



GROWTH, YIELDING AND HEALTHINESS OF GRAPEVINE CULTIVARS ‘SOLARIS’ AND ‘REGENT’ IN RESPONSE TO FERTILIZERS AND BIOSTIMULANTS

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ABSTRACT

In the years 2008–2015, field experiments were conducted on the vines of cultivars ‘Solaris’ and ‘Regent’ grafted on SO4 rootstock. The following treatments: 1. control (untreated), 2. NPK (mineral fertilization 70 kg N·ha⁻¹; 40 kg P·ha⁻¹; 120 kg K·ha⁻¹), 3. mycorrhizal substrate (AMF – Arbuscular Mycorrhizal Fungi), 4. NPK + AMF, 5. manure (before planting), 6. NPK + manure (before planting), 7. Bioilsa, 8. NPK + Bioilsa, 9. BF-Ecomix, 10. NPK + BF-Ecomix, 11. Ausma and 12. NPK + Ausma were applied to evaluate the usefulness of biostimulants and mineral and organic fertilizers in organic grapevine production in “cool climate” conditions of Poland. The tests did not show a definite positive effect of the biostimulants and organic fertilizers on growth, yielding and healthiness of the cultivars ‘Solaris’ and ‘Regent’. There were no substantial differences in total marketable yield in the years 2009 to 2015 between control and other treatments. Grapevines planted in soil rich in minerals grew and yielded well despite no mineral fertilization for a number of years. In 2014, when the air humidity was high during vegetation, intensive rotting of the berries of cultivar ‘Solaris’, caused by *Botrytis cinerea*, was observed on plants fertilized with NPK.

Key words: *Vitis* sp. L., field trials, fertilization, bioproducts

INTRODUCTION

Grapevine is one of the most important fruit crops in the world. Majority of fruit picked from the cultivation area of 7.6 million ha is processed into wine, and the annual global production of this wine amounts to 265 million hectoliters (OIV – International Organization of Vine and Wine 2013). In Poland, the total vineyard area is estimated at 600–700 ha, but in the past decade, it has been systematically expanding every year. The cultivars ‘Solaris’ and ‘Regent’, commonly cultivated in Poland, were bred in Germany and are classified either as *Vitis vinifera* cultivars (Vitis International Variety Catalogue 2016) or as inter-intraspecific hybrids (Theocharis et al. 2010). Both ‘Regent’ and ‘Solaris’ are characterized by resistance to frost higher than most of the original *Vitis vinifera* cultivars and low sensitivity to fungal diseases (Lisek 2010; Lott et al. 2010).

The roots of grapevine (*Vitis vinifera* and other *Vitis* species) in field conditions are commonly colonized by arbuscular mycorrhizal fungi (Schreiner 2003; Schreiner & Mihara 2009; Balestrini et al. 2010). The presence of mycorrhizal fungi is vital for the normal growth and development of grapevine (Biricolti et al. 1997; Linderman & Davis 2001). Improved growth of grapevine of various cultivars, which results from mycorrhization, is closely related to the uptake of the following minerals from soil: phosphorus (Schreiner 2007; Ozdemir et al. 2010), nitrogen (Hawkins et al. 2000; Mäder et al. 2000; Hodge et al. 2001; Patrick et al. 2004), iron, copper and zinc (Turan & Köse 2004; Ozdemir et al. 2010). AM fungi increase grapevine’s tolerance to drought (Nikolaou et al. 2003; Schreiner 2003; Schreiner & Linderman 2005; Schreiner et al. 2007, Donkó et al. 2014). AM fungus *Glomus versiforme* activates

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grapevine's (*Vitis amurensis* Rupr.) defense mechanism against parasitic nematodes *Meloidogyne incognita* (Li et al. 2006). Inoculation of grapevine roots with the *Glomus iranicum* mycorrhizal fungi reduces the effects of water stress, improves photosynthesis and yield, and speeds up the ripening time of table grapes cv. 'Crimson' (Nicolás et al. 2015). The soil pH below 5.5 reduces the colonization of roots by the arbuscular mycorrhizal fungi – AMF (Schreiner & Linderman 2005), as does the soil cultivation in the interrows (Schreiner 2005). Shallow soil cultivation accompanied by weed control in the grapevine row does not limit the colonization of grapevine roots by the arbuscular mycorrhizal fungi (Baumgartner et al. 2005).

