Scientific Papers Series Management, Economic Engineering in Agriculture and Rural Development
Vol. 19, Issue 3, 2019
PRINT ISSN 2284-7995, E-ISSN 2285-3952

THE EFFECT OF PLANTS DENSITY AND NITROGEN FERTILIZATION ON THE ECONOMIC EFFICIENCY OF SOYBEAN SEED PRODUCTION IN THE IRRIGATED CONDITIONS OF THE SOUTH OF UKRAINE

Raisa VOZHEHOVA, Vira BOROVYK, Iryna BILIAIEVA, Pavlo LYKHOVYD, Danylo RUBTSOV

Institute of Irrigated Agriculture of NAAS, Naddniprianske, Kherson, Ukraine, Phone/Fax:021/3182411, E-mails: izz.ua@ukr.net, veraborovik@meta.ua, inb95@ukr.net, pavel.likhovid@gmail.com, daniilrublev3@gmail.com

Corresponding author: pavel.likhovid@gmail.com

Abstract

The goal of the study was to determine the effect of crop density of middle-ripening soybean variety Sviatogor at different doses of nitrogen fertilizers on the economic and energy efficiency of its cultivation. Results of the study allowed determining that the highest profitability of 237% was provided by the variant with mineral fertilization at the dose of N_{30} with the density of 600 K plants per 1 ha. At the background of mineral nutrition N_{30} and N_{60}, the expenditures per 1 ha decreased by 29.1-28.2%, respectively, in comparison to the unfertilized variants, which led to a significant increase in the net profit. The economic efficiency of growing the middle-ripening soybean variety Sviatogor is significantly reduced at the nutritive background of N_{30} and N_{60}, in comparison to the unfertilized variants, combined with an increase in plant density per hectare from 700 to 1,000 K. The energy coefficient on the fertilized background was higher at the plant density of 600 K plants per 1 ha, and on the unfertilized one - at 500 K plants per 1 ha. We recommend cultivation of soybean variety Sviatogor in the irrigated conditions of the South of Ukraine by the agrotechnological complex with mineral nutrition of N_{30}, plant density of 600 K per 1 ha.

Key words*: *soybean, irrigation, plants density, nitrogen fertilizers doses, profitability level

INTRODUCTION

Soybean is one of the most prospective leguminous crops, which is in great demand on the domestic and world markets [21]. On the irrigated lands both of the South of Ukraine and abroad soybean brings agrarians not only positive practical but also valuable economic results, especially, as a highly profitable crop [18]. Its profitability allows returning the costs spent on the cultivation [1, 16].

From the point of view of economic efficiency, soybean provides production of the cheapest plant protein; through the feature of biological fixation of the Nitrogen from the atmosphere it significantly decreases requirements in the application of mineral fertilizers in agriculture; it grants obtaining of environmentally friendly products [2, 4]. However, in recent years prices on fertilizers, fuel, water, pesticides increased and, respectively, the expenditures on cultivation technology raised that is leading to increasing of the seed cost price and the decrease in profitability of production [11, 22]. Therefore, on the modern stage of development of plant science, it is important to enhance soybean production under less expenditure of resources and costs on its cultivation with the purpose of getting the maximum profits from seeds [3, 6, 12].

To achieve the goal scientific and research institutions are constantly trying to improve energy- and resource-saving elements of existent soybean cultivation technologies [7, 13]. The application of such innovative scientific developments will contribute to getting high profits, thereby increasing the volumes of soybean production [5]. That is why the question of study of scientific developments is relevant.

Economic efficiency of new soybean varieties production has been studied insufficiently. The aim of our study was to determine the influence of soybean crops density at the background of different Nitrogen fertilization on economic and energy efficiency of its cultivation.

MATERIALS AND METHODS

The study was conducted during 2016-2018 on the experimental field of the Institute of Irrigated Agriculture of NAAS in the Plant Breeding Department, which is situated in the zone of Southern Steppe of Ukraine, with accordance to common methods of field investigations and methodical recommendations [19].

