Study of physical parameters of soybeans in comparative varietal aspect

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Abstract. The paper examines some physical properties of young green beans and soybean seeds to identify promising grain varieties bred at the Federal Scientific Center of Soybean Research Institute (Lastochka and Evgeniya) for use as vegetable crops. The linear dimensions of the beans and seeds, the thousand-seed weight, their size, and strength were studied. It was found that the grain varieties are significantly inferior to the standard vegetable variety in terms of linear dimensions of the beans: length by 7.16–16.12% for the Lastochka variety and by 6.02–11.88% for the Evgeniya variety, width by 11.19–20.87% and 15.79–23.52%, respectively. It was found that the weight of 1000 seeds with actual moisture content (54.93±0.59 – 77.69±0.59%) is lower than the values of the standard variety by 34.05–47.70% (Lastochka) and by 29.73–46.22% (Evgeniya), and in terms of dry matter by 17.51–41.59 and 20.26–46.56%, respectively. It is shown that the seed size coefficient is reliably lower than the values of the standard variety by 43.90–60.37% (Lastochka) and 42.73–53.56% (Evgeniya). It was found that, despite smaller linear parameters, grain soybean varieties are characterized by increased resistance to mechanical stress. It was found that seed strength exceeded that of the standard variety by 34.52–66.39% for the Lastochka variety and by 21.43–40.98% for the Evgeniya variety. The obtained data can serve as a basis for developing criteria for selecting grain soybean varieties promising for use as vegetable crops and can be used to create a database for developing vegetable soybean varieties with specific consumer and technological properties.

1 Introduction

Depending on the source of dietary protein, global protein resources are traditionally classified into two main categories: animal and plant proteins. A comprehensive analysis of the global food security situation indicates a persistent trend toward a structural deficit in animal protein products (they account for approximately 20% of the total protein produced globally), as well as changes in the diet, eating habits, and nutrient requirements associated

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with increasing consumer demand for affordable, environmentally friendly, and functionally significant plant-based alternatives to traditional animal proteins. Despite these trends, the body's biological need for essential amino acids remains undeniable, and proteins with a biologically complete amino acid composition can provide these [1, 2].

One of the most promising sources of plant-based, biologically complete protein is soybeans, particularly their vegetable form, known internationally as edamame (Japanese for "green beans on a stalk") and mao dou (Chinese for "hairy beans"). Unlike traditional grain soybean varieties, whose seeds are processed at full maturity, vegetable soybean seeds are processed when they are still young – immature. They are green in color, have a delicate texture, and a sweetish flavor, making them similar in organoleptic properties to green peas. At this time, they are characterized by a balanced nutrient composition: protein content is 11-13 g/100 g, fats - 5.0-6.8 g/100 g (including polyunsaturated fatty acids: ω-3 - 361 mg% and ω-6 - 1794 mg%), carbohydrates - 10-11 g/100 g and dietary fiber - about 4.2 g/100 g. The vitamin profile of soybeans is represented by ascorbic acid (27-29 mg%), niacin (1.65 mg%), thiamine (0.31-0.44 mg%), riboflavin (0.15-0.18 mg%), folic acid (165-320 mcg%). Mineral composition includes potassium (590–620 mg%), calcium (58–197 mg%), phosphorus (170–194 mg%), magnesium (62–65 mg%), iron (2.70–3.55 mg%), copper (128–410 μg%), and selenium (91.5 μg%). However, the amount of anti-nutritional components (trypsin inhibitors, oligosaccharides, etc.) is minimal. Vegetable soybeans are widely used in the national cuisines of Japan, China, and other Southeast Asian countries. Due to their high technological properties – that is, the ability to maintain structural integrity and nutritional value during short-term heat treatment – they are used as an ingredient in a variety of dishes: from cold appetizers and salads to soups, stews, main courses, and side dishes. Today, vegetable soybeans are becoming increasingly popular throughout the world, not only among gourmets who love exotic dishes and culinary innovations, but also, thanks to their nutritional and biological value, among the general population who prefer plant-based diets and natural foods [3–5].

In the Russian Federation, consumer interest in vegetable soybeans is also showing steady positive momentum. However, domestic consumers are primarily exposed to this crop as imported frozen products, as industrial cultivation and commercial production on a national scale are not organized. The primary constraints to the development of this segment are the lack of adapted domestic vegetable soybean varieties officially registered in the State Register of Breeding Achievements approved for use, as well as scientifically sound cultivation technologies applicable to the soil and climatic conditions of various regions of the country. Scientific publications contain only a few references to research conducted by Russian scientists to examine the feasibility and viability of cultivating vegetable soybeans in certain regions of Russia [6, 7].

