tops, damaged grain, bean stalks, as well as dry straw are a valuable protein feeds for farm animals. After harvesting, nodule bacteria that grow on the roots of plants leave in the soil up to 100 kg/ha of nitrogen, which corresponds to 12–16 tons of manure and has a positive effect on subsequent crops in crop rotation. By the chemical composition, green pea contains (in % by crude matter): dry matter – 19–21, sugar – 5.0–7.2, starch – 1.2–1.4, fiber – 1.8–2.2, protein – 5.6–8.1, ash – 0.5–0.7, oil – 0.7–0.9 and vitamin C – 37–45 mg/100 g (Almashova et al., 2006).

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Among vegetable crops, garden pea is one of the most common. However, insufficient amount of pea products are produced, which does not meet the needs of the population and recommended consumption rates (vegetables – only 160 kg/year, green peas and other legumes – 3.3 kg) (Andriushko et al., 2004; Norik and Mulyarchuk, 2018).

Garden pea (*Pisum sativum* L.) is grown to produce green peas. The yield of green pea depends on the harvesting terms. The earlier the pea is harvested, the higher taste and nutritional properties will be and the lower yield it will provide. To establish optimal harvesting terms for green pea, a penetrometer (by hardness) is used. The optimal ripeness of pea at its highest quality corresponds to 40–42 divisions of the indicator on the device (Tkachyk, 2016). It differs from other legumes as its grain is harvested when it achieves milk or milk-wax ripeness under the humidity of 80–85%. The obtained unripe grain is used to produce canned "Green peas". In addition, it is consumed fresh, frozen and dried (Mostovenko, 2020)

Pea is also able to provide itself with nitrogen by 60–70% and leave 60–140 kg/ha of its biological equivalent in the soil. But for purpose, it is necessary to provide plants with trace elements, improve their availability, in addition, they are low-cost when applied and do not harm the environment (Andriushko et al., 2004; Mostovenko, 2020).

These issues were studied by the scientists (Almashova et al., 2006; Karkanis et al., 2016; Didur and Mostovenko, 2020; Didur and Shevchuk, 2020; Mazur et al., 2021). However, the issues of developing technological methods of cultivation by improving the effect of nitrogen-fixing bacteria(NFB), which will increase yields and product quality, have not been sufficiently studied.

Hence, there is a need to develop elements of resource-saving technology for its cultivation using small doses of fertilizers of synthetic origin by increasing the effect of nitrogen-fixing nodule bacteria.

In addition to the yield increase, these techniques will help to increase soil fertility due to accumulation of bigger amount of biologically pure nitrogen after garden pea harvesting.

Today, due to the high cost of mineral fertilizers, the nutrition system mainly involves two of its elements: pre-sowing seed treatment and foliar nutrition of plants. Even pre-sowing fertilization is not applied by all farms in plant growing technologies (Poberezhets et al., 2021). Therefore, there is a need to focus on this area of research (Almashova et al., 2006).

It is very important to provide plants with micronutrients and biologically active substances together with microfertilizers and plant growth regulators, which are currently an integral part of modern plant growing technologies, especially when introducing new high-yield varieties of legume crops, including garden pea, which require a balanced nutrition (Chynchyk, 2013; Didur and Mostovenko, 2021).

The aim of the research was to reveal the peculiarities of growth, development and formation of the yield of pea varieties and seed quality as a result of fertilization, liming, pre-sowing seed treatment with inoculants and micronutrients as well as foliar nutrition.

2 Material and methods

To research the studied elements of the technology of growing garden pea in 2017–2019, a field trial was conducted on the research field of Vinnytsia National Agrarian University.

The territory of the trial field had a flat relief. The soil of the trial site was represented by gray podzol mid-loam soils. In terms of morphological features, physical and physico-chemical parameters, they are typical for Vinnytsia region and in general for the right-bank Forest-Steppe and the soils are favorable for growing peas. According to the agrochemical survey, the arable soil layer had the following physicochemical parameters: humus content (according to Turin) was 2.02–2.25%, alkaline hydrolyzed nitrogen (according to Cornfield) was 60–67 mg/kg, mobile phosphorus and exchangeable

Table 1 Agrochemical characteristics of the soil of the trial site

Soil type		Gray podzol mid-loamy
Humus content according to Turin (%)		2.02–2.25
Content of mobile forms (mg/kg)	N	60–67
	P_2O_5	149–212
	K_2O	80–92
pH of the soil extract		5.3–5.4
Hydrolytic acidity, mg-eq per 100 g of soil		1.6–1.7
The sum of absorbed bases, mg-eq per 100 g of soil		14.6–15.3

potassium (according to Chirikov) was 149–212 mg/kg and 80–92 mg/kg of soil, respectively, pH of salt extract was 5.3–5.4. Hydrolytic acidity was 1.6–1.7 mg-eq per 100 g of soil (Table 1).

The hydrothermal regime was contrasting over the years. It should be noted that there was a deficit of precipitation during critical periods of plant growth and development in 2017, its relatively satisfactory amount in 2018 and a sufficient amount in 2019. The temperature regime differed insufficiently from the long-term averages.

The scheme of the experiment included the study of the following options: Factor A – varieties: 1. Skinado. 2. Somerwood; Factor B – liming: B 1 (without liming); B 2 (0.5 norms of lime per year); B 3 (1.0 norms of lime per year); Factor C – Feeding: C 1 control (N30R60K60 + Inoculation) – background; C 2 (Background + Wuxal Extra CoMo – 1 l/t of seeds); C 3 (Background + Wuxal Extra CoMo – 1 l/t of seeds + Wuxal Microplant at the microstage of BBCH 12–13 – 1.5 l/ha); C 4 (Background + Wuxal Extra CoMo – 1 l/t of seeds + Wuxal Microplant at the microstage BBCH 12–13 – 1.5 l/ha + Wuxal Calcium, Boron at the microstage BBCH 51–59 – 1.5 l/ha).

Calculation of fertilizer doses by the method of calculations, method of calculated balance and normative methods for the planned yield was carried out according to the methodology (Lisoval et al.,2002).

The trials were carried out in the crop rotation after winter wheat. The main soil tillage involved double peeling of the stubble by the unit of the tractor YuMZ-6AKL and cultivator LDG-15 A: the first one at the depth of 6–8 cm, the second one at the depth of 10–12 cm. Transportation and application of mineral fertilizers was undertaken by the unit of the trctor YuMZ-6AKL and MVU-5A. Phosphorus-potassium fertilizers in the form of granular superphosphate – 20% a.i. and potassium sulfate were applied under fallow plowing at the rate of 60 kg/ha of P_2O_5 and K_2O, as well as defecates (0.5 and 1.0 norm of lime per ha or 1.25–2.5 t/ha). Plowing was carried out at the depth of 25–27 cm by the unit of the tractor YuMZ-8244 and a plow PLN 3–35. After plowing, in autumn the soil was leveled with the unit of the tractor YuMZ-6AKL and cultivator KPS-4G. In early spring, when the soil achieved physical maturity, the field was cultivated with the unit of the tractor YuMZ-6AKL and cultivator KPS-4G in the unit with harrows BZTS-1.0 at the depth of 10–12 cm. Before sowing, there were applied nitrogen fertilizers in the form of ammonium nitrate at the rate of 30 kg of a.i. per ha, followed by the second cultivation with the unit USMK-5.4V + BZSS-1.0 at the seeding depth. The control variant was the one where mineral fertilizer was applied in the dose of $N_{30}P_{60}K_{60}$, pre-sowing seed treatment with bio-agent Rhizobophyte (with nitrogen-fixing bacterial cells *Ryzobium leguminosarum* 245 a, 200 g of preparation per hectare seed rate) was the background of the experiment. Bacterization was carried out on the day of sowing after seed treatment with microfertilizer Wuxal Extra CoMo.

Crop density was calculated at the microstage BBCH 09 and at the microstage BBCH 77–79. Recording of plant density at the microstage BBCH 09 taking into account the seeding rate allows us to determine the field germination rate. Recording of crop density *t* the microstage BBCH 77–79 allows us to calculate plant survival during the growing season (Pylypenko et al., 2016).

Phenological observations establishing occurrence of the microstages BBSH 09, BBSH 51–59, BBSH 61–69, BBSH 77–79 were conducted according to the methodology (Tkachyk, 2016).

Determination of the number and mass of nodules was performed by the method of monoliths, imposing a frame sized 300 × 167 mm (0.05 m^2). Thus, knowing the area of the monolith and the average plant density, the number and mass of nodules per plant determined (Pryanishnikov, 1963). Pylypenko et al., 2016). Active symbiotic potential (*ASP*) was calculated by the formula (1):

$$ASP = (M1 + M2) : 2 \times T \quad (1)$$

where: *T* – the period between two adjacent terms of analysis, days; (*M*1 + *N*2): 2 – average mass of nodules with leghemoglobin during the period *T* (kg/ha)

The amount of fixed nitrogen was calculated based on ASP and specific activity of symbiosis (SAS), using the methodology (Posypanov, 1991).

