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Prospects for Sunflower Cultivation in the Krasnodar Region with the Use of Plant Growth Regulator

DOI 10.1515/helia-2016-0018
Previously published online December 21, 2016

Abstract: Based on the biological characteristics of sunflower, Krasnodar region is the most favorable area for high and stable yields of this crop in the Russian Federation. However, there is a manifestation of the drought in the summer time that adversely affects the productivity and quality of sunflower seeds. Increased resistance to adverse weather conditions is possible only on the basis of deep studying of the physiological features of formation of productivity and quality of seeds, which is a very urgent task The effect of plant growth regulator furolan on growth, productivity and the formation of physical and chemical indicators of quality of sunflower seeds of the P-453 varieties, the SEC and the RMS selection by VNIIMK were investigated. The treatment of vegetative plants by furolan has activated the growth and biomass accumulation in the stems, improved the photosynthetic activity of plants, leaf area increased, thereby increasing their life expectancy and productivity of photosynthesis. Increased plants productivity reduced their empty grain, increasing the geometric dimensions of the seeds and sunflower kernels, reduced seed husk content, oil content and increased oleic acid content in the oil.

Keywords: sunflower, furolan, efficiency, anti-stress activity, oil content, fatty acid composition

Introduction

Sunflower is one of the most important oilseed crops, which has the great economic importance in the Russian Federation and in the world. World sunflower crop area is more than 22.33 million hectares. It is cultivated in Argentina,

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the USA, Canada, Spain, Turkey, Romania, France, Bulgaria, Austria, Tanzania, the Republic of Moldova, Ukraine and other countries. There is 75 % of planting acreage of all oilseeds and up to 80 % of the produced vegetable oil (Sonin et al., 2010a, 2010b; Kalaydzhyan et al., 2007).

The increased resistance to adverse weather conditions is possible only on the basis of deep studying of the physiological features of formation of productivity and quality of seeds, which is a very urgent task (Yablonskay, 2015a, 2015b, 2015c; Kalaydzhyan et al., 2009a).

One of the ways to address this issue is the use of growth regulators with anti-stress activity, contributing to the improvement of sowing qualities of seeds and increase in the productivity and resistance of plants to stressful environmental factors (Yablonskay, 2015a, 2015c; Kalaydzhyan et al., 2009a).

Such drugs ranks created in the Kuban State University of Technology (KubSTU) a growth regulator, furolan 2-(2-furyl)-1,3-dioxolane with anti-stress activity, permitted for use in Russia. It contains in its structure a furan cycle, which accounts for its low toxicity. The drug is used in doses of 2–6 g/ha, in its residual products and environments are not available. Furolan has a positive effect on physiological and biochemical processes, increases productivity of plants of rice, winter wheat, maize, increases their resistance to adverse growing conditions, increasing the resistance to dehydration and giving the leaves xenomorphic structure and leads to defeat of fungal diseases due to an increase in the levels of lignin in plants.

Furolan increases the length of poly (A) sequence at the 3′ end of the mRNAs, increases their stability, which causes the activation of protein synthesis.

We studied the effect of growth regulator furolan drug for sowing qualities of seeds, growth, productivity formation of physico-chemical indicators of quality of sunflower seed P-453 varieties, the SEC and the RMS selection VNIIMK's named of V.S. Pustovoyt.

Materials and methods

Objects of research were varieties of sunflower P-453, SEC and ECM, selections of all-Russian Scientific Research Institute of Oilseeds (FGBNU VNIIMK them. Pustovoyt VS). Furolan drug is synthesized in the Problem Research Laboratory (KubSTU), quality indicators conform to TU 2449-006-02067862-2000. The study was carried out in a multi-factor experiment on the experimental fields of the central base FGBNU VNIIMK them. VS Pustovoyt and production conditions in the "Kuban" Pavlovsk district of the Krasnodar region in 2013–2015.

The experiment was conducted for three times. The area of the plot is 28 m^2, accounting area plot is 14 m^2. To achieve the objectives the applied laboratory and field research methods, in the field experiments were laid in accordance with the scheme:

1. control (water treatment),
2. pre-sowing seed treatment with an aqueous solution of furolan (drug consumption 5 g and water 10 dm^3/t of seeds),
3. processing of sunflower plants in the early phase of bud formation an aqueous furolan (drug consumption 5 g and water 300 dm^3/ha),
4. consistent treatment of seeds before sowing and growing plants – in the early phase of budding in the mentioned doses.

