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Effect of gibberellic acid concentration and number of treatments on yield components of "Einset Seedless" grapevine cultivar

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Abstract

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Studies were conducted in the Faliszowice Vineyard (50°39'N; 21°34'E), Sandomierz Upland, Poland in 2011–2013. This research aimed to assess the influence of gibberellic acid (GA_3) concentrations and number of applications on the table grape cultivar 'Einset Seedless'. The objective was to evaluate the yield and quality after one, two, or three spray applications of GA_3 (7, 14 and 21 days after full bloom) at 100, 200 and 300 mg/l. Unsprayed vines constituted the control. GA_3 increased yield per vine, cluster weight, and berry weight. Vines sprayed three times had higher yields than treatments performed once or twice. Similar responses were determined for cluster weight and berry weight. Generally, treatments had beneficial effects on cluster length and width. This three-year study, on average, did not indicate impacts of either concentration or number of GA_3 applications on cluster and berry number and shape as well as fruit soluble solids.

Keywords: cluster weight; berry weight; soluble solids; berry composition

Grapevine cultivation in Poland is of minimal economic importance; however, growing interest in viticulture and increasing grape acreage have been recently observed. It is attributed to, among others, a more and more popular trend for grapevine cultivation and making wine from home grown fruit as well as rapidly developing enotourism (Kapłan 2011). Lately studies have been conducted in Poland to assess potential conditions for table grape cultivation. Seedless cultivars have been recognized and preferred by many consumers, but small berry size is inconvenient for commercialization (Weaver 1976; Halbrooks, Mortensen 1987; Surasak, Choopong 1988; Casanova et al. 2009).

Table grape production is profitable when it satisfies the most stringent market requirements, i.e. production of excellent quality fruit of equal size clusters, uniform size and shape of the berry as well as equal coloration and higher resistance to transportation. Seedlessness is an important trait (Dimovska et al. 2014). Consumer demand for seedless grapes has been still high and notably, table grape production with the desired traits developed by natural agricultural methods dates back to Roman times (Varoquaux et al. 2000). Historically, grapes without seeds were widely used for raisin production and highly appreciated by, among others, Hippocrates, Plato or in the writings of ancient

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Egypt of 3000 BC (Varoquaux et al. 2000). The seedless cultivars, however, despite beneficial characteristics, have some drawbacks, like poor fruit set and a need for increasing berry size. In response to these problems, new agrotechnical means have been developed to produce the best quality seedless grapes through exogenous application of gibberellic acid (GA) (Nampila et al. 2010; Dimovska et al. 2014). Many research studies highlight efficiency of GAs applied in parthenocarpic fruit production (Seçer 1989; Bora, Sarma 2006; Korkutal et al. 2008; Kapłan 2011).

GA increases productivity of seedless grape cultivars, promoting fruit growth and improving cluster architecture. Treatment efficiency relies on its timing, concentration of GA_3 solution and weather conditions following the application. However, despite many studies (Dass, Randhawa 1968; Halbrooks, Mortensen 1987; Surasak, Choopong 1988; Pommer 1995; Lu 1996; Korkas et al. 1999; Pérez, Gómez 2000; Casanova et al. 2009; Formolo et al. 2010; Kapłan 2011) no explicit guidelines as to rates and the number of applications of these compounds have been provided. According to Korkutal et al. (2008) GAs applied too early or at too high concentration affect negatively yield following the treatment year as well as reduce vine vigor. These authors indicated that GA_3 use is very effective if applied during flowering at 10–20 mg/l up to 200 to 300 mg/l, while concentrations > 600 mg/l during flowering adversely affect growth of male and female parts of flower. GA treatments, apart from improving yield and quality of parthenocarpic cultivars, has significant influence on grape berry hardness and elasticity of the skin (Yamada et al. 2003). Dokoozlian (2003) found grape berries treated with GA_3 to be more resistant to cracks caused by the rains, especially close to the harvest time.

The objective of the present studies was assessment of the effects of concentration and the number of GA applications on yield components of grapevine 'Einset Seedless' cultivar.