The harvest was recorded as follows: the green mass was mown, weighed by repetitions, one sample weighing 10 kg was taken, technically ripe beans were cut by hand and weighed. After that, the average sample of beans weighing 2 kg was taken and the peas were peeled on a laboratory peeler or by hand and the percentage of output of grain from the beans was determined. Its output from the green mass (*Ogm*, %) was calculated by formula (2) (Tkachyk, 2016):

$$O\,g.\,m. = (B \times Ob) : A \quad (2)$$

where: *A* – the mass of the average sample of green mass (kg); *B* – the mass of technically ripe beans in the sample (kg); *Ob* – output of grain from the beans (%)

$$\text{In}\ z.\,m. = (B \times Wb) : A \quad (3)$$

The method of recalculation determines the yield of green peas in t/ha in repetitions and in general of varieties and the average yield of green mass.

Peeled green peas were passed through sieves with holes of 5, 7, 9 and 10 mm. Each fraction was weighed and the percentage of total weight was calculated. Smooth varieties are considered to be high-quality if the grains are 5–7 mm in size (Tkachyk, 2016; Karkanis et al., 2016).

Processing of experimental data and statistical analysis of the results were performed on a PC using MS Excel 2019 software (Microsoft, USA) and Statistica 12.6 (Dell Technologies, USA) using built-in statistical functions. Statistical functions are functional software modules that implement individual statistical formulas (calculation of average values, correlation coefficient, etc.), and can be used in formulas. The small sample method was used. The method of small samples provided for the determination of the arithmetic mean values (*x*) and the deviation of the arithmetic mean values (± Sx). The data in the tables are presented in the form of *x* ± Sx (mean ± standard deviation). Statistical evaluation of differences was performed using Student's *t*-test. The difference was considered significant if the calculated criterion for the reliability of the difference (experimental) is equal to or exceeds the standard value of the Student's t-test. The results of the average values were considered statistically significant at * P <0.05; ** P <0.01; *** P <0.001 (Moiseychenko et al., 1996).

The results of yield recording were subjected to analysis of variance according to the methodology by Moiseychenko et al. (1996). The lowest significant difference (LSD) was calculated to determine available reliable difference between the variants of the experiment.

The analysis of pea grain was performed by the content of dry matter, vitamin C and sugars (Tkachyk, 2016; Poberezhets et al., 2021) at the Department of Assessment of Feed Quality, Safety and Raw Materials of the Institute of Feed Research and Agriculture of Podillia of NAAS.

3 Results and discussion

Crop density is a decisive factor in the formation of crop yields and garden pea yield, in particular. The density that is optimal for a particular variety in specific soil and climatic conditions ensures its maximum photosynthetic and symbiotic activity, efficient use of soil fertility, growth of individual plant productivity and formation of high seed yields (Biliavska et al., 2021; Chynchyk, 2013).

In recent years, more and more attention has been paid to plant density. High field germination rate of pea seeds and maximum plant survival before harvesting are the determining factors for the formation of highly productive agrophytocenoses of peas (Li et al., 2020).

The seeding rate of each batch of seeds depends on the seed size, germination rate, varietal characteristics, soil and climatic conditions and ranges within 150–350 kg/ha. Under adverse arid conditions, it is increased by 10%. Optimal plant density is 80–130 plants per 1 m^2 (early varieties – 120–130 plants, mid varieties – 100–110 plants, late varieties – 70–80 seeds). Increase in the density over 130 plants/m^2 leads to the yield reduction. The seeding rate of 1.4 million garden pea seeds was set according to the optimal plant density, taking into account the field germination rate and plant survival during spring and summer period (Vdovenko et al., 2018). Plant survival in garden pea (Table 2) depends on the technological methods of cultivation, which were studied in the trial.

Plant density in garden pea depended primarily on the pre-sowing seed treatment with microfertilizer Wuxal Extra CoMo, soil liming and foliar nutrition of plants with microfertilizer Wuxal Microplant at the microstage BBCH 12–13 and microfertilizer Wuxal Calcium, Boron at the microstage BBCH 51–59 as well as varietal characteristics.

Thus, in the control variant, plant density in Skinado and Somerwood varieties at the microstage BBCH 77–79 was 1088.5 and 1092.3 thousand per ha, and during soil liming (0.5 norm of lime per ha) plant density increased to 1109.8 and 1142.4 thousand per ha, and when lime was applied (1.0 norm of lime per hectare), plant density increased to 1128.7 and 1132.5 thousand per ha.

However, during pre-sowing seed treatment with microfertilizer Wuxal Extra CoMo, plant density increased in all trial variants: without liming – by 51 and 50.1 thousand per ha (4.5 and 4.5%) as well as in trial variants where liming was applied: 0.5 norm of lime per ha – 45 and 45.2 thousand per ha (4.1 and 3.9%) and 1.0 norm of lime per ha – 36.5 and 32.7 thousand per ha (3.1 and 2.8%).

Plant density was higher in the trial variants, where against the background of mineral fertilizers $N_{30}P_{60}K_{60}$, pre-sowing seed treatment with Rhizobophyte and microfertilizer Wuxal Extra CoMo and foliar nutrition with microfertilizer Wuxal Microplant were applied. Thus, plant density in Skinado and Somerwood varieties was 1151.9 and 1154.8 thousand plants per ha in the trial variant without liming, and it was 1163.4 and 1157.6 thousand plants per ha when applying 0.5 norm of lime per ha, and 1174.3 and 1176.5 thousand plants per ha when applying 1.0 norm of lime per ha. These values were higher by 63.4 and 62.5; 74.9 and 65.3; 85.8 and 84.2 thousand plants per ha compared to the control variant.

Table 2 Plant density in garden pea depending on the variety, liming and nutrition (average of 2017–2019)

Fertilization (factor C)	Liming (factor B)	Plant number		Field germination rate (%)	Plant survival (%)
		at the microstage BBCH 09	at the microstage BBCH 77–79		
Skinado					
C 1 – control (back-ground)	B 1	1231.4 ±4.6	1088.5 ±4.4	87.9 ±0.2	88.0 ±0.5
	B 2	1245.3 ±4.9	1109.8 ±4.1	88.9 ±0.1	89.0 ±0.8
	B 3	1258.8 ±2.2	1128.7 ±4.4	89.9 ±0.2	89.6 ±0.6
C 2	B 1	1264.1 ±5.0**	1139.5 ±5.3**	90.3 ±0.2***	90.1 ±0.4*
	B 2	1276.6 ±6.1*	1154.8 ±4.9**	91.2 ±0.2***	90.5 ±0.6
	B 3	1285.5 ±4.9**	1165.2 ±4.6**	91.8 ±0.2*	90.6 ±0.6
C 3	B 1	1263.2 ±2,8**	1151.9 ±4.3***	90.3 ±0.2***	91.2 ±0.6*
	B 2	1274.4 ±3.2**	1163.4 ±4.6***	91.1 ±0.2***	91.3 ±0.5
	B 3	1286.7 ±4.4**	1174.3 ±3.9***	91.8 ±0.2**	91.3 ±0.6
C 4	B 1	1265.5 ±4.6**	1161.1 ±5.2***	90.4 ±0.4***	91.8 ±0.6*
	B 2	1275.3 ±5.7*	1177.7 ±4.9***	91.1 ±0.5**	92.0 ±0.6*
	B 3	1281.1 ±4.8*	1179.8 ±4.7*	91.5 ±0.4**	92.0 ±0.6*
Somerwood					
C 1 – control (back-ground)	B 1	1235.6 ±5.2	1092.3 ±5.5	88.2 ±0.4	88.4 ±0.6
	B 2	1247.1 ±3.8	1112.4 ±3.7	89.1 ±0.3	89.2 ±0.7
	B 3	1260.6 ±4.8	1132.5 ±4.6	90.0 ±0.2	89.8 ±0.5
C 2	B 1	1267.3 ±4.7*	1142.4 ±5.4**	90.5 ±0.2*	90.1 ±0.4
	B 2	1278.2 ±5.1**	1157.6 ±5.5**	91.3 ±0.2**	90.5 ±0.6
	B 3	1285.5 ±3.5*	1165.2 ±4.2**	91.9 ±0.2**	90.6 ±0.6
C 3	B 1	1266.7 ±3.7**	1154.8 ±6.8**	90.5 ±0.2**	91.1 ±0.5*
	B 2	1277.5 ±3.8**	1165.6 ±6.5**	91.2 ±0.3**	91.2 ±0.5
	B 3	1289.4 ±3.3**	1176.5 ±6.3**	92.0 ±0.3*	91.2 ±0.5
C 4	B 1	1268.1 ±3.5**	1165.6 ±3.3***	90.6 ±0.2***	91.9 ±0.6*
	B 2	1279.2 ±2.9**	1176.8 ±5.6***	91.4 ±0.2***	91.9 ±0.6*
	B 3	1284.8 ±3.4*	1183.1 ±5.5**	91.8 ±0.2***	92.1 ±0.6*

* significant at $P < 0.05$ compared with control group; ** significant at $P < 0.01$ compared with control group; *** significant at $P < 0.001$ compared with control group

However, the best trial variant provided plant density of 1179.8 and 1183.1 thousand plants per ha in Skinado and Somerwood varieties of garden pea, when there was applied liming (1.0 norm of lime per ha), mineral fertilizers, pre-sowing seed treatment with Rhizobophyte and microfertilizer Wuxal Extra CoMo, foliar nutrition with microfertilizer Wuxal Microplant at the microstage BBCH 12–13 and Wuxal Calcium, Boron at the microstage BBCH 51–59.

