Bioenergy component of seeds and green mass of indian pea in various growing conditions

Sergey Zaitsev[1*], *Denis* Babushkin[1], *Albina* Leovkina[1], *Vladislav* Svetlov[1], and *Tatiana* Marakaeva[2]

[1]Russian Research Institute for Sorghum and Maize "Rossorgo", 4, st. 1st Institutskiy proezd, Saratov, 410050, Russia,
[2]Omsk State Agrarian University named after P.A. Stolypin, 1, Institutskaya Ploshchad, Omsk, 644008, Russia

Abstract. The article is devoted to the analysis of the results of studying cultivars of indian pea (Lathyrus sativus L.) under the conditions of the Nizhnevolzhsky (Saratov) and West Siberian (Omsk) regions of the Russian Federation. Indianpea serves a variety of purposes: compound feed, forage, an alternative source of protein for the population, due to the high protein content in seeds and mature leaves. In the arid conditions of the Russian Federation, the indianpea is able to occupy its own agronomic niche and become an additional source of replenishing cheap protein and improving the quality of the forage base. In this connection, a study of four varieties of the indianpea breeding of the [1]Russian Research Institute for Sorghum and Maize "Rossorgo" (Racheika, Zhemchuzhina, Elena, Mramornya) was carried out according to economically valuable parameters, data were obtained on the biochemical composition of seeds and green mass, and an assessment was carried out on bioenergetic parameters. The influence of factors "A", "B" and their interaction "AB" on the manifestation of signs was noted. According to the results of a two-factor analysis of variance, it follows that the factor of growing conditions (A) has the greatest influence on the seed yield index – 64.2%, and the yield of green mass - the genotype factor (B) - 59.5%. The study revealed a high protein content in seeds (28.3-31.1%) and green mass (21.0-26.3%). Determination of the biochemical composition makes it possible to evaluate varieties in terms of gross energy output with seeds and green mass. According to the parameters of the bioenergetic efficiency of seeds, the best indicators were found in the varieties Elena and Zhemchuzhina. Variety Elena was distinguished by the highest content of total energy in the green mass of 48.0-94.8 GJ/ha. Variety Zhemchuzhina was characterized by the maximum content of total energy in the grown seed crop – 26.0-29.3 GJ/ha, the largest increment in gross energy – 12.6 GJ/ha and the highest energy efficiency coefficient of all four varieties – 1.94.

* Corresponding author: zea_mays@mail.ru

1 Introduction

Legumes are of great importance as one of the main sources of protein for farm animals. They serve as the basis for the biologization of agriculture and play an important role in solving the problem of energy conservation [1]. It is impossible to solve the problem of creating a proper forage base without increasing the area under legumes. The creation of a stable fodder base for animal husbandry in most soil and climatic zones of our country depends to some extent on intensive field grass sowing. The productivity of mixtures of sown grasses is higher if the herbage contains legumes [2]. The main purpose of the indian pea is fodder. Indian pea serves for various purposes: fodder, fodder, an alternative source of protein for the population, due to the high content of protein in seeds and mature leaves [3, 4]. In the arid conditions of the Russian Federation, the indian pea can occupy its own agronomic niche and become an additional source of replenishing cheap protein and improving the quality of the forage base [5, 6].

The purpose of the study: To conduct a study of the varieties of the indian pea in various ecological and geographical conditions and to identify differences in economic characteristics and bioenergetic parameters.

2 Materials and methods

An experiment on the ecological study of cultivars of the indian pea was laid on the experimental plots of the Russian Research Institute for Sorghum and Maize "Rossorgo" (Saratov), on the fields of the educational and experimental farm of the Omsk State Agrarian University, located in the southern forest-steppe of the Omsk region.

The climate of the Saratov region is sharply continental and severe. HTC in wet years is 1.20–1.45; in medium-provided – 0.70-0.95 and arid – 0.60-0.68. The average annual precipitation is 360–455 mm. The soil is southern low-humus, medium-thick, heavy loamy chernozem. In the arable layer, the humus content (according to Tyurin) is 3.80–4.60%, the pH is close to neutral (pHsalt – 6.1; pHwater – 7.0); the sum of absorbed bases is 38.0–41.0 meq/100 g of soil. Soil density is 1.20 – 1.32 g/cm^3.