Between biostimulants, applied successfully in the cultivation of grapevine, the following were reported: chitosan (Górnik et al. 2008), nitrophenols (Asahi SL) (Górnik et al. 2007) and marine-plant extracts (Colapietra & Alexander 2006; Norrie & Keathley 2006; Kok et al. 2010; Mohamed et al. 2013; Popescu & Popescu 2014; Stroe & Budescu 2013).

The aim of the application of biostimulants is also the reduction of sensitivity of grapevine (*V. vinifera* L.) to fungal and phytoplasmatic diseases. It was successful in using different preparations containing extracts of algae (Aziz et al. 2003; Žežlina et al. 2010; Le Mire et al. 2016). Glutathione + oligosaccharides and benzothiadiazole applied as foliar treatment, inhibit the development of *Phytoplasma* (Bois noir) on grapevine (Romanazzi et al. 2009). Biofertiliser improved both vegetative growth, yield and fruit quality of two seedless grapevine cultivars (El-Sabagh et al. 2011a, b).

The aim of the study was to assess the effect of biostimulants, mineral and organic fertilizers on growth, yield and health status of plants of the grapevine cultivars 'Solaris' and 'Regent' in a multi-year field experiment and also, to evaluate their usefulness in organic production in "cool climate" conditions.

MATERIALS AND METHODS

The field experiment was conducted in the Experimental Orchard of the Research Institute of Horticulture in Skierniewice, central Poland (latitude 51°57' N, longitude 20°08' E), located on a medium

quality pseudo-podsolic soil (graded Class IV), slightly acidic (pH 6.0), containing (as % DW): 2.37 N, 0.15 P, 1.35 K, 0.22 Mg, 1.64 Ca; microelements (mg kg⁻¹): 3.2 B, 13.5 Cu, 1084 Fe, 96.6 Mn and 11.8 Zn, and 1.3% of organic matter. The average sum of active temperatures (SAT) – medium daily temperature higher than 10 °C – in Skierniewice in the years 2008–2015 amounted to 2627 °C. SAT varied from 2422 °C in 2010 to 2851 °C in 2014. The average annual total precipitation amounted to 500 mm and ranged from 316 mm in 2015 to 680 mm in 2010. In the course of the study, the following minimum winter temperatures below –20.0 °C were noted: –23.0 °C (6.01.2009); –28.1 °C (26.01.2010); –22.3 °C (22.02.2011); –23.3 °C (04.02.2012); –21.4 °C (24.03.2013). Plants of two "PIWI" (abbreviation from German "Pilzwiderstandsfähig" – fungus resistant) grapevine cultivars 'Solaris' (with yellow-green berry skin) and 'Regent' (blue-black), grafted onto rootstock SO4 (*V. berlandieri* x *V. riparia*), were planted in the spring of 2008 and trained as a double Guyot with 10–14 bud canes and low (0.3–0.4 m) trunk. The experiment was conducted in randomized complete blocks with 4 replications and 4 plants in each (16 vines per treatment). The spacing between plants in the row was 1.25 m, in the inter-rows 2.7 m, and the isolation strip between the plots was 1 m wide. From the time of planting until 2012, in the months between May and August, the soil in the inter-rows was cultivated with a rototiller every 4–6 weeks. From 2013, the inter-rows were maintained under spontaneous vegetation, mowed several times during the season. Weeds under the vine canopies were removed by hand. During the growing season, 1–2 treatments were performed with pesticides containing mancozeb and sulphur. The experimental plots were not irrigated throughout in the entire study period.

In the years 2008–2015, the experimental combinations, arranged in a system of randomized blocks, were as follows:

1. Control combination – untreated plants.
2. Mineral NPK fertilization (at the doses of 70 kg N; 40 kg P; 120 kg K were used per hectare. In spring, 70 g ammonium nitrate, 77.5 g granular triple superphosphate and 97.5 g potassium sulfate were used per plant.