The experiment is double-factored: factor A – sowing rate (300, 400, 500, 600, 700, 800, 900, 1,000 K seeds per ha); factor B – Nitrogen fertilizer doses (no fertilizer, N_{30}, N_{60}), as in the Table 1.

Table 1.Design of the experiment

Mineral nutrition levels (factor A)	**Plants densities (factor B)**							
	300	**400**	**500**	**600**	**700**	**800**	**900**	**1,000**
No fertilizer	1	2	3	4	5	6	7	8
N_{30}	9	10	11	12	13	14	15	16
N_{60}	17	18	19	20	21	22	23	24

Source: Own development of the study design.

Sowing rates were established by taking into account 1,000 seeds weight and sowing suitability. A weight sowing rate of soybean variety Sviatogor at 300, 400, 500, 600, 700, 800, 900, 1,000 K seeds was, correspondingly, – 51, 68, 85, 102, 119, 136, 153, 170 kg per 1 ha. Ammonium nitrate (with 34.6% content of the active substance) was used as a fertilizer. In weight regard the dose of the fertilizer N_{30} equaled to 0.087 tones per 1 ha, N_{60} – 0.170 tones per 1 ha, respectively.

There were four replications with placement of the variants by the method of randomized split plots. The area of sowing plots was 22 m^2, the area, which was taken into account, was 18.5 m^2.

In the researches we used the middle-ripening soybean variety Sviatogor, which had been included into the State Register of Plants Varieties of Ukraine since 2014 and recommended for seminal cultivation in the Steppe zone, were used. The agrotechnology of the middle-ripening soybean variety Sviatogor under the experiment conduction was common for the Steppe zone of Ukraine. The previous crop for this crop was winter wheat. Ammonium nitrate was applied under pre-sowing cultivator tillage with accordance to the study design manually scattering it by the field surface. Sowing was performed by a standard drill SKS-6-10 with wide inter-row spacing of 45 cm on the 2nd of May in 2016, on the 6th of May in 2017, and on the 26th of April in 2018.

Soybean seeds on the day of sowing were treated by the preparation of Nitrogen-fixing bacteria *Bradyrhizobium japonicum 634 b*; protection of the seeds against insects was performed by the treatment with preparation Maxim XL (1 L per 1 ton of the seeds). Soil moisture in the layer of 0-50 cm was maintained at the level of about 70% of the field water-holding capacity. During the period of vegetation there were 7 irrigation performed in 2016, 9 – in 2017, and 8 – in 2018. Irrigation was performed by the means of a machine DDA-100MA with the rates of 40-50 mm.

Weed management was performed by application of the soil herbicide *acetochlor* (2 L per 1 ha) after sowing and rolling of the crops.

Seed yields were determined by the method of entire harvesting of every plot by the breeding self-propelled combine «Sampo-130» with further weighing at the stage of technological ripeness. An average sample of seeds was selected from every plot for further purification and recalculation in the laboratory to the standard moisture of 14% by using the formula:

$$X = A \times (100\text{-}B) / 100 - 14,$$

where:

X is grain yield at 14%-moisture, tones per 1 ha;

A – grain yield without amendment for moisture, tones per 1 ha;
B – grain moisture at the time of harvesting, %.

Energy and economic efficiency of the cultivation technology of soybean depending on the influence of the studied factors was assessed by the method of Martjianov [8].

The researches were carried out on the dark-chestnut middle-loamy slightly solonets soils. The characteristics of weather conditions are provided in the Table 2.

Table 2. Weather conditions in the years of conduction of the experiments for 2016-2018

Month	Year	Air temperature, ºC	Precipitation, mm	Relative air humidity, %
April	2016	12.6	56.8	71
	2017	9.3	87.9	72
	2018	14.1	1.6	58
May	2016	16.1	71.7	76
	2017	16.3	25.6	64
	2018	19.5	35.7	59
June	2016	22.1	43.0	68
	2017	22.0	10.3	61
	2018	22.9	23.1	51
July	2016	24.4	46.3	58
	2017	23.4	39.8	60
	2018	24.2	90.8	61
August	2016	24.7	26.7	59
	2017	25.4	1.8	51
	2018	25.5	0.0	46
September	2016	18.0	33.2	63
	2017	19.9	0.7	61
	2018	18.7	42.8	64

Source: The observations and accounting of the weather conditions were performed by Kherson Regional Meteorological Station

The years of the study by the gradation of total evapotranspiration were dry with severe soil and atmospheric drought. That is why soybean cultivation in the South of Ukraine was possible only at performing 8-9 irrigation during the vegetative period. Meteorological conditions during the study were typical for the South of Ukraine.