The southern forest-steppe of the Omsk region is characterized by a warm, moderately humid climate. The hydrothermal coefficient is 1.0–1.2, which indicates a satisfactory moisture supply during the period of active vegetation. The average long-term annual precipitation is 300–350 mm, during the period with a stable average daily air temperature above 10ºC, 190–220 mm of precipitation falls. The soil of the field is ordinary chernozem, medium thick, medium humus. Humus content – 5.2%, total nitrogen – 0.31-0.34%, total phosphorus – 0.16-0.17%, total potassium – 2.3-2.8%. The density of the soil in the upper layer (0–40 cm) is 1.20–1.25 g/cm^3, the density of the solid phase is 2.64–2.65 g/cm^3. The composition of the soil-absorbing complex is dominated by calcium – 19.8–23.3 mg eq./100 g. The reaction of the soil solution is close to neutral, the pH of the water extract in the 0–30 cm layer is 6.5–7.1.

Field experiments were laid out according to generally accepted research methods [7-9]. The accounting area of the plots is 5 m^2. Agricultural technology is generally accepted for the regions. Early spring sowing: in the conditions of Saratov - May 3-5 with the SKS 6-10 seeder, Omsk - May 16 with the SSFC-7 seeder. The placement of plots is systematic, the depth of seed placement is 5 cm. grains per 1 ha. Harvesting was carried out by hand during the ripening phase in the second decade of august.

3 Results and Discussion

The main task of the breeding of the indian pea, as well as other plants, is the development of new high-yielding varieties adapted to certain soil-climatic and agrotechnical conditions, characterized by good quality seeds and green mass, meeting the increased requirements of the agro-industrial industry. The biological features of the indian pea allow plants to successfully go through the development phases and fully mature not only in the hot semi-arid conditions of the Saratov region, but also in more northern latitudes (55°) of the southern forest-steppe of the Omsk region (Table 1). The results of a two-factor analysis of variance indicate that the influence of weather conditions (factor A) on the manifestation of the interphase period "seedlings-flowering" is 68.5% and the genotype (factor B) on the value of the indicators found that the growing conditions.

Table 1. Duration of interphase periods of indian pea, days, 2022.

Variety	Seedlings-flowering		Vegetation period	
	Saratov	Omsk	Saratov	Omsk
Mramornaya	39.0	38.0	79.0	93.0
Racheyka	36.0	36.0	81.0	85.0
Elena	40.0	33.0	85.0	79.0
Zhemchuzhina	37.0	35.0	81.0	84.0
Mean	38.0	35.5	81.5	85.3
$LSD_{0.5}$	1.7	2.1	1.4	2.3
Factor share A, %	68.5		48.8	
Factor share B, %	4.5		0.3	
Share of interaction AB, %	19.7		46.4	
Random deviation, %	6.7		4.3	

The length of the stem and the height of the attachment of the lower bean are of great importance, as they determine the manufacturability of the variety, affect the resistance to lodging, suitability for mechanized harvesting. Tall varieties tend to produce higher yields than dwarf, short varieties, but are more prone to lodging. The tallness of plants is often associated with their longer development, but at the same time can be correlated with root length, which affects the overall drought tolerance. The height of attachment of the lower bean is an important sign of suitability for mechanized harvesting, with a high location, you can adjust the cutting height without fear of losing the largest seeds of the lower tiers. At the same time, the influence of soil and climatic conditions on the manifestation of the trait was noted (Table 2). Two factor analysis of variance showed that the magnitude of the manifestation of morphometric indicators significantly (at P = 95) changes under the influence of both growing conditions (factor A), genotype (factor B - variety), and their interaction (A x B). Growing conditions make the greatest contribution to the variability of the stem length (83.1%) and the height of attachment of the lower bean (49.1%). It should be noted that the contribution of the interaction of both factors was (9.9% and 28.8%). The share of the influence of the genotype (B) in the studied varieties ranged from 3.6% (stem length) and 12.8% in terms of the height of attachment of the lower bean.

Seed yield is the most important indicator in assessing the parameters of ecological plasticity and stability of a variety, which gives an idea of the level of intensity of its cultivation technology and makes it possible to judge its responsiveness to improving or worsening conditions. The high potential of seed productivity of cultivars under the soil and climatic conditions of the Saratov and Omsk regions manifests itself depending on the specific growing conditions, while their individual response to environmental conditions is different (Table 3). So formed seed yield of indian pea varieties varied: in the Saratov region from 0.93 t/ha to 2.22 t/ha, in the Omsk region - from 0.88 t/ha to 1.84 t/ha.

