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Economic Efficiency and Bioenergetic Assessment of Predecessors and Fertilizer Systems in the Sunflower Cultivation

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Abstract: Sunflower is one of the most profitable crops in Russia. Research was carried out in a multivariate experiment in two 10-course crop rotations with long stationary monitoring. The influence of the crop rotation type and fertilizer doses on sunflower yield and its economic efficiency were studied. The soil is heavy black soil with low humus content arable in layer – 3.90–4.05 %. It was found that it is appropriate and cost-effectively to introduce $N_{20}P_{30}$ under a sunflower, and with sufficient provision of soil mobile phosphates it is possible to apply some nitrogen fertilizer at 40 kg per ha.

Keywords: agroecological monitoring, crop rotation, predecessor, the dose of fertilizer, crop, bioenergetic assessment, economic efficiency

Introduction

The determining factor in growing of any crop is the yield (Korobka *et al.*, 2015; Kvashin, 2008) and the economic efficiency (Maiorana *et al.*, 2005; Maljuga *et al.*, 2011; Romanenko *et al.*, 2010). The sunflower productivity depends on a number of biological and morphological characteristics (Maljuga *et al.*, 2011; Penchukov *et al.*, 2007) as well as on soil (Sheudzhen *et al.*, 2011; Shtompel *et al.*, 2009) and climatic conditions of the region (Dmitrieva *et al.*, 2010; Gontcharov and Zaharova, 2008; Jablonskaja *et al.*, 2016).

In the formation of the yield the priority cultivar is that which determines the level of its genetic potential of productivity (De la Vega *et al.*, 2007; Gontcharov, 2012).

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The effectiveness of sunflower cultivation is also defined by agricultural practices. The main in sunflower technology is the maintenance of crop rotation. The use of pesticides and herbicides (Neshhadim *et al.*, 2015, 2014), fertilizers (Baldini *et al.*, 1996; Kvashin *et al.*, 2011; Neshhadim *et al.*, 2012; Vasilko *et al.*, 2010) and seed industry (Prudnikov and Gorpinchenko, 2013) is also cost-intensive. Genetic resistance of sunflower to some diseases and broomrape can reduce production cost significantly (Gontcharov, 2009, 2014; Skoric, 1988).

Among agricultural crops one of the most profitable field crops is sunflower. Economic efficiency of sunflower cultivation is shown by increasing gross yield of oilseeds and improvement of its technological quality. Reserve of increase of this crop is cultivar changing, science-based crop rotations and fertilizer rational system.

Materials and methods

The research program involved the examination of the influence of crop rotation type, the predecessor, and the systems of fertilizer on productivity and technological quality of sunflower oilseeds, and the cost-effectiveness was calculated.

Ordinary black soil differs with low humus content 4.5–5.5 % and is characterized by large capacity of humus horizon. The amount of total nitrogen is in the range 0.22–0.33 %, of phosphorus – 0.16–0.19 %. The potassium content of ordinary black humus exceeds at 8–10 times the reserves of nitrogen and phosphorus.

The studies were carried out in the northern area of Krasnodar region in the North–Kuban Agricultural Experiment Station in two 10-course crop rotations: grain plowing (GP) and grain-grass plowing (GGP). Alternation of crops in the GP: winter wheat – winter wheat – sugar beet – winter wheat – maize for grain – pea – winter wheat – sunflower – spring barley – maize for grain; in GGP: winter wheat – sugar beet – winter wheat – maize for grain – pea – winter wheat – sunflower – spring barley with over seeding sowing under alfalfa cover – alfalfa (for seeds) – winter wheat.

The fertilizers were applied as follows: 1 – without fertilization (control); 2 – average dose of P (P_{60}); 3 – average dose of N (N_{40}); 4 – minimum dose of NP ($N_{20}P_{30}$); 5 – average dose of NP ($N_{40}P_{60}$); 6 – average dose of NP ($N_{40}P_{60}$) + N_{40} in top dressing; 7 – high dose of NP ($N_{40}P_{120}$ + N_{40} in top dressing). The total area of a plot is 190 m^2, analyzed area – 108 m^2. The experiment was done from 2010 to 2016 in four replications.