Results of preliminary experimental studies have shown that some soybean varieties bred at the All-Russian Soybean Research Institute (hereinafter referred to as the Center) produce young, green beans suitable for consumption when harvested at the full seed-filling stage. At this stage, young grain-type soybean seeds have a tender and juicy texture and contain sugars, which determine their flavor, at the level of vegetable soybeans. Therefore, further research to isolate grain-type soybean varieties from the Center's genotype collection for potential use as vegetable products is scientifically sound and practically significant. The obtained results can be used to develop a database for the development of vegetable soybean varieties with desired consumer and technological properties, to conduct breeding work in this area, and to develop technologies for the production of functional foods from vegetable soybeans.

Unlike other food soybeans, the consumer qualities of vegetable varieties are determined not only by nutritional value and organoleptic characteristics (appearance of green beans and seeds; texture, aroma, and taste of seeds), but also by physical properties, including the size of the beans and seeds [3, 5, 8]. Therefore, the aim of the research was to examine certain physical properties of young, green beans and soybeans to identify promising grain varieties for the Center's breeding program and determine the possibility of their use as vegetable products.

2 Materials and methods

The study involved green beans and soybean seeds of three varieties from the Center's genotype collection: Lastochka and Evgeniya (for grain crops, bred by the Center), and Mikawashima (for vegetables, a Japanese selection), which was adopted as the standard. The experimental soybean varieties were grown in the village of Sadovoe, Tambovsky Municipal District, Amur Region, on meadow chernozem-like soil. Sowing was carried out at the optimal time for grain soybeans, using standard seeding rates. Cultivation techniques included autumn plowing and harrowing. The experimental plot underwent spring disking, followed by cultivation, harrowing, rolling, and herbicide application to the soil after soybean sowing. Repeated manual weeding was performed throughout the growing season. In order to determine the optimal sampling period for healthy green soybeans free from disease and pest damage, additional studies - phenological observations - were conducted [9]. The studies were conducted in a laboratory for agricultural product processing and biochemical analysis, from the onset of the R6 reproductive phase to the R7 seed maturation phase (days 1, 7, 14, 21, and 28 of the study). To ensure a representative sample, selection was randomized: an average of 50–60 plants were selected from each studied variant, excluding the outer rows of the plot in order to minimize the edge effect. All collected beans were thoroughly mixed, after which an average sample weighing 600±10 g was formed by random sampling. In the selected samples of each variety, the following were determined: linear dimensions of seeds (length (l), width (d), thickness (h)) and beans (length (l), width (d)) - by direct measurement of 10 seeds and beans using a caliper with an accuracy of 0.1 mm; seed size - by calculating the magnitude coefficient determined as the product of three linear dimensions and determining the weight of 1000 seeds at their actual moisture content and dry matter - in accordance with the requirements of GOST ISO 520-2014; structural and mechanical properties (strength) of seeds - according to the developed operating algorithm, measuring the force required to through-pierce a soybean seed with a "Cylinder Ø 1" indenter at a speed of 1 mm / s on a "Structurometer ST-2" texture analyzer. The study was repeated three times. Experimental data were processed using mathematical statistics methods using Microsoft Office (Excel) software packages. The significance of differences was assessed using the least significant difference (LSD) at a significance level of $p = 0.95$.

3 Results

The research revealed that the length and width of two- and three-seeded pods varied across all soybean varieties studied throughout the study period. Compared to the standard, the grain soybean varieties Lastochka and Evgeniya were characterized by smaller linear dimensions of green pods. The most significant differences were observed in pod width, and this pattern persisted regardless of the number of seeds contained within them (Table 1).

Table 1. Linear dimensions of soybeans* (M ± Δ at p = 0.95), mm.

Period R6–R7, research days	**Soybean variety**					
	Mika-washima (standard)	**Lastochka**	**Evgeniya**	**Mika-washima (standard)**	**Lastochka**	**Evgeniya**
	Length			**Width**		
Two-seeded beans						
1	47.38±0.72	42.50±0.58	44,53±0,50	13,24±0,28	10,66±0,38	11,15±0,29
7	48.28±0.89	41.00±0.52	43,88±0,45	12,87±0,28	10,33±0,38	10,46±0,23
14	47.98±0.38	41.10±0.12	43,35±0,40	12,73±0,23	10,81±0,23	10,46±0,24
21	48.40±0.65	40.60±0.69	42,65±0,75	12,54±0,12	10,52±0,23	10,48±0,15
28	47.75±0.87	40.90±0.52	42,83±0,38	12,84±0,13	10,30±0,35	9,82±0,16
HCP_{05}	0.94			0.38		
Three-seeded beans						
1	57.52±0.37	53.40±0.64	53,25±0,06	13,27±0,31	10,50±0,23	11,12±0,06
7	57.68±0.78	51.65±0.75	52,10±0,46	13,01±0,32	10,68±0,39	10,78±0,26
14	56.88±0.43	51.60±0.69	52,28±0,03	12,69±0,23	10,82±0,35	10,59±0,26
21	56.85±0.56	50.92±1.06	51,10±0,43	12,63±0,20	10,66±0,38	10,37±0,23
28	56.33±0.38	50.90±0.62	51,68±0,49	11,89±0,17	10,56±0,23	9,91±0,07
HCP_{05}	0.64			0.43		

Note – * average values for 2024-2025.