According to the results of a two factor analysis of variance, it follows that the factor of growing conditions (A) has the greatest influence on the seed yield index – 64.2%. The proportion of the genotype (factor B) on the yield value was 20.2%, and the proportion of the interaction of two factors (AB) was 14,8%. The formation of the green mass yield was largely influenced by the genotype factor (B) – 59.5%, as well as the interaction of factors (AB) – 37.7%.

Table 2. Economic characteristics of indian pea varieties, 2022.

Variety	Stem length, cm		Lower bob attachment height, cm	
	Saratov	Omsk	Saratov	Omsk
Mramornaya	71.2	74.3	15.4	20.3
Racheyka	59.0	72.0	14.3	16.0
Elena	75.8	62.0	18.0	23.3
Zhemchuzhina	72.5	69.7	18.0	24.0
Mean	69.6	69.5	16.4	20.9
$LSD_{0.5}$	7.4	7.4	1.6	3.6
Factor share A, %	83.1		49.1	
Factor share B, %	3.6		12.8	
Share of interaction AB, %	9.9		28.8	
Random deviation, %	3.3		9.0	

Table 3. Yield of indian pea seeds, t/ha, 2022.

Variety	Seed yield		The yield of green mass	
	Saratov	Omsk	Saratov	Omsk
Mramornaya	0.93	0.88	13.5	12.8
Racheyka	1.24	1.53	16.8	15.0
Elena	1.44	0.97	14.1	20.0
Zhemchuzhina	1.59	1.84	13.0	10.9
Mean	1.30	1.31	14.4	14.7
$LSD_{0.5}$	0.11	0.15	0.96	1.01
Factor share A, %	64.2		0.3	
Factor share B, %	20.2		59.5	
Share of interaction AB, %	14.8		37.7	
Random deviation, %	0.9		2.0	

Indian pea has a great agronomic potential for use in the field of fodder production and animal husbandry: for fodder purposes, it is sown on grain, green fodder, grass meal, hay, silage and for grazing. At the same time, it is sown in a mixture with oats, barley or annual cereal grasses [10]. An important feature that characterizes the nutritional value of the feed is the protein content. Most of them belong to water-soluble (albumin) proteins (up to 84%). This makes it possible to use indian pea seeds in compound feed formulations, increasing the level of metabolic energy and creating an optimal combination of protein [11]. Analysis of the results indicates that the main contribution (59.2-60.9%) to the yield of seed nutrients consists of the collection of nitrogen-free extractive substances (Table 4). The role of other biochemical substances in the yield of corn grain averaged: protein from 28.3-31.1%, fat – 0.7%, fiber – 6.3-7.7%, ash – 3.1-3.8 %.

It is mandatory to assess the quality of pasture (green) fodder and raw materials for harvesting bulky fodder (hay, haylage, silage). The protein content in the green mass of this crop in 2022 varied from 21.0% to 26.3%, fat - within: 3.1-4.4%, fiber – 21.6-27.6%, ash – 8.3-10.2%, nitrogen-free extractive substances (NFES) – 30.2-43.1%.

Table 4. Qualitative composition of seeds and green mass of the indian pea, %, 2022.

Variety	Protein		Fat		Fiber		Ash		NFES	
	Saratov	Omsk	Saratov	Omsk	Saratov	Omsk	Saratov	Omsk	Saratov	Omsk
seeds										
Mramornaya	29.4	31.1	0.6	0.9	7.0	6.5	3.3	3.4	59.7	60.1
Racheyka	29.0	28.4	0.5	0.9	7.6	6.4	4.2	3.2	58.7	60.9
Elena	29.4	28.3	0.7	0.9	7.4	6.4	3.3	3.1	59.2	60.6
Zhemchuzhina	29.2	29.0	0.8	0.9	7.3	6.4	3.2	3.1	59.5	57.6
Mean	29.3	29.2	0.7	0.9	7.3	6.4	3.5	3.2	59.3	59.8
green mass										
Mramornaya	26.3	21.9	3.3	3.3	24.1	21.6	8.3	10.2	30.2	43.0
Racheyka	24.8	22.8	3.5	4.4	26.0	22.7	8.3	9.1	30.2	41.0
Elena	21.0	23.2	3.9	4.0	23.3	27.6	8.7	9.4	43.1	35.8
Zhemchuzhina	26.1	22.4	3.5	3.1	27.4	24.9	9.8	9.1	33.2	38.5
Mean	24.6	22.6	3.6	3.7	25.2	24.2	8.8	9.5	34.2	39.6

