Research Article

Effect of gibberellic acid at different phenological stages on the quality of plum

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Abstract

The experiment was conducted at Agricultural Research Institute Tarnab, Peshawar, Pakistan during the year of 2017. Different concentrations of Gibberellic acid (GA₃) i.e., 0, 20 and 30 ppm were sprayed at two different phenological stages i.e. at full bloom and after fruit set (80% petal fall) and the results were compared with control treatment. The experiment was laid out in two factors Randomized Complete Block Design with Split Plot arrangement having three replications. The results revealed that treatment of GA₃ concentrations at different phenological stages had significant effect on the parameters having high total soluble solids (8.85), low fruit pH (4.49), maximum sugars (9.12 %), low acidity (0.18 %), high sugar: acid ratio (52.01) and high vitamin C content (5.54 mg/100g) with the application of GA₃ after fruit set while, low total soluble solids (8.03), high fruit pH (4.86), minimum sugars (8.98 %), high acidity (0.21 %), low sugar: acid ratio (43.43) and high vitamin C content (5.34 mg/100g) were recorded with GA₃ application at full bloom. Gibberellic acid at 30 ppm, resulted in highest total soluble solids (9.44), low fruit pH (4.03), maximum sugars (9.16 %), low acidity (0.17 %), high sugar: acid ratio (54.40) and high vitamin C (5.63 mg/100g) while, the lowest total soluble solids (7.23), high fruit pH (5.51), minimum sugars (8.88 %), high acidity (0.22 %), low sugar: acid ratio (40.41) and low vitamin C contents (5.22 mg/100g) were recorded in untreated control trees. From the current investigation it can be concluded that the treatment of GA₃ at 30 ppm after fruit set found better in most of quality attributes of plum as compared to control.

Keywords: Gibberellic acid; Phenological stages; Plum; Quality

Introduction

Plum (*Prunus domestica* L.) is a stone fruit of the family Rosaceae, locally known as Alocha and Alobukhara. The fruit develops with seed having a hard shell or stone. The inner part of the ovary wall develops into seed and the outer part into soft flesh [1]. Different plum species are originated in different parts of the world such as *Prunus domestica* (European plum) in Europe, *Prunus insititia* (Damson plum) in Western Asia, *Prunus salicina* (Japanese plum) in

China, *Prunus cerasifera* (cherry plum) in Western and Central Asia and *Prunus americana* (American plum) in North America [2, 3]. There are fifteen cultivated species of plum in which *Prunus domestica* (European Plum) and *Prunus salicina* (Japanese plum) are commonly grown in Pakistan [4, 5]. Plum is a rich source of vitamin A, vitamin C, iron and fibers. It is consumed in fresh, dry, canned, and also preserved into jams and jellies [6, 7].

In Pakistan, total area under plum cultivation was 7019 hectares (ha) which included 26 ha in Punjab, 2981 ha in Khyber Pakhtunkhwa and 4012 ha in Baluchistan. Total production was 54304 tonnes which represented production of 172, 26269 and 27863 tonnes in Punjab, KP and Baluchistan respectively [8].

The plant growth regulators required in small quantities and at low concentrations to carry message from one part to another part of the plant for performing certain actions. Similarly, they are synthesized in one place and go to the other place to perform different functions. Moreover, plant growth regulators improve productivity by changing physiological and biochemical characteristics of a crop through rapid mobility inside plant [9, 10].

Gibberellic acid has three important actions which include the ability of an organ to be used as a sink for the nutrients, the increase in synthesis of IAA in plant tissues and acceleration of hydrolytic enzymes synthesis in Aleurone cells [11, 12]. Gibberellic acid has great effect on plant physiological systems including fruit setting, leaf expansion, germination, breaking dormancy, increasing fruit size, improving fruit quality and many other aspects of plant growth and crop production [13]. Gibberellic acid at 30 and 40 ppm was considered effective treatment when applied after berry set which resulted in improving quality of seedless grapes [14, 15].

In view of these prospective, an attempt has been made to find out the suitable treatment which could improve the quality of plum. Therefore, the present research study “Effect of Gibberellic acid at different phenological stages on the quality of plum” was designed and conducted at Agricultural Research

Institute Tarnab, Peshawar during the year, 2017 with the following objectives:

Objectives

To find the optimum concentration of GA₃ for fruit quality of plum

To find the proper phenological stage for spray for the increase in quality attributes in plum

To find the interactive effect of GA₃ and phenological stage on quality of plum

Materials and methods

The present experiment was carried out at Agricultural Research Institute Tarnab, Peshawar, Khyber Pakhtunkhwa, Pakistan during 2017. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with Split Plot arrangement having three replications. Eighteen trees (10 years old; receiving same cultural practices and are in healthy condition and vigor) of plum cv. Red Beaut (*Prunus salicina*, L.) budded on Peshawar local peach rootstock were selected. Different concentrations of GA₃ i.e. 0, 20 and 30 ppm were sprayed at different phenological stages included phase at full bloom and after fruit set (≈80% petal fall) and their results were compared with control treatment.

Treatments

Aqueous solutions of 20 and 30ppm were prepared according to the standard formula (2.5g of GA₃ dissolved in 100 liter of water =10 ppm) given by product ProGibb®. Chemical weight for 10 ppm was find out for 10L distilled water treatment⁻¹ as (No. of grams dissolved in 10L = $\frac{2.5g \times 10 L}{100}$ and then the chemical weight for 10 ppm multiplied by 2 and 3 for making 20ppm and 30ppm solutions respectively [16]. These solutions were applied at two different phenological stages that is, at full bloom and after fruit set.

Factor A

Main Plot

Phenological stages

Factor B

Sub Plot

GA₃ concentrations

PS ₁ = At full bloom		G ₁ = 0 ppm