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Fruit set and seed traits affected by N-phenyl-phetalamic acid in four grapevine (*Vitis vinifera* L.) cultivars

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Summary

Grapes are an important horticultural crop that is popularly consumed in a variety of different forms; the fruit is eaten in at its immature stage, as ripe fruit and dried as raisins and vine leaves are also consumed. Therefore any research on ways to improve production of Iranian grapes in terms of quality and quantity is valuable. The main purpose of this study was to test the use of Phenyl Phetalamic Acid (PPA) to improve fruit set and quality. The experiment was designed as a factorial for four grapevine cultivars; 'Razeghi', 'Askari', 'Sefidaly' and 'Rishbaba' and three concentrations of PPA (0, 500, 1000 mg·L^{-1}). Treatments were arranged in a completely randomized design with three replications. The experiment was done in the Kashmar vineyard (Khorasan Razavi province) during 2010 spring. PPA treatment was applied by foliar spraying at the stage of 50 % anthesis. Results showed that PPA levels had a significant effect on evaluated cluster traits (weight, length and number) and berry (number, weight, length and diameter). Fruit set index (number of berries per cluster) was 263.11 for 'Sefidaly' followed by 113, 109.89 and 76.11 for 'Askari', 'Razeghi' and 'Rishbaba', respectively. 'Askari' and 'Razeghi' cultivars showed similar and insignificant reactions but their difference was significant compared to 'Rishbaba'. The effect was significant for interactions of traits for cluster, berry and seed except for number of berries per cluster. Based on these results, cluster characters were significantly and positively affected by PPA treatment at the concentration of 1000 mg·L^{-1}. This concentration increased fruit set by 26.2 % compared to the control in all cultivars except for Askari. The PPA concentration 500 mg·L^{-1}, observed as the most effective treatment for improved berry characters, provided its non-significant difference with 1000 mg·L^{-1}. Seed number per berry decreased significantly in 'Askari' and 'Rishbaba' at 500 mg·L^{-1}, which was considered positive in terms of quality. In summary, results determined that PPA had a positive effect on fruit as an auxin synergist. These improved berry characteristics are hypothesized to occur through a decrease in the dominance of apical buds that would allow more metabolites to be directed to development of fruit clusters, although further research is required.

K e y w o r d s : grapevine cultivars, PPA, auxin synergistic, cluster, berry, seedlessness.

Introduction

Grapevine, *Vitis vinifera* L., from the Vitaceae family was one of the first fruit species to be domesticated. Nowadays, it is an important, commercially grown fruit crop (Keller 2010). Iran produces about three million tons of grapes annually, and it is ranked as the world's eleventh largest producer (FAO 2011). Grapevine yield is nine tons per ha in Iran, but the growth rate of the cultivated area under vine production is +18. However, Italy, as the world's largest producer of grapes, produces 10 tons per ha, and as such is classified as negative growth rate country. (FAO 2006, Creasy and Creasy 2009). Therefore Iranian grape productivity needs improvement in both terms of quality and quantity.

Auxin (Indole acetic acid) is the first known chemical plant growth regulator that has been identified in grapevine. Auxin is produced in young plant tissues such as primordial leaves, young leaves and developing seeds, and it is involved in many plant physiological processes (Davies 1995). The highest auxin concentration is found during anthesis and berry growth stages, which are coincided with rapid cell division after fruit set. The chemical has a direct effect on flowering and fruit set and, on the other hand, indirectly influences the metabolism of ethylene. Auxin in seeds is involved in processes of cell division, development of ovaries and berries. Auxin concentration in the ovary increases after bloom up to 10 d, and this increase is particularly rapid inside the very active tissue growth of the nucleus in the ovule and during the slower growth of the endosperm (Nitsch *et al.* 1965). Treating grapevine with a pre-harvest spray of auxin delays ripening and this is attributed to delayed accumulations of sugars and anthocyanin (Buttcher *et al.* 2011). Studies have shown that gene expression of down regulated genes is continuous, so it coincides with the late ripening effect of auxin treatment (Davies *et al.* 1997). Therefore, it is important to establish methods to maximize the benefits of auxin treatment without inducing its undesirable effects. Phenyl Phetalamic Acid (PPA) can improve conditions for pollination and fruit set. PPA increases the lifespan of stigmata