3. Mycorrhizal substrate (produced by MY-KOFLOR, Poland), containing 1 000 000 g⁻¹ propagules of arbuscular mycorrhizal fungi (*Glomus intraradices*, *G. mosseae*, *G. etunicatum*) was used in the area of the root system at 200 g per vine, at the beginning of the experiment; however, it was added to the soil in the spring of each year (AMF).
4. Mineral NPK fertilization (applied as in the treatment 2) + AMF (as applied in the treatment 3).
5. Fertigo granulated manure (product of the Dutch company Ferm-O-Feed) was applied at the rate of 25 dm³ per plot, in the year of vines planting (plot surface area 5 m²).
6. Mineral NPK fertilization (as in the treatment 2) + Fertigo manure (as in the treatment 5).
7. Bioilsa (commercial product in the form of granules applied to the soil, produced by ILSA Group Arzignano, Vicenza, Italy, containing organic nitrogen N – 12.5%, including organic nitrogen soluble in water – 5%, organic carbon of biological origin C – 42%, including extracted organic carbon – 95%) was applied in an amount of 24 g per plant to the soil in the spring every year.
8. Mineral NPK fertilization (as in the treatment 2) + Bioilsa (as in the treatment 7).
9. BF-Ecomix (commercial product of plant origin in the form of granules applied to the soil; AgroBio Products, Wageningen, NL) was applied at the rate of 100 g per plant to the soil every year in the spring.
10. Mineral NPK fertilization (as in the treatment 2) + BF-Ecomix (as in the treatment 9).
11. Ausma (plant product derived from steam-distilled pine needles, applied in a liquid form to the leaves; produced by Biolat, Lithuania) was used every year as a foliar application at 9, 6, and 3 weeks before harvest at the concentration of 0.1%.
12. Mineral NPK fertilization (as in the treatment 2) + Ausma (as in the treatment 11).

Plant growth assessment

Plant growth was assessed after each summer pruning, by weighing the fresh herbaceous shoots removed from the end of July until the end of August. Main branches were pruned higher than the 8th to 10th

leaf, above the highest growing cluster on the shoot. The side shoots were pruned 2 or 3 times, above the 1st or 2nd leaf from the base. The removed ligneous (mature) shoots were weighed after winters, during pruning which was carried out from the end of February until mid-March.

Yield assessment

The following features were assessed: time of overall ripening (typical color of berry skin, firmness of flesh and brown seeds), marketable yield, weight of clusters and berries, soluble solids content of fruit and susceptibility of vines to fungal diseases. Mature grapes were harvested separately from each evaluated vine. All clusters were counted. 100 berries collected from 3 typical bunches on each vine were weighed. Soluble solids content of a grape juice was determined by the index of refraction and was measured using a digital hand-held “pocket” refractometer PAL-1 (ATAGO Co. Ltd, Tokyo, Japan). It was measured on 3 randomly chosen clusters from each bush. Juice was squeezed from 15 berries from each cluster (berries were gathered equally from the base, the middle and the top of the bunch). Statistic calculations were conducted with the use of arithmetical averages from the refractometer readings.

Assessment of damage caused by fungal diseases

An assessment of damage caused by downy mildew (*Plasmopara viticola*) and powdery mildew (*Erysiphe necator*) was conducted directly before harvest on each plot in five-grade scale, according to the following criteria: 1 – lack of damage, 2 – less than 20% of leaves and young shoots infested by both type of mildew, 3 – 21–50% of infested leaves and young shoots, 4 – heavily infested leaves and young shoots, together with slight (up to 10%) infestation of berries, and 5 – heavily infested leaves, shoots (more than 50%) and berries (more than 10%). Susceptibility to decay caused by grey mold (*Botrytis cinerea*) was assessed during harvest, in six-grade scale: 1 – lack of damage, 2 – damage up to 3%, 3 – 4–10%, 4 – 11–25%, 5 – 26–60%, and 6 – more than 60% of fruit infested. In 2014, due to strong infestation of fruit of the cultivar ‘Solaris’ with grey mold, the weight of rotten fruit was determined. The occurrence of excoriosis (*Phomopsis viticola* Sacc.), which causes death of wood and buds, was assessed in the period of pruning (February–

March) in five-grade scale: 1 – lack of damage, 2 – damage up to 20%, 3 – 21–50%, 4 – 51–100% of shoot internodes infested, 5 – death of skeletal parts of bushes and whole plants. Infestation was assessed on the basis of both the color of shoots (change from brown to grey) and the excoriose visible on cross-sections of older shoots.

Statistical analysis

Results concerning the weight of the removed shoots, fruit yield, rotten fruit yield, weight of clusters and berries, and soluble solids content were analyzed statistically, using analysis of variance. The significance of the means was evaluated using Duncan's test at the 5% level.

RESULTS

There were no substantial differences in the weight of fresh herbaceous shoots of the cultivar 'Solaris', removed in the years 2009–2015 between the control (non-fertilized) and the other treatments (Table 1). The highest weight of removed shoots was that of NPK + AMF followed by NPK + BF-Ecomix; however, the lowest weight of removed shoots was that of Bioilsa treatment. On the bushes of the cultivar 'Regent', which grew weaker than 'Solaris', the

weight of herbaceous shoots removed from the control bushes was only significantly smaller than the weight of shoots removed from the bushes fertilized with NPK + Bioilsa. There were no substantial differences in the weights of the removed ligneous shoots among all assessed treatments performed on both cultivars.