Results and discussion

In our studies, the mineral fertilizers in conjunction with weather conditions were affecting the elements of the crop structure, and were changing the gross productivity of the crop. Under the same weather conditions, the lowest productivity of sunflower was formed against the emerging natural agrochemical nutrition of control variants, where the average sunflower yield without fertilizers amounted to 2.69 t/ha, varying from year to year depending on the crop rotation in the range 1.50–3.50 and 1.54–3.43 t/ha (Table 1) during the research period. The rise of the level of mineral nutrition by the application of fertilizers with different combination and ratio of the nutrition was increasing the sunflower seed productivity by 0.10–0.32 and 0.25–0.42 t/ha.

Table 1: The effect of crop rotation and fertilizers on crop yield of sunflower, t/ha.

Fertilizer system	Grain plowing crop rotation		Grain-grass plowing crop rotation	
	crop yield, t/ha	addition to control	crop yield, t/ha	addition to control
Without fertilizer (control)	2.69		2.69	
P_{60}	3.09	0.40	2.98	0.29
N_{40}	3.07	0.32	2.94	0.25
$N_{20}P_{30}$	3.07	0.38	3.01	0.32
N_{40} P_{60}	3.25	0.56	3.10	0.41
$N_{40}P_{60}$ + N_{40} in top dressing	3.39	0.70	3.11	0.42
$N_{40}P_{120}$ + N_{40} in top dressing	3.29	0.60	3.09	0.40
LSD_{05}		0.29		0.24

The response of sunflower plants to fertilizers primarily depended on the provision of the soil by nutrients, so the reaction of the culture to the same dose in different backgrounds of fertility was different. Adding phosphate fertilizer, the value of the collection of seeds from unit of area amounted to an average 3.09 and 2.98 t/ha, that is higher relative to the control variants by 0.40 and 0.29 t/ha or 10.8–14.9 %. The remove of phosphorus against the introducing only nitrogen increased yield by 9.3–11.9 %. The constant use of only nitrogen and phosphate fertilizers ($N_{40}P_{60}$) under sunflower against permanent remove of the potassium fertilizers from the composition (variant 5) promoted the formation of oilseeds yield on the level of 3.07 t/ha, and against the complete mineral fertilizer 3.10–3.25 t/ha. Significant gain in yield is obtained only with respect to the control variants.

Increasing of fertilization rates from medium to high is not accompanied by a significant increase in productivity that indicates the low response of the crop to the high fertilizer rates.

During the research a different effect of crop rotation type on the sunflower productivity was established. A higher crop was formed in the grain plowing crop rotation. These differences probably can be explained by the presence of three crops with deep root system (alfalfa, sugar beet and sunflower) using the moisture from the deeper soil layers in grain-grass plowing crop rotation.

Payback of fertilizers was calculated for the experimental results: the additional crop yield in kg/ha in each variant was divided on the amount of active ingredient of fertilizer in kg/ha. The most effective for the payback of fertilizers were variants with the introduction of only phosphorus (P_{60}) – 6.66–4.83, nitrogen (N_{40}) – 8.00–6.25 and minimum ($N_{20}P_{30}$) – 7.60–6.40 kg/kg fertilizer rates (Table 2).

Table 2: The payback of fertilizers by oilseeds harvest kg/kg.

Fertilizer system	The amount of fertilizer, kg, active ingredient	Crop rotation	
		crop plowing	grain-grass plowing
Without fertilizers, control	–	–	–
P_{60}	60	6.66	4.83
N_{40}	40	8.00	6.25
$N_{20}P_{30}$	50	7.60	6.40
N_{40} P_{60}	100	5.60	4.10
$N_{40}P_{60} + N_{40}$in top dressing	140	5.00	3.00
$N_{40}P_{120} + N_{40}$in top dressing	200	2.85	2.00

In process of increase from N_{40} to $N_{80}P_{120}$ the production expenses were increasing. In comparison with the unfertilized background it was 14.1–56.6 %, while the value of gross output depending on the crop rotation increased only by 2.6–26.0 and 9.3–15.6 %.