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and serves as a regulator for the period of pollination. It is not an auxin as such, but it facilitates auxin synergy, and is free from toxic and parthenocarpic effects (NYÉKI 1980, RACSKO 2004). Effects of factors of agricultural technology, cultivar and climate conditions on production would be reduced by PPA application and uncertainty of yield will decrease and yield would also be increased (HOLB 2002). Applications of PPA have been reported at the time of flowering in the field, greenhouse and other protected conditions for various crops due to its obvious benefits. It is important to point out that PPA is effective in terms of increasing production because it facilitates better provision of plant nutrients (RACSKÓ and LAKATOS 2003). Artificial pollination of horticultural crops may be used to increase yield but this is often not effective due to the undesirable effects of environmental and genetic factors (NYÉKI and SOLTÉSZ 1996, KOZMA *et al.* 2003). PPA is involved in the process of pollination and as such affects the quantity and the quality of yield (BÚZA 1986). Fruit production is a process that quantitatively determines how many ovaries will undergo the physiological and the morphological changes necessary to produce berries (MAY 2004). Grapevine cultivars have high reproductive potential due to full flower inflorescence. A plant's reproductive potential is inherently higher than the amount of fruit that it actually produces. Performance is evaluated in terms of yield, which is generally regulated by horticultural management that affects the nutritional conditions of fruit and its weight. This study used evaluations for number of berries in a cluster and fruit set index to determine yield quantity (MAY 2004).

Seedlessness is an important trait that identifies the quality of fruit for both table grapes and raisins. Approximately 80 % of the world's fresh grapes are seedless (YUSHI MITSU 2001). There are two types of seedless grapes, parthenocarpic and stenospermocarpic. Stenospermocarpic grape varieties require pollination and fertilization to induce fruit set, and embryo is aborted subsequently during fruit development, leaving only the seed remaining visible. Parthenocarpic varieties produce fruit independent from fertilization (PRATT 1971). The fruit produces enough growth regulators before embryonic abortion to develop berries. Abortion signs are observable from seed remains after exploration of a berry. In some cases, the seed is only a husky shell without an embryo (CREASY and CREASY 2009). Consumption of seedless grapes is increasing daily. EBADI *et al.* (2009) identified a high correlation between taste and fresh or dry weight of seeds, especially for percentage of seed dry matter after evaluation of seed and berry characteristics of seedless and seeded cultivars. The research concluded that these traits are important factors for evaluations of seedlessness and are used to identify seedless varieties (EBADI *et al.* 2009). Product development in terms of the commercial value of seedless grapes could be increased by horticultural operations such as girdling or spraying with growth regulators (MAY 2004).

The purpose of this study was to test the use of PPA to improve the quality and the quantity of berries and seeds of four commercial (seeded and seedless) grape cultivars.

Material and Methods

This experiment was conducted in a commercial vineyard in Kashmar (as a city of Khorasan Razavi province in NE Iran) in spring 2010. The Kashmar region is an area of about 5000 km^2 at the geographical location of 35° 58' N and 11° 27' E. Records of average annual temperature and rainfall were 17.6 °C and 180 mm, respectively. Plants used in this study were 15 years old and at the stage of fruit production, the training system was self or stake-supported and was flood irrigated. Details of the cultivars are presented in Tab. 1. The experiment was arranged as a factorial testing of four cultivars; 'Razeghi', 'Askari', 'Sefidally' and 'Rishbaba'; and three concentration levels of PPA spray application. The experiment was set up as a completely randomized design and nine plants of each cultivar were sprayed. PPA spraying was done when flowers were 50 % open. Treatments were made by foliar application at concentrations of 0, 500 and 1000 mg·L^{-1} sprayed on each plant. PPA in Iran is produced with the formulation of 60 WP, its brand name is BAR AFSHAN I and production is under license of academic Jihad of University of Tehran. It is commercially available (Fig. 1).

Traits measured and statistical analysis: In this study, based on yield characteristics of grape varieties [cluster weight (g), panicle length (cm), number of clusters, number of berries in a cluster], quantitative traits of berry [weight (g), berry diameter and length (mm)] and

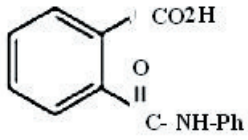

Fig. 1: Chemical structure of N-phenyl phetalamic acid (phenyl phetalamic acid) known as Nevirol has the Iranian brand name of Barafshan1. Toxicity is 8837 mg·kg^{-1} (Pesticide & Metabolite Standards Catalog, 2009).

