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ASSESSMENT CRITERIA OF EFFICIENCY OF THE VARIETY DURING BREEDING OF THE GREEN BEAN

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Abstract

The article presents the results of a comprehensive assessment of the suitability of varieties of green bean for growing them for vegetable purposes in the conditions of the Forest-Steppe of Ukraine. Thirteen main indicators (yield, maturity, marketability, technological evaluation, resistance against pathogens, height of attachment of the bottom bean, the content of dry matter and sugars, the presence of parchment and fibers, length, thickness, shape of the beans, weight 1000 seeds) were conducted. The weight and the share of the impact of each indicator on the efficiency of cultivation of each variety were taken into account. The given scale allowed to give an objective assessment of varieties of green bean. As a result of the researches the varieties with the highest points of the total index of efficiency of a variety Dynamit (23.7 points), Goldjawel (25 points), Tenderette (25.1 points), Sina (22.3 points), were obtained and can be recommended as initial material. The reaction of highlighted varieties to inoculation with effective *Rhizobium phaseoli* 657 and 700a strains was investigated.

Key words: Green beans, assessment criteria, scale of variety efficiency, selection, yield, valuable economic trait, inoculation, effective strains.

Introduction

The standard of living of any country's population has recently been determined by the amount of protein consumed by humans. According to the Institute of Nutrition, the rate of human consumption of legumes per year should be 13 kg. In Ukraine, over the past ten years, the quality of nutrition of the population has deteriorated sharply. The reason for this is the sharp decline in the production of high protein animal foods and their high cost (I.V. Kamins'kyy). According to experts, livestock production has almost reached its biological limit and there is no reason to expect a significant increase in productivity and gross production of livestock products (Bernardi, D.L.S., Pilosof, A.L.R., Bartolomai, G.B.).

Protein deficiency is reduced worldwide by the use of vegetable proteins (Kozidub, N.G.). Among leguminous crops, vegetable beans are one of the most important. Young beans with unripe seeds, "scapula", are characterized by high taste, rich in protein, vitamins A, B, C, sugars, salts of iron and calcium and have high nutritional value. The introduction into the diet, in addition to the main vegetables, vegetable beans will not only diversify it, but also meet people's need for protein and vitamins during the winter, when used in canned or frozen form (Harvesting of crops, fruits, berries and grapes in the regions of Ukraine for 2014. Stat. bul.).

Ukraine belongs to traditional vegetable bean production areas. Rich chernozem soils, sufficient moisture, heat, light, long enough frost-free periods make it possible to get high crop productivity of this crop. In Ukraine, vegetable beans are grown on rather small areas and it is one of those crops whose cultivation is focused on small plots and small farms, but here it is not received in the quantities for which it deserves.

In 2019, the establishments of all types of ownership grew beans on 28.8 thousand hectares of, including 4.8 thousand hectares in agricultural enterprises. Yields are also low: 0.77 and 1.03 t/ha (grain), respectively. Among

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the objective factors that largely inhibit the spread of culture are, first of all, the high costs of manual labor in harvesting; low level of mechanization during cultivation and lack of machinery for mechanized harvesting; lack of varieties adapted to specific soil and climatic conditions; significant morbid affection of disease; lack or low level of seed business; insufficient promotion of the valuable qualities of culture. Available varieties do not meet the requirements of modern agricultural production. The State Register of Plant Varieties Suitable for Distribution in Ukraine for 2020 includes 33 varieties of vegetable beans, from which 10 Ukrainian and 23 foreign. There is an unstable yield and incomplete realization of genetic potential, which often does not exceed 25-30% (State register of plant varieties suitable for distribution in Ukraine).

