Bulgarian Journal of Agricultural Science, 18 (No 2) 2012, 227-232
Agricultural Academy

ECOLOGICAL ASPECTS OF RESOURCE-SAVING TECHNOLOGY OF SOYBEAN

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Abstract

SULEYMENOVA, N., I. RAIYMBEKOVA and D. PETKOVA, 2012. Ecological aspects of resource-saving technology of soybean. *Bulg. J. Agric. Sci.,* 18: 227-232

The elements of a resource-saving technology of soybean growing, providing higher yield and ecological-economic efficiency, were studied. New science-based elements of a resource-saving technology of growing were applied and replacement of soybean after better predecessors, minimizing soil cultivation, increasing the yield (up to 29.8 – 32.3 kg.ha^{-1}) and profitability (up to 60.6 – 83.5 g.kg^{-1}).

Key words: soybean, resource-saving technology, herbicide, weeds, damage criterion of harmfulness, productivity
Abbreviations: q - quintal, ha - hectare, l – litre, m – meter, mm - millimeter, cm – centimeter, pcs. – pieces, THE - Threshold of Economic Harmfulness, AET - Appropriate Economic Threshold, HTC -hydrothermal coefficient

Introduction

At the present stage of the agrarian production, the primary task is the implementation of resource-saving, ecologically safe technologies for growing of agricultural crops. This includes the technologies with minimal, zero cultivation of soil, using herbicides and scientifically based crop rotation (Aliev and Ladonin, 1990; Bazdyrev, 1986). The use of these elements in cultivation of agricultural crops enables the losses of power per a unit output to be significantly reduced (Suleymenova, 2010). It should be taken into consideration, that environmentally correct use of intensive technologies should be entered in biochemical circle of resources and create sustainable agro-phytocenoses. Moreover, the control over the parameters of the technologies in growing of crops allows hidden forms of impaired sustainability and operational maintaining the stability of agro-ecosystems to be shown.

Therefore, search and development of resource-saving and ecologically safe technology of crop cultivation is particularly relevant as it corresponds to the principals of the rational use of the agro-landscape (Zaveryuhin et al., 2000). In this connection, we set to study ecological aspects of a resource-saving technology of soybean growing and its in-

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fluence on scientifically based crop rotation after the best predecessors, determination of its place in crop rotation, minimizing of soil cultivation and replacement of inter-row crops cultivation with herbicides. Moreover, the appropriateness of the elements of the new technology was determined in increase of phytosanitary condition of stand, soil, yield and ecological safety, economic efficiency in cultivation of the main oil crop under conditions of irrigation in South-East Kazakhstan.

It should be noted that in solving of such important and very topical issues of the agro- industrial complex of the Republic of Kazakhstan, a decisive role was played by the project "Increase of competitiveness of the agricultural production", developed in the Ministry of Agriculture, together with the World Bank, turning our attention to conducting investigations, developments and implementation of the complex of events in order the competitiveness of the agricultural production to be improved. Free release of funds within the System of competitive grants for the project and conducting subproject events enabled us to obtain experimental, methodically sound and reliable data about the problems studied in their subsequent formation in scientific papers and recommendations for the production. The realization of the innovative project "Development of a resource-saving technology in growing of soybean and canola under conditions of irrigation in South-East Kazakhstan" was conducted at the Educational Experimental Station "Agro University" of the Kazakh National Agrarian University during the period 2008 – 2011.

Material and Methods

The investigations were conducted at the Educational Experimental Field "Agro University" in the Saymasay village located in North-West part of the Enbekshikazakh region of the Almaty district. The aria is foothill-steppe zone with altitude of 550 – 700 m. The Experimental Field is located in drought foothill zone. The climate of the region is abruptly continental with large daily and annual variations of air temperature, precipitation being 509 mm (MS Almaty, Airport) and 540 mm (MS Esik).

The soils of the Experimental Field are meadow-brown, with heavy mechanic composition, typical for a foothill zone. They are dark brown colored in the humus horizon, its thickness is within 30 – 40 cm, and humus content in the plough horizon is from 2.44 to 2.45 $g.kg^{-1}$.

The study was conducted after the generally accepted methodology in agronomy: experiment, observation, using conventional methods of research. The object of the investigation was crop rotation in stationary experiment of the department of General agriculture and plant growing of Kaz SAU. The variants were situated after the method of randomized plots. Total area of crop rotation was 7360 m^{-2}, plot being 112 m^{-2} (14.0 m x 8.0 m). The harvesting area of the plot was 72 m^{-2} (7.2 m x 10 m).