Table I

List of studied Iranian grape varieties and some of their typical important characters

Cultivar name	Type of consumption	Berry shape	Berry color	Seedlessness	Full bloom	Marketing	Date of ripening
Razeghi(rezghi)	fresh	drawn	white	seeded	24th may	average	23th Sept
Askari	fresh/raisins	round	white	semi seedless	23th may	good	19th Sept
Sefidali	fresh	round	white	seeded	24th may	average	23th Sept
Rishbaba (mavizi)	fresh/raisins	rrawn	white	seeded	24th may	very good	30th Aug

seed [seed number/berry, seedlessness (seed fresh weight (gr), seed length (mm), seed diameter (mm)] were measured using a caliper, ruler and balance. Measurements were taken from healthy clusters selected with similar weight in three replicates. Cluster number was the total number of clusters in each replication. The number of berries from each of three clusters were counted. For evaluations of other traits, berry samples were prepared from each separate cluster, and for each treatment five average medium-sized berries were evaluated from each of the three replicates.

Firstly, data were written into EXCEL 2010, (Microsoft, USA) software and then analyzed with SAS, (Cary NC, USA) statistical software. MSTATC software was used to calculate significance of compared means and the software EXCEL 2010 was used to draw diagrams.

Results

Results from analysis of variance showed that PPA application had a very significant effect at different levels on the characters of cluster (weight, length and number), berry (number, weight, length and diameter) and seed (number, fresh weight, length and diameter). The effect of cultivar on the traits evaluated for cluster, berry and seed was very significant. Results showed that PPA interaction with cultivar was very significant for traits of cluster, berry and seed at 1 %, however it was not significant for number of berries in a cluster.

Comparison of averages: Significant difference was found for cluster characters (weight, length and number), berry characters (weight, length, diameter and number) and seeds (weight, length, diameter and number of seeds per berry, Tab. 2). 'Sefidaly' showed the highest values for cluster weight, berry number per cluster, seed number per berry, seed weight and diameter as a seeded cultivar with big clusters its average of evaluations with regards to the other cultivars. 'Sefidaly' had, on the contrary the lowest record for cluster number. On the other hand, 'Razeghi' had the highest record for weight and diameter and its berries showed the longest seeds. 'Rishbaba' showed significant difference (1 %) in terms of maximum cluster length and berry and seed diameter. 'Askari' is a seedless cultivar; and showed the high record for number of clusters.

Averages for comparisons of effects of PPA concentrations on characteristics of cluster and berry are shown in Tab. 2. Results demonstrated that treatment with PPA concentrations of 1000 and 500 mg·L^{-1} had no significant effect on berry weight and length. PPA concentration of 500 mg·L^{-1} had the greatest impact on cluster number and seed length; however, there was no significant difference at this concentration in terms of berry number compared to Control treatment. Treatment with PPA at 1000 mg·L^{-1} had a significant effect on cluster weight and berry length and number whereas PPA at 500 mg·L^{-1} decreased seed traits (Tab. 2).

Cluster characteristics: Results of the interaction of cultivar and PPA showed that the concentration 1000 mg·L^{-1} had the most significant effect on cluster weight in 'Sefidaly' and 'Razeghi'. This level of concentration increased the average cluster weight in 'Rishbaba' and 'Askari', but it was not significantly different from their control not for PPA at 500 mg·L-1 (Fig. 2). It was noticeable that 'Askari' produced smaller clusters than the other cultivars evaluated.

Results demonstrated that the treatment with the most significant effect was PPA spray at 1000 mg·L^{-1} on cluster length of 'Rishbaba' and 'Askari'; whereas for 'Sefidaly' the greatest effect were observed at 500 mg·L^{-1} PPA. There were no significant differences between 500 and 1000 mg·L^{-1} for 'Razeghi' cultivar, but both showed significant differences compared to control treatment (Fig. 2).

PPA treatment at 500 mg·L^{-1} had a significant and substantial effect on number of clusters in 'Razeghi' and 'Askari' showed a significantly reduced cluster number in 'Rishbaba' (Fig. 2)

The results for PPA concentration of 1000 mg·L^{-1} illustrate that the treatment had produced an unwanted side effect, which implied cluster thinning. It is possible that spraying PPA caused an increased sink ability of the bigger clusters due to the effect of PPA on auxin synergy that halted the growth of weak clusters as the bigger clusters absorbed more nutrients. Treatment with PPA at 1000 mg·L^{-1}

Table 2

Effect of PPA treatment and grape cultivars on the average of cluster, berry and seed characteristics