In the Mikawashima variety, accepted as the standard, the maximum values of linear indicators were: pod width - 13.27 ± 0.31 mm, length - 57.68 ± 0.78 mm. In the Lastochka and Evgeniya soybean varieties, these indicators for both two-seeded and three-seeded beans were reliably below the standard. A significant difference in the width of two-seeded beans was 16.11 - 19.78% (Lastochka variety) and 15.79 - 23.52% (Evgeniya variety); length - 10.29 - 16.12 and 6.02 - 11.88%, respectively. In three-seeded soybeans, width values were significantly below the standard, ranging from 11.19 to 20.87% (Lastochka variety) and 16.20 to 17.89% (Evgeniya variety), while length values ranged from 7.16 to 10.45% (Lastochka variety) and 7.42 to 10.11% (Evgeniya variety).

Bean growth dynamics were nonlinear: the most rapid increase in length and width was recorded from the first to the seventh day of the study, after which the growth rate decreased.

Next, seed size was determined. This indicator is one of the main visual distinguishing factors determining the commercial appearance of vegetable soybeans: large soybeans (with a 1,000-seed weight of 220 grams or more based on absolutely dry matter) are superior to small soybeans in terms of taste and texture after cooking [8]. A comparative evaluation of experimental soybean varieties revealed that grain-grade soybean seeds of the Lastochka and Evgeniya varieties differed significantly from the Mikawashima variety by 17.51–41.59% and 29.63–46.56%, respectively, with a lower 1,000-seed dry matter weight. Furthermore, on the first day of testing, the Lastochka variety's dry matter weight was within the range of the standard variety (Table 2).

Table 2. Weight of 1000 soybean seeds* (M ± Δ at p = 0.95), g.

Period R6–R7, research days	Soybean variety					
	Mika-washima (standard)	Lastochka	Evgeniya	Mika-washima (standard)	Lastochka	Evgeniya
	At actual humidity			On a dry matter basis		
1	370±11	244±3	260±4	78.8±2.4	65.0±0.9	52.9±0.8
7	608±12	318±2	327±8	151±3	88.2±0.6	80.7±2.0
14	658±15	418±6	408±3	200±5	139±2	119±1
21	721±23	440±11	465±4	229±7	171±4	161±1
28	675±13	429±2	430±5	274±5	189±1	173±2
HCP_{05}	56			22.7		

Note – * average values for 2024-2025.

With actual seed moisture varying between 54.93±0.59 and 77.69±0.59%, grain varieties were also significantly inferior to the standard variety throughout the entire R6–R7 observation period: Lastochka by 34.05–47.70%, Evgeniya by 29.73–46.22%. For grain soybean varieties, the 1000-seed weight reached its maximum value, similar to the standard, by the 21st day of the study. Calculation of the seed size coefficient showed that the seed size of the Lastochka and Evgeniya varieties, in relation to the standard, was significantly lower by 43.90–60.37 and 42.73–53.56%, respectively. For all studied varieties, the maximum values of the seed size coefficient were observed by the 21st day (Table 3).

Table 3. Linear indicators and coefficient of soybean seed size at actual moisture content* (M ± Δ at p = 0.95), mm.

Variet y	Period R6–R7, research days	Indicator			
		Length	Width	Thickness	Grain size coefficient
Mikawashima (standard)	1	12.36±0.08	7.84±0.12	9.58±0.09	928.32
	7	13.89±0.17	8.66±0.12	9.71±0.06	1167.99
	14	14.19±0.06	8.79±0.16	10.01±0.06	1248.55
	21	14.19±0.20	8.85±0.14	10.02±0.12	1258.33
	28	14.01±0.03	8.69±0.01	9.61±0.13	1170.00
Lastochka	1	11.31±0.13	7.26±0.15	4.48±0.09	367.86
	7	12.45±0.17	8.10±0.12	5.89±0.10	593.98
	14	12.56±0.18	8.33±0.15	5.98±0.09	625.66
	21	13.28±0.21	8.42±0.14	6.21±0.07	694.39
	28	12.40±0.12	7.83±0.14	6.76±0.07	656.34
Evgeniya	1	11.76±0.18	6.11±0.16	6.00±0.12	431.12
	7	12.32±0.13	6.62±0.14	6.89±0.08	561.94
	14	12.98±0.16	6.69±0.12	7.16±0.09	621.75
	21	13.45±0.23	7.26±0.08	7.38±0.09	720.63
	28	13.07±0.12	6.93±0.09	7.30±0.08	661.20
HCP_{05}		0.41	0.26	0.60	51.51

Note – * average values for 2024-2025.