RESULTS AND DISCUSSIONS

Anthropogenic energy consumption (Ea) for the cultivation of agricultural product included the following points: direct energy consumption (fuel, electricity); energy consumption for production of fertilizers, pesticides, seeds, etc., and energy consumption of productive labor.

As the presented data certify, the higher seed yield is, the higher cost of the cultivated product is (Table 3). At the cultivation of the soybean without application of mineral fertilizers productive expenditures was less in comparison to inclusion of the above-mentioned factor in the agrotechnology.

Production of soybean seed is quite efficient and profitable. In all the variants of the experiment it is provided by the high indexes of net profit and profitability. Conditional net profit was 686-1,898 USD per 1 ha, profitability level – 88-233%.

The elements of cultivation technology and yield have considerable influence on the indexes of economic efficiency of soybean seeds. The maximum share of influence on the index of energy consumption of the technology had agricultural machines – 31.2% and fuels – 25.0% (Table 4).

The less influence had seeds and water – 9.2-15.1%, almost equal share had labor, pesticides and fertilizers – 5.8-6.5%, and the least influence on the energy consumption had electricity – 1.0%.

On the plots of low resource supply, at non-fertilized background, the maximum profit (1074 USD per 1 ha) was got at the plant density of 500 K per 1 ha.

This variant had the least cost price of 23.8 USD per 1 ton, and the highest level of profitability – 155%, and yields of soybean seeds – 2.94 tons per 1 ha.

Table 3. Economic efficiency of soybean cultivation depending on sowing rates and nutritive background (average for 2016-2018)

Nutritive background	Plants density, K per 1 ha	Conditional net profit, USD per 1 ha	Cost price, USD per 1 tonne	Profitability level, %	Seed yield, tonnes per 1 ha
No fertilizers	300	907	25.4	139	2.60
	400	870	26.4	130	2.56
	500	1,074	23.8	155	2.94
	600	984	25.4	139	2.82
	700	870	27.6	120	2.65
	800	824	28.8	111	2.61
	900	776	30.0	102	2.41
	1,000	686	31.3	88	2.44
N_{30}	300	1,209	22.2	173	3.14
	400	1,202	22.7	168	3.16
	500	1,256	22.5	169	3.29
	600	1,844	18.0	237	4.32
	700	1,475	21.1	188	3.72
	800	1,161	24.5	147	3.39
	900	1,244	24.0	153	3.39
	1,000	1,190	25.0	143	3.33
N_{60}	300	1,423	20.9	191	3.57
	400	1,411	21.3	185	3.58
	500	1,679	19.5	212	4.07
	600	1,898	18.2	233	4.47
	700	1,749	19.6	210	4.25
	800	1,584	21.0	189	3.99
	900	1,935	22.6	168	3.77
	1,000	1,969	23.6	157	3.69

Source: Own calculations with accordance to the results of the experiments

Table 4.Share of energy consumption of soybean cultivation with application of fertilizers dose of N_{30} and sowing rate 600 K seeds per 1 ha

The constituents of the energy consumption	The share, %
Seeds	9.2
Fertilizers	6.5
Fuels	25.0
Electricity	1.0
Pesticides	6.2
Labor	5.8
Water	15.1

Source: Own calculations with accordance to the results of the experiments.

Under an increase of plants density from 600 to 1,000 K plants per 1 ha soybean seed yields decreased (from 2.82 to 2.44 tons per 1 ha) and, respectively, profit (from 984 to 686 USD) and profitability (from 139 to 88%) did so, and cost price of the production increased from 25.4 to 31.3 USD.