		Cluster weight (g)	Length cluster (cm)	Number of cluster	Number of erries in cluster	Number of seeds in berry	Berry weight (g)	Berry length (mm)	Berry diameter (mm)	Seed weight (g)	Seed length (mm)	Seed diameter (mm)
Concentration (mg·L^{-1})	1000	823.3 ^{a}	25.66 ^{a}	23.83 ^{c}	161.5 ^{a}	2.91 ^{a}	5.95 ^{a}	26.25 ^{a}	18.4 ^{b}	0.04 ^{b}	6.65 ^{a}	3.65 $^{a\,b}$
	500	644.9 ^{b}	24.25 ^{b}	30.91 ^{a}	132 ^{b}	2.54 ^{b}	5.77 ^{a}	26.72 ^{a}	17.08 ^{a}	0.042 ^{a}	6.79 ^{b}	3.53 ^{a}
	0	557.2 ^{c}	22.68 ^{c}	25.75 ^{b}	128 ^{b}	3 ^{a}	4.68 ^{b}	20.25 ^{b}	16.12 ^{c}	0.045 ^{c}	6.25 ^{c}	3.81 ^{b}
Cultivars	Razeghi	805.2 ^{b}	19.11 ^{d}	14.66 ^{c}	109.9 ^{b}	2.5 ^{c}	8.02 ^{a}	28.97 ^{b}	20.94 ^{a}	0.05 ^{b}	8 ^{a}	3.98 ^{a}
	Askari	213.58 ^{d}	22.2 ^{c}	48.77 ^{a}	113 ^{b}	2.16 ^{d}	2.05 ^{d}	15.61 ^{d}	12.55 ^{d}	0.023 ^{c}	5.47 ^{d}	2.95 ^{b}
	Sefidali	1129.15 ^{a}	24.94 ^{b}	11.44 ^{d}	263.11 ^{a}	3.66 ^{a}	4.21 ^{c}	19.66 ^{c}	15.92 ^{c}	0.076 ^{a}	6 ^{c}	3.83 ^{a}
	Rishbaba	552.86 ^{c}	30.55 ^{a}	32.44 ^{b}	76.11 ^{c}	2.94 ^{b}	7.57 ^{b}	33.38 ^{a}	19.44 ^{b}	0.02 ^{d}	6.79 ^{b}	3.89 ^{a}

Common letters are based on least significant test and show no significant difference at 5 % level.

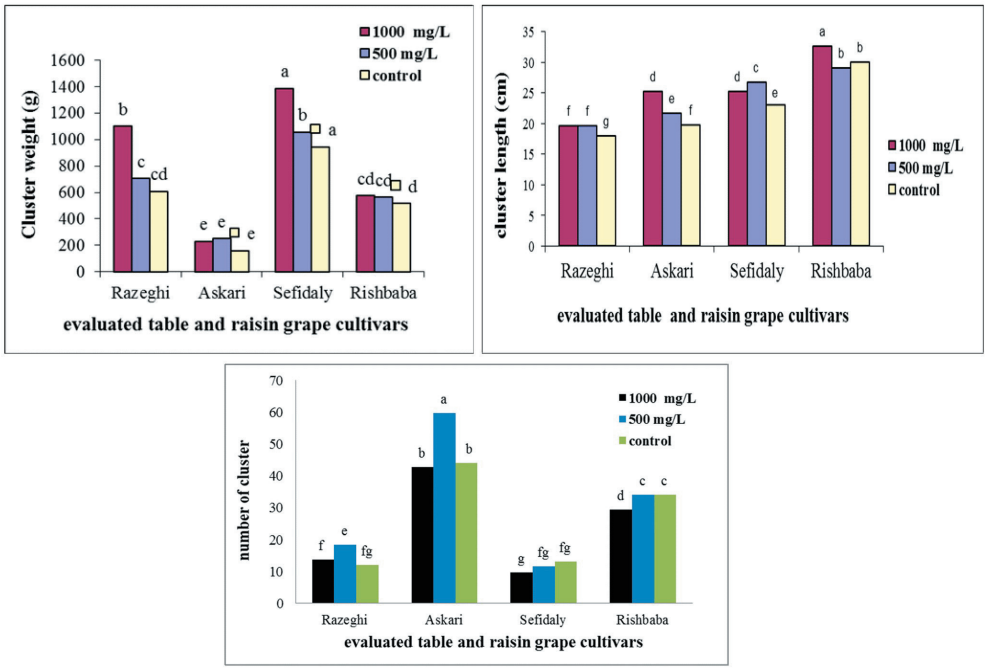

Fig. 2: Top: Effects of different concentrations of PPA on weight (right) and cluster length (left) of studied grape cultivars. Bottom: Interaction effects of different concentrations of PPA and grape cultivars in cluster number.

