

The source material estimation of early-maturing group soybeans by adaptability parameters

Anna Galichenko*, and Evgeniya Fokina

Federal State Budgetary Scientific Institution Federal Scientific Center “All-Russian Research Institute of Soybeans”, 675027 Blagoveshchensk, Russian Federation

Abstract. The article presents the results of 2018—2020 study of 22 early-maturing group soybeans samples of the collection nursery; those samples are of various ecological-geographical origin according to adaptability parameters, plasticity and stability in the conditions of the south of the Amur region, the analysis of yield variability was carried out. The research was carried out on the experimental field of the laboratory of selection and genetics of soybeans FSBSI FSC All-Russian Scientific and Research Center of soybean, Sadovoye village, Tambov region. The average varietal soybean seeds yield in the years of research amounted to 2.37 t/ha. Based on the results of agro-ecological assessment of 22 soybean samples, adaptive, plastic and stable samples have been identified, which have an insignificant variation indicator in yield: Heihe 25 ($V=3.23\%$; $Ka=1.14$; $bi=1.00$; $Si_2=0.03$), Hei 06-1625 ($V=4.69\%$; $Ka=1.06$; $bi=1.29$; $Si_2=0.01$), Hei 05-1031 ($V=3.74\%$; $Ka=1.03$; $bi=1.60$; $Si_2=0.01$) and McCall ($V=2.34\%$; $Ka=1.06$; $bi=1.03$; $Si_2=0.01$). These genotypes are of practical interest as initial parent forms in selection for adaptability in conditions of the Amur region.

1 Introduction

Soybeans are one of the most valuable and popular protein-oilseeds crops in world agriculture. Its national economic importance increases every year as it is used as food, feed and technical crop. Soybean seeds contain 35... 45% protein, 16... 23% oil, up to 30% carbohydrates, 5% minerals and various vitamins [1, 2, 3].

Over the last decade, the world soybeans consumption increased by about 1.6 times, while the gross harvest of crops in Russia increased more than 5 times (from 0.7 to 3,6 million tons) [4,5,6]. The leading role in increasing soybean yields is given to the variety, which requires the creation of highly productive varieties adapted to the crop growing regions and the development of variety technologies, ensuring the realization of potential variety yield of 80... 90% [7,8].

Today in Russia, the main producer of soybean grain is the Amur region, where more than 33% of its acreage is concentrated. However, the strategy of innovative AIC development of the Amur region is aimed at an even greater increase in soybean production due to the development of new lands and crop promotion to regions with the sum of active

* Corresponding author: gap@vniisoi.ru

temperatures 1800... 2000°C for vegetation. In this regard, there is a need to create new early-maturing soybean genotypes, since today most cultivated varieties in production belong to medium and late-ripening groups.

Therefore, at present, special attention in the soybeans breeding is paid to the comprehensive study of the source material for early-ripening varieties breeding that are resistant to stressful weather conditions [9, 10, 11].

As it is known, breeding studies progress is impossible without in-depth study of “genotype environment” interaction [12, 15]. The main criterion for assessing the adaptability of the studied varieties is their reaction to environmental factors. Almost all reactions of the studied material to growing conditions are concentrated in the “yield” trait [13].

Agroclimatic conditions of the Amur region often prevent obtaining of stable and high rates of soybean yield. Therefore, the ability to form a high yield under different growing conditions is put first [14].

In this regard, the study of soybeans' collective material by indicators of productivity, adaptability, ecological plasticity and stability allows to give a correct assessment of the initial forms at the first selection process stage.

The purpose of the study was to carry out a comprehensive agro-ecological assessment of collective early-maturing group soybeans samples in the conditions of the south of the Amur region for their use as initial parent forms when creating early-maturing highly productive varieties.

Objectives: to determine the productivity and adaptive potential of soybean samples using the yield indicator; analyze the variability of this characteristic; calculate ecological plasticity and stability.