Mineral fertilizers significantly increased the seed yield. Both application of N_{30} and N_{60} caused an increase of conditional net profit with changes in the plant density from 300 to 600 K of plants per 1 ha by 52.0% (at the background of N_{30}) and by 33.4% (at the application of N_{60}). Profitability also increased, and cost price decreased.

An increase of the plant density per unit of area all the indexes changed inversely: yields decreased from 3.72 to 3.33 tons per 1 ha at N_{30}, and from 4.25 to 3.69 tons per 1 ha at the background of N_{60}, and conditionally net income by 24.0 (at the background of N_{30}) – 27.8% (at the background of N_{60}), profitability from 188 to 143%, and from 210 to 157%.

The obtained data certify that the variants with plants density of 600 K of plant per 1 ha at the application of fertilizers both in the dose of N_{30} and N_{60} provide almost equal economic efficiency. Notwithstanding the fact that at the plant density of 600 K of plants per 1 ha at the background of N_{60} the highest soybean yield was obtained – 4.47 tons per 1 ha, however, profitability was higher (237%) and cost price of the product lower (18.0 USD) at the application N_{30}. The lowest economic efficiency under the application of fertilizers was at the background of the less dose of N_{30} accompanied by high sowing rate of 1,000 K per 1 ha – conditionally net profit was 1,190 USD. High economic indexes were provided by the plants density of 600 K per 1 ha at the application of N_{30}. At the application of mineral fertilizer in the dose of N_{60} at the plant density of 600 K of plants per 1 ha the expenditures slightly rose up (by 1.2%) and conditional net profit increased by 3% comparatively with the plots where N_{30} was applied. The results of the study show that an increase of Nitrogen fertilizer dose just slightly increased both conditional net profit and soybean yield. That is why it is more efficient to cultivate soybean with application of N_{30} and plants density of 600 K per 1 ha. This provided the least cost price of 18 USD per 1 ha, and the highest profitability of 237%.

Efficient energy use allows increasing production at less expenditure. A number of scientists convince that objective assessment of the introduction of new agricultural method is possible only under the conduction of economic and energy analysis that means a comparison not only of money effect but energetic sides of the problem [9, 17, 20].

Energy analysis in agriculture is the assessment of non-renewable energy consumption for crop production and quantity of the obtained with yield energy. The comparative assessment of energy consumption for the studied agrotechnological elements allows using crops cultivation technologies with high yields and the minimum energy resources consumption [15].

These questions are not sufficiently studied for soybean, so, the aim was posed to investigate the energy efficiency of the agrotechnological complex of its cultivation. The index of energy assessment is the energy coefficient (Ke), which is determined as a ratio of obtained with yield energy, to the total amounts of spent anthropogenic energy. A cultivation technology of a crop might be considered as a resource-saving if Ke is more than 1.

To determine the total energy consumption in the variants of the experiment we used its energy equivalents for all means of production, labor resources, fertilizers, fuel, water, seeds, etc., which are presented in scientific works [10, 14].

The total energy consumption per 1 ha of soybean cultivation depending on the variant of the experiment is 33.43-43.74 MJ (Table 5). The least amount of energy was spent in the variants with plants density of 300 K per 1 ha, while thickening of the crops to 900 K per 1 ha increased energy consumption that is explained by high expenses on seed material for sowing with comparatively low yield – 2.77 tons per 1 ha. The total energy consumption was the lowest in the variant with sowing of 300 K of plants per 1 ha without mineral fertilizers, and at the same variant the least energy amount was accumulated in the yield.

Application of Nitrogen fertilizer significantly increased soybean seed yield whereupon energy consumption of its cultivation raised, amount of the accumulated in the yield energy and energy coefficient increased. The energy coefficient changed directly proportionally with the changes in the yields. At the crop density of 600 K of plants per 1 ha on the non-fertilized background the energy coefficient was 1.39, at the application of N_{30} – 1.91, and under the dose of N_{60} – 1.85. At the background of the same plants density the increase of mineral fertilizers dose increased energy consumption by 6.8% because of high energy content in fertilizers, however, it did not provide a considerable increase in yield and energy accumulation that led to the decrease of the energy coefficient, comparatively with the variants where less fertilizer doses were applied (N_{30}). At the application of N_{30} energy coefficient was 1.42-1.91, and at the dose of N_{60} it was 1.47-1.85.