For the investigation of phytosanitary health, species composition and economic threshold of harmfulness of weeds, micro plot and vegetation experiments were used. To study the features of formation of the agro-phytocenoses, route researches were conducted; quantitative reports were made in relation to the area of the investigated field (Methodical instructions, Libershtayn, Tulikov, 1980). The study of harmfulness of weeds was determined after the methods of VIZR (Methodical guidelines for assessing the harmfulness of weeds - L.: VIZR, 1983).

Phenological observations of crops and weeds were made after Naidin (1959); structure, biometrical indices and yield quality were registered according to "Methods of the State variety testing of agricultural crops (M: Kolos-1971). Mathematical processing of data about yield and statistical processing were made via computer programs Microsoft Excel and Statistics and generally accepted methods (Rokitskii, 1973; Dospehov, 1979); variance analyses of stability of yield was made after Kilchevskii and Hotileva (1977). In the article,

the results from 2008, 2009, 2010 and 2011 were summarized.

Results and Discussion

Soybean is the main oil crop under conditions of irrigation in South-East Kazakhstan, source of a cheap vegetable oil and forage protein it is characterized with a high content of vegetable oil (17 – 26 $g.kg^{-1}$) and well-balanced amino acid composition of proteins (29 – 53 $g.kg^{-1}$). The areas occupied by soybean on the territory of the Republic expand. The increase of areas is connected with the diversification of crop production and optimization of the structures of the area sown. In addition, the expansion of areas of this valuable crop is associated with the favorable conjuncture on the market of vegetable oils. Using conventional technology of soybean growing does not provide the obtaining of potentially possible yield. In that context, we studied the elements of a resource-saving technology, providing yield increase and eco-economic effect of cultivation.

For reasons of efficiency of soybean growing, a herbological monitoring was made of the weed component of agro-phytocenoses where the species composition of weeds and the degree of weed infestation were determined. It was found that in permanent stands of soybean, the species composition of weed vegetation was represented by 35 species belonging to 10 botanical families, as the number of weeds varied from 93.0 to 147.3 $pcs.m^{-2}$. The most commonly found were 25 species, 11 dominant, as: wild hemp (*Cannabis ruderalis* Jan.), field thistle (*Cirsium arvense* Scop), ragweed (*Ambrosia artermisiifolia* L), grey foxtail (*Setaria glauca* P.B), chicken millet (*Echinochloa crus-galli* P.B.), amaranth (*Amaranthus retroflexus* L.), hibiscus (*Hibiscus trionum*), ordinary cane (*Phragmutes communis*), common cocklebur (*Xanthium strumarium*), sugar cane (*Andropogon halepensis*) and crawling couch (*Elytrigia repens*). The soybean stands were of high degree of weed infestation, ratio of the agro-biological groups being - late spring weeds - 53.6 $g.kg^{-1}$, rhizomatous - 17.0 $g.kg^{-1}$.

We determined the place of soybean in crop rotation as agro-method providing scientific-grounded yield increase and soil fertility at the expense of the biological peculiarities of predecessors that did not require additional financial expenses. Depending on the specifics of the growing conditions of predecessors, the phytosanitary condition of the field and studied crop rotations improved, as the weed infestation reduced to 42.3 – 50.2 $pcs.m^{-2}$ (Table 1).

Weed infestation in soybean stands in crop rotation with young and perennial weeds after good predecessors was significantly lower compared with permanent stands due to the ability of the culture itself to suppress weeds, i.e. competitiveness and technology features of its growing.

Main criteria of harmfulness of weeds are the Threshold of Economic Harmfulness (TEH), the Appropriate Economic Threshold (AET), and Critical Period of Weed Harmfulness. For their study, we started field experiments with micro plots with variants where the weeds were from 5 $pcs.m^{-2}$ to 100 $pcs.m^{-2}$. The zero number of weeds was achieved via hand weeding throughout the vegetation period. The next level of infestation was

Table 1
Weed infestation depending on soybean predecessors (average for 2008 – 2011)

Soybean predecessors	Number of weeds		Efficiency of methods of weed control, $g.kg^{-1}$
	Total, $pcs.m^{-2}$	Including perennial, $pcs.m^{-2}$	
Monoculture	147.3	56.9	-
Permanent stand	93.0	46.5	-
After wheat	42.3	14.5	54.4
After maize for grain	50.2	12.0	46.0

5 pcs.m^{-2} and the step of the other variants studied was in 10 pcs.m^{-2}. Soybean stands showed that the Threshold of Economic Harmfulness (THE) of weeds was = 9.8 pcs.m^{-2}, and AET = 19.7 pcs.m^{-2}. When the quality of weeds is higher than THE and AET, the weeds should be exterminated, and such control will be economically reasonable. The critical period of weed harmfulness was determined during the first 20 – 30 day of their development, when the soybean stands were weak, and non-competitive against the weeds.