2 Materials and methods

The study was carried out in 2018—2020 at the experimental site of breeding crop rotation of the laboratory of selection and genetics of soybeans, FSC of the All-Russian Research Institute of Soybeans, Sadovoye village, Tambov region. The object of research was 22 collective soybeans samples of the early ripening group with a vegetation period of 93... 104 days, of which: Chinese selection - 17, American - 3, domestic - 2 and standard variety Lydia (vegetation period 104 days). Lidia soybean variety is highly productive, plastic, well adapted to the hydrothermal regime of the Amur region, official early-ripening standard in the Amur region since 2009; it is also the regional standard on the state crop testing site.

Field experiments were laid according to the generally accepted soybean cultivation technology, characteristic to the southern agricultural zone of the Amur region [16, 17, 21]. Seeds were sown using hand planters in three repetitions on three meter rows with 45 x 10 cm nutritional area per each plant. Phenological observations were carried out during the seedlings and maturation phases. During flowering and maturation, an assessment on morphological traits was carried out. The plans were harvested manually (sickle); biometrics were carried out on the root before harvesting: the number of plants on the plot was counted, the height of plants and the height of of the lower bean attachment was measured. Samples threshing was carried out on a sheaf thresher “MPS-1M”; after threshing the seeds were cleaned and weighed according to GOST 10854-88 [18]. The number of sick and damaged seeds was determined.

The soils of the experimental site are meadow chernozem soil, medium-deep, occupying the main massifs of the southern agricultural zone of the region. Meadow chernozem soils are the most fertile in the Amur region with the humus content — 2.3... 2.8%, mineral nitrogen — 15.9... 17.2 mg/kg of soil; labile phosphorus 75... 98 mg/kg and potassium — 199 mg/kg soil. Reaction of soil solution - medium acidic with pH_{KCl} 4.8... 5.0.

According to the technique of L.A. Zhivotkov et al., assessment of the productive and adaptive potential of soybean varieties was performed by the “yield” indicator [13].

For each year and sample of soybeans, the adaptability factor (Ka) was calculated by the formula:

$$Ka = (x_{ij} \times 100 / x) / 100 \quad (1)$$

where x is the average yield of the year, x_{ij} — the yield of i -grade in the j -th year of the experiment.

Ecological plasticity (regression coefficient) and stability (mean square deviation from the regression line) of soybean samples were calculated according to E.A. Eberhart and W.A. Russell, as outlined by V. A. Zykin et al. [12, 19].

$$b_i = \sum_j x_{ij} I_j / I_j \quad (2)$$

where I_j — index of environment conditions for the j -th year of the experiment, x_{ij} — yield of the i -th varietal specimen in j -l conditions.

$$I_j = (\sum_i x_{ij} / v) - (\sum_i \sum_j x_{ij} / v n) \quad (3)$$

Where $\sum_j x_{ij}$ — the sum of the yield of all samples in the j -th year of the test, v — number of samples tested, n — number of tests, $\sum_i \sum_j x_{ij}$ — the amount of yield in all years of research of all varieties.

Theoretical yield was determined by the formula:

$$x_{ij} = x_i + b_i I_j \quad (4)$$

where b_i — regression coefficient, I_j — index of environment conditions, x_i — average yield of the i -th grade specimen for the years of testing.

For the stability variance calculation, the deviation of theoretical yields from the actual ones was calculated according to the formula:

$$d_{ij} = x_{ij} - x_{ij} \quad (5)$$

and the stability variance - as the sum of squares of deviations (d_{ij}) divided by the number of degrees of freedom:

$$S_i^2 = \sum_j d_{ij}^2 / n - 2 \quad (6)$$

Analysis of variability of the soybean yield trait was carried out according to B.A. Dospekhov [20].

During research years, meteorological conditions were difficult for cultivation of the studied crop and differed in the variability of the main indicators (temperature regime and water supply), as evidenced by the value of the hydrothermal coefficient (HTC) (figure).