Therefore, the main task of the selection of vegetable beans is to create high-yielding varieties with stable yields, disease-resistant and pests, tolerant of limiting environmental factors, suitable for mechanized cultivation and harvesting with improved taste. An important requirement for new varieties is environmental plasticity, the ability to provide high yields in different conditions, geographical locations and at different sowing times (Gvozdenovich, D., Vasich, M., Gvozdenovich-Varga, Ye., Bugarski, D., Takach, A., Yovichevich, D., Chervensk, Y.;. Yepikhov, V.A, Samarin, N.A., Drozd, A.M.). However, when choosing varieties suitable for cultivation in specific soil and climatic conditions, it is quite difficult to navigate in their wide variety. Therefore, there is a need to combine common criteria for evaluating the effectiveness of a variety, taking into account the technology of cultivation and harvesting it in local conditions.

Often, grade evaluation is performed only on yields and maturity and does not take into account other rather important indicators. Often, the producers, when choosing a variety, take into account only its yield, but such a variety may ultimately not satisfy the manufacturer not only by the quality characteristics of the products obtained, unsuitability for mechanized cultivation, but also by the lack of resistance against pathogens characteristic of the growing zone which can lead to a decrease in the yield expected by the manufacturer.

Following the elaborated methodology proposed by M. Gurkina, a comprehensive assessment of the suitability of varieties of vegetable beans for growing them for vegetable purposes in the conditions of the Forest-Steppe of Ukraine (Gurkina, M.V.).

Green beans more common than other leguminous crops are characterized a rather small nodulation by spontaneous inoculation of local races of nodule-forming bacteria. The nitrogen-fixing potential of bean symbiosis with rhizobia which present in the soil is often limited by the low nitrogen-fixing activity of bacteria (Shkatula, YU.M, Krayevs′ka, L.S.).

In addition, rhizobia density may not be sufficient in the soil or bacteria may be absent. Separate data indicate that on certain varieties of beans, tubercles may not be formed at all, even in the case of inoculation (varieties Geliada, Samaryanka, Strila and line 05-82) (Gur'yev, G.P., Vasil'chikov, A.G.).

In this regard, a mandatory step in bean cultivation technology should be to pre-sow seed treatment with biological products based on selected highly efficient strains of specific rhizobia, which enhances the productivity of bean plants.

For pre-sowing inoculation of cereal and vegetable bean seeds, rhizobophyte and rhizogumine (peat form) biological products have been proposed based on the new highly efficient *R. phaseoli* FB1 strain. This strain is an active symbiotic nitrogen fixer, able to withstand competition with local bean Rhizobium populations and increase plant resistance to root rot pathogens. The use of rhizobophyte and rhizogumine preparations based on *R. phaseoli* FB1 strain in different soil and climatic conditions contributed to a stable increase in the yield of common beans compared to the control by 11-32% and to an improvement in the quality of the products (Krutylo, D.V., Nadkernychna, O.V., Ivanyuk, S.V., Kuts, O.V.).

The efficiency of bean inoculation for the improvement of symbiotic indices and grain yield in organic production systems has been experimentally proven (Minnesota, local *Rhizobium leguminosarum bv. phaseoli* (OrgK9) and commercial *R. tropici* (CIAT899) strains and varieties of beans Eclipse, Redhawk) (Abou-Shanab, R.A.I., Wongphatcharachai, M., Sheaffer, C. C., Sadowsky, M.J.).

Purpose and tasks

To determine the criteria for evaluating the efficiency of cultivation varieties in the conduct of the breeding process with green beans; establish objectivity of evaluation and investigate the response of the best varieties to inoculation with effective strains.

Materials and Methods

The research was conducted in the fields of the Agricultural Research Station of NULES of Ukraine in 2006-2014.

• Materials: 117 samples of green beans with different ecological and geographical origin were using, variety

Saks without fiber 615 is accepted as standard.