In crop rotations studied, in growing of wintering wheat in layers and inverted layer of perennial grasses, the weed infestation was approaching THE and AET. That's why against the background of that predecessor an optimal phytosanitary condition was created for the next crop. The number of weeds in the soybean stands after that predecessor was 43.7 – 50.9 pcs.m^{-2}, while in soybean, grown as monoculture the weed infestation was 81.0 pcs.m^{-2}.

The efficiency of the resource-saving agromethod - the best predecessor in weed control in soybean stand was 54.4 – 46.0 g.kg^{-1} and influenced significantly on productivity (Table 2).

Soybean yield after wheat increased up to 28.8 q.ha^{-1}, and after maize up to 28.2 q.ha^{-1}, as the yield increased from 5.5 to 7.1 q.ha^{-1} compared to the permanent stand (21.7 q.ha^{-1}).

The results of the statistical processing of the experimental data by variance analysis proved the reliability of the results obtained, where the accuracy of the field experiment was 3.17 g.kg^{-1}. The magnitude of the significant difference between the studied and control variants was 1.88 q.ha^{-1}, so all studied variants of soybean predecessors were considered to be significant and a acceptable.

On the basis of the reliable results obtained (actual weed infestation in crop and soil) and correlation-regression analysis, a model was developed for prediction of weed infestation of agro-phytocenoses of soybean, depending on the weed infestation of soil by weed seeds and ecological conditions – hydrothermal coefficient during the period of vegetation.

$$Y = 0.0117\ X_1 + 29.52\ X_2 - 21.01$$

where X_1 – number of seeds (million pcs.ha^{-1}); X_2 – the hydrothermal coefficient (HTC), coefficient of multiple correlation being 0.89, which shows a high correlation.

For resource saving, we studied the possibility of reducing the compactions of grounds via replacement of the second and third inter-row soil tillage in soybean by herbicides and the possibilities for minimizing soil cultivation were examined. The effects of Bazagran at a dose of 3.0 l.ha^{-1} and Zenkor at a dose of 7.0 l.ha^{-1} were investigated. Soybean yield in the usual inter-row cultivation according to the adopted technology was only 19 q.ha^{-1} (Table 3).

Replacing the second cultivation with herbicide (Bazagran at a dose of 3.0 l.ha^{-1}) provided 80 g.kg^{-1} destruction of weeds, creating good conditions for growth and development of soybean. Against the background of that herbicide in that variant the third inter-row cultivation at a depth of 14-16 cm improved the soil aeration and air nutrition of the crop and increased yield to 25.8 q.ha^{-1}.

In replacement of the second (Bazagran at a dose of 3.0 l.ha^{-1}) and third inter-row tillage (with

Table 2
Influence of the predecessor on soybean yield (average for 2008 – 2011)

№	Predecessors	Yield, q.ha^{-1}	Addition to yield	
			q.ha^{-1}	g.kg^{-1}
1	Permanent stand	21.7	-	-
2	Wintering wheat (after perennial grasses)	28.8	+ 7.1	+ 41.5
3	Maize for grain	27.2	+ 5.5	+ 30.5
	HCP_{05}, q.ha^{-1}		1.88	
	S_x,g.kg^{-1}			3.17

Table 3
Soybean yield, depending on the minimal soil cultivation (average for 2008 – 2011)

№	Variants of the experiment in inter-row soil cultivation	Soybean, $q.ha^{-1}$	St deviation	
			$q.ha^{-1}$	$g.kg^{-1}$
1-st variant Conventional technology	1-st inter-row soil cultivation, depth of 6-8 cm 2-nd – depth of 10-12 cm 3-rd – depth of 14-16 cm	19.5	St	-
2-nd variant Minimal soil cultivation	1-st inter-row soil cultivation, depth of 6-8 cm 2-nd – replacement with herbicide 3-rd – depth of 14-16 cm	25.8	6.3	32.8
3-rd variant	1-st inter-row soil cultivation, depth of 6-8 cm 2-nd and 3-rd – replacement with herbicide	27.6	8.1	41.5
	HCP_{05}, $q.ha^{-1}$	3.3		
	S_x, $g.kg^{-1}$	1.65		

Zenkor at a dose of 7.0 $l.ha^{-1}$,) the high weed infestation decreased to medium. Using Zenkor at a dose of 7 $l.ha^{-1}$and Bazagran at a dose of 3.0 $l.ha^{-1}$, the number of annual weeds decreased to 22.0 $pcs.m^{-2}$ and perennial – to 3.0 $pcs.m^{-2}$, thus yield increase was provided up to 25.8 – 27.6 $q.ha^{-1}$ or 32.8 – 41.5 $g.kg^{-1}$ and profitability - 60.6 – 83.5 $g.kg^{-1}$. Furthermore, minimizing soil cultivation via replacement of the second and third inter-row cultivations with herbicides improved agro-physical indices of soil fertility, providing resource savings.