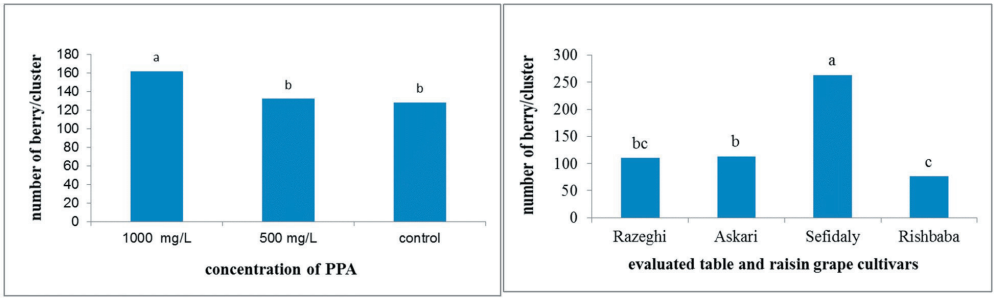

Fig. 3: Effects of different concentrations of PPA (left) and grape cultivars (right) on number of berries per cluster.

had a highly significant effect on number of berries, but non-significant difference was found between 500 mg·L^{-1} and the control treatment (Fig. 3). The number of berries in cluster at harvest time was used as fruit set index (MAY 2004). 'Sefidaly' showed highest fruit set index (263.11) and 'Askari', 'Razeghi' and 'Rishbaba' had lower fruit set index (113, 109.89, and 76.11, respectively). The difference between 'Askari' and 'Razeghi' was insignificant but they were significantly different from 'Rishbaba' (Fig. 3).

Berry characters: Based on results of interactions of cultivar and different levels of PPA, results were significant for berry weight except for 'Sefidaly' (Fig. 4). Results indicated that PPA at 1000 mg·L^{-1} decreased berry weight in 'Askari' and 'Rishbaba', although this reduction was not significant. It can be concluded that these two cultivars treated with PPA concentration of 500 mg·L^{-1} had higher increased berry weights than those resulting from PPA concentration of 1000 mg·L^{-1}, while the opposite was true for the Razeghi cultivar. Interactions of PPA and cultivar had a significant effect on berry length for all cultivars except for 'Sefidaly'. The impact of PPA concentration of 500 mg·L^{-1} PPA on berry length was significant for 'Askari', although there was no difference in 'Razeghi' and 'Rishbaba' at that concentration of PPA but this difference was significant compared to the Control (Fig. 5). Results showed that the interaction of cultivar and PPA had a significant effect on berry diameter in all cultivars except for 'Rishaba'. PPA concentration of 1000 mg·L^{-1} had a significant effect on diameter of berry in Sifidaly but not for berry weight and length characters. It can be concluded that the shape of 'Sefidaly' berries changed from stretched to round. However, at PPA 500 mg·L^{-1} concentration, there was reduced berry diameter. In 'Askari', significant difference was observed between PPA treatment and the Control; however there was a significant effect in 'Razeghi' compared to 'Askari' at both levels of PPA (Fig. 5).

Traits related to seed and seedlessness: The effect of interaction of PPA and cultivar on number of seeds per berry was significant except for 'Razeghi' (Fig. 5). PPA concentration did not cause any difference among treatments on 'Sefidaly'. It is interesting that the PPA at 500 mg·L^{-1} significantly reduced seed number for 'Rishbaba' and 'Askari' cultivars as seeded and semi seedless varieties, respectively. Reduction in seed number for 'Rishbaba' was smaller than for 'Askeri', and there was no significant difference between PPA concentration of 1000

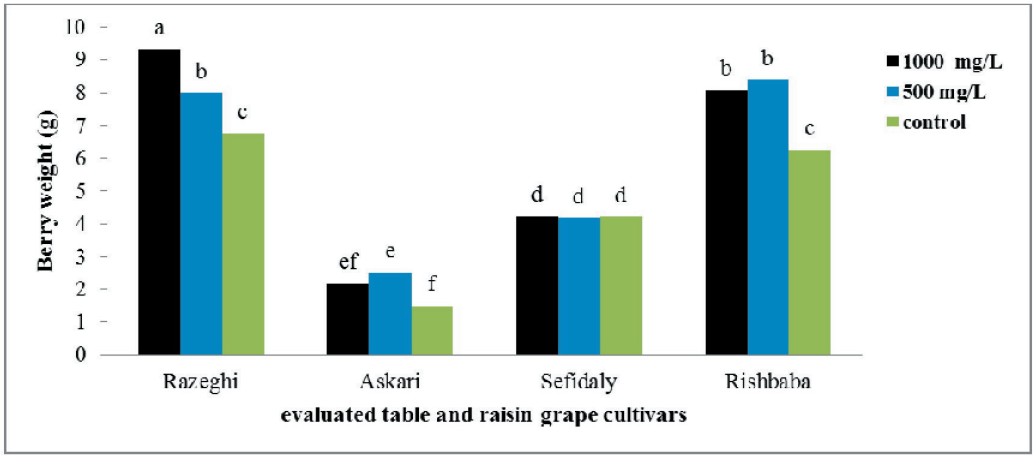

Fig. 4: Effects of different concentrations of PPA and cultivars of grapevine on berry weight.