Fruit of the cultivar 'Solaris' were harvested in mid-September, and the fruit of the cultivar 'Regent', one week later. The use of fertilizers or biostimulants did not affect in any way the time of ripening of the fruit of the two cultivars. There were no significant differences in the yield of both cultivars within single years. The only exceptions in the years mentioned were the higher marketable yield of 'Solaris' treated with Bioilsa in 2014 and 'Regent' treated with NPK + manure in 2014 and 2015. There were no significant differences found in the sum of the marketable yields in the years 2009–2015 between the untreated control and other combinations, either in the case of the cultivar 'Solaris' (Table 2) or 'Regent' (Table 3).

In 2011, the yield was low due to damage to the grapevine caused by spring frosts, and the bushes of the cultivar 'Solaris' produced significantly poorer yield on the control vines than on the vines fertilized with NPK (Table 2).

Table 1. Vine growth – cumulative weight of fresh removable shoots of 'Solaris' and 'Regent' grapevine (kg/vine), Skierniewice, 2009–2015

Treatment	'Solaris'		'Regent'	
	Herbaceous shoots	Mature shoots	Herbaceous shoots	Mature shoots
Control	14.9 abc ± 2.23	5.71 a ± 0.43	4.36 a ± 1.59	2.37 a ± 0.69
NPK (mineral fertilizers)	17.0 abc ± 1.58	6.61 a ± 0.48	6.89 ab ± 1.79	3.41 a ± 1.02
AMF	14.5 ab ± 2.04	5.65 a ± 0.57	5.26 ab ± 0.92	2.88 a ± 0.21
NPK + AMF	20.0 c ± 2.17	6.43 a ± 0.66	5.22 ab ± 1.87	2.83 a ± 0.65
Manure	15.9 abc ± 1.97	5.69 a ± 0.21	5.55 ab ± 1.83	3.15 a ± 0.70
NPK + manure	17.7 abc ± 1.92	6.06 a ± 0.67	6.79 ab ± 1.03	3.57 a ± 0.52
Bioilsa	12.6 a ± 2.09	5.23 a ± 0.60	5.41 ab ± 1.15	3.13 a ± 0.48
NPK + Bioilsa	18.6 bc ± 2.24	6.32 a ± 0.58	8.06 b ± 1.86	3.41 a ± 0.70
BF-Ecomix	16.5 abc ± 1.80	6.08 a ± 0.49	6.43 ab ± 1.13	3.20 a ± 0.60
NPK + BF-Ecomix	19.5 bc ± 2.24	6.32 a ± 0.55	7.04 ab ± 1.02	3.49 a ± 0.49
Ausma	14.4 ab ± 2.16	6.13 a ± 0.44	5.40 ab ± 0.53	2.94 a ± 0.54
NPK + Ausma	17.6 abc ± 2.17	6.42 a ± 0.63	6.40 ab ± 1.75	3.14 a ± 0.68

Explanation. Means in column marked by the same letter do not differ significantly at the $p = 0.05$ according to Duncan test, means \pm SD ($n = 4$). The averages were compared separately for each cultivar.