The values were higher compared to the control by 91.3 and 90.8 thousand plants per ha. Field germination of seeds was higher in the trial variant where against the background of mineral fertilizers, there was applied pre-sowing seed treatment with Rhizobophyte and microfertilizer Wuxal Extra CoMo as well as liming (1.0 norm of lime per ha).

Thus, seed germination rate was 91.8 and 91.9%, in Skinado and Somerwood varieties, which was higher compared to the control by 3.9 and 3.7%, respectively. In addition, it was found that formation of garden pea plant density was influenced by hydrothermal conditions of the year at the time of sowing. The lowest field germination rate was in 2018, which can be explained by the lower amount of precipitation in April – 15 mm, while an average figure is 36 mm.

The best conditions for crop density formation in garden pea were observed in 2019 due to the optimal regime of moisture supply during the critical period of plant growth and development. The lowest rates of crop density of garden pea were observed in 2017, as that year was the driest compared to other years of research. Application of mineral fertilizers with liming, pre-sowing seed treatment with Rhizobophyte and microfertilizer Wuxal Extra CoMo foliar nutrition with microfertilizer Wuxal Microplant at the microstage BBCH 12–13 and Wuxal Calcium, Boron at the microstage BBCH 51–59 had a positive effect on plant survival during the growing season and before the microstage BBCH 77–79.

According to researchers, crop productivity depends mainly on the photosynthetic activity of plants. The latter is determined by the coefficient of photosynthesis efficiency, which is calculated by the ratio of the energy of the crop organic compounds to the energy received by the sowing (or energy that was absorbed by green leaves) during the growing season from BBCH 09 to BBCH 77–79. It is established that the higher coefficient of photosynthesis efficiency is, the more intensively organic matter of plants is accumulated and the higher the yield is. The use of solar radiation energy to build organic compounds of the crop depends on the conditions of mineral nutrition, water and light regimes of plants in the sowings. Coefficient of photosynthesis efficiency depends primarily on the amount of photosynthetically active radiation (PAR) that comes to crops during the growing season. Theoretically, coefficient of the use of solar radiation energy by leaves for photosynthesis can reach 20% (Nychyporovych et al., 1961).

According to our research results, it was established (Table 3) that the when the growing conditions were

Table 3 Coefficient of PAR used by the garden pea crops depending on liming and nutrition system (average of 2017–2019)

Fertilization (factor C)	Liming (factor B)	Phenological phase		Coefficient of PAR used (%)
		dry matter (t/ha)	bound energy (MJ/ha)	
Skinado				
C 1 – control (back-ground)	B 1	4.81 ±0.1	94.9 ±2.7	0.91 ±0.05
	B 2	4.99 ±0.1	98.5 ±2.1	0.94 ±0.04
	B 3	5.39 ±0.1	106.4 ±2.2	1.10 ±0.07
C 2	B 1	5.48 ±0.1**	108.2 ±2.2*	1.14 ±0.06*
	B 2	5.57 ±0.1*	109.9 ±2.3*	1.15 ±0.06*
	B 3	5.65 ±0.1	111.5 ±2.3	1.18 ±0.05
C 3	B 1	5.71 ±0.2***	112.7 ±1.9**	1.22 ±0.06*
	B 2	5.82 ±0.2**	114.9 ±2.1**	1.25 ±0.06*
	B 3	5.88 ±0.2*	116.0 ±1.5*	1.26 ±0.06
C 4	B 1	5.94 ±0.2***	117.2 ±1.4**	1.30 ±0.05**
	B 2	6.12 ±0.2**	120.8 ±1.3***	1.35 ±0.05**
	B 3	6.23 ±0.2**	122.9 ±1.4**	1.38 ±0.04*
Somerwood				
C 1 – control (back-ground)	B 1	5.96 ±0.1	117.6 ±1.4	1.32 ±0.06
	B 2	6.11 ±0.1	120.6 ±1.1	1.36 ±0.05
	B 3	6.22 ±0.1	122.7 ±1.2	1.39 ±0.05
C 2	B 1	6.34 ±0.1	125.1 ±0.8*	1.48 ±0.05
	B 2	6.45 ±0.1	127.3 ±1.4*	1.50 ±0.05
	B 3	6.57 ±0.2	129.6 ±1.8*	1.54 ±0.05
C 3	B 1	6.65 ±0.2**	131.2 ±1.4**	1.61 ±0.05*
	B 2	6.74 ±0.2**	133.0 ±2.0**	1.63 ±0.06*
	B 3	6.87 ±0.2**	135.6 ±1.7**	1.68 ±0.07*
C 4	B 1	7.06 ±0.2**	139.3 ±1.2***	1.79 ±0.04**
	B 2	7.25 ±0.2**	143,1 ±1.3***	1.85 ±0.03**
	B 3	7.39 ±0.2**	145.8 ±1.6***	1.89 ±0.03**

* significant at $P < 0.05$ compared with control group; ** significant at $P < 0.01$ compared with control group; *** significant at $P < 0.001$ compared with control group

improved, in particular, liming (0.5 and 1.0 norm of lime per hectare) was applied against the background of mineral fertilizers $N_{30}P_{60}K_{60}$ and pre-sowing seed treatment with Rhizobophyte, coefficient of PAR used was 0.94 and 1.1; 1.36 and 1.39%.

Higher coefficients of PAR used were observed in the trial variants, where the seeds were treated with the complex fertilizer Wuxal Extra CoMo against the background of mineral fertilizers $N_{30}P_{60}K_{60}$, and pre-sowing seed treatment with Rhizobophyte. At the same time, the coefficient of PAR used was 1.14% in Skinado variety and 1.48% in Somerwood variety, which was 0.23 and 0.16 t/ha higher than in the control.

The increase in coefficients of PAR used was observed in the trial variant where there were applied mineral fertilizers $N_{30}P_{60}K_{60}$ and seed treatment with Rhizobophyte, micronutrients Wuxal Extra CoMo and foliar nutrition with a complex of micronutrients Wuxal Microplant at the microstage BBCH 12–13. At the same time, coefficients of PAR used were 1.22 in Skinado variety and 1.61% in Somerwood variety-, which was higher than in the control by 0.31 and 0.29%.

Maximum coefficients of PAR used were observed in the trial variant in Skinado variety – 1.38 and Somerwood variety – 1.89%, where liming was applied (1.0 norm of lime per ha) against the background of mineral fertilizers $N_{30}P_{60}K_{60}$, and pre-sowing seed treatment with Rhizobophyte and microfertilizer Wuxal Extra CoMo, foliar nutrition foliar nutrition with microfertilizers Wuxal Microplant at the microstage BBCH 12–13 and Wuxal Calcium, Boron at the microstage BBCH 51–59. This was 0.47 and 0.57% higher compared to the control.

Many researchers consider that inoculation promotes rapid colonization of the root system by NFB, formation of nodules on the roots, regardless of environmental conditions. There is also a varietal sensitivity of legumes by the rate of penetration of active strains of nodule bacteria to the root parenchyma, although this figure depends not only on the genotype of a particular variety, but also on the species or strain of bacteria (Karkanis et al., 2016).

The development of symbiotic bacteria in the tubers of legume roots was also influenced by the level of the cultivation technology intensification (Animal feed, 2005).

Powerful development of the symbiotic apparatus of grain legume crops depends not only on the effective interaction of genotypes of the host plant and nodule bacteria in certain growing conditions, but also on the fact that its intensity can be influenced by certain elements of cultivation technology, namely bacterial agents, different doses of mineral fertilizers and methods of application of microfertilizer and plant growth stimulants (Didur and Mostovenko, 2021; Mostovenko and Didur, 2021).