The higher fertilizer dose was used, the higher total energy consumption was.

The energy coefficient at the fertilized background was higher under the crop density of 600 K plants per 1 ha, and at the non-fertilized – at 500 K plants per 1 ha. At the variant of N_{30} the highest quantity of energy accumulated in the yield (76.42 MJ per 1 ha) was at the plant density of 600 K plants per 1 ha, and this variant provided the best payout of energy consumption (36.32 MJ per 1 ha). An increase of the crop density resulted in a decrease of payout of energy consumption on the both backgrounds of mineral fertilizers. Energy consumption for production of 1 ton of soybean seeds at the plant density of 600 K plants per 1 ha had almost equal indexes at the nutritive background of N_{30} (17,689 MJ), and at the application of N_{60} – 17,691 MJ.

Table 5. Energy efficiency of soybean cultivation depending on the crops density and nutritive background, average for 2016-2018

Nutritive background	Plants density, K per 1 ha	Energy consumption, MJ per 1 ha	Energy income, MJ per 1 ha	Energy coefficient	Energy consumption, MJ per 1 ton of yield
No fertilizers	300	33.43	12.03	1.36	1.30
	400	34.06	10.88	1.32	1.34
	500	34.86	16.62	1.48	1.20
	600	35.43	13.92	1.39	1.27
	700	35.99	10.54	1.29	1.37
	800	36.56	9.08	1.25	1.42
	900	37.17	7.58	1.20	1.47
	1,000	37.74	4.89	1.13	1.57
N_{30}	300	36.47	19.08	1.52	1.16
	400	37.12	18.78	1.51	1.17
	500	38.34	19.86	1.52	1.17
	600	40.10	36.32	1.91	0.93
	700	39.85	25.96	1.65	1.07
	800	39.63	17.16	1.43	1.23
	900	40.91	19.06	1.47	1.21
	1,000	41.52	17.39	1.42	1.25
N_{60}	300	39.87	23.28	1.58	1.12
	400	40.52	22.81	1.56	1.13
	500	41.95	30.05	1.72	1.03
	600	42.81	36.27	1.85	0.96
	700	43.33	31.86	1.74	1.02
	800	43.22	27.36	1.63	1.08
	900	43.74	22.95	1.52	1.16
	1,000	44.34	20.94	1.47	1.20

Source: Own calculations with accordance to the results of the experiments.

CONCLUSIONS

The conditional net profit of 1,844 USD per 1 ha, the highest profitability of 237%, and the lowest expenditures per 1 ha of 18 USD were provided at the variant with N_{30} and 600 K plants per 1 ha.

Mineral fertilizer dose of N_{60} at 600 K plants per 1 ha increased the expenditures by 1.2%, and this resulted in the increase of the net profit by 3%, comparatively to the variants with N_{30}.

600 K plants per 1 ha at the fertilization both in the dose of N_{30} and N_{60} provided the equal economic efficiency. Mineral nutrition both of N_{30} and N_{60} caused a considerable increase of the net profit.

The economic efficiency of the soybean cultivation decreased at the fertilizers background of N_{30} and N_{60} in a combination with the increase of the plant density from 700 to 1,000 K. The energy coefficient at the fertilized background was higher at the crop density of 600 K, and at the unfertilized – at 500 K plants per 1 ha.

REFERENCES

[1]Andriyets, D.V., 2013, Soybean yield depending on fertilization on typical black-earths of the Forest-Steppe of Ukraine, Scientific Bulletin of the National University of Bioresources and Natural Resources of Ukraine. Series: Agronomy, 183(2): 87-94.

[2]Calisjan, S., Ozkaya, I., Caliskan, M.E., Arslan, M., 2008, The effects of nitrogen and iron fertilization on growth, yield and fertilizer use efficiency of soybean in a Mediterranean-type soil, Field Crops Research, 108(2): 126-132.

[3]Cavalett, O., Ortega, E., 2009, Energy, nutrients balance, and economic assessment of soybean production and industrialization in Brazil. Journal of Cleaner Production, 17(8): 762-771.