Most of the acreage is used for fodder production. At the same time, an important role is played by increasing the bioenergetic efficiency of products. As a result, there is a need to take into account the bioenergetic aspects of selection and the creation of adaptive agrocenoses [12]. Determination of the biochemical composition makes it possible to evaluate varieties by the output of gross energy with seeds and green mass [13, 14]. The amount of gross energy formed with seeds in 2022 varied from 15.2 GJ/ha to 26.0 GJ/ha in the conditions of Saratov and from 14.7 GJ/ha to 29.3 GJ/ha in the conditions of Omsk. The advantage in this parameter was noted in the Zhemchuzhina variety (26.0-29.3 GJ/ha). An assessment of the bioenergy efficiency of green mass revealed fluctuations in the collection of gross energy within the limits: 40.8-56.0 GJ/ha (in the conditions of Saratov) and 54.7-94.8 GJ/ha (in the conditions of Omsk). Thus, the highest content of gross energy in the crop of green mass (48.0-94.8 GJ/ha) was obtained for the variety Elena (Table 5).

Table 5. Harvest of gross energy with indian pea seeds and green mass, GJ/ha, 2022.

Variety	Total energy		Protein		Fat		Fiber		NFES	
	Saratov	Omsk	Saratov	Omsk	Saratov	Omsk	Saratov	Omsk	Saratov	Omsk
seeds										
Mramornaya	15.2	14.7	5.7	5.7	0.2	0.3	1.0	0.9	8.3	7.9
Racheyka	20.0	24.9	7.5	9.0	0.2	0.5	1.5	1.5	10.9	13.9
Elena	23.5	15.7	8.8	5.7	0.4	0.3	1.6	1.0	12.7	8.8
Zhemchuzhina	26.0	29.3	9.6	11.1	0.4	0.6	1.8	1.8	14.1	15.8
Mean	21.2	21.3	7.9	7.9	0.3	0.4	1.5	1.3	11.5	11.6
green mass										
Mramornaya	40.8	54.7	15.0	16.1	3.2	4.1	10.2	11.8	12.4	22.7
Racheyka	50.2	63.7	17.3	19.0	4.1	6.1	13.6	14.1	15.2	24.5
Elena	48.0	94.8	13.3	28.9	4.1	8.4	11.0	25.6	19.6	32.0
Zhemchuzhina	56.0	60.7	19.2	18.4	4.3	4.3	15.0	15.3	17.5	22.8
Mean	48.7	68.4	16.2	20.5	3.9	5.6	12.4	16.4	16.2	25.8

With the same methods of cultivation, the cost of total energy per unit area of pea varieties varies within small limits. These variations are mainly formed by the difference in energy consumption for harvesting and primary processing of grain, which depends on the yield, grain moisture before harvesting, and the degree of plant lodging. An analysis of the parameters of the energy assessment of grain production indicates varieties with the best estimates of energy efficiency parameters: Zhemchuzhina (qi=1.94), Elena (qi=1.75). These forms are also characterized by lower energy costs for the production of 1 ton of grain – 8.43 – 9.31 GJ / t with an average of 10.31 GJ / t for varieties (Table 6).

Table 6. Evaluation of the energy efficiency of the production of seeds of the indian pea in the conditions of the Saratov region, 2022.

Variety	Total energy consumption, GJ/ha	Energy efficiency coefficient, qi	Gross energy increment, GJ/ha	Grain yield in calculation - per 1 GJ of energy costs, t	Specific energy intensity of production, GJ/t
Mramornaya	13.4	1.13	1.8	0.07	14.41
Racheyka	13.4	1.49	6.6	0.09	10.81
Elena	13.4	1.75	10.1	0.11	9.31
Zhemchuzhina	13.4	1.94	12.6	0.12	8.43
Mean	13.4	1.58	7.8	0.10	10.31

4 Conclusion

The sowing crop of seeds (1.27-2.09 t/ha) and green mass (10.9-20.0 t/ha) formed by the indian pea is distinguished by a high content of protein, fiber, nitrogen-free extractive substances. The qualitative composition of seeds and green mass makes it possible to use it to create various types of feed (mixed feed, green fodder, haylage). According to the parameters of the bioenergetic efficiency of seeds, the best indicators were found in the varieties Elena and Zhemchuzhina. Variety Elena was distinguished by the highest content of total energy in the green mass of 48.0-94.8 GJ/ha. Variety Zhemchuzhina was characterized by the maximum content of total energy in the grown seed crop – 26.0-29.3 GJ/ha, the largest increment in gross energy – 12.6 GJ/ha and the highest energy efficiency coefficient of all four varieties – 1.94.

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