Developed elements of resource-saving technology for soybean cultivation provided high economic efficiency. The average yield in conventional technology of soybean growing was 22.5 $q.ha^{-1}$. The value of the production in realization of yield obtained per a hectare according to the accepted technology was 111.5. 10^3 KZT. ha^{-1}, and according to the resource-saving one – 142.7. 10^3 $KZT.ha^{-1}$.

In cultivation of soybean 81.5. 10^3 KZT were spent, considering the loss in soybean cultivation, certain sum conditional net income coming at the expense of using of new scientific-based elements of resource-saving technologies of cultivation, as replacement the soybean after the best predecessors, and minimizing soil cultivation.

In conventional technology of soybean cultivation, 30.0.10^3 $KZT.ha^{-1}$ conditional net incomes were obtained. In resource-saving technology conditional net incomes increased to 34.5. 10^3 $KZT.ha^{-1}$.

The positive economic results and the economic efficiency of the developed resource-saving technology of cultivation of soybean proved also the necessity of implementation in production and continuity of the a project “Resource-saving technology in soybean cultivation under conditions of irrigation in South-East Kazakhstan” in terms of the market.

Conclusion

According to the herbological monitoring of agro-phytocenoses of soybean, it was shown that in permanent stands of soybean the weed species were represented by 35 species, belonging to 10 botanic families, as the number of weeds varied

from 93.0 to 147.3 pcs.m^{-2}, 11 species being dominant and distinguished with high harmfulness.

In study of ecological aspects of resource-saving technologies of cultivation, the place of soybean was determined in crop rotation as agro method providing scientific-based yield increase and soil fertility at the expense of biological features of predecessors, as additional funds were not required. Depending on the specifics and growing conditions of predecessors, the phytosanitary condition of the field of the crop rotation improved when the number of weeds decreased to 42.3 – 50.2 pcs.m^{-2}. The efficiency of the best predecessors (wheat and maize coming after it) in weed control in soybean stands was 54.4 – 46.0 g.kg^{-1} and influenced significantly on the productivity. Soybean yield after wheat increased to 28.8 q.ha^{-1}, and after maize – to 28.2 q.ha^{-1}, as yield increased by 5.5 – 7.1 q.ha^{-1} compared with the permanent stand (21.7 q.ha^{-1}).

On the ground of the reliable results obtained (actual weed infestation of soil) and correlation-regression analysis, a model was developed for prediction of the agro-phytocenoses of soybean, depending on weed infestation of soil by seeds of weed plants and ecological conditions – the hydrothermal coefficient during the period of vegetation, with high level of multiple correlation r = 0.89.

The possibility to reduce compactions of grounds was confirmed via replacement of the second and third inter-row soil cultivation with herbicides and the possibilities to reduce soil cultivation were considered. Replacing the second soil cultivation with herbicide (Bazagran at a dose of 3.0 l/ha) provided 80 g.kg^{-1} destruction of weed plants, creating good conditions for growth and development of soybean. Against the background of that herbicide in that variant, the third inter-row soil cultivation at depth of 14-16 cm improved aeration and air nutrition of crop and yield increase to 24.8 q.ha^{-1}.

In replacement of the second (Bazagran at a dose of 3.0 l.ha^{-1}) and third (Zenkor at a dose of 7.0 l.ha^{-1}) inter-row soil cultivation, the high weed infestation reduced to medium. The use of Zenkor at a dose of 7.0 l.ha^{-1}and Bazagran at a dose of 3.0 l.ha^{-1} decreased the number of annual weeds to 22.0 pcs.m^{-2} and perennial – to 3.0 pcs.m^{-2}, thus provided yield increase up to 25.8 – 27.6 q.ha^{-1} or 32.8 – 41.5 g.kg^{-1} and profitability reached 60.6 – 83.5 g.kg^{-1}. Furthermore, minimizing soil cultivation via replacement of the second and third inter-row cultivations with herbicides improved agro physical indices of soil fertility, providing energy savings.

It has been shown the expedience of the implementation of the elements of the new – resource-saving technology for increase of phytosanitary condition of the stand, soil, yield and the economic efficiency of growing of the main oil crop – the soybean under conditions of irrigation in South-East Kazakhstan in terms of the market.

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Received September, 2, 2011; accepted for printing February, 2, 2012.