• Methods: In the experiments, the samples were sown in triplicate with a plot area of 1.35 m^2. Observations and recording on experimental field were performed in accordance with the method of field experiment B. Dospekhov (Dospekhov, B.A.). Analysis of the crop structure was performed in the laboratory on 25 plants in each repetition. The resistance of the samples to the harmful organisms was determined on a natural infectious background. Evaluating varieties according to the main economic and valuable features, were guided by the "Methodological guidelines for the study of the collection leguminous crops" (Guidelines for the study of the collection of leguminous crops) and "Broad unified classifier of Ukraine of the genus Phaseolus" (Broad unified classifier of the *genus Phaseolus* L.), the results of the studies are reported in scientific publications, (Grishchenko, Ye.N., Zhemoyda, V.L., Hryshchenko, O.M., Tynkevych, T.O., Hryshchenko, O.M., Zhemoyda, V.L.] and others.

A comprehensive assessment of the suitability of vegetable bean varieties for growing them in the conditions of the Forest-Steppe of Ukraine was carried out according to 13 main indicators. The weight and the share of the impact of each indicator on the efficiency of cultivation variety were taken into account.

The bean varieties, which as a result of the calculations received the highest value of the total indicator, are accordingly the best for growing for vegetable purposes in the conditions of the Forest-Steppe of Ukraine.

The total performance index of the variety (PI) was calculated by the formula:

$$PI=Y\times C_m\times C_{mb}\times C_{ts}\times C_{dr}+ I_{ha}+I_{dm}+I_{sc}+I_{pp}+I_l+I_{cs}+I_t+I_w$$

Y- yield, t / ha

C_m- maturity, days to technical maturity

C_{mb}- marketability of beans, %

C_{ts}- technological assessment for suitability for processing, score

C_{dr}- disease resistance, degree of damage

I_{ha}- height of lower bean attachment, cm

I_{dm}- dry matter content of unripe beans, % per 100 g green weight

I_{sc}- sugar content in young beans, % per 100 g green weight

I_{pp}- the presence of parchment and fiber in young beans

I_l- bean length, cm

I_{cs}- cross-sectional shape of the bean

I_t- bean thickness, mm

I_w- weight of 1000 seeds, g

In determining the total indicator of the variety efficiency used a scale (Table 1), which shows the normative indicators and the values of the coefficients.

Table 1: Main indicators for evaluating the effectiveness of vegetable beans varieties

Indicator	Norm	Ratio and metric	
		Value	Marking
Yield, t / ha	absolute value		Y
Maturity, days to technical maturity	less 50 50-55 more 55	1,00 950 90	C_m
Marketability of beans, %	more 90 80-90 less 80	1,0 0,9 0,8	C_{mb}
Technological assessment for suitability for processing, score	1 2 3 4 5	0,6 0,7 0,8 0,9 1,0	C_{ts}
Disease resistance, degree of damage	missing weak medium intense	1,0 0,9 0,8 0,7	C_{dr}
Height of lower bean attachment, cm	less 10 10-12 more 12	0 1 2	I_{ha}
Dry matter content of unripe beans, % per 100 g green weight	less 10 10-12 more 12	2 1 0	I_{dm}
Sugar content in young beans, % per 100 g green weight	less 1,5 1,6-2,0 2,0-2,5	1 2 3	I_{sc}
The presence of parchment and fiber in young beans	missing weak medium intense	3 2 1 0	I_{pp}
Bean length, cm	less 10 10-12 more 12	0 1 2	I_l
Cross-sectional shape of the bean	rounded flat-rounded flat	2 1 0	I_{cs}
Bean thickness, mm	less 8 8-10 more 10	0 1 2	I_t
Weight of 1000 seeds, g	less 200 200-300 more 300	1 2 0	I_w

Table 2: Evaluation of bean varieties on a scale of variety efficiency.