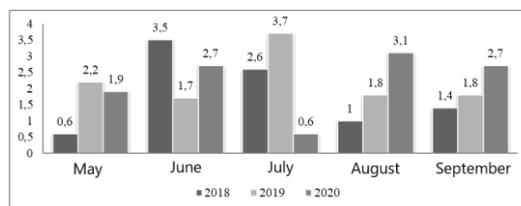


Fig. 1. Hydrothermal coefficient during 2018-2020 soybean growing season

In 2018, due to early spring, there was a rapid snow melt down. In May, low rainfall and high temperatures (HTC = 0.6) led to topsoil drying during soybean sowing and, as a result, the rarity of sprouting. Heavy rains in June and July (HTC = 3.5; 2.6) complicated the situation and led to severe soil overwetting, resulting in oppression and partial loss of plants [21].

Hydrothermal conditions in spring 2019 were comparatively favorable for soybean sowing. Precipitation in May (HTC = 2.2) contributed to moisture accumulation in the soil and the creation of favorable conditions for seed germination. In the flowering phase, adequate moisture of the soil and warm weather contributed to the productive development of soybean plants. The third decade of July was characterized by abundant precipitation (HTC = 3.7) due to which there was a short-term soil overwetting followed by oppression of soybean plants [21].

In 2020, hydrothermal conditions differed significantly from the average long-term norm and were mainly characterized by overwetting. During the entire soybean growing season, an excess of the amount of active temperatures and precipitation (HTC = 0.6... 3.1) was observed. In July there was an increased temperature background and insufficient precipitation — 40.2% of the norm (HTC = 0.6). However, the abundant precipitation of June (HTC = 2.7) contributed to the accumulation of soil moisture reserves leveling July deficit, thereby ensuring normal conditions for growth and development of soybean plants.

3 Results and discussion

On average for 2018—2020, the yield of studied varieties in the south of the Amur region amounted to 2.37 t/ha. When using the “average yield of the year” indicator, it is possible to fully assess the role of environmental factors in the formation of a particular trait of any crop or variety. A rule of thumb states that the yield comparison of the studied varieties with medium varietal allows to correctly estimate their potential productivity [22]. In our studies, a slight variation (1.69%) in the average varietal yield of soybeans by year (from 2.32 to 2.41 t/ha) (table 1) was revealed.

Table 1. Characteristics of collective soybean samples by adaptability parameters.

Variety, soybean sample	Seed yield, t/ha			x_i	V, %	Ka	b_i	S_i^2
	2018	2019	2020					
Lydia (standard)	2.57	2.52	2.65	2.58	2.08	1.09	1.06	0.01
Heihe 13	2.10	2.07	2.22	2.13	3.04	0.89	0.92	0.01
Heihe 20	1.93	1.87	2.32	2.04	9.78	0.86	1.05	0.10
Heihe 21	1.97	2.35	1.77	2.03	11.85	0.85	0.43	0.18
Heihe 25	2.76	2.58	2.77	2.70	3.23	1.14	1.00	0.03
Heihe 33	2.51	2.21	2.66	2.46	7.60	1.03	0.94	0.11
Heihe 35	2.27	2.54	2.20	2.34	6.27	0.98	1.01	0.32
Heihe 40	2.76	2.19	3.19	2.71	15.10	1.14	1.11	0.51
Heihe 41	1.91	1.87	2.80	2.19	19.57	0.80	1.45	0.48
Heihe 44	2.01	1.90	1.92	1.94	2.46	0.82	0.58	0.01
Hei 2043	2.44	2.16	1.94	2.18	9.39	0.92	0.41	0.15
Hei 2254	2.75	3.31	2.97	3.01	7.65	1.26	1.61	0.11
Hei 06-1625	2.35	2.61	2.59	2.52	4.69	1.06	1.29	0.01
Hei 13-3345-1	2.19	2.82	2.49	2.50	10.29	1.05	1.49	0.14
Hei 13-3345-3	2.60	2.25	2.32	2.39	6.33	1.01	0.61	0.09
Hei 02-5075	1.52	2.31	1.80	1.88	17.43	0.79	1.31	0.26
Hei 05-1031	2.39	2.40	2.59	2.46	3.74	1.03	1.60	0.01
No. 2-2014 J1	1.74	1.86	1.57	1.72	6.90	0.72	0.63	0.05
Daksoy	2.93	2.70	2.71	2.78	3.82	1.17	0.86	0.06
Jim	2.52	3.17	2.69	2.79	9.85	1.18	1.53	0.17
McCal	2.50	2.60	2.46	2.52	2.34	1.06	1.03	0.01