Table 2. Yielding of grapevine 'Solaris', Skierniewice, 2009-2015

Treatment	Marketable fruit yield (kg/vine)										Total in 2009-2015	Rotten fruits (with grey mold) in 2014 (kg/vine)
	2009	2010	2011	2012	2013	2014	2015					
Control	0.92 a ± 0.39	2.65 abc ± 0.60	0.08 a ± 0.01	1.99 a ± 0.75	1.44 ab ± 0.35	6.98 ab ± 0.87	5.37 a ± 0.82	19.4 ab ± 2.77	0.67 ab ± 0.05			
NPK (mineral fertilizers)	1.08 a ± 0.32	3.34 abc ± 0.80	0.43 b ± 0.21	3.15 a ± 0.68	1.30 ab ± 0.12	6.62 ab ± 0.78	5.49 a ± 0.97	21.4 b ± 2.86	1.31 d ± 0.25			
AMF	0.71 a ± 0.38	3.61 bc ± 0.39	0.20 ab ± 0.12	2.38 a ± 0.63	1.62 b ± 0.33	7.08 ab ± 0.80	5.09 a ± 0.91	20.7 b ± 3.05	0.77 b ± 0.09			
NPK + AMF	1.30 a ± 0.48	2.98 abc ± 0.84	0.29 ab ± 0.10	2.68 a ± 0.83	1.46 ab ± 0.29	6.61 ab ± 0.83	4.95 a ± 0.63	20.3 ab ± 2.95	1.55 f ± 0.07			
Manure	0.86 a ± 0.35	3.55 abc ± 0.52	0.26 ab ± 0.14	2.30 a ± 0.17	1.51 ab ± 0.37	7.82 bc ± 0.71	5.10 a ± 0.81	21.4 b ± 2.90	0.99 c ± 0.14			
NPK + manure	1.07 a ± 0.39	2.97 abc ± 0.86	0.26 ab ± 0.11	2.53 a ± 0.45	1.44 ab ± 0.17	6.47 ab ± 0.81	4.46 a ± 0.92	19.2 ab ± 3.05	1.54 f ± 0.09			
Bioilsa	0.78 a ± 0.34	2.79 abc ± 0.41	0.23 ab ± 0.14	2.67 a ± 0.69	1.14 a ± 0.08	8.99 c ± 0.83	5.43 a ± 0.95	22.0 b ± 2.73	0.57 a ± 0.06			
NPK + Bioilsa	1.15 a ± 0.27	2.48 ab ± 0.51	0.21 ab ± 0.16	2.59 a ± 0.69	1.18 a ± 0.17	6.71 ab ± 0.95	4.72 a ± 0.97	19.0 ab ± 3.14	1.48 ef ± 0.12			
BF-Ecomix	0.95 a ± 0.31	3.69 bc ± 0.28	0.30 ab ± 0.16	2.18 a ± 0.78	1.43 ab ± 0.33	7.40 abc ± 0.96	5.26 a ± 0.99	21.2 b ± 2.71	0.73 b ± 0.05			
NPK + BF-Ecomix	1.05 a ± 0.44	3.93 c ± 0.74	0.29 ab ± 0.12	2.45 a ± 0.82	1.41 ab ± 0.23	5.86 a ± 0.43	5.36 a ± 0.62	20.3 ab ± 3.02	1.35 de ± 0.09			
Ausma	0.85 a ± 0.43	2.20 a ± 0.79	0.32 ab ± 0.20	2.00 a ± 0.69	1.45 ab ± 0.15	6.82 ab ± 0.66	3.42 a ± 0.58	17.0 a ± 2.90	0.58 a ± 0.06			
NPK + Ausma	0.98 a ± 0.37	3.36 abc ± 0.98	0.28 ab ± 0.06	2.56 a ± 0.78	1.25 ab ± 0.24	6.84 ab ± 0.62	4.70 a ± 0.98	19.9 ab ± 2.43	1.37 de ± 0.09			

Explanation: Means in column marked by the same letter do not differ significantly at the $p = 0.05$ according to Duncan test, means \pm SD (n = 4).