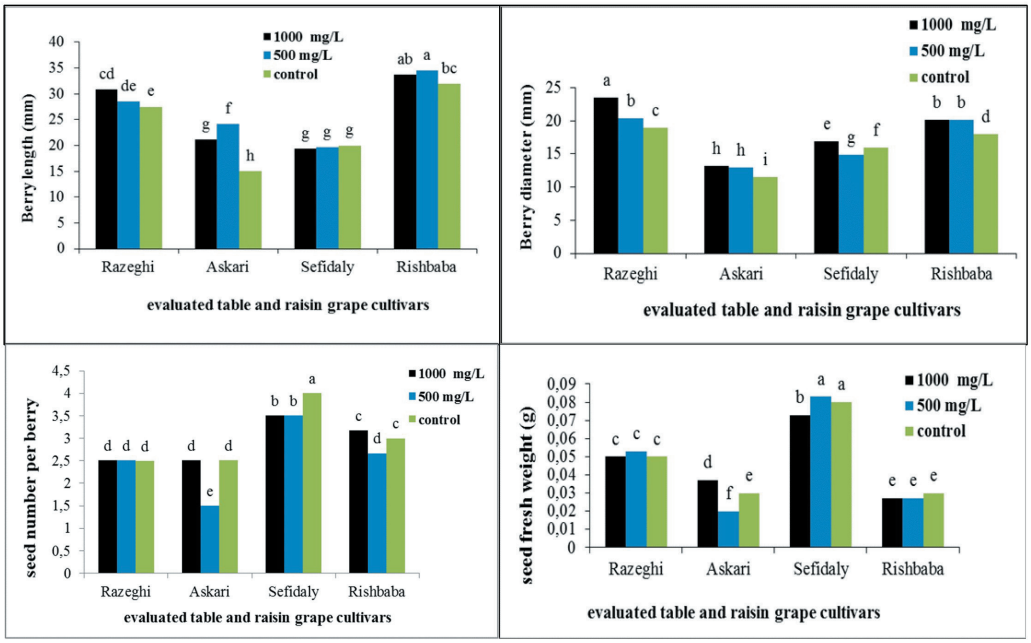

Fig. 5: Top: Effect of different concentrations of PPA and cultivars of grape on the berry diameter (right) and length (left). Bottom: The interaction of various concentrations of PPA and grapevine cultivars on the seed number (left) and seed fresh weight (right) per berry.

mg·L^{-1} and the control for seed number per berry (Fig. 5). Based on these results the effect of interaction of cultivar and PPA on fresh weight of seed showed significant difference from the control except for 'Razhegi' and 'Rishbaba'. PPA concentration of 1000 mg·L^{-1} increased seed fresh weight significantly in Askari with embryo abortion during seed development due to its stenospermic nature (Fig. 5).

Finally, the most effective concentration of PPA for application to the cultivars tested in this study is briefly presented in Table III. These results demonstrate concentrations of PPA for each cultivar to provide current market demands. In Askari, as a semi seedless cultivar, the length of cluster and berry number tended to increase after the application 1000 mg·L^{-1} concentration of PPA, although with a significant reduction of seed length. Based on the results in Tab. 3, length, weight and diameter of berries would increase, and whereas the seed weight would decrease if 500 mg·L^{-1} concentration of the PPA are sprayed at full bloom in 'Askari'. Increase in the cluster weight and the number of berries and decrease of seed fresh weight would result from using 1000 mg·L^{-1} of PPA on the 'Razeghi' and 'Sefidaly' as seeded cultivars. Some vineyards included 'Askari' (semi seedless) and 'Rishbaba' (seeded) cultivars to produce raisins from their high quality berries. They could equal values of PPA and find equal positive significant effects, as well as 1000 mg·L^{-1} concentration of PPA to increase berry number and cluster length, and 500 mg·L^{-1} concentration of PPA that will improve weight, length and diameter of berry (Tab. 3).