Jag 30	2.91	2.50	2.38	2.60	8.74	1.09	0.49	0.18
Mageva	1.68	2.39	2.42	2.16	15.81	0.91	1.69	0.22
Σx_{ij}	53.31	55.18	55.43					
x_{ij}	2.32	2.40	2.41					
I_i	-0.05	+0.03	+0.04					

Varieties with high and stable grain yield, exceeding the standard Lydia variety by 0.02... 0.43 t/ha were identified: Heihe 40 — 2.71t/ha (+0.13 t/ha to st), Hei 2254 — 3.01 t/ha (+0.43 t/ha to st), Daksoy — 2.78 t /ha (+0.20 t/ha to st), Jim — 2.79 t/ha (+0.21 t/ha to st), Jag 30 — 2.60 t/ha (+0.02 t/ha to st).

It was found that yield variability in 17 (73.9%) samples was insignificant from 2.08 to 9.85%, in 6 (26.1%) it was average: Heihe 21 — 11.85%, Heihe 40 — 15.10%, Heihe 41 — 19.57%, Hei 13-3345-1 — 10.29%, Hei 02-5075 — 17.43%, Mageva—15.81%. The average variation coefficient value is characteristic of varieties that are more limited by the growing conditions.

Adaptability to local climatic conditions is of great importance for obtaining a stable yield with high quality grain [23]. The productive possibilities of a variety can be judged by the adaptability coefficient (K_a) [12]. K_a approaching or exceeding one means that the sample is highly adaptive. It was found that 14 soybeans samples had high adaptability coefficient — 0.98... 1.26. The average adaptability degree (0.72... 0.92) was shown by 9 samples.

Response to the growing conditions change of the studied samples is shown by the linear yield regression coefficient (b_i). In case of $b_i > 1$, the variety better responds to environment conditions changes. If $b_i < 1$, then variety reacts weaker. When $b_i = 1$, the yield of the variety corresponds to the changing growing conditions.

Comparative analysis of linear regression coefficients revealed that soybean samples Heihe 40 ($b_i = 1.11$), Heihe 41 ($b_i = 1.45$), Hei 2254 ($b_i = 1.61$), Hei 06-1625 ($b_i = 1.29$), Hei 13-3345-1 ($b_i = 1.49$), Hei 02-5075 ($b_i = 1.31$), Hei 05-1031 ($b_i = 1.60$), Jim ($b_i = 1.53$) and Mageva ($b_i = 1.69$) are of an intense type and are more responsive to environmental conditions changes. Such varieties require high agrotechnics level, otherwise their yield will sharply drop.

Soybean samples Heihe 21 ($b_i = 0.43$), Heihe 44 ($b_i = 0.58$), Hei 2043 ($b_i = 0.41$), Hei 13-3345-3 ($b_i = 0.61$), No.2-2014 J1 ($b_i = 0.63$), Daksoy ($b_i = 0.86$), Jag 30 ($b_i = 0.49$) are better to be used on an extensive background, where they have the greatest output at minimal cost.

Soybean variety Lydia and samples Heihe 13, Heihe 20, Heihe 25, Heihe 33, Heihe 35, McCall, whose regression coefficient is equal to or close to one, showed high ecological plasticity. The change in yield corresponds to change in growing conditions.

At present, a particular concern in breeding is the stability of the studied trait, i.e. the ability of the variety to maintain the optimal level of the trait in different soil-climatic conditions. At the present stage, the stability of the studied trait becomes particularly important in selection, i.e. the ability of the variety to maintain the optimal level of the trait in various soil-climatic conditions [24].

Stability variance (S_i^2) shows the deviation of actual harvests from theoretical ones calculated on the basis of average variety yield and environment index. The smaller the deviation, the more stable the variety. Dispersion S_i^2 seeks zero [25].

The greatest deviation of theoretical yield (TY) from actual yield (AY) was observed in soybean samples Heihe 40 (-0.44... +0.55 t/ha), Heihe 41 (-0.55... +0.36 t/ha) and Hei 02-5075 (-0.40... +0.29 t/ha), Mageva (-0.19... +0.39 t/ha) (Table 2).