Table 3. Yielding of grapevine 'Regent', Skierniewice, 2009-2015

Treatment	Marketable fruit yield (kg/vine)										Total in 2009-2015
	2009	2010	2011	2012	2013	2014	2015				
Control	0.94 ab ± 0.35	4.52 a ± 1.18	1.76 a ± 0.45	1.24 a ± 0.27	1.87 a ± 0.30	4.80 a ± 0.81	2.51 a ± 0.34	17.6 a ± 1.63			
NPK (mineral fertilizers)	1.58 ab ± 0.50	3.56 a ± 0.76	1.13 a ± 0.29	1.77 a ± 0.57	2.14 a ± 0.41	5.82 ab ± 0.88	3.99 ab ± 0.61	20.0 a ± 1.77			
AMF	1.33 ab ± 0.38	4.18 a ± 1.13	1.39 a ± 0.24	1.24 a ± 0.56	2.03 a ± 0.51	6.54 ab ± 0.72	3.35 ab ± 0.94	20.0 a ± 1.98			
NPK + AMF	1.09 ab ± 0.40	3.63 a ± 0.53	1.29 a ± 0.21	1.13 a ± 0.58	2.04 a ± 0.61	5.35 ab ± 0.80	2.82 a ± 1.03	17.3 a ± 1.68			
Manure	1.17 ab ± 0.27	4.43 a ± 0.33	1.25 a ± 0.30	2.11 a ± 0.50	2.39 a ± 0.53	5.62 ab ± 0.72	3.08 a ± 1.07	20.0 a ± 1.69			
NPK + manure	1.37 ab ± 0.46	3.15 a ± 1.06	1.04 a ± 0.28	2.05 a ± 0.54	2.49 a ± 0.39	7.30 b ± 0.80	4.73 b ± 0.56	22.1 a ± 2.20			
Bioilsa	0.97 ab ± 0.38	3.83 a ± 1.10	0.61 a ± 0.20	1.78 a ± 0.51	2.49 a ± 0.44	5.47 ab ± 0.90	3.23 ab ± 0.79	18.4 a ± 1.74			
NPK + Bioilsa	0.78 a ± 0.39	3.45 a ± 1.19	1.09 a ± 0.26	1.67 a ± 0.57	2.96 a ± 0.53	5.16 ab ± 0.58	3.50 ab ± 0.91	18.6 a ± 1.69			
BF-Ecomix	1.35 ab ± 0.33	3.98 a ± 0.96	1.41 a ± 0.30	1.75 a ± 0.50	2.48 a ± 0.49	5.23 ab ± 0.90	3.43 ab ± 1.01	19.7 a ± 1.66			
NPK + BF-Ecomix	1.55 ab ± 0.63	3.38 a ± 1.02	1.33 a ± 0.25	2.19 a ± 0.47	2.29 a ± 0.24	6.40 ab ± 1.04	3.51 ab ± 0.90	20.6 a ± 1.91			
Ausma	1.14 ab ± 0.32	4.01 a ± 1.09	1.06 a ± 0.27	1.25 a ± 0.32	2.12 a ± 0.48	6.05 ab ± 0.97	2.65 a ± 0.95	18.3 a ± 1.90			
NPK + Ausma	1.69 b ± 0.54	3.67 a ± 0.69	0.80 a ± 0.29	1.68 a ± 0.41	2.76 a ± 0.62	5.70 ab ± 1.08	3.22 ab ± 0.96	19.5 a ± 1.72			

Explanation: Means in column marked by the same letter do not differ significantly at the $p = 0.05$ according to Duncan test, means \pm SD (n = 4).

Table 4. Grape quality of grapevine 'Solaris' and 'Regent', Skierniewice, 2009-2015

Treatment	'Solaris'				'Regent'				
	Mean weight of cluster (g)	Mean weight of berries (g)	Mean total soluble solids (%)	Mean weight of cluster (g)	Mean weight of berries (g)	Mean total soluble solids (%)	Mean weight of cluster (g)	Mean weight of berries (g)	Mean total soluble solids (%)
Control	93.8 ab ± 37.4	173 a ± 28	22.0 a ± 1.1	106 a ± 20	202 a ± 43	18.0 a ± 0.7			
NPK (mineral fertilizers)	97.8 ab ± 24.1	170 a ± 12	21.9 a ± 1.1	113 a ± 24	208 a ± 34	18.4 a ± 1.8			
AMF	93.6 ab ± 26.4	178 a ± 23	21.8 a ± 1.3	115 a ± 24	201 a ± 33	18.4 a ± 1.4			
NPK + AMF	94.7 ab ± 30.6	172 a ± 22	21.9 a ± 1.6	106 a ± 29	204 a ± 26	18.1 a ± 1.2			
Manure	93.3 ab ± 29.5	174 a ± 16	22.2 a ± 1.2	107 a ± 26	205 a ± 34	18.5 a ± 1.4			
NPK + manure	96.0 ab ± 27.8	169 a ± 13	21.9 a ± 1.6	112 a ± 27	207 a ± 27	18.0 a ± 2.2			
Bioilsa	98.8 b ± 23.4	168 a ± 18	21.9 a ± 0.9	104 a ± 24	205 a ± 29	18.5 a ± 1.7			
NPK + Bioilsa	93.9 ab ± 27.4	172 a ± 20	21.9 a ± 1.6	109 a ± 24	208 a ± 36	18.1 a ± 1.5			
BF-Ecomix	93.0 ab ± 30.7	171 a ± 11	21.8 a ± 1.2	114 a ± 31	205 a ± 35	17.7 a ± 1.1			
NPK + BF-Ecomix	98.6 ab ± 22.9	170 a ± 20	21.9 a ± 1.1	115 a ± 27	208 a ± 34	17.7 a ± 1.3			
Ausma	89.3 a ± 30.6	168 a ± 14	21.6 a ± 1.5	108 a ± 22	200 a ± 25	18.5 a ± 1.6			
NPK + Ausma	92.6 ab ± 29.3	168 a ± 13	21.7 a ± 1.7	114 a ± 28	204 a ± 29	17.9 a ± 1.2			

Explanation. Means in column marked by the same letter do not differ significantly at the $p = 0.05$ according to Duncan test, means \pm SD ($n = 4$). The averages were compared separately for each cultivar.