The payback of fertilizer was determined by the sunflower crop and production expenses per unit of area invested in its cultivation. This economic indicator was different in variants of the experiment. The high value of a clear profit in the grain plowing crop rotation was obtained by introducing only phosphate fertilizers (P_{60}) and $N_{20}P_{30}$, $N_{40}P_{60}$.

The low cost of sunflower oilseeds and the highest profitability of its production were received by us on the unfertilized control variants as well as using the minimum dose of nitrogen-phosphorus fertilizer.

The use of elevated and high doses is not economically feasible as it leads to higher prices for products by 24.3–46.1 %, and lower profitability.

In the structure of costs in sunflower cultivation the maximum share 24.4–41.0 % is for the cost of seeds, 15.0–40.3 – for fertilizers, 12.8–21.6 % is for energy and only 6.7–11.2 % – for wages (Table 3).

Table 3: Structure of production costs in sunflower cultivation with different fertilizer systems, %.

Fertilizer system	Seeds	Fertilizers	Fuel and lubri-cants	Pesticides	Wage	Operating expenditures
Without fertilizer (control)	41.0		21.6	8.5	11.2	17.7
P_{60}	34.0	16.9	17.9	7.2	9.3	14.7
N_{40}	35.9	12.3	18.9	7.5	9.8	15.6
$N_{20}P_{30}$	35.5	15.0	18.7	5.7	9.7	15.4
N_{40} P_{60}	30.5	25.3	16.1	6.8	8.3	13.0
$N_{40}P_{60}$ + N_{40}in top dressing	26.2	36.1	13.8	5.6	7.1	11.2
$N_{40}P_{120}$ + N_{40} in top dressing	24.4	40.3	12.8	5.2	6.7	10.6

The difference in the value of the production costs is mainly related with the expenses on the purchase and application of mineral fertilizers.

On this basis it follows that it is unprofitably to use higher fertilizer doses under sunflower as the expenses on the sunflower cultivation increase by 1.56–1.68 times.

Bioenergetic assessment of technological methods of sunflower production allows selecting resource-saving methods, reducing the material and technical resources.

In our studies, the expenses of produced and consumed total energy were determined on the basis of energy equivalents. For the calculation of the gross energy its content coefficient accumulated in main and secondary production was used (Table 4).

Resumptive indicator in the energy assessment of crops cultivation technologies is a payback of each included cumulative energy by output of the gross energy.

Table 4: Bioenergetic efficiency of sunflower cultivation with different fertilizer systems.

Fertilizer system	Crop yield, t/ha	Output of gross energy, GJ/ha	Expenses on gross energy, GJ/ha	Increment of cumulative energy, GJ/ha	Net energy efficiency	Expenses on fuel and lubricants per tonnes of seeds	Expenses on labor, person-hour/t
grain plowing crop rotation							
Without fertilizer (control)	2.69	108.96	8.73	100.23	11.5	25.7	1.47
P_{60}	3.09	116.24	9.56	106.68	11.5	22.4	1.28
N_{40}	3.01	113.92	11.93	101.99	8.5	23.0	1.32
$N_{20}P_{30}$	3.07	118.65	11.16	107.49	9.6	22.5	1.29
$N_{40}P_{60}$	3.25	123.86	14.50	121.36	7.5	21.3	1.22
$N_{40}P_{60}$ + N_{40}in top dressing	3.39	129.01	17.86	111.16	6.2	20.4	1.17
$N_{40}P_{120}$ + N_{40} in top dressing	3.269	128.16	20.26	107.90	5.3	21.2	1.21
grain grass plowing crop rotation							
Without fertilizer (control)	2.69	115.36	8.73	106.63	12.2	25.7	1.47
P_{60}	2.98	132.21	9.56	122.65	12.8	23.2	1.33
N_{40}	2.94	136.69	11.93	124.76	10.5	23.6	1.35
$N_{20}P_{30}$	3.01	129.49	11.16	118.33	10.6	23.0	1.31
$N_{40}P_{60}$	3.10	131.34	14.50	116.85	8.1	22.3	1.28
$N_{40}P_{60}$ + N_{40}in top dressing	3.11	133.88	17.86	116.02	6.5	22.2	1.27
$N_{40}P_{120}$ + N_{40} in top dressing	3.09	139.30	20.26	119.04	5.9	22.4	1.28