MATERIAL AND METHODS

The studies were conducted in the Faliszowice Vineyard (50°39'N; 21°34'E), Sandomierz Upland, Poland, in the years 2011–2013. The research material was 'Einset Seedless' ('Fredonia' × 'Canner'; Reisch et al. 1986) grapevines planted at a 2.0 × 1.0 m spacing in summer 2003. Vines were trained to the single Guyot system with 40 cm-high trunks, with one cane ca. 0.9 m length and one two- bud spur. Objectives were to assess the influence of GA concentration and number of treatments on yield components after one, two or three GA3 applications at three doses: 100, 200 and 300 mg/l. GA was sprayed 7, 14 and 21 days after the full bloom. The solution was formulated to contain 98% of gibberellic acid and SILWET® Gold (K. & N. Efthymiadis S.A., Greece) a strongly adhesive and wetting preparation at 0.015% concentration, i.e. 150 µl. The solution was prepared immediately before the treatment. The clusters were sprayed using a handheld sprayer to thoroughly cover grape peduncles and berries. Unsprayed vines constituted the control.

The following variables were measured: the number and weight of clusters, number of berries per cluster, cluster and berry length and width, soluble solids content. The yield from each post-length replicate was determined by weighing all fruit from each vine to 0.1 kg accuracy. Mean cluster weight, length and width were estimated by weighing and measuring 15 typical clusters, with five clusters randomly sampled from each vine. Mean berry weight, number, length and width were estimated by weighing, counting and finally measuring berries from five medium-sized clusters from each replicate. Fruit soluble solids was measured using an Abbe refractometer WAY 2W (EnviSense, Poland), based on squeezing juice from 20 representative berries collected from different positions within the cluster, from each vine. Titratable acidity was (TA) determined in accordance with Polish Norm PN-90/A/75101/02 (Fruit and vegetable preserves. Sample preparation and physicochemical methods of examination. Total acidity determination). The analytical evaluation was carried out in the Laboratory for Vegetable and Herbal Material Quality at the Department of Vegetable Crops and Medicinal Plants, University of Life Sciences in Lublin. All reagents and solvents were analytical grade chemicals used to measure TA were supplied from POCh (Gliwice, Poland), GA from Acoros Organics (Thermo Fisher Scientific Geel, Belgium) and SILWET Gold from Chemtura Europe Limited (Warsaw, Poland).

Table 1 summarizes the mean monthly air temperatures and total precipitation in the years 2011–2013. Weather conditions in each study year favored grape production. Annual mean air temperature in each research year was slightly higher

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Table 1. Mean and minimum monthly air temperatures and total precipitation according to weather station in Sandomierz, Poland 2011–2013

Month	Mean air temperature (°C)				Precipitation (mm)			
	2011	2012	2013	mean (1988–2008)	2011	2012	2013	mean (1988–2008)
January	–1.0	–1.8	–3.4	–1.6	25.6	34.2	48.1	22.4
February	–3.6	–7.2	–0.8	–0.4	14.2	11.3	25.2	21.8
March	3.4	4.9	–1.5	3.0	10.1	23.0	56.6	28.8
April	10.8	9.9	9.0	8.8	49.9	29.2	31.8	45.7
May	14.3	15.2	15.1	14.2	30.7	41.2	88.6	57.0
June	18.5	17.9	18.3	16.9	55.5	76.5	111.2	68.7
July	18.1	21.2	19.5	19.1	382.9	53.6	33.4	82.4
August	19.0	19.1	19.5	18.4	17.8	38.8	14.9	58.7
September	15.5	14.9	12.2	13.4	5.9	39.6	73.6	57.0
October	8.0	8.2	10.3	8.6	23.8	124.0	5.4	37.9
November	2.4	5.4	5.3	2.8	0.0	21.7	73.7	30.5
December	1.8	–3.3	1.4	–1.2	21.3	24.0	11.0	24.0
Mean	8.9	8.7	8.7	8.5	637.7	517.1	573.5	534.9

than the multi-year mean (1988–2008). Total annual precipitation in 2011 was over 100 mm higher than the multi-year mean, while 2013 exceeded the mean by nearly 40 mm. Total precipitation in 2012 was lower than the multi-year mean. The analysis of precipitation distribution in each growing season showed that by July 2011 the accumulated precipitation was 382.9 mm, which was over 300 mm more than the multi-year mean. In August through- November, the total precipitation was markedly lower than the multi-year mean. In the 2012 season, high precipitation was noted in October (124 mm), while June 2013 precipitation was likewise very high (111 mm).