In accordance with the methodology and agronomic field experiments was determined by height of plants, mass of stems, the weight of the baskets, the mass of leaves, leaf area per plant in the phase of beginning of bud formation, growth of seeds and fully mature seeds; the diameters of the baskets and pustozernoy in the middle of the baskets (the central zone of the basket without seeds) – in the phase of full maturity of the seeds, the crop structure (weight of seeds in a basket, quantity, distribution of seeds in the zones of the inflorescence) in the phase of full maturity of seeds biological harvest seed collected accounts of plots; the leaf area, photosynthetic potential (PP), the net productivity of photosynthesis (PEF) was determined on selected plants from each variant in phases: the beginning of budding, seeds, growth and full maturity, seed size by measuring the linear dimensions (Nichiporovich, 1961), the quality of seeds is in accordance with the requirements of the existing standards, the oil content – by means of NMR analyzer NMR AMV 1006 M VNIIMK laboratory under GOST R 8.620-2006, sunflower oil fatty acid composition of seed oil – by the method of gas-liquid chromatography apparatus Crystal 2000-M. Experimental data were processed using statistical analysis methods.

Results and discussion

From the literature it is known that pre-sowing seed treatment with growth regulators can improve their vigor, activating the growth and development of seedlings. In the laboratory we determined the influence of the drug in furolan in the previously established optimal dose (0.05 %) on the growth seedlings of sunflower varieties P-453, the SPK and the SUR, differing in growth rate and resistance to stress factors (Figure 1).

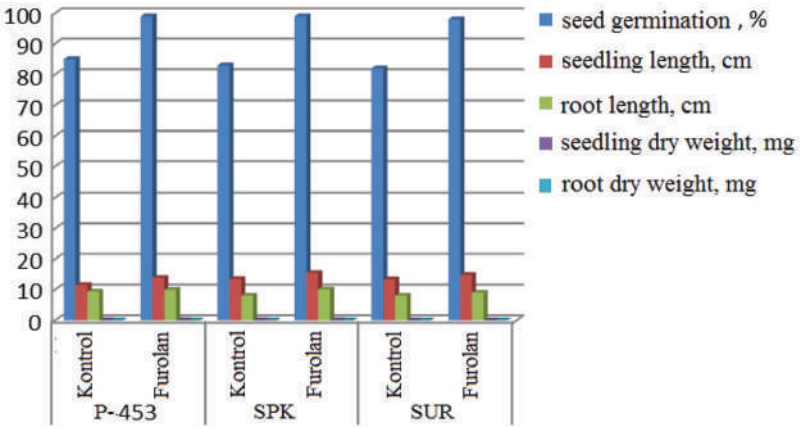

Figure 1: Impact of furolan on sowing qualities of sunflower seeds.

It was found that pre-sowing treatment with furolan affected the germination of seeds of sunflower, activating while in the variety P-453 growth of the sprout system, the variety of SEC – growth and biomass accumulation in the roots and varieties SPK – primarily biomass accumulation, both sprout and seedling root systems. Thus, the drug furolan preliminary treatment of seeds srednerosloe grade P-453 activates the growth of seedlings sprout system taller SPK – root growth, stunted in SUR – both the root and sprout systems.

The use of growth regulators is one of the most effective agricultural practices in the cultivation of sunflower and allows one to more fully realize the genetic potential of plants. In this regard, there was worked out the optimal technology (timing and frequency of application) of the drug (Figure 2).

It was found that the most effective single modification of the drug furolan on sunflower varieties SPK was in the beginning phase of budding, which allows to increase the height of the plants by 8.9–14.2 % in comparison with the control. The impact of furolan on the growth of sunflower was the most evident in the most responsive tall cultivar SUR and less responsive short-stem varieties P-453 and SUR. In 2007, the plant height of sunflower varieties P-453 in the full maturity phase was lower than in 2013 and 2015, 8.5 cm (5 %), SUR – 9.0 cm (4.8 %), due to the negative impact of drought on growth. Application of furolan during the beginning of budding reduced drought effects on plant growth, the height of which reaches full maturity phase at the grade P-453 189.3 in 2013, 188.5 cm in 2014 and 189.0 cm in 2015, the variety of SPK 223.9, 206.0 and 230.0 cm and grade SUR 165.0, 159.5 and 166.0 cm, respectively.