Quality indicators	Leg-end	Variety of beans									
		Saks without fiber 615		Ermitage		Purple Queen		Misceva ovocheva 50		Dynamit	
		AV[1]	C & I[2]	AV	C & I	AV	C & I	AV	C & I	AV	C & I
Yield, t / ha	Y	7,0	7,0	**12,9**	12,9	**12,9**	12,9	**13,0**	13,0	**13,2**	13,2
Maturity, days to technical maturity	C_m	52	0,95	50	0,95	58	0,9	73	0,9	59	0,90
Marketability of beans,%	C_{mb}	80,2	0,9	83,5	0,9	71,9	0,8	68,9	0,8	92,2	1
Technological assessment for suitability for processing, score	C_{ts}	2	0,7	2	0,7	1	0,6	1	0,6	5	1
Disease resistance, degree of damage	C_{dr}	weak	0,9	weak	0,9	weak	0,9	weak	0,9	weak	0,9
Height of lower bean attachment, cm	I_{ha}	13,4	2	14,6	2	17,0	2	15,0	2	12,2	2
Dry matter content of unripe beans,% per 100 g green weight	I_{dm}	11,14	1	10,6	1	16,7	0	10,4	1	12,8	0
Sugar content in young beans,% per 100 g green weight	I_{sc}	2,07	3	1,76	2	1,53	1	1,62	2	1,67	2
The presence of parchment and fiber in young beans	I_{pp}	missing	3	medium	1	weak	2	weak	2	missing	3
Bean length, cm	I_l	12,8	2	15,4	2	15,9	2	18,1	2	14,8	2
Cross-sectional shape of the bean	I_{cs}	rounded	2	rounded	2	rounded	2	rounded	2	rounded	2
Bean thickness, mm	I_t	7,67	0	8,17	2	8,10	2	11,2	1	8,63	2
Weight of 1000 seeds, g	I_w	305	0	319	0	326	0	341	0	374	0
Total score	PI		**16,8**		**19,0**		**16,0**		**17,1**		**23,7**

[1]Absolute value; [2] C & I - coefficients and indicators

Indicator values were determined according to current methodologies and classifiers.

After a thorough analysis, ranking of the starting material, selection of the best samples, evaluation and determination of the criteria for the value of the variety, the efficiency of inoculation of seeds with effective strains of nitrogen-fixing bacteria to yield was studied.

To establish the response of the best vegetable bean varieties to inoculation with effective strains of *Rhizobium phaseoli* 657 and 700a, the bean plants were grown in 4-kg containers under natural light and temperature.

The vessels were pre-sterilized with a 20% H_2O_2 solution. A1: 1 mixture of soil and river sand served as a substrate for growing plants. The source of mineral nutrition was a nutrient mixture of Hergrigel enriched with trace elements: molybdenum, boron and copper and depleted in nitrogen - 0.20 by norm (1 norm corresponds to 708 mg Ca $(NO_3)_2 \cdot 4H_2O$ per 1 kg of sand).

For increase the preparation of inoculation suspensions of biomass bacteria were washed from the surface of the agar nutrient medium with sterile tap water. Aqueous suspensions of nodule-forming bacteria were aligned one with other in according to standard of turbidity. For inoculation 2 strains of Rhizobium phaseoli 657 and 700a were used. The duration of bacterization of the seeds with a suspension of bacteria was 60 minutes. The infectious load was 10^9 cells/ml. To determine the nitrogen-fixing activity of the plants were selected on the 25^{th} and 40^{th} day after emergence of sprouting.

Nitrogen-fixing activity (AFA) was determined by the acetylene method by the level of acetylene-reducing activity of root tubercles and expressed in nanomoles of ethylene formed by the tubercles of one plant for 1 hour.

The gas mixture containing ethylene formed by the reduction of acetylene by nitrogenase was analyzed on a gas chromatograph Agilent Technologies 6850 Network GC System, USA. The volume of the The volume of the sample of gas mixture wich analyzed was 1 ml.

Results and discussion

Using the scale of efficiency of Green bean varieties the total efficiency index of 117 varieties was found. However, according to the results of the calculations, it can be concluded that varieties with the same yield received different values of the total index of the variety efficiency (Table 2).