The experiment was set up in a randomized block design, with 10 combinations and five blocks. The postlengths with three vines constituted replicates. All results were analysed using the Statistical 10.0 (StatSoft, Inc., USA) software package. Results were analysed statistically using ANOVA analysis of variance and Tukey`s confidence intervals. Statistical inferences were based on $P < 0.05$.

RESULTS AND DISCUSSION

During the three-year study period, the mean number of clusters per vine ranged from 17.8 up to 19.4 and did not differ between treatments. GA improved the yield per vine (Table 2). These results confirmed earlier observations (Kapłan 2011). GA had only a minor influence on yield components, which increased slightly with increasing GA_3 concentration. Irrespective of concentration, the vines sprayed three times had higher yields than those with one and two GA treatments applied. On average during the three-year study period, there were no differences in yield between the control vines and those treated once as well as between vines sprayed once and twice.

Similar findings were reported by Dimovska et al. (2014) who studied 'Flame Seedless' (*Vitis vinifera* L.) after 5, 10 and 20 mg/l GA_3 applications and several treatments. They showed that their native seedless vine cultivars demonstrated larger and higher quality clusters and berries with increasing concentration of the solutions applied. It was also noted that the aforementioned parameters of the plants sprayed three times were better as compared to treatments performed twice. However, Lu (1996) presented contrary results studying 'Orlando Seedless' treated with different rates of GA_3 sprayed twice. The author reported that vines treated with 100 and 150 mg/l had larger clusters and higher berries per cluster than those treated with 200 and 300 mg/l of GA_3.

Cluster weights ranged between 107 and 260 g and differed between combinations. Concentra-

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Table 2. Effect of gibberellic acid on size of yield of grapevine 'Einset Seedless' cultivar (means for 2011–2013)

Treatment (mg/l GA_3)	No. of applications	Clusters/vine	Yield (kg/vine)	Cluster		Berry
				weight (g)	berries/ cluster	weight (g)
Control	–	19.1	2.2^{e}	107.5^{d}	62.3	1.7^{d}
	1	18.7	2.5^{de}	140.0^{cd}	78.2	1.9^{cd}
100	2	18.0	3.0^{cde}	170.0^{bc}	80.0	2.1^{bcd}
	3	17.8	4.0^{ab}	223.5^{a}	81.2	2.7^{abc}
	1	18.4	2.6^{cde}	130.2^{d}	61.3	2.2^{bcd}
200	2	18.3	3.2^{bcd}	177.5^{b}	77.0	2.3^{bcd}
	3	18.7	4.5^{a}	241.0^{a}	82.3	2.9^{ab}
	1	19.4	2.8^{cde}	140.2^{cd}	74.5	2.0^{cd}
300	2	19.2	3.5^{bc}	185.0^{b}	76.0	2.4^{bcd}
	3	18.7	4.8^{a}	260.0^{a}	79.3	3.3^{a}
Significant standard error		ns	0.9	37.0	ns	0.8

mean values marked with the same letters do not differ significantly at $P < 0.05$; ns – not significant

tion did not have an effect on the trait. The grapevines after a single application, irrespective of a concentration level used, produced clusters only slightly heavier than the control. There was an influence of number of treatments on cluster weights in the case of 200 and 300 mg/l GA_3 applications. Importantly, increased number of treatments impacted cluster weights. It is noteworthy that the weight of clusters in vines sprayed three times, irrespective of GA_3 concentration, was over two-fold greater than the control, but half as large, when applied twice. Studies conducted by Dimovska et al. (2011) on the 'Belgrade' cultivar demonstrated that the highest concentration applied (20 mg/l) in three spray treatments caused cluster weight to increase by 31%, and by 19% in the case of 'Thompson Seedless'. Dimovska et al. (2014) reported a 66% increase in cluster weight in 'Flame Seedless' after three 20 mg/l GA_3 applications.