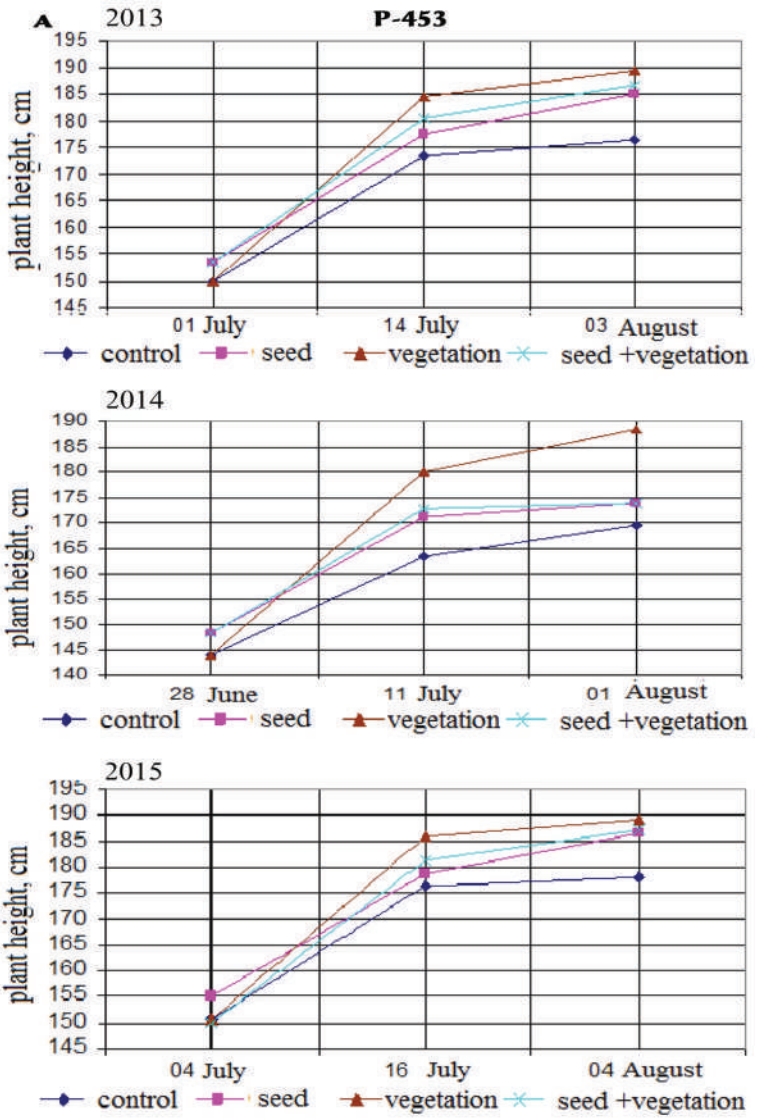

Figure 2: (a, b, c) Effect of the drug on the growth furolan sunflower plants.

Spare material stored in the stems of sunflower plants, then used in the formation of achenes in a basket. In this regard, in 2013–2015 we studied the accumulation of the mass of sunflower stalks. The most effective was a single introduction of the drug in phase furolan beginning of budding, which allows