Table 2. Theoretical yield of collective soybean samples, t/ha (2018—2020)

Variety, soybean sample	TY			AY deviation		
	2018	2019	2020	2018	2019	2020
Lydia (st)	2.53	2.60	2.62	-0.04	+0.08	-0.03

Heihe 13	2.08	2.16	2.17	-0.02	+0.09	-0.05
Heihe 20	1.99	2.07	2.08	+0.05	+0.20	-0.23
Heihe 21	2.01	2.04	2.05	+0.04	-0.31	+0.28
Heihe 25	2.65	2.73	2.74	-0.11	+0.15	-0.03
Heihe 33	2.41	2.49	2.50	-0.10	+0.27	-0.16
Heihe 35	2.29	2.37	2.38	+0.02	-0.17	+0.18
Heihe 40	2.65	2.74	2.75	-0.10	+0.55	-0.44
Heihe 41	2.12	2.23	2.25	+0.21	+0.36	-0.55
Heihe 44	1.91	1.96	1.96	-0.10	+0.06	+0.04
Hei 2043	2.16	2.19	2.20	-0.28	+0.03	+0.26
Hei 2254	2.93	3.06	3.07	+0.18	-0.26	+0.10
Hei 06-1625	2.45	2.56	2.57	+0.10	-0.06	-0.02
Hei 13-3345-1	2.42	2.54	2.56	+0.23	-0.28	+0.07
Hei 13-3345-3	2.36	2.41	2.41	-0.24	+0.16	+0.09
Hei 02-5075	1.81	1.92	1.93	+0.29	-0.40	+0.13
Hei 05-1031	2.38	2.51	2.52	-0.01	+0.10	-0.07
No. 2-2014 J1	1.69	1.74	1.74	-0.05	-0.12	+0.17
Daksoy	2.74	2.80	2.81	-0.19	+0.10	+0.10
Jim	2.71	2.83	2.85	+0.19	-0.33	+0.16
McCall	2.47	2.55	2.56	-0.03	-0.05	+0.10
Jag 30	2.57	2.61	2.62	-0.34	+0.11	+0.24
Mageva	2.07	2.21	2.23	+0.39	-0.18	-0.19

A significant difference in the value of theoretical and actual yields indicates the instability of these genotypes.

When evaluating by S. A. Eberhart and W. A. Russell, 10 soybean specimens were characterized by high stability: Heihe 13, Heihe 25, Heihe 44, Hei 06-1625, Hei 13-3345-3, Hei 05-1031, No.2-2014 J1, Daksoy, McCall and Lydia variety ($S_i^2 = 0.01—0.09$). Low stability was shown by 56.52% of soybean samples ($S_i^2 = 0.10—0.51$).

Genotypes with linear regression coefficient b_i more than one and the stability variance S_i^2 seeking zero are the most valuable. Such genotypes include: Lydia, Heihe 25, Hei 06-1625, Hei 05-1031, McCall.

4 Conclusions

As a result of a comprehensive agro-ecological assessment of 22 collective early-maturing soybeans samples differing in ecological-geographical origin, samples with relative high adaptability, plasticity and stability with small indicators of the yield variation coefficient were distinguished. These include: Heihe 25 ($V = 3.23\%$; $K_a = 1.14$; $b_i = 1.00$; $S_i^2 = 0.03$), exceeding the yield of the standard Lydia variety by 0.12 t/ha. Soybean samples Hei 06-1625 ($V = 4.69\%$; $K_a = 1.06$; $b_i = 1.29$; $S_i^2 = 0.01$), Hei 05-1031 ($V = 3.74\%$; $C_a = 1.03$; $b_i = 1.60$; $S_i^2 = 0.01$) and McCall ($V = 2.34\%$; $C_a = 1.06$; $b_i = 1.03$; $S_i^2 = 0.01$), although slightly inferior to the standard in productivity by 0.06... 0.12 t/ha, but ripen 3... 9 days earlier.

These samples are recommended as a source material in selection for early ripeness and adaptability in conditions of the Amur region.

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