There were no treatment effects on berries per cluster. A trend occurred that as the number of applications increased, the number of berries per cluster grew. An exception to this trend were the clusters sprayed once with 200 mg/l GA_3 as their number was slightly lower than in the control. A similar negative influence of GA_3 was noted by Lu (1996) at 50 and 300. Mean berry weight ranged between 1.7 and 3.3 g and differed between treatments. Regardless of concentration, the clusters sprayed once or twice were not heavier compared to the controls. Effect of number of applications was observed only in the case of the highest concentration used. GA applied three times at 300 mg/l had impact on berry weight as against the treatments performed once and twice.

GA sprays had a beneficial effect on the size of clusters and berries (Table 3). The length and width of clusters treated with GA_3 were greater than the control ones with the exception of the clusters sprayed once with 200 mg/l whose length did not differ from the control. There was a trend indicating that the number of treatments affects the traits under study, i.e. a rising number of applications contributed to increased length and width of clusters. The influence of concentration and the number of treatments on cluster width was reported by Dimovska et al. (2014). Regarding cluster shape, treatments did not have any effect. Contrary to the finding, Dimovska et al. (2014) highlighted influence of GA on the shape of clusters of 'Flame Seedless', which changed from natural oval to conic-cylindrical as a result of treatments.

The berry length ranged from 17.0 to 21.4 mm and differed between the treatments, with beneficial influences of GA. There was no direct effect of GA concentration or number of treatments. Considering all the concentrations applied, the increase in the number of treatments had favourable impact. For 200 and 300 mg/l GA_3, differences were determined between one and three times of application. Similar results were obtained by Dimovska et al. (2014). GA applied at 300 mg/l concentration

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Table 3. Effect of gibberellic acid on quality of yield of grapevine 'Einset Seedless' cultivar (means for 2011–2013)

Treatment (mg/l GA3)	No. of applications	Cluster length (cm)	Cluster width (mm)	Berry length (mm)	Berry width (mm)	Soluble solids (°Brix)	Titrable acidity (g/l)
control	–	15.0[b]	9.2[b]	17.0[d]	15.5[b]	17.9	12.0
	1	19.8[a]	11.9[a]	19.9[abc]	16.4[ab]	18.7	10.5
100	2	19.8[a]	12.0[a]	20.0[abc]	16.5[ab]	18.6	10.7
	3	20.0[a]	12.2[a]	20.4[abc]	17.0[ab]	18.1	11.8
	1	16.7[ab]	12.1[a]	19.0[c]	16.4[ab]	18.3	11.5
200	2	19.8[a]	12.2[a]	20.5[abc]	16.9[ab]	18.1	11.7
	3	21.0[a]	12.9[a]	21.0[ab]	17.3[ab]	18.0	12.0
	1	19.9[a]	12.4[a]	19.4[bc]	16.7[ab]	18.1	11.5
300	2	20.1[a]	12.8[a]	20.8[abc]	17.0[ab]	18.3	11.5
	3	20.8[a]	13.2[a]	21.4[a]	18.1[a]	17.7	12.1
Significant standard error		4.5	1.9	1.9	1.8	ns	ns

mean values marked with the same letters do not differ significantly at $P < 0.05$; ns – not significant

and only when administered three times affected berry width. On average, during the three-year research period, no influence of GA_3 on berry shape was noted and this finding is consistent with the observations reported by Dimovska (2014). There was no effect of GA on soluble solids content. Generally, only slight beneficial influence of GA was observed. No relationships between concentration and/or the number of treatments vs. soluble solids were observed. TA ranged from 10.5 to 12.1 g/l and did not differ between treatments. In most cases berries treated with GA solution had a tendency towards lower TA vs. the control. It was also observed that several treatments increased the TA contrary to fruit extract content, especially in the case of plants under the gibberellic acid treatment applied at 100 and 200 mg/l concentration.

CONCLUSIONS

Application of GA under the climatic conditions of Poland had beneficial effects on the yield, cluster weight, and berry weight of 'Einset Seedless' grape cultivar. The vines with clusters sprayed three times during the growing season yielded better compared to one or two GA_3 sprays. Similar relationships were noted for cluster weight. An influence of the number of sprays on berry weight was observed only at the highest GA_3 concentration. Most treatments applied favorably affected length and width of clusters. On average, during the three-year research period, there was no impact of GA_3 concentration and the number of applications on cluster number, shape of clusters and berries, soluble solids, or TA.

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