Since the speed and parameters of technological processes, as well as the organoleptic properties of finished soybean products (texture, consistency, etc.), depend on seed strength, the next stage of research was to determine seed strength - the ability to resist destruction during mechanical cooking (softening, grinding, and rubbing), as well as exposure to various thermal and chemical treatments. Assessing the strength of soybean seeds will allow us to predict their behavior during industrial processing and optimize processing conditions for maximum preservation of marketable products [5, 10, 11].

Table 4. Strength of soybean seeds* (M ± Δ at p = 0.95), N/mm^2

Period R6–R7, research days	Soybean variety		
	Mikawashima (standard)	Lastochka	Evgeniya
1	0.063±0.001	0.099±0.001	0.071±0.001
7	0.068±0.001	0.106±0.002	0.079±0.001
14	0.084±0.002	0.113±0.002	0.102±0.001
21	0.105±0.002	0.162±0.002	0.140±0.002
28	0.122±0.002	0.203±0.003	0.172±0.002
HCP_{05}	0,017		

Note – * average values for 2024-2025.

The data presented in Table 4 demonstrate that the seed strength of the soybean varieties studied increased throughout the observation period: for the Mikawashima (standard) variety, the seed strength exceeded the initial value by 93.65%, for the Lastochka variety by 105.05%, and for the Evgeniya variety by 142.25%. The increase in seed strength during ripening is presumably due to a complex of interrelated biochemical and morphological processes: the polymerization of protein molecules to form denser structures and a decrease in the free moisture content of soybean seeds.

Seed strength indicators for the Evgeniya soybean variety were within the range of values for the Mikawashima variety on days 1 and 7 of the study; from day 14 onward, they significantly exceeded the standard by 21.43% to 40.98%. The Lastochka soybean variety had significantly higher seed strength indicators than the standard variety, starting from the first day of the research – by 34.52 – 66.39%.

4 Discussions

It was found that the length of two-seeded pods in the Lastochka and Evgeniya soybean varieties is close to the minimum permissible lower limit for vegetable varieties, while the parameters of three-seeded pods of these varieties are within the recommended range. However, the pod width of both grain varieties and the standard vegetable variety does not meet the recommended standard values (pod length - at least 45.0 mm, width - at least 14 mm) [8].

The recommended dry weight of 1000 seeds per 1000 seeds was recorded for the Mikawashima vegetable variety by the 21st day of the study; for the Lastochka and Evgeniya grain soybean varieties, this value remained below the established standard for vegetable soybeans throughout the study period.

The increased mechanical strength of grain soybean varieties helps reduce losses during mechanized harvesting, transportation, and primary processing, ensuring product safety and increasing the economic efficiency of production.

A review of literary sources shows that vegetable variety breeding in Southeast Asia and Japan is focused on increasing seed size and developing a delicate, thin seed coat [12]. In the Russian Far East, breeding efforts are focused on developing genotypes resistant to low temperatures and moisture deficits, which has contributed to the development of the specific morphology of grain soybeans [13].

Using Lastochka and Evgeniya soybean seeds and beans as vegetable products requires adjustments to processing methods: increasing the duration of heat treatment, optimizing freezing parameters, and developing technologies and food product formulations that compensate for the denser seed coat texture.

5 Conclusion

A comparative assessment of the physical properties of young green beans and seeds revealed that the grain soybean varieties Evgeniya and Lastochka are significantly inferior to the standard vegetable soybean variety Mikawashima:

– In pod length by 7.16–16.12% for the Lastochka variety and by 6.02–11.88% for the Evgeniya variety; in pod width by 11.19–20.87% and by 15.79–23.52%, respectively;

– In 1000-seed weight at actual moisture content by 34.05–47.70% for the Lastochka variety and by 29.73–46.22% for the Evgeniya variety; in terms of dry matter by 17.51–41.59% and by 20.26–46.56%, respectively.

– By seed size coefficient, the Lastochka variety had a 43.90–60.37% increase; the Evgeniya variety had a 42.73–53.56% increase.

Along with smaller bean and seed sizes, grain soybean varieties are characterized by increased seed strength: seed piercing force significantly exceeded that of the standard variety for the Lastochka variety by 34.52–66.39%; for the Evgeniya variety, it was 21.43–40.98% (differences were significant from the 14th day of the study).

These data allow us to recommend the Lastochka and Evgeniya grain soybean varieties as vegetable crops, provided harvesting timing is optimized and heat treatment parameters are adjusted.

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