Discussion

Increased fruit set is desirable in grape clusters with uncompact clusters but in some varieties (such as 'Yaghuti'), with very dense clusters, thinning of clusters and the

Table 3

Best performance concentrations of PPA (g·L^{-1}) to increase the quality and quantity of fruit of four grapevine cultivars

Evaluated traits		Cultivars			
		Razeghi	Askari	Rishbaba	Rishbaba
Cluster	weight	1	-	-	-
	length	0.5	1	*1	*1
	number	0.5	*0.5	*0.5	(-)1
Berry	number	1	1	1	1
	weight	*1	0.5	0.5	0.5
	length	1	0.5	*0.5	*0.5
	diameter	*1	0.5	0.5	0.5
Seed	number	-	0.5	0.5	0.5
	fresh weight	(-)1	(-)0.5	(-)0.5	(-)0.5
	length	*1	(-)1	0.5	0.5
	diameter	-	-	*(-)0.5	*(-)0.5

* The most significant value of trait compared to other cultivars from using PPA.
(-) Negative effect on the evaluated average of trait.

subsequent reduction in fruit set is usual. All of the evaluated varieties in this study had low density clusters.

'Askari': 'Askari' has negative response to application of gibberellin for increased berry and cluster quality and quantity, dropping of berries occurred due to its genetic weakness in berry attachment to cluster. In Kashmar (eastern Iran) and nearby Afghanistan as two major raisin producer areas, 'Askari' is the most cultivated grapevine cultivar, and any improvement in fruit set and production could have a positive effect of the livelihood of viticulture farmers in those regions. The results illustrated that berry traits were more affected than cluster traits by PPA. Berry weight, length and diameter and the number of clusters were significantly affected by 500 mg·L^{-1} PPA concentration. Cluster weight was the only trait that did not show significant difference compared with the control. It can be concluded that treatment with the 500 mg·L^{-1} concentration of PPA is recommended to increase the quality of 'Askari' berries but increasing quantities require attention to regulation of nutrition supplied to the vines. RACSKÓ and LAKATOS (2003) concluded that different apple varieties had different responses to PPA treatment.

'Askari' seeds have more growth and delay in embryo abortion compared to Sultana as major seedless cultivar. Therefore, 'Askari', as a semi seedless cultivar, located between 'Sultana' as seedless cultivar and other seeded cultivars with production of bigger berries than 'Sultana', and smaller than seeded cultivars (ERFANI *et al.* 2008). It could be related to semi seedlessness of 'Askari'. In semi seedless cultivars embryo abortion is later than in seedless cultivars and occurs after the abortion of their embryo, therefore the synthesis of seed-born plant growth regulators will continue longer than in seedless cultivars and result in bigger berries.

Maintaining its seedlessness is an important determination for evaluating the effects of PPA application, in 'Askari'. These results showed that 'Askari', as a semi seedless cultivar retains its seedlessness and shows the lowest seed length, diameter and number compared to other seeded cultivars in the study (Tab. 2). The genetic weakness of seeds in semi seedless 'Askari' caused a reduction of berry weight, length and diameter and decreased cluster weight significantly compared to other seeded cultivars in the current study. Significant and positive increments were recorded for traits of cluster (length and number), berry (number, weight, length and diameter) parallel to reduction in weight and length of seed without bad effect on seedlessness. It seems that PPA affected seeds of 'Askari' during embryo abortion, which improved berry growth and development by recovering its requirement for auxin plant growth regulator. MAY (2004) cites that plant growth regulators are effective in fruit set and they originate from the seed during seed development.

'Razeghi': PPA treatment improved all cluster and berry traits in 'Razeghi'. The concentration of 1000 mg·L-1 PPA had a more significant effect on berry traits than on cluster traits. Cluster weight significantly increased under this treatment. It can be concluded that PPA sprayed at 1000 mg·L^{-1} in 'Razeghi' improved weight, length, diameter and number of berries, that also contributed to increased cluster weight.

It seems that PPA treatment, as an auxin synergist, led to continuity of berry growth and increased berry length, diameter and weight, and the treatment sustained growth of the weaker berries leading to increase in berry weight.

Auxin is produced and released in flowering meristems (tips of each flowering organ) and controls the formation and differentiation of flowers. Auxin stimulation also leads to the development of vascular tissue (KELLER 2010).

'Rishbaba': The reaction of 'Rishbaba' to spraying as a seeded cultivar was very similar to that of 'Askari' as a seedless (semi seedless) cultivar. Spraying with 500 mg·L^{-1} PPA concentration resulted in significant effects on weight, length and diameter of berries in both cultivars. Both cultivars have thin clusters, and it seems they have similar genetic capacities to increase berry size. The only

difference between them is in terms of embryo abortion in 'Askari' during seed development, which leads to a loss of its hormonal effects. However, early onset of ovary development is started by pollination before fertilization, after that, fruit set required access to seed originated auxin (O'Neill 1997). Therefore, the period prior to berry set usually requires pollination, fertilization and development of at least one seed (Pratt 1971). 'Rishbaba' is a marketable cultivar because of its long berries but the presence of big seeds in its berries limits consumption, as consumers tend to prefer seedless grapes. Results showed that PPA decreased seed fresh weight and diameter significantly. With consideration of the synergistic role of PPA and auxin, the same influence in 'Askari' (seedless) and 'Rishbaba' (seeded) cultivars may be related to a reduction of apical dominance and to a more suitable distribution of carbohydrate reserves and nitrogen. That would increase the contribution of auxin at flowering that increased the values for berry weight, length and diameter. Nitrogen compounds and carbohydrate reserves are directed to enhance the vigor of vegetative shoots due to apical dominance in the early spring that does reduce fruit set (May 2004) on the other hand.