Symbiotic nitrogen fixation (SNF) begins at the microstage BBCH 12–13, reaches a maximum at the microstage BBCH 51–59 BBCH 61–65, and ends at the microstage BBCH 81–99 (Didur and Mostovenko, 2021).

Due to the mutually beneficial symbiosis, the plant supplies bacteria with products of photosynthesis, which are used to build their body (especially in the initial stages of ontogenesis), they provide the plant with 50–90% of its need for nitrogen nutrition (Mostovenko, 2020).

According to some researchers, in symbiosis with NFB, pea is able to absorb up to 200 kg of biological nitrogen per ha, of which up to 60–75% goes to crop formation, and 25–40% remains in soil with post-harvest plant residues increasing its fertility (Okhrimenko, 1998).

Thus, application of starting doses of nitrogen fertilizers at the beginning of the growing season helps to provide plants with nitrogen, but then, under its deficiency, due to NFB, plants begin to synthesize biological nitrogen, which they use themselves and accumulate it in the soil for subsequent crops.

Liming and foliar nutrition affected the formation of general and symbiotic potential and its productivity (Fig. 1, Fig. 2).

Lower indicators of general and symbiotic potential were obtained in the trial variant, where seed treatment with micronutrients Wuxal Extra CoMo and foliar nutrition with Wuxal Microplant – 34.2 and 35.3 were applied against the background of control; 24.5 and 25.4 days in Skinado and Somerwood varieties. A shorter period of symbiosis, both general and active, was observed in the trial variant, where sowing was carried out with inoculated seeds treated with micronutrients Wuxal Extra CoMo against the background of mineral fertilizer $N_{30}P_{60}K_{60}$, liming (norm of lime per year) – 33.6 and 35.4; 24.2 and 25.5 days. The duration of symbiosis and the mass of nodules was determined by the indicators of general symbiotic potential (GSP) and ASP (Fig. 3, Fig. 4).

Thus, the highest indicators of GSP and ASP were obtained in the trial variant, where sowing was carried out with inoculated seeds treated with micronutrients Wuxal Extra CoMo against the background of mineral fertilize $N_{30}P_{60}K_{60}$r and liming (1.0 norm of lime per ha), foliar nutrition with Wuxal Microplant and Wuxal Calcium, Boron. The indicators of symbiotic and active potential in Skinado and Somerwood varieties were 14.0 and 15.4, 7.8 and 8.6 thousand kg days/ha. These values were higher compared to the control by 7.97 and 8.7, 4.7 and 5.0 thousand kg days/ha by the varieties, respectively.

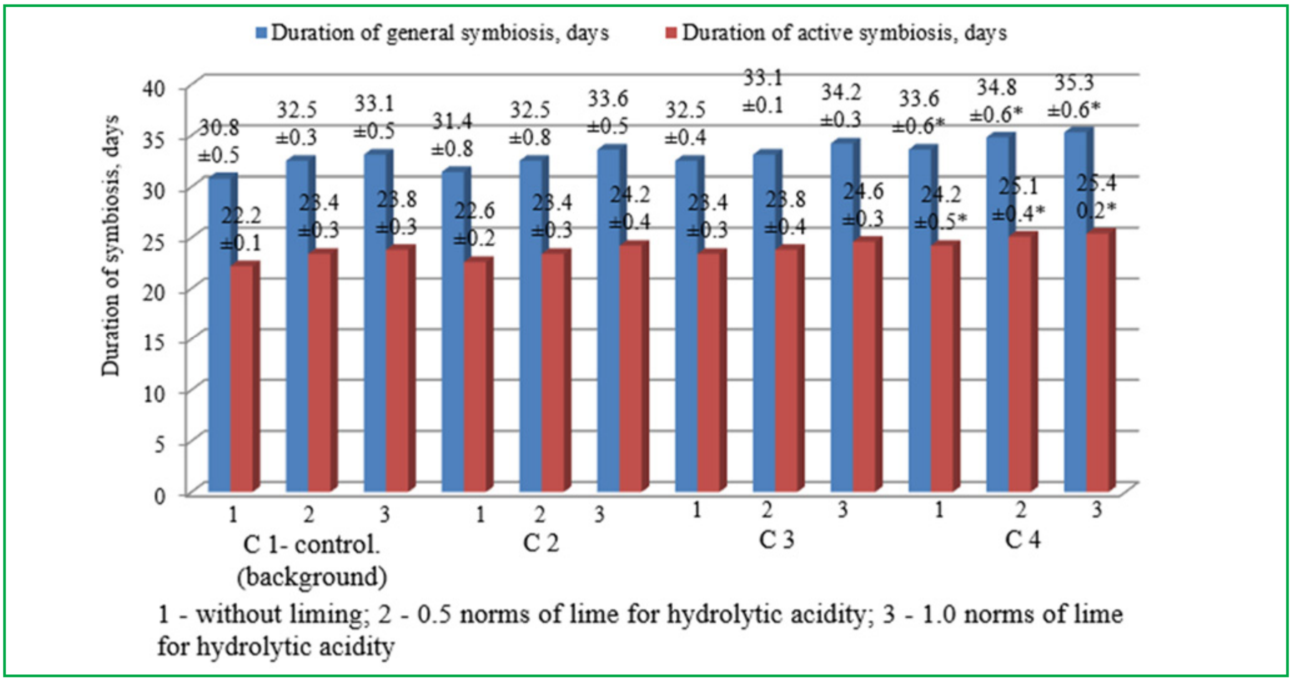

Figure 1 Duration of general and active symbioses, days in Skinado pea variety depending on liming and nutrition system (average of 2017–2019)
* significant at *P* <0.05 compared with control group; ** significant at *P* <0.01 compared with control group; *** significant at *P* <0.001 compared with control group

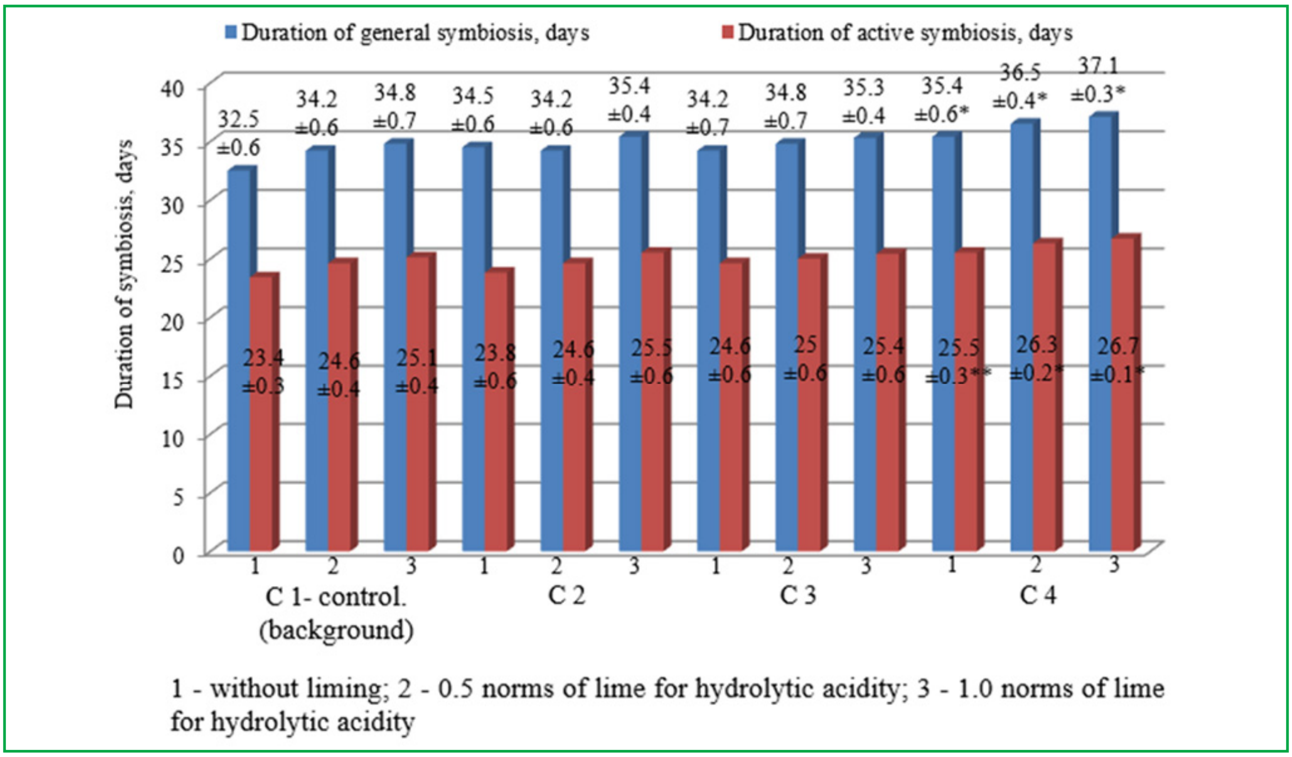

Figure 2 Duration of general and active symbioses, days in Somerwood garden pea variety depending on liming and nutrition system (average of 2017–2019)
* significant at *P* <0.05 compared with control group; ** significant at *P* <0.01 compared with control group; *** significant at *P* <0.001 compared with control group