In all studied fertilizer systems the expenses on cumulative energy in sunflower cultivation were completely compensated by the output of gross energy. However, their bioenergetic effectiveness was different. The minimum output of cumulative energy with main and secondary production of sunflower with rate 108.96 and 115.36 GJ/ha, respectively to type of crop rotation was observed in the sunflower cultivation without the use of fertilizer. With the improvement of the mineral nutrition conditions by applying fertilizers, the cumulative energy output increased by 4.96–20.05 GJ/ha and 14.13–23.94 GJ/ha or 4.55–18.8 % and 12.2–20.7 %, respectively to type of crop rotation. At the same time expenses on energy were increasing. They reached its maximum in both crop rotations at introducing average doses of nitrogen and phosphate fertilizers for a given crop ($N_{40}P_{60}$), higher doses ($N_{80}P_{60}$) and the highest doses ($N_{80}P_{120}$). The expenses were 14.50–20.26 GJ/ha in both type of crop rotation. The largest increment of the cumulative energy in the grain plowing crop rotation was 107.9–121.4 GJ/ha as noted in these cases, and in grain grass crop rotation at introducing P_{60}, N_{40} and $N_{40}P_{60}$ was 118.56–124.76 GJ/ha. These differences are associated with almost equal cumulative energy output and the raise of the expenses with increasing doses of introduced fertilizers.

Thus, at introducing only phosphate fertilizer the output of cumulative energy increased by 6.7–14.6 %, and the expenses by 9.5 %. At introducing only nitrogen it increased by 4.6–18.5 and 36.7 %.

The expenses on fuels and lubricants, share of expenses of which varied accordingly studied fertilizer systems within the 14.6–33.9 %, occupied a significant place in the structure of energy expenses. As the energy expenses connected with the saturation of the fertilizer systems with nitrogen and phosphorus were increasing, the share of fuel expenses in the total amount of expenses reduced from 33.9 % to 14.6 % at the unfertilized background with the introduction of high doses of nitrogen-phosphorus fertilizer. Similarly, the share of expenses on living labor, on operation was changing.

Estimating the role of studied agricultural practices it should be noted that the most energy-intensive in expenses are fertilizer systems with higher and high saturation of nitrogen and phosphorus.

The comparison of two crop rotations on economic and bioenergetic efficiency in the sunflower cultivation shows the advantage of grain plowing crop rotation where the productivity of this crop was higher by 0.12 t/ha. With equal doses of fertilizers and similar expenses a clear profit here was higher by 3.6 % and the level of profitability by 5.9 %.

In evaluating the bioenergetic efficiency the same regularity was found with high energy self cost of 1 ton of seeds, also at a rate of liquid fuel per unit of commodity output was 0.5 kg/ha.

Conclusion

Based on the data of yield it follows that at the sunflower cultivation in crop rotations with the application of different fertilizer systems affecting soil fertility the rate of fertilizer should be reduced, because the increase in doses of fertilizer from medium to high does not provide a gain showing weak sunflower responsiveness to their raise.

In the conditions of insufficient humidifying of Krasnodar region northern area it is feasible and economically justified to introduce a minimum dose of nitrogen-phosphorus fertilizer ($N_{20}P_{30}$) under the sunflower in the ordinary black humus of the Western Ciscaucasia. And with sufficient provision of the soil with mobile phosphates it is possible to apply only nitrogen fertilizer at the rate of 40 kg/ha.

At the given fertilizer systems high profitability 194.9–201.2 % and low production costs 2.98–3.22 thousand rub/t with the coefficient of bioenergetics efficiency 8.5–10.6 are assured.

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