'Sefidaly': Based on these results, spraying with PPA improved cluster characteristics, especially cluster weight. PPA also showed positive and significant effects on berry number and diameter.

Results showed that the shape of 'Sefidaly' berries changed from long to round, which could be attributed to cause an increase in cluster weight. Auxin leads to re-activation of cell division and gibberellin that stimulates cell enlargement (Serrani *et al.* 2007). Therefore, fruit set depends on both auxin and gibberellin. They stimulate ovaries to make fruit and differentiate exocarp (skin) and mesocarp (berry flesh) (Keller 2010). It seems that auxin increase in 'Sefidaly' and lacks of gibberellin have a complementary role, affecting length of berries. Significant increase in the number and weight of berry clusters with PPA treatment could be observed despite 'Sefidaly' had a reduced number of clusters. It seems that PPA led carbohydrate reserves to reproductive growth increasing fruit set, however it should be noted that if there is a loss of the optimal level of nutrient and carbohydrates distribution among the clusters, it would be possible for a vine to develop weak clusters, which was evident in 'Sefidaly'. The process of photosynthesis to produce carbohydrates will not be completely initiated until a vine has produced five to six leaves. Growing organs will deplete sources of stored food during this time and at flowering a plant's reserves reach the lowest level which makes vines sensitive to stress at flowering (Lebon *et al.* 2008). Therefore it is necessary to provide enough fruiting capacity in vines by spraying with PPA.

Conclusion

This research attempted to study the effect of N-phenyl-phetalamic acid (PPA) on the fruit production and characters of the seeds in four native Iranian grapevine cultivars at three different concentrations in eastern Iran. We originally assumed that PPA as an auxin synergist would be more effective in fruit set of grapevine than direct application of auxin or gibberellin, as the application of gibberellins and auxin in seeded cultivars results in unwanted vegetative growth and abscission of berries in cluster in 'Askari' as semi seedless.

PPA was sprayed after 50 % anthesis in inflorescence. The results of variance analysis showed that PPA levels had significant effects on cluster (weight, length and number), berry (number, weight, length and diameter) and seed (weight, length and diameter). Based on the results interaction effect of cluster, berry and seed traits were significant with the exception of number of berries per cluster. The most effective treatment level for berries characteristics was 500 $mg \cdot L^{-1}$ PPA, it showed insignificant difference with the treatment at PPA concentration of 1000 $mg \cdot L^{-1}$.

The results of this study determine concentrations of PPA recommended for each cultivar that are applicable to horticultural practice (Tab. 3). Based on these findings cluster characteristics were significantly and positively affected by PPA concentration of 1000 $mg \cdot L^{-1}$. The treatment increased fruit set by 26.2 % compared to the control except for 'Askari'. The highest percentages were achieved from 'Sefidaly' and 'Razeghi' at 58 % and 53 %, respectively. The highest evaluated fruit set index (berry number per cluster) was recorded in 'Sefidaly' with 263.11 followed by' Askari', 'Razeghi' and 'Rishbaba', with values of 113, 109.89 and 76.11 respectively. 'Askari' and 'Razeghi' showed similar and non-significant reactions, but their differences were significant relative to 'Rishbaba'. These results can be explained by assuming that PPA led carbohydrate reserves to reproductive growth and increased fruit set. Our findings provide evidence that PPA affects the seed quality and quantity surprisingly. The number of seeds in berries of Askari and Rishbaba decreased significantly under PPA treatment at the concentration of 500 $mg \cdot L^{-1}$ and demonstrate a positive improvement in quality, although further research is needed. Finally, PPA is an auxin synergist, and as such, it had a positive effect on grapevine fruit set with a decrease of apical dominance of the terminal buds; metabolites deviated to clusters that resulted in better berry characteristics. Further research is recommended to investigate the mechanism of PPA effect through the use of hormone assessment tools. PPA treatment can be applied in horticultural practice in combination with application of nutrients to maximize yield productivity in terms of quality and quantity.

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