The use of fertilizers or biostimulants had no substantial influence on the mean weight of berries, mean weight of clusters, and extract content in the fruit of both cultivars in comparison to the untreated control (Table 4).

In the years 2009–2015, there were no differences observed in the two cultivars between the assessed treatments as to the degree of infestation with downy mildew (healthiness of bushes of both cultivars assessed at 1.2), powdery mildew ('Solaris' – 1.6; 'Regent' – 1.4), and excoiiose ('Solaris' – 1.7; 'Regent' – 2.9). No differences were observed between treatments as to the degree of infestation with grey mold of the fruits of 'Regent' in the years 2009–2015 (1.1) and 'Solaris' in the years 2009–2013 and 2015 (1.9). In 2014, which was characterized by high air humidity from May to September (81–86%), the infestation of fruits of cultivar 'Solaris' fertilized with NPK (NPK only or in combination with other fertilizers and biostimulants) was higher (4 on a scale of 6) than in the fields where the NPK was not used, including the control (3 on a scale of 6). In 2014, the weight of rotten fruits of cultivar 'Solaris' from plants fertilized with NPK, NPK + AMF, NPK + manure, manure, NPK + Bioilsa, NPK + BF-Ecomix, NPK + Ausma, was considerably higher than from plants not fertilized with NPK (Table 2).

DISCUSSION

Methodical research on viticulture in Poland is still in its early stages. In the study presented here, the usefulness of both fertilizers and biostimulants was assessed. Due to different mechanisms of action, the effects of fertilizers and biostimulants were compared with the untreated control and not with one another. Grapevine cultivation in Poland takes place in conditions described as "cool climate". These conditions are strikingly different from those existing in traditional areas of cultivation of this species. This situation creates the need for specific recommendations concerning cultivars selection, fertilization and verification of results obtained in other natural conditions. Due to the nature of "cool climate", it is worth explaining the parameter which served as an illustration of the vegetative growth of the plants tested in this research. Low winter temperature and

excoiiose in Polish conditions cause withering of trunks whose diameter is sometimes used as an indicator of the growing rate of the plants. The weight of removed fresh herbaceous and ligneous shoots was chosen as the optimal parameter of bush growth; it also included growth of side shoots and regular summer pruning. After pruning the bushes to the same size in summer, as expected, there were no substantial differences in the weight of ligneous shoots removed during winter pruning, either in the vigorous cultivar 'Solaris' or the moderate growth rate cultivar 'Regent'.

The effects of application of fertilizers and biostimulants depend largely on the growth condition and genotype. Generally, the cultivars evaluated here react in a similar manner to mineral fertilization with NPK. Fertilization and the use of biostimulants did not increase the total weight of herbaceous and mature shoots removed from the vines of the studied cultivars in comparison with the untreated control vines, although using NPK + AMF, NPK + Bioilsa and NPK + BF-Ecomix caused an increase in the weight of herbaceous shoots, and Bioilsa decreased it. The application of NPK + Bioilsa caused a significant increase in the weight of herbaceous shoots removed from the bushes of the 'Regent'. Improvement in growth of the cultivar 'Regent' did not result in higher yield, which is a confirmation of Popescu and Popescu (2014) reports that indicated that better vegetative growth of the bushes of the cultivar 'Feteasca Alba' has no influence on their fertility.

Fertilizers and biostimulants applied here did not cause any substantial increase in the cumulative yield in the years 2009–2015 of the two cultivars in comparison to the untreated control. Some increases were observed in some years of the study after treatment with Bioilsa, NPK + manure. The tested organic fertilizers and biostimulants did not affect significantly the other parameters, such as the weight of clusters and berries and total soluble solid (TSS%) of the two tested cultivars. Our experiment did not confirm reports on the positive effects of biostimulants or organic fertilizers on yielding and fruit quality in the cultivation of grapevine by Stroe and Budescu (2013); Colapietra and Alexander (2006); Norrie and Keathley (2006); Kok et al. (2010); Mohamed et al. (2013) obtained in experiments with other stimulators

and cultivars. Ausma used here as foliar treatment on both tested cultivars had no effect on yielding and weight of fruit. Similar results were achieved by Sas-Paszt et al. (2008), who used Ausma on the bushes of blackcurrant, cultivars 'Tiben' and 'Tisel'.