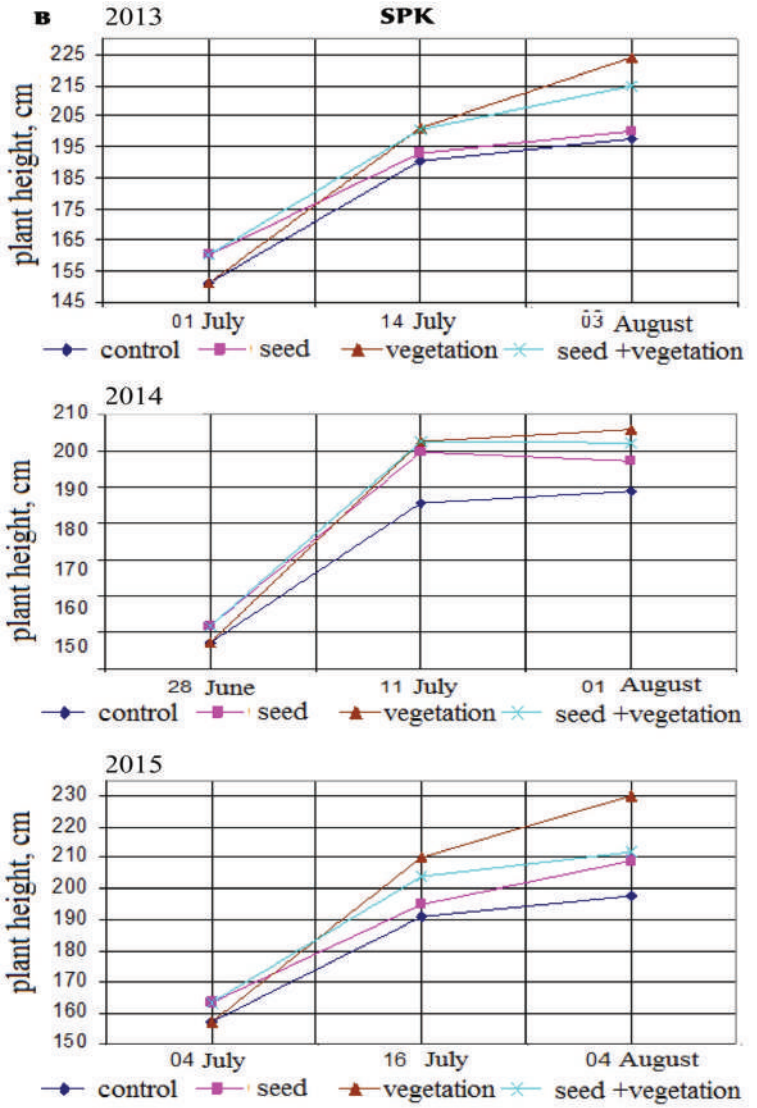

Figure 2: (Continued).

to increase the weight of the sunflower stems in full maturity phase at the grade P-453 25.4–25.7 %, from the SPK grade 53.5–58.4 % and the variety SUR 55.2–79.0 % compared with the control. Consequently, a short-stemmed varieties of sunflower R-453 and SUR furolan activates the biomass accumulation in the stems, and at average height SPK growth.