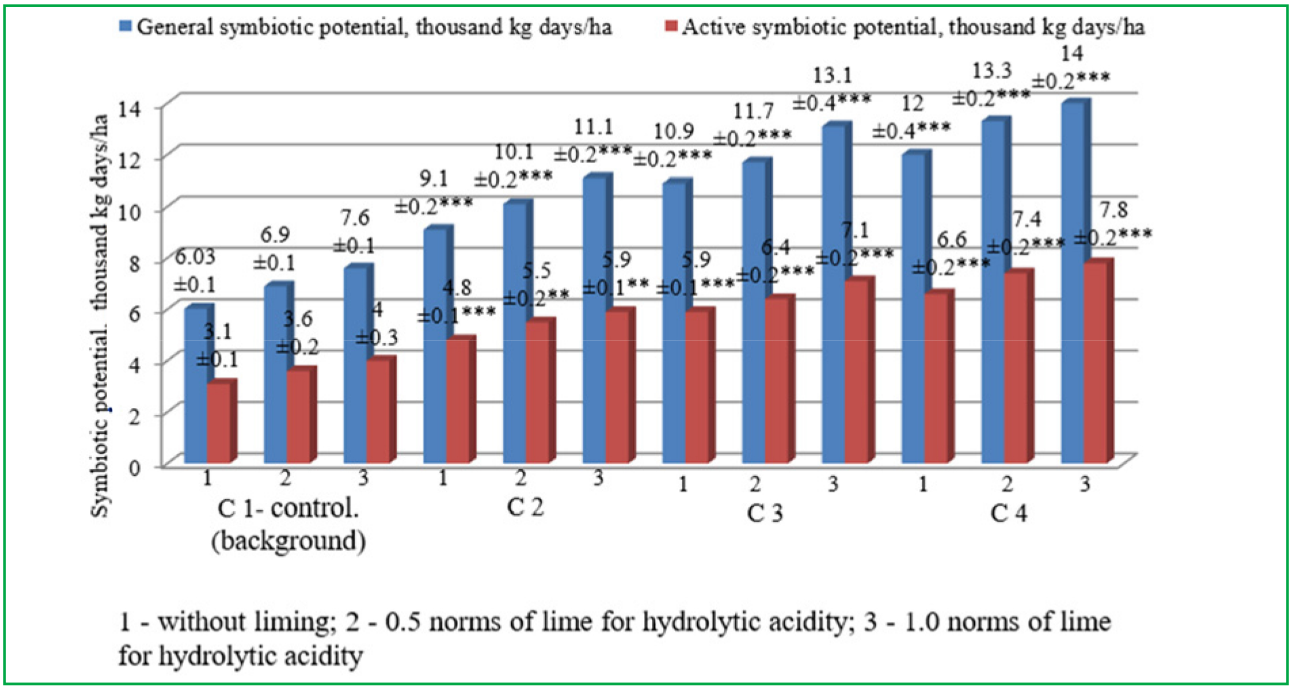

Figure 3 Duration of GSP and ASP of Skinado variety depending on liming and nutrition system, thousand kg days/ha over the period from microstage BBCH 13 to BBCH 77–79 (average of 2017–2019)

* significant at P <0.05 compared with control group; ** significant at P <0.01 compared with control group; *** significant at P <0.001 compared with control group

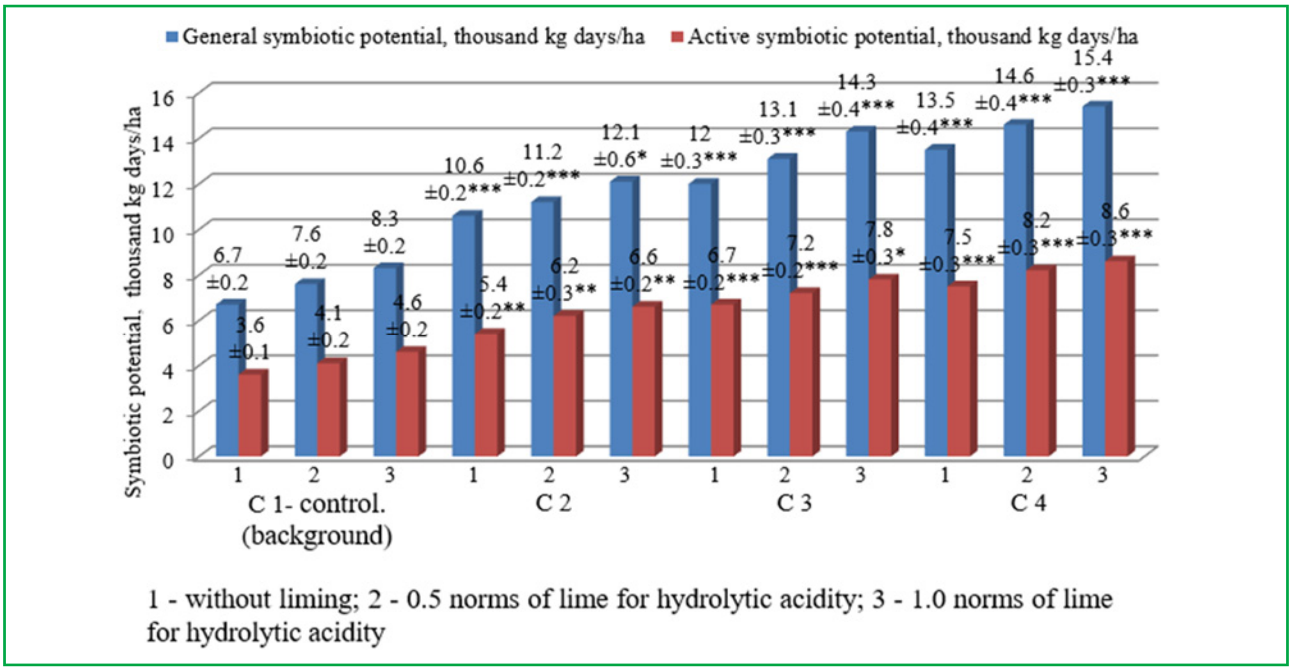

Figure 4 Duration of GSP and ASP of Somerwood variety of garden pea depending on liming and nutrition system, thousand kg days/ha over the period from microstage BBCH 13 to BBCH 77–79 (average of 2017–2019)

* significant at P <0.05 compared with control group; ** significant at P <0.01 compared with control group; *** significant at P <0.001 compared with control group

The amount of symbiotically fixed nitrogen was determined by the values of ASP and SAS. SAS is the amount of air nitrogen that fixes one kilogram of raw nodules daily (Posypanov, 1991; Pylypenko et al., 2016).

As a result of our research, it was found that the amount of symbiotically fixed nitrogen significantly depended on the seed treatment with micronutrients, soil liming and foliar nutrition (Table 4). The amount of symbiotically fixed nitrogen depended on the trial variant and varied from 58.9 to 148.2 kg/ha in Skinado variety and from 72 to 172 kg/ha in Somerwood variety.

Maximum values of SNF were observed in the trial variant, where against the background of control there was applied soil liming (1.0 norm of lime per ha), seed treatment with micronutrients Wuxal Extra CoMo, foliar nutrition with microfertilizers Wuxal Microplant at the microstage BBCH 12–13 and Wuxal Calcium, Boronat the microstage BBCH 51–59 – 148.2 and 172 kg/ha in Skinado and Somerwood varieties, respectively.

Table 4 Amount of symbiotically fixed nitrogen by the garden pea depending on liming and nutrition system, kg/ha (average of 2017–2019)

Fertilization (factor C)	Liming (factor B)	Fixed biological nitrogen (, kg/h
Skinado		
C 1 – control (background)	B 1	58.9 ±2.5
	B 2	68.4 ±2.6
	B 3	76.0 ±2.1
C 2	B 1	91.2 ±2.3***
	B 2	104.5 ±2.2***
	B 3	112.1 ±3.8**
C 3	B 1	112.1 ±4.1***
	B 2	121.6 ±2.9***
	B 3	134.9 ±1.3***
C 4	B 1	125.4 ±2.3***
	B 2	140.6 ±2.8***
	B 3	148.2 ±2.6***
Somerwood		
C 1 – control (background)	B 1	72 ±2.7
	B 2	82 ±1.9
	B 3	92 ±1.9
C 2	B 1	108 ±1.7***
	B 2	124 ±2.8***
	B 3	132 ±2.8***
C 3	B 1	134 ±2.6***
	B 2	144 ±2.7***
	B 3	156 ±2.0***
C 4	B 1	150 ±3.6***
	B 2	164 ±1.6***
	B 3	172 ±2.3***

* significant at $P < 0.05$ compared with control group; ** significant at $P < 0.01$ compared with control group; *** significant at $P < 0.001$ compared with control group

Seed yield of garden pea varieties under natural moisture supply depending on liming and foliar nutrition are shown in table 5.

In the control variant, where mineral fertilizers $N_{30}P_{60}K_{60}$ and pre-sowing seed treatment with Rhizobophyte were applied, the yield of seeds at the microstage BBCH 77–79 under 68% moisture supply was at the level of 7.21 and 8.95 t/ha in Skinado and Somerwood varieties of garden pea (Didur and Mostovenko, 2020).

When pre-sowing treatment of seeds with microfertilizer Wuxal Extra CoMo was applied in the trial variant against the background of mineral fertilizers $N_{30}P_{60}K_{60}$ and pre-sowing seed treatment with Rhizobophyte in Skinado and Somerwood varieties of garden pea, the yields were higher compared to control by 0.54 and 0.56 t/ha.

Application of foliar nutrition with microfertilizer Wuxal Microplant during the growth of vegetative mass against the background of mineral fertilizers $N_{30}P_{60}K_{60}$ and pre-sowing seed treatment with Rhizobophyte and microfertilizer Wuxal Extra CoMo provided the increase in yields of Skinado and Somerwood varieties by 1.17 and 1.0 t/ha compared to the control.

The highest yield of Skinado variety (9.36 t/ha) and Somerwood variety (11.09 t/ha) was provided in the trial variant where liming was applied (1.0 norm of lime per ha) against the background of mineral fertilizers $N_{30}P_{60}K_{60}$ and pre-sowing seed treatment with Rhizobophyte and microfertilizer Wuxal Extra CoMo and foliar nutrition with microfertilizers Wuxal Microplant at the microstage BBCH 12–13 and Wuxal Calcium, Boron at the microstage BBCH 51–59. That was higher compared to the control by 2.15 and 2.14 t/ha.

An important indicator that affects the yield and quality of the garden pea is the output of garden peas from the mass of beans (Table 6).

Grains of green peas should be homogeneous, fresh, whole, with a thin and delicate shell of dark green color, delicate texture and sweet non-starchy taste. Pea grain should be no more than 8–10 mm in diameter. Green peas are divided into three grades in terms of quality: higher, I and II. An important characteristic of the quality of raw materials is the degree of pea ripeness. It is determined by a special device, namely a phynometer. For peas of the highest and first grades the hardness measured by the phynometer should be 29–56 degrees. Grain, which

Table 5 Seed yield of garden pea under natural moisture supply depending on liming and nutrition system (t/ha)

Fertilization (factor C)	Liming (factor B)	Years			Mean
		2017	2018	2019	
Skinado					
C 1 – control (background)	B 1	6.77	7.18	7.68	7.21
	B 2	7.06	7.43	7.96	7.49
	B 3	7.28	7.65	8.22	7.71
C 2	B 1	7.31	7.69	8.25	7.75
	B 2	7.59	7.90	8.53	8.00
	B 3	7.84	8.16	8.76	8.25
C 3	B 1	8.00	8.28	8.85	8.38
	B 2	8.35	8.57	9.04	8.66
	B 3	8.47	8.76	9.23	8.85
C 4	B 1	8,38	8.95	9.29	8.88
	B 2	8.66	9.29	9.84	9.17
	B 3	8.88	9.48	9.70	9.36
Somerwood					
C 1 – control (background)	B 1	8.54	9.07	9.29	8.95
	B 2	8.69	9.29	9.48	9.16
	B 3	8.88	9.48	9.61	9.32
C 2	B 1	9.01	9.60	9.89	9.51
	B 2	9.21	9.79	10.11	9.67
	B 3	9.32	9.92	10.30	9.86
C 3	B 1	9.60	9.89	10.36	9.95
	B 2	9.73	10.11	10.52	10.11
	B 3	9.95	10.23	10.74	10.31
C 4	B 1	10.27	10.49	11.06	10.58
	B 2	10.55	10.77	11.24	10.86
	B 3	10.80	11.06	11.47	11.09

LSD_{05}: 2017 A – 0.1; B – 0.11; C – 0.13; AB – 0.23; AC –0.16; BC – 0.19; ABC –0.33; 2018 A – 0.1; B – 0.1; C – 0.1; AB – 0.17; AC – 0.12; BC – 0.14; ABC – 0.25; 2019 A – 0.1; B – 0.1; C – 0.1; AB – 0.12; AC – 0.1; BC – 0.1; ABC – 0.17

has hardness of over 72 degrees, contains less sugar, more starch and dry matter, it is larger and coarser, so it is suitable only for the production of canned peas of soup variety (Snoad, 1974; Varchenko et al., 2020; Mazur et al., 2021).

High nutritional and taste qualities have made it very popular. As a rich source of protein, carbohydrates and vitamins, it is eaten fresh, canned, frozen and dried. It should be noted that the highest seed output of pea beans was obtained in the trial variant, where against the background of control there was applied pre-sowing seed treatment with microfertilizer Wuxal Extra CoMo, foliar nutrition with microfertilizers Wuxal Microplant at the microstage BBCH 12–13 and Wuxal Calcium, Boron at the microstage BBCH 51–59 and it was 46.4% in Skinado variety and 50.3% in Somerwood variety. In Skinado variety, it varied from 42.0 to 46.4%.

Higher seed yield was in Somerwood variety and varied from 47.3 to 50.3% in the previously mentioned trial variant, which provided the highest seed yield of garden pea when applying 1.0 norm of lime per ha, which exceeded the control by 4.0 and 3.0%, respectively.

A mean diameter of the garden pea seeds is one of the indicators determining its quality. For smooth-grained varieties, grains of 5–7 mm in size are considered to be of high quality (Snoad, 1974; Vdovenko et al., 2018).

According to our research results, a mean diameter of the garden pea seeds depended on the year of vegetation, i.e. hydrothermal regime, varietal characteristics and

Table 6 Seed output of garden pea depending on liming and nutrition system (%)

Fertilization (factor C)	Liming (factor B)	Years			Mean
		2017	2018	2019	
Skinado					
C 1 – control (background)	B 1	40.5	42.1	43.2	42.0 ±0.7
	B 2	40.8	42.5	43.8	42.4 ±0.8
	B 3	41.0	42.9	44.0	42.6 ±0.8
C 2	B 1	42.1	43.2	44.2	43.2 ±0.6
	B 2	42.5	44.1	44.4	43.7 ±0.6
	B 3	42.7	44.3	45.3	44.1 ±0.7
C 3	B 1	43.2	44.6	44.5	44.1 ±0.5
	B 2	43.9	45.0	45.3	44.7 ±0.4
	B 3	44.8	45.2	45.4	45.1 ±0.2
C 4	B 1	44.8	45.0	45.8	45.2 ±0.3*
	B 2	45.0	46.0	46.6	45.9 ±0.5*
	B 3	45.6	46.4	47.1	46.4 ±0.4*
Somerwood					
C 1 – control (background)	B 1	46.0	47.8	48.0	47.3 ±0.6
	B 2	45.9	48.0	48.0	47.3 ±0.7
	B 3	46.3	48.3	48.0	47.5 ±0.6
C 2	B 1	45.4	48.4	48.8	47.8 ±0.7
	B 2	46.9	48.8	49.4	48.4 ±0.9
	B 3	46.9	48.9	50.4	48.5 ±0.9
C 3	B 1	48.1	48.5	49.8	48.8 ±0.5
	B 2	48.2	49.0	50.0	49.0 ±0.5
	B 3	48.6	48.9	50.4	49.3 ±0.6*
C 4	B 1	49.1	49.2	50,9	49.7 ±0.6
	B 2	49.4	49.4	50.5	49.8 ±0.5*
	B 3	49.9	50.1	50.9	50.3 ±0.3*

* significant at *P* <0.05 compared with control group; ** significant at *P* <0.01 compared with control group; *** significant at *P* <0.001 compared with control group

soil liming, fertilizer application, seed treatment with micronutrients and foliar nutrition.

In the control trial variant, in the conditions of 2019, the seeds of Skinado variety were of high quality.

Liming (0.5 norm of lime per ha) had a positive effect on the seed diameter having increased this figure up to 5 mm in conditions 2018 and 5.1 mm in the conditions of 2019 (Table 7).

Other trial variants provided an increase in the seed diameter to high quality requirements. According to the requirements for high-quality seeds, against the background of the control variant and seed treatment with micronutrients Wuxal Extra CoMo, foliar nutrition with microfertilizers Wuxal Microplant and Wuxal Calcium, Boron, the trial variants provided an increase in a mean diameter of garden pea to the indicators of high-quality seeds, the diameter of which varied from 5.0 to 5.4 mm in Skinado variety. Seed diameter was higher in Somerwood variety. Its seeds met the requirements of the highest grade in all trial variants, starting with the control, in which seed diameter varied from 5.3 to 5.4 mm depending on soil liming (0.5 and 1.0 norm of lime per ha). Seed treatment with micronutrients Wuxal Extra CoMo against the background of the control variant of research resulted in an increase in seed diameter to 5.4–5.5 mm. Plant nutrition with microfertilizer Wuxal Microplant against the background of the control

Table 7 Mean diameter of the garden pea seeds depending on liming and nutritious system (mm)

Fertilization (factor C)	Liming (factor B)	Years			Mean
		2017	2018	2019	
Skinado					
C 1 – control (background)	B 1	4.8	4.9	5.0	4.9 ±0.1
	B 2	4.9	5.0	5.1	5.0 ±0.1
	B 3	5.0	5.0	5.1	5.0 ±0.1
C 2	B 1	4.9	5.0	5.1	5.0 ±0.1***
	B 2	5.0	5.1	5.1	5.1 ±0.05***
	B 3	5.1	5.2	5.2	5.2 ±0.05***
C 3	B 1	5.0	5.1	5.1	5.1 ±0.05***
	B 2	5.1	5.2	5.2	5.2 ±0.05***
	B 3	5.2	5.3	5.3	5.3 ±0.05***
C 4	B 1	5.1	5.2	5.2	5.2 ±0.05***
	B 2	5.2	5.3	5.3	5.3 ±0.05***
	B 3	5.3	5.4	5.4	5.4 ±0.05***
Somerwood					
C 1 – control (background)	B 1	5.2	5.3	5.4	5.3 ±0.6
	B 2	5.3	5.3	5.5	5.4 ±0.5
	B 3	5.4	5.4	5.5	5.4 ±0.5
C 2	B 1	5.2	5.4	5.5	5.4 ±0.1*
	B 2	5.4	5.4	5.6	5.5 ±0.1***
	B 3	5.4	5.4	5.6	5.5 ±0.1***
C 3	B 1	5.3	5.5	5.6	5.5 ±0.1***
	B 2	5.4	5.6	5.7	5.6 ±0.1***
	B 3	5.5	5.6	5.7	5.6 ±0.1***
C 4	B 1	5.4	5.7	5.8	5.6 ±0.12***
	B 2	5.4	5.7	5.8	5.7 ±0.12***
	B 3	5.5	5.7	5.9	5.7 ±0.12***

* significant at $P < 0.05$ compared with control group; ** significant at $P < 0.01$ compared with control group; *** significant at $P < 0.001$ compared with control group

variant and seed treatment with micronutrients Wuxal Extra CoMo increased seed diameter to 5.5–5.6 mm in Somerwood variety.

The highest indicator of seed diameter was observed in the trial variant, where against the background of the control variant there was applied soil liming (1.0 norm of lime per ha), seed treatment with micronutrients Wuxal Extra CoMo, fertilization with micronutrients Wuxal Microplant and Wuxal Calcium, Boron, while seed diameter varied from 5.6 to 5.7 mm.

Thus, soil liming against the background of mineral fertilizer $N_{30}P_{60}K_{60}$ and seed treatment with inoculants and micronutirents Wuxal Extra CoMo, foliar nutrition with Wuxal Microplant and Wuxal Calcium, Boron increased seed diameter of garden pea, but these parameters were within the requirements for high-quality seeds.

Technological evaluation of garden pea varieties was carried out by the size (no more than 10 mm), color, taste, content of dry matter, sugar, starch, vitamin C, protein, etc. Seed quality indicators depended primarily on the varietal characteristics and technological methods of crop growing. Seed of Somerwood variety had higher seed quality, and depending on the trial variant, its protein content varied from 5.2 to 6.2%, sugar content from 5.5 to 6.8%, vitamin C content from 39.2 to 41.5 mg/100 g, and starch content from 4.5 to 6.0% (Table 8).

Lower seed quality was observed in Skinado variety. Depending on the trial variant, its protein content varied from 5.0 to 5.9%, sugar content from 5.1 to 5.8%, vitamin

Table 8 Indicators of the garden pea seed quality depending on liming and nutrition system (%) (average of 2017–2019)

Fertilization (factor C)	Liming (factor B)	Protein content (%)	Sugar content (%)	Vitamin C content (mg/100 g)	Starch content (%)
Skinado					
C 1 – control (background)	B 1	5.0 ±0.11	5.1 ±0.11	36.1 ±0.61	4.2 ±0.11
	B 2	5.0 ±0,12	5.1 ±0.11	36.1 ±0.61	4.2 ±0.11
	B 3	5.1 ±0.11	5.2 ±0.11	36.3 ±0.61	4.3 ±0.11
C 2	B 1	5.2 ±0.12	5.3 ±0.11	36.5 ±0.89	4.4 ±0.12
	B 2	5.2 ±0.11	5.3 ±0.11	36.7 ±0.81	4.5 ±0.12
	B 3	5.4 ±0.11	5.4 ±0.11	36.9 ±0.78	4.6 ±0.12
C 3	B 1	5.5 ±0.12*	5.5 ±0.11	37.8 ±0.64	4.7 ±0.12*
	B 2	5.5 ±0.12*	5.5 ±0.11	38.2 ±0.46	4.8 ±0.12*
	B 3	5.6 ±0.12*	5.6 ±0.12	38.5 ±0.46	4.8 ±0.12*
C 4	B 1	5.7 ±0.12*	5.7 ±0.12*	39.0 ±0.32*	5.0 ±0.12**
	B 2	5.8 ±0.12***	5.7 ±0.12*	39.0 ±0.29*	5.2 ±0.12**
	B 3	5.9 ±0.12***	5.8 ±0.12*	39.2 ±0.32*	5.4 ±0.12**
Somerwood					
C 1 – control (background)	B 1	5.2 ±0.11	5.5 ±0.11	39.2 ±0.29	4.5 ±0.1
	B 2	5.2 ±0.11	5.5 ±0.11	39.3 ±0.29	4.5 ±0.1
	B 3	5.3 ±0.11	5.6 ±0.11	39.5 ±0.29	4.6 ±0.1
C 2	B 1	5.4 ±0.11	5.9 ±0.11	40.3 ±0.26	4.8 ±0.1*
	B 2	5.4 ±0.11	5.9 ±0.11	40.3 ±0.32	4.8 ±0.1*
	B 3	5.6 ±0.11	6.3 ±0.11*	40.5 ±0.26	5.0 ±0.12*
C 3	B 1	5.7 ±0.12*	6.5 ±0.11**	40.9 ±0.26*	5.3 ±0.12**
	B 2	5.7 ±0.12*	6.5 ±0.12**	41.1 ±0.26**	5.3 ±0.12**
	B 3	5.8 ±0.12*	6.6 ±0.12**	41.1 ±0.26*	5.5 ±0.12**
C 4	B 1	6.0 ±0.12**	6.7 ±0.12**	41.3 ±0.26**	5.8 ±0.17**
	B 2	6.0 ±0.12**	6.7 ±0.12**	41.3 ±0.26**	5.8 ±0.17**
	B 3	6.2 ±0.12**	6.8 ±0.12**	41.5 ±0.26**	6.0 ±0.17**

* significant at $P<0.05$ compared with control group; ** significant at $P<0.01$ compared with control group; *** significant at $P<0.001$ compared with control group

C content from 36.1 to 39.2 mg/100 g, and starch content from 4.2 to 5.4%.

The highest seed quality indicators were observed in the trial variant, where against the background of the control variant there was applied seed treated with microfertilizer Wuxal Extra CoMo and soil liming (1.0 norm of lime per ha), foliar nutrition with microfertilizers Wuxal Microplant at the microstage BBCH 12–13 and microfertilizer Wuxal Calcium, Boron at the microstage 51–59. This provided a significant increase in seed quality in Skinado and Somerwood varieties. In particular, protein content was 5.9 and 6.2%, sugar content was 5.8 and 6.8%, vitamin C content was 39.2 and 41.5 mg/100 g and starch content was 5.4 and 6.0%, which was higher compared to the control variant by 0.8 and 0.9%; 0.6 and 1.2%; 2.9 and 2.0%; 1.1 and 1.4%, respectively. Thus, along with the quantitative increase in yield in completely dry matter, the quality indicators also improved.

This proves the possibility of combining high quantitative and qualitative indicators in one genotype when applying research practices (liming of the soil, fertilization with macro- and micronutrients, seed treatment with inoculant, foliar nutrition) (Tkachuk & Telekalo, 2020; Biliavska et al., 2021).

4 Conclusions

To achieve maximum field germination rates of seed varieties, it is necessary to apply mineral fertilizers at the dose of $N_{30}P_{60}K_{60}$, pre-sowing seed treatment with

Rhizobophyte and microfertilizer Wuxal Extra CoMo with application of lime (1.0 norm of lime per ha). To ensure the highest survival of plants, it is necessary to apply foliar nutrition with microfertilizers Wuxal Microplant and Wuxal Calcium, Boron, on the basis of the previously mentioned technological methods.

SNF increased from 58.9 to 148.2 kg/ha in Skinado variety and from 72 to 172 kg/ha in Somerwood variety when applying seed treatment with Wuxal Extra CoMo, soil liming (1.0 norm of lime per ha) and foliar nutrition with microfertilizers Wuxal Microplant at the microstage BBC 12–13 and Wuxal Calcium, Boron at the microstage BBC 51–59 against the background of mineral fertilizers at the dose of $N_{30}P_{60}K_{60}$ and pre-sowing seed treatment with Rhizobofit. In the same variant, the highest level of yield was obtained in Skinado pea variety – 9.36 t/ha and Somerwood variety – 11.09 t/ha. Possibility of combining high quantitative and qualitative indicators in one genotype for the studied activities (soil liming, pre-sowing seed treatment with Rhizobophyte, fertilization with macro- and microelements, foliar nutrition) is confirmed by the obtained data: protein content was 5.9 and 6.2%, sugar content was 5.8 and 6.8%, vitamin C content was 39.2 and 41.5 mg/100 g and starch content was 5.4 and 6.0% in Skinado and Somerwood varieties. This was higher compared to the control variant by 0.8 and 0.9%; 0.6 and 1.2%; 2.9 and 2.0%; 1.1 and 1.4%, respectively.

References

Almashova, V.S. et al. (2006). Influence of micronutrients and Rhizotorphyne on productivity of garden peas in the conditions of Kherson region. *Taurian Scientific Bulletin*, 49, 18–21.

Andriushko, A. et al. (2004). Specifics of demand and consumption of vegetable products in Ukraine. *Agro-Review*, 6, 47–51.

Animal feed. (2005). Determination of crude ash content: DSTU ISO 5984–2004. Developed for the first time; introduced on January 1, 2006. Kyiv, Derzhspozhyvstandart Ukrainy.

Biliavska, L. et al. (2021). Adaptability and breeding value of soybean varieties of Poltava breeding. *Bulgarian Journal of Agricultural Science*, 27 (2), 312–322.

Chynchyk, O.S. (2013). Influence of fertilization system and methods of basic tillage on the formation of pea plant structure. *Feed and feed production: interdepartmental thematic collection of scientific papers*, 77, 123–127.

Didur, I., & Mostovenko, V. (2020). Photosynthetic activity of vegetable peas depending on varietal characteristics, soil liming and food system. *Agriculture and forestry*, 4 (19), 42–50. https://doi.org/10.37128/2707-5826-2020-4-4

Didur, I., & Mostovenko, V. (2021). Dynamics of the number and weight of nitrogen bacteria bubbles of peas growing. *Agriculture and Forestry*, 20 (1), 49–59. https://doi.org/10.37128/2707-5826-2021-1-4

Didur, I., & Shevchuk, V. (2020). Increase in soil fertility as a result of accumulation of biological nitrogen by legumes. *Agriculture and Forestry*, 16 (1), 48–60. https://doi.org/10.37128/2707-5826-2020-1

Hrushetskyi, S. et al. (2021). The heap parts movement on the shareboard surface of the potato harvesting machine. *Bulletin of the Transilvania University of Braşov. Series II: Forestry, Wood Industry, Agricultural Food Engineering*, 14 (1), 127–140. https://doi.org/10.31926/but.fwiafe.2021.14.63.1.12

Karkanis, A. et al. (2016). Field pea in European cropping systems: Adaptability, biological nitrogen fixation and cultivation practices. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, 44 (2), 325–336. https://doi.org/10.15835/nbha44210618

Kovbasa, V. et al. (2021). Functions derivation of stresses in the soil and resistance forces to the motion of a plough share for cavity creation. *UPB Scientific Bulletin, Series D: Mechanical Engineering*, 83 (3), 305–318.

Li, M. M. et al. (2020). Identification of traits contributing to high and stable yields in different soybean varieties across three Chinese latitudes. *Frontiers in plant science*, 10, 1642.

https://doi.org/10.3389/fpls.2019.01642

Lisoval, A.P. et al. (2002). *Fertilizer application system: a textbook*. Kyiv: Vyshcha shkola.

Mazur, V. et al. (2021). Ecological suitability peas (*Pisum sativum*) varieties to climate change in Ukraine. *Agraarteadus*, 32 (2), 276–283. https://doi.org/10.15159/jas.21.26

Moiseychenko, V. et al. (1996). *Fundamentals of scientific research in agronomy.* Moscow: Kolos.

Mostovenko, V., & Didur, I. (2021). Economic and energy efficiency of growing vegetable peas. *Colloquium-journal*, 99 (12), 47–52. https://doi.org/10.24412/2520-6990-2021-1299-47-52

Mostovenko, V. (2020). Formation of the crop structure of garden pea varieties depending on varietal characteristics, soil liming and nutrition system. *Agriculture and Forestry*, 18 (3), 223–232. https://doi.org/10.37128/2707-5826-2020-3

Norik, N.O., & Mulyarchuk, O.I. (2018). Treatment with vegetable pea seed growth regulators (*Pisum sativum* l., Subspecium commune gov) in the Western Forest-Steppe of Ukraine. *Podolsk Bulletin: agriculture, technology, economics*, 28, 86–93.

Nychyporovych, A.A. et al. (1961). *Photosynthetic activity of plants in sowings.* Moscow: USSR Academy of Sciences.

Okhrimenko, S. (1998). Influence of clones of nodule bacteria resistant to mineral nitrogen on physiological processes and productivity of pea plants. *Physiology and Biochemistry of Cultivated Plants*, 2, 138–143.

Paziuk, V. et al. (2021). Substantiation of the energy efficient schedules of drying grain seeds. *Bulletin of the Transilvania University of Braşov, Series II: Forestry, Wood Industry, Agricultural Food Engineering,* 14 (2), 137–146. https://doi.org/10.31926/but.fwiafe.2021.14.63.2.13

Poberezhets, Yu et al. (2021). Effect of probiotic supplement on nutrient digestibility and production traits on broiler chicken. *Agraarteadus*, 32 (2), 296–302. https://doi.org/10.15159/jas.21.28

Posypanov, G. (1991). *Methods for studying the biological fixation of air nitrogen*. Moscow: Agropromizdat.

Pryanishnikov, D. (1963). *Agrochemistry*. Moscow: Selkhozizdat.

Pylypenko, V.S. et al. (2016). Formation of pea productivity depending on the elements of cultivation technology. Interdepartmental thematic scientific collection of papers *Agriculture*, 91 (2), 51–55.

Snoad, B. (1974). A preliminary assessment of 'leafless peas. *Euphytica*, 23, 257–265.

Tkachuk, O., & Telekalo, N. (2020). Agroecological potential of legumes in conditions of intensive agriculture of Ukraine. *Integration of traditional and innovation processes of development of modern science: collective monograph*. Latvia, Riga: Baltija Publishing (pp. 91–108).
https://doi.org/10.30525/978-9934-26-021-6-33

Tkachyk, S. (2016). *Methodology of examination of varieties of plants of the group of vegetables, potatoes and mushrooms on difference, uniformity and stability*. Vinnytsia: FLP Korzun D.J.

Varchenko, O. et al. (2020). Supply chain strategy in modernization of state support instruments for small farms in Ukraine. *International Journal of Supply Chain Management*, 9 (1), 536–543.

Vdovenko, S. et al. (2018). Symbiotic potential of snap beans (*Phaseolus vulgaris* L.) depending on biological products in agrocoenosis of the right-bank forest-steppe of Ukraine. *Ukrainian Journal of Ecology*, 8 (3), 270–274.