[4]Dobereiner, J., 1997, Biological nitrogen fixation in the tropics: Social and economic contributions, Soil Biology and Biochemistry, 29(5-6): 771-774.

[5]Ghosh, P.K., Mohanty, M., Bandyopadhya, K.K., Painuli, D.K., Misra, A.K., 2006, Growth, competition, yield advantage and economics in soybean pigeonpea intercropping system in semi-arid tropics of India: I. Effect of subsoiling, Field Crops Research, 96(1): 80-89.

[6]Kazakova, I.V., 2012, Economic and energy assessment of resource-saving technologies of cultivation of agricultural crops, Innovative economics: Ukrainian scientific magazine, 2: 113-116.

[7]Krayniak, O.K., 2012, Economic and energetic analysis of technologies for growing legumes, Innovative economics: Ukrainian scientific magazine, 2: 109-113.

[8]Martjianov, V.P., 1996, Methodical instructions for preparation and writing of graduation projects (works) on economic and energy assessment of research results: methodical recommendations, Kharkov, 32 pp.

[9]Medvedovsky, O.K., Ivanenko, P.I., 1989, Energy analysis of intensive technologies in agricultural production, 206 pp.

[10]Nair, B.G., Malthane, G.B., Deshmukh, A.S., 2012, Measurement of economic and allocative efficiency of soybean growers - A data envelopment analysis approach. International Research Journal of Agricultural Economics and Statistics, 3(1): 128-132.

[11]Netis, V.I., 2018, Optimization of elements of soybean cultivation technology on irrigated lands of the South of Ukraine. Thesis for obtaining a scientific degree of the candidate of sciences, Kherson, 250 pp.

[12]Omotayo, B.A., Schultz, B., Adekalu, K.O., Prasad, K., 2015, Crop water productivity and economic evaluation of drip-irrigated soybeans (Glyxine max L. Merr.), Agriculture & Food Security, 4: 10.

[13]Peoples, M.B., Herridge, D.F., Ladha, J.K., 1995, Biological nitrogen fixation: An efficient source of nitrogen for sustainable agricultural production?, Plant and Soil, 174: 3-28.

[14]Peter, D.G., 2008, Economics of soybean production, marketing, and utilization soybeans, Chemistry, Production, Processing, and Utilization: 117-150.

[15]Pimentel, D., Hepperly, P., Hanson, J., Douds, D., Seidel, R., 2005, Environmental, Energetic, and Economic Comparisons of Organic and Conventional Farming Systems, BioScience, 55(7): 573–582.

[16]Rotz, A.C., Roth G.W., Soder, K.J., Schnabel, R.R., 2001, Economic and environmental implications of soybean production and use on Pennsylvania dairy farms, Agronomy Journal, 93(2): 418-428.

[17]Tarariko, Y.O., 2001, Energy assessment of agricultural systems and technologies for growing crops, 380 pp.

[18]Tauer, L., 1989, Economic impact of future biological nitrogen fixation technologies on United States agriculture, Plant and Soil, 119(2): 261-270.

[19]Ushkarenko, V.O., Holoborodko, S.P., Kokovikhin, S.V., Vozhegova, R.A., 2014, Methods of field and laboratory research on irrigated land, Kherson, 286 pp.

[20]Vera-Diaz, M.C., Robert, K.K., Nepstad, D.C., Schlesinger, P., 2008, An interdisciplinary model of soybean yield in the Amazon Basin: The climatic, edaphic, and economic determinants, Ecological Economics, 65(2): 420-431.

[21]Vozhehova, R.A., Borovik, V.O., Rubtsov, D.K., Marchenko, T.Y., 2017, Formation of seed yield of soybean variety of Svyatogor depending on fertilization and density of plants standing under conditions of irrigation of the South of Ukraine, Irrigated agriculture, 68: 45-49.

[22]Vozhehova, R.A., Naidionova, V.O., Melnyk, M.M., 2015, Intensive technologies of soybean cultivation under conditions of irrigation in the South of Ukraine: monograph, Kherson, 176 pp.