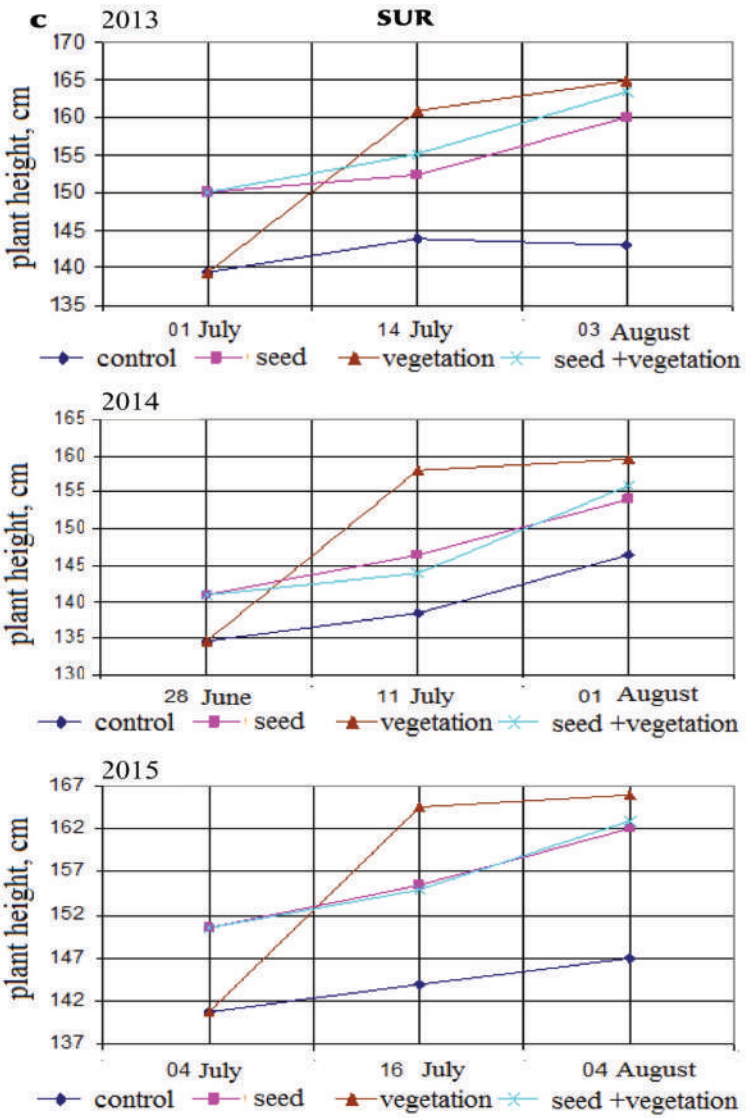

Figure 2: (Continued).

Indicators of activity are photosynthetic sunflower area and density of the leaf blade, leaf surface area of the plant, photosynthetic potential (PP) and net photosynthetic productivity (PEF). Leaf area is an important factor in the accumulation of dry weight of plants and, ultimately, the value of the crop. The

amount of leaf surface – a sign of a dynamic, constant changing in the process of growth and development of plants. Furolan single application of drug in the beginning of budding phase most effectively and increases in leaf area seed growth phase at 78.2–99.4 % in comparison with the control and to a greater extent to full maturation phase, which characterizes the leaves a longer duration of life. Reduction of leaf surface area, in some cases after the beginning of budding phase is due to the withering away of the lower leaves on the plants. Processing seeds and sunflower plants preparation furolan in all variants of the experiment led to an increase in the surface area of the sheet and to a greater extent in short stature varieties SUR, which is associated with a reduction in the intensity of the withering away of the lower leaves as compared to control samples.

The interphase period beginning bud – growth of seeds, an increase of the photosynthetic capacity of the average over three years: in grades P-453 up to 20.8 %, SPK grade to 38.0 %, and SUR grade to 42.7 %. Net photosynthetic productivity over the same period increased more effectively by treatment of vegetating plants: the variety P-453 46.2 g/m^2 per day, grade SPK 29.8 g/m^2 day and varieties SUR 73.9 g/m^2 per day.

The interphase period of growth of seeds – full maturity of seeds increased photosynthetic potential: in grades P-453 to 35.5 %, SPK grade to 36.4 % and grade SUR to 94.3 %. Net photosynthetic productivity over the same period increased: from P-453 grade of 4.6–10.4 g/m^2 per day, SPK grade 3.7–17.3 g/m^2 per day and varieties SUR 10.2–26.2 g/m^2 per day.

The interphase period beginning bud – growth of seed varieties have studied the processing of sunflower plants in the beginning phase of budding furolan photosynthetic activity sheet device was more effective, which is characterized by greater PEF value, especially in varieties of P-453. The drug furolan restrained decreasing of PEF, which is associated with the extension of the life cycle of leaves.

In the context of 2013 and 2015, diameter sunflower basket increased in all grades in comparison with the dry 2014.

Determination of the diameter of the basket was carried out in full seed ripening phase. Processing furolan sunflower plant has increased the diameter of the basket grade P-453 2.9–6.6 cm, grade SPK 0.5–3.4 cm and SUR grade 1.7–4.1 cm, compared to control. Most effective increase basket size occurred in the processing of vegetating plants in the phase of preparation of the start of budding.

One of the indirect signs that characterize the productivity of sunflower, is the basket area occupied by the seeds. It is also known as a productive area of the basket. The productive area of the basket is determined by the difference of the total area and the area of its baskets pustozernoy (having empty or hollow

Table 1: The effect of furolan on the productive area on sunflower basket in different sunflower varieties (cm^2).

Variety	P-453			SPK			SUR		
	2013	2014	2015	2013	2014	2015	2013	2014	2015
1	224.2	193.5	234.9	254.3	191.0	257.2	148.3	114.7	159.8
2	329.9	271.6	342.9	268.7	221.6	274.5	207.1	167.3	218.9
3	415.3	352.8	448.4	342.9	274.5	362.9	242.7	221.6	283.4
4	383.4	317.1	390.4	329.9	265.8	346.2	217.7	181.4	237.7

Notes: 1 – control; 2 – seed treatment; 3 – treatment of vegetative plants; 4 – treatment of seeds and vegetating plants.

seeds) part. Studies have been conducted on the effect of the drug on furolan productive area of the basket (Table 1).

The diameter of the basket pustozernoy grade RMS in the control sample was as follows: in 2013 4.3 cm, in 2014 4.3 cm, and the remaining samples of the treatment options empty grain were not observed 4.5 cm in 2015. Furolan increased the productive area of the basket compared to the control:

- At grade P-453 in 2013 to 47.1–85.2 %, in 2014 40.4–45.9 and 90.9 % – 82.3 %, in 2015;
- At the SPK grades in 2013 to 5.7–34.8 %, in 2014 to 16.0–6.7 and 41.1 % – 43.7 %, in 2015;
- The variety of SUR in 2013 to 39.6–63.7 %, in 2014 45.9–36.9 and 77.3 % 93.2 %, in 2015.

Thus, furolan increased the productive area of the baskets by 5.7–93.2 % compared with the control and the most effective impact of the drug had at processing plants especially short-stemmed varieties in the beginning of budding.

Studies conducted in 2013–2015 revealed that seed weight in the basket in 2013 and in 2015 was higher than in 2014. This can be explained by more favorable weather conditions. The results on the influence of drug furolan on sunflower seed weight basket are shown in Table 2. Processing drug sunflower growing plants furolan most effectively increases seed weight in the basket, especially in shortness variety ECM in all zones of inflorescences.

In drought conditions, the mass of seeds in the edge of the basket in the studied varieties (SPK and SUR) is reduced, and in the middle part of basket is increasing. The drug Furolan has a positive effect on the weight distribution of seeds, increasing its in central and marginal areas and reducing in the middle.

Table 2: The influence of the drug on the weight of furolan basket sunflower seed (g).

Sort	Variety	Seed mass (g)											
		General			Central zone			Middle zone			Edge zone		
		2013	2014	2015	2013	2014	2015	2013	2014	2015	2013	2014	2015
P-453	1	56.98	54.96	57.87	1.49	1.41	1.55	21.00	19.91	21.18	34.49	33.64	35.14
	2	68.01	62.86	68.22	2.06	1.95	2.25	21.42	20.28	21.91	44.53	40.63	44.06
	3	83.75	80.38	84.59	4.00	3.57	4.03	28.75	28.31	28.81	51.00	48.50	51.75
	4	76.53	67.36	76.82	3.26	3.04	3.42	22.38	22.76	22.62	50.89	41.56	50.78
SPK	1	66.63	57.21	67.72	2.05	1.83	2.11	19.43	17.55	19.94	45.15	37.83	45.67
	2	80.15	73.45	80.42	2.98	2.71	3.03	23.11	23.10	23.61	54.06	47.64	53.78
	3	91.42	73.50	91.81	2.99	2.77	3.07	25.09	23.56	25.10	63.34	47.17	63.64
	4	82.31	71.00	83.26	2.91	2.65	3.02	21.97	21.05	22.13	57.43	47.30	58.11
SUR	1	27.29	30.03	25.06	0.17	0.16	0.17	12.21	16.22	12.37	14.91	13.65	12.52
	2	42.53	35.02	44.20	1.06	0.98	1.08	18.15	12.82	18.96	23.32	21.22	24.16
	3	74.01	67.17	75.61	2.75	2.67	2.98	29.85	28.98	30.01	41.41	35.52	42.62
	4	50.75	49.82	50.84	2.66	2.36	2.74	22.01	21.58	22.18	26.08	25.88	25.92

Notes: 1 – control; 2 – seed treatment; 3 – treatment of vegetative plants; 4 – treatment of seeds and vegetating plants.

In 2013–2015 years a study was conducted furolan influence of the drug on the number of seeds in a sunflower basket. In the variety P-453 the number of seeds in the basket increased by 110–380 pieces, SUR varieties 107–191 pieces and grade SPK at 60–885 pieces. Furolan allowed to increase the number of seeds in a basket of sunflower varieties. The yield of any crop, including sunflower a quantitative trait, which directly affects the economy.

The different natural conditions, the value yield of sunflower varieties depends on many factors, including plant stand, perform baskets, seed weight per plant, weight of 1,000 seeds, resistance to diseases, pests and adverse conditions (Table 3).

Table 3: Effect of furolan on seed yield of different sunflower varieties.

Sort	Variety	Seed moisture (%)			The mass of seeds with a plot (kg)			Biological seed yield (t/ha)		
		2013	2014	2015	2013	2014	2015	2013	2014	2015
P-453	1	8.1	8.1	8.2	4.2	3.9	4.3	2.99	2.76	3.01
	2	8.0	8.0	8.3	4.9	4.7	5.1	3.52	3.31	3.58
	3	8.2	8.3	8.3	5.1	5.1	5.2	3.61	3.59	3.67
	4	8.4	8.3	8.4	4.5	4.5	4.6	3.19	3.17	3.21
SPK	1	8.0	8.0	8.4	4.4	3.9	4.4	3.11	2.81	3.12
	2	8.1	8.0	8.3	4.9	4.9	5.0	3.50	3.43	3.52
	3	7.9	7.9	8.3	5.2	5.1	5.3	3.65	3.62	3.71
	4	8.3	8.1	8.3	4.5	4.5	4.6	3.15	3.18	3.23
SUR	1	7.9	7.9	7.7	3.7	3.3	3.8	2.59	2.35	2.67
	2	7.9	7.8	7.8	4.1	4.0	4.1	2.87	2.84	2.91
	3	7.7	7.8	7.7	4.4	4.3	4.4	3.09	3.08	3.11
	4	7.9	7.8	7.7	3.8	3.7	3.9	2.68	2.61	2.76

Notes: 1 – control; 2 – seed treatment; 3 – treatment of vegetative plants; 4 – treatment of seeds and vegetating plants.

In the variety P-453 furolan increased biological yield in 2006 to 6.7–14.9, in 2007 6.6–21.9 % and in 2008 20.7 % – 30.1 %; at the SPK grade 1.3–17.4 %, 13.2–28.8 % and 3.5–18.9 %, respectively; cultivar SUR 3.5–19.3 %, 11.1–31.1 % and 3.4–16.5 %, respectively, compared to control and was the most effective in the treatment of plants in the beginning phase of budding. Higher yields and oil seeds provides a higher yield of oil per unit area.

In the treatment of drug oil collection increased:

– At the P-453 varieties in 2013 at 109.2–304.2 kg/ha in 2014 to 251.1–428.4 kg/ha and in 2015 96.7 – 304.5 kg/ha;

– At grade SPK in 2013 32.7–287.9 kg/ha in 2014 to 143.6–383.3 kg/ha and in 2015 76.0–276.0 kg/ha;
– The variety of SUR in 2013 61.5–259.9 kg/ha in 2014 to 114.7–297.4 kg/ha and in 2015 52.6–224.4 kg/ha, compared to the control.

When processing drug furolan sunflower plants at the onset of budding all varieties studied significantly increased seed size and geometry of the nucleus in the central zone predominantly baskets and increasingly – width and thickness. The most responsive varieties were P-453 and RMS less as in the SEC drought, and in favorable weather conditions. Weight of 1,000 seeds was increased in all treatment options: in grades P-453 4.27–6.13 g, y SPK grade 1.26–7.68 g and grade SUR 0.47–1.87 g in 2014, the mass of 1,000 seeds was lower than in 2013 and 2015, due to drier conditions of the growing season (Table 4).

Table 4: Physical and chemical quality of sunflower seeds grade.

Sort	Variety	Mass of 1,000 seeds (g)	Husk content (%)	Oil content (%)
P-453	1	56.25	25.2	44.6
	2	60.52	22.9	45.2
	3	62.38	20.9	46.7
	4	61.93	22.5	46.1
SPK	1	82.75	30.4	43.4
	2	84.01	29.1	43.5
	3	90.43	24.5	45.5
	4	84.31	27.1	44.1
SUR	1	55.44	25.1	48.3
	2	56.01	23.8	49.1
	3	57.31	20.6	49.3
	4	55.91	22.5	49.0

The wetter, the mass of 1,000 grains has increased significantly as a result of more favorable conditions for ripening seeds. All the studied sunflower varieties in the central zone of the basket of seed husk content when making furolan increases, and in the medium and marginal areas of the basket decreases. The most effective use of the drug in phase at the beginning of budding is middle-tall SEC with a lower oil content, reduces husk content as the middle and in the marginal areas of the same.

Thus, in 2013–2015 from varieties of P-453 and SUR seeds of regional zones of inflorescences accumulate more oil than the seeds of the middle zone. This is

primarily due to the fact that the period of accumulation of the oil in them is longer. Processing of sunflower plants of all varieties studied in the beginning of budding drug furolan increases oil content in the seeds of highly varieties. In the variety P-453 oil content increased 2.1 %, from the SEC grade 2.1 % and the grade of RMS 1.0 %.

In vegetable oil for human body nutritional value are the following fatty acids: palmitic, stearic, oleic and linoleic acids. The results determining the effect of furolan on the fatty acid composition of sunflower seeds on the average for 2013–2015 are presented in Table 5.

Table 5: The effect of the drug furolan on the fatty acid composition of sunflower seeds.

Sort	Variety	Fatty acid (%)				
		Palmitic	Stearic	Oleic	Linoleic	Other
P-453	1	5.58	3.88	34.04	55.28	1.23
	2	5.46	4.04	35.44	53.85	1.22
	3	5.30	4.00	38.44	51.16	1.11
	4	5.41	3.86	37.33	52.27	1.14
СПК	1	5.50	4.00	37.12	52.14	1.25
	2	5.48	4.03	39.24	50.06	1.19
	3	5.29	4.38	41.46	47.62	1.26
	4	5.41	4.08	40.10	49.16	1.26
СУР	1	5.67	4.14	35.75	53.33	1.13
	2	5.66	4.33	36.07	52.73	1.22
	3	5.50	4.35	38.91	50.11	1.15
	4	5.66	4.13	37.68	51.33	1.21

In the P-453 grade oleic acid content is increased by 1.40–4.40 %, and linoleic – reduced by 1.43–4.12 %; at the SEC grade oleic acid increased by 2.12–4.34 %, and linoleic – reduced by 2.08–4.52 %; the variety RMS oleic acid increased by 0.32–3.16 %, and linoleic – reduced by 0.60–3.22 %.

The drug is most effective influence on the increase of stearic acid and oleic acid in the processing of vegetative plants. by reducing the content of other fatty acids.

Increasing the oleic acid content in sunflower seeds under the influence of furolan improves the digestibility of vegetable oil. Some decrease of linoleic acid does not reduce the nutritional value of vegetable oil.

Use of the preparation furolan on vegetating plants in the processing phase beginning in the most efficient budding seeds allows to obtain a higher quality,

increase profitability for growing sunflower varieties on P-453–102%, SEC – 161% and RMS – 77.5% in comparison with the control due to increased seed yield, weight, personality and increase oil collection per unit area by an average of 39.6%.

Thus, the use of the drug in furolan sunflower cultivation in the beginning of budding increases biological seed yield by 0.44–0.83 t/ha. The economic effect from the use of furolan in this case is 7,911.00–17,260.00 rubles/ha.

Conclusions

Based on the research conducted for the first time we have found that the plant growth regulator furolan affects the donor-acceptor ratio in seedlings of sunflower varieties, activating growth-ripening varieties primarily shoots, while the middle – the root system. It is shown that the treatment of vegetative plants in the beginning of budding furolan drug activates the growth and biomass accumulation in the stems, and the most effective in low-growing varieties, thereby improving the photosynthetic activity of sunflower plants, increased leaf area, which in turn improves their life expectancy and net photosynthetic productivity.

The application of growth regulator furolan significantly increases the productivity of sunflower plants due to the increased mass of 1,000 seeds and their amounts in the basket, reduced their pustozernost. Also the increase of the geometric dimensions of seeds and kernels of sunflower is mainly from more oilseeds varieties in the central zone of the basket and to a greater extent, width and thickness, reduced seeds husk content in the middle and edge zones of the inflorescences, increased oil content and oleic acid content in the oil.

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