Also, our results did not confirm the reports of Aziz et al. (2003); Žežlina et al. (2010); Le Mire et al. (2016) on the reduced sensitivity of grapevine to fungal diseases after the application of various biostimulants. Also, no analogies were found, with the results showing that the use of Bioilsa and Ausma reduces the sensitivity of tomato to *Phytophthora infestans* (Schulte-Geldermann 2008; Sharma et al. 2012). Mineral fertilization with NPK in 2014 in the conditions of high air humidity confirmedly caused intense rotting of fruits of the cultivar 'Solaris' caused by *Botrytis cinerea*, and the loss in yield was substantially more profound than on control fields (with no fertilization) or after application of organic fertilizers or biostimulants.

Obtained results confirm a general opinion that the effect of biostimulants and organic fertilizers on growth and yielding may be varied, unpredictable, limited only to some features and dependent on the crop cultivar or growing conditions. Conifer needle extract (Ausma) did not influence plant growth; it even reduced the number of rhizomes of the strawberry cultivar 'Zefyr' but increased the leaf growth and the number of rhizomes of the cultivar 'Kokin-skaya Pozdnaya' (Laugale et al. 2006). The effect of nitrophenols (Atonic, Asahi SL) on the quality and chemical composition was ambiguous and differed depending on the tested parameter and the plant cultivar in cucumber (Przybysz et al. 2014) and eggplant fruit (Majkowska-Gadomska & Wierzbicka 2013). *Ascophyllumnodosum* extract (Goëmar BM 86) caused an increase in fruit weight in three out of five tested raspberry cultivars, and its effect on dry matter, extract content, simple sugar content, organic acid and anthocyanins was insignificant and depended largely on growing season and cultivar (Krok & Wieniarska 2008). The effect of nitrophenols (Asahi SL) on growth and yielding of three strawberry cultivars varied and differed depending on the cultivar (Sas-Paszt et al. 2008). *Ecklonia maxima* extract (Kelpak) and *Ascophyllumnodosum* extract (Goëmar BM 86) applied on strawberry cultivars

'Elkat' and 'Salut' increased the yield produced of the cultivar 'Salut' but reduced the fruit firmness in both cultivars (Masny et al. 2004). *Ascophyllumnodosum* extract (Goëmar BM 86) + nitrophenols (Asahi SL) had a positive effect on the yield produced by chokeberry only during dry summers, and had no effect on plant growth and quality of fruit (Krawiec 2008).

Biostimulants can be applied in different ways. One method involves using them together with synthetic fertilizers and pesticides in order to reduce the use of the latter two (Le Mire et al. 2016). Such approach works in growing fruits where the use of mineral fertilizers with the addition of seaweed extract in the "N Pro technology and seactiv complex" technology increases the fertility, length of one-year shoots and the surface area of apple leaves of the cultivar 'Šampion' (Kaplan et al. 2013). The results of our study showed no significant influence of mixture of biostimulants and organic fertilizers with mineral fertilizers on improving the growth and yielding of plants.

Another method holds that biostimulants such as mycorrhizal agents are especially attractive in reduced input cultivation systems in long-term cultivation of fruit plants, including grapevine, where the mineral fertilizing does not have as strong an effect as in annual crop growing (Balestrini et al. 2010). Taking into account the results of our study, this method seems more interesting since it allows adjustment of the cultivation to the certified organic production.

CONCLUSIONS

1. The study showed no definite positive effect of the organic fertilizers and biostimulants on growth, yielding and healthiness of the grapevine cultivars 'Solaris' and 'Regent'.
2. Bushes of cvs 'Solaris' and 'Regent', grafted on the SO4 rootstock and planted in soil rich in mineral compounds, grew well and produced good yield despite lack of mineral fertilization for many years.
3. The annual use of AMF and organic fertilizers Bioilsa and BF-Ecomix, which are recommended in organic farming, resulted in yield at the same level as mineral fertilizing with NPK.

4. In the conditions of high air humidity during vegetation, on fields fertilized with NPK, an intensive rotting of fruit of the cultivar 'Solaris' was observed, which was caused by *Botrytis cinerea*.
5. Good tolerance to fungal diseases and lack of mineral fertilization showed that the grapevine cultivars 'Solaris' and 'Regent' may be recommended for organic production.

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