Thus, the Ermitage and Purple Queen varieties at the same yield of 12.9 t/ha have a difference of 3 points at total efficiency index, with increasing direction to variety Ermitage which had better other quality indicators. Unlike the Purple Queen variety, the Ermitage variety has a shorter growing season, which promotes the synchronized maturity of the beans, the use of mechanized harvesting and allows the critical stages of growth and development to pass quickly. Beans of this variety in the technical maturity phase contain the optimal amount of dry matter and are characterized by high sugar content and, as a consequence, have higher marketability and technological evaluation.

However, among the tested varieties with low yields, those that scored enough large number of points on the scale of variety efficiency were identified.

According to the data, the Saxon variety without fiber 615, which had a yield of 7.0 t/ha, received more points (16.8), almost the same as the Purple Queen variety (16 points) in yield 12.9 t/ha. This was made possible by the fact that most of the indicators on which the efficiency of cultivation was calculated were optimal or better than to the variety being compared. So unlike the Purple Queen variety, Saks without fiber 615 is characterized by a shorter growing season. Grade beans in the phase of technical maturity are characterized by high marketability and workability, do not contain in the shutters of the parchment layer and fibers in the seams, which significantly improves the quality of marketable products. The variety is characterized by a low content of dry matter with a high content of sugars in the shell of bean.

Studies have shown that the yield of green beans may not be a major indicator in the evaluation and selection of a variety for cultivation and breeding purposes without taking into account other important characteristics. The highest score of the total indicator in the evaluation on this scale received sorts: Dynamit (23.7 points), Goldjawel (25 points), Tenderette (25.1 points), Sina (22.3 points) (Table 3). The same varieties were identified as sources of utility character as a result of the study by conventional methods, thereby confirming the effectiveness of this method of assessment. One purpose of objectives was to investigate the response of the best green bean varieties

Table 3: Evaluation results of vegetable bean varietal samples obtained according to the variety efficiency scale.

Quality indicators	Legend	Variety of beans							
		Dynamit		Goldjawel		Tenderette		Sina	
		AV[1]	C & I[2]	AV	C & I	AV	C & I	AV	C & I
Yield, t / ha	Y	13,2	13,2	9,9	9,9	8,7	8,7	10,2	10,2
Maturity, days to technical maturity	C_m	59	0,9	49	1	58	0,9	53	0,95
Marketability of beans, %	C_{mb}	92,2	1	90,3	1	92,9	1	83,8	0,9
Technological assessment for suitability for processing, score	C_{ts}	5	1	4	0,9	5	1	5	1
Disease resistance, degree of damage	C_{dr}	weak	0,9	weak	0,9	weak	0,9	weak	0,9
Height of lower bean attachment, cm	I_{ha}	12,2	2	12,6	2	14,3	2	17,4	2,0
Dry matter content of unripe beans, % per 100 g green weight	I_{dm}	12,8	0	9,76	2	7,05	2	9,29	2
Sugar content in young beans, % per 100 g green weight	I_{sc}	1,67	2	1,61	2	3,14	3	1,81	2
The presence of parchment and fiber in young beans	I_{pp}	missing	3	missing	3	missing	3	missing	3
Bean length, cm	I_l	14,8	2	12,9	2	15,5	2	18,4	2
Cross-sectional shape of the bean	I_{cs}	rounded	2	rounded	2	rounded	2	rounded	2
Bean thickness, mm	I_t	8,63	2	8,17	2	9,2	2	9,47	2
Weight of 1000 seeds, g	I_w	374	0	255	2	267	2	350	0
Total score	PI		**23,7**		**25,0**		**25,1**		**22,9**

[1]Absolute value; [2] C & I - coefficients and indicators

to inoculation of seeds with two effective strains of *Rhizobium phaseoli* 657 and 700a.

The process of activating the symbiotic fixation of molecular nitrogen depends on the variety sensitivity of legumes to bacterialisation by nodule-forming bacteria and the specificity of Rhizobia strains (S.YA. Kots', V.V. Morgun, I.A. Tikhonovich, N.A. Provorov, V.F. Patyka, V.F. Petrichenko, N.N. Mel'nikova, P.N. Mamenko).

The beginning of breeding work should be the selection to the released or perspective varieties of legumes of the strain of nitrogen-fixing bacteria which is most effective and genetically complementary. Considerable attention should be paid to the association of symbiotic nitrogen fixation with the various economically valuable plant properties (dynamics of development, biochemical composition, resistance to pathogens and stress effects, etc), which determines the need to include symbiotic nitrogen fixation in general programs of plant breeding (V.P. Patyka, S.YA. Kots′, V.V. Volkohon, O.V. Sherstoboyeva, T.M. Mel'nychuk, A.V. Kalinichenko, I.V. Hrynyk).

An important factor that determines the effectiveness of symbiotic nitrogen fixation is the compatibility of strains of nodule-forming bacteria and legumes. The most productive symbiosis occurs when the plant and the population of nodule-forming bacteria have evolved together.

Investigation with the best varieties of conventional vegetable beans and two effective strains of nodule-forming bacteria have shown that most varieties form effective symbiotic systems with Rhizobium phaseoli 657 and 700a strains.

It was established that the highest nitrogen fixing activity on the 25th day after sprouting was characterized by the Dynamit and Tenderette varieties with the strain 657 of nodule-forming bacteria The nitrogen fixing activity was lower and was accordingly 53.4 and 50.9 nmolC_2H_4/(plant/h) to inoculation of these varieties seeds with the strain rhizobia 700a (Table 4).

The efficacy of symbiotic systems formed by Coldjawel and Sina varieties and strains of nodule-forming bacteria 657 and 700a on the 25th day after germination was significantly lower and ranged from 23.4 to 28.62 nmolC_2H_4/(plant/h).

Table 4: Nitrogen-fixing activity (nmolC_2H_4/(plant/h) of tubercles green beans of inoculated with effective *Rhizobium phaseoli* strains.

Variety	Strain	
	657	700a
Dynamit	124.7±12.1	53.4±3.7
Coldjawel	23.4±2.0	26.7±2.2
Tenderette	181.3±15.2	50.9±4.8
Sina	28.5±2.2	23.5±1.8

It should be noted that these varieties later began to form a symbiotic apparatus and the tubercles were small in size, so the level of atmospheric nitrogen fixation was lower during this period.

On the 40th day after emergence, the highest nitrogen-fixing activity was recorded in the Sina variety by inoculation with strain 657, while the plants of this variety had slightly less activity after inoculation with strain 700a.

The significant increase in nitrogen-fixing activity in this variety is primarily due to the onset of the budding phase. It should be noted that the other varieties of beans on the 40th day after sprouting had not buds. The nitrogen-fixing activity during this period was quite high in the of varieties Tenderette and Dynamit plants to inoculated with strain 657.

Conclusions

When selecting varieties of conventional vegetable beans suitable for cultivation, it is necessary to use the scale of variety efficiency, which uses the evaluation criteria for 13 main indicators (yield, maturity, marketability, technological evaluation, resistance against pathogens, height of attachment of the bottom bean, the content of dry matter and sugars, the presence of parchment and fibers, length, thickness, shape of the beans, weight of 1000 seeds). The impact of each indicator on the performance of the variety should be taken into account, as the scale provided allows it to give an objective assessment.

The samples with the highest scores of the total index of variety efficiency are distinguished: Dynamit (23.7 points), Goldjawel (25 points), Tenderette (25.1 points), Sina (22.3 points), which can be recommended as initial material.

Among the research symbiotic systems, the highest nitrogen fixation activity on the 25th day after emergence of sprouts was characterized by Dynamit and Tenderette varieties and on the 40th day after sprouting varieties Sina and Tenderette were inoculated with strain 657. The highest nitrogen fixation activity by inoculation with strain 700a were observed of variety Sina on the 40th day after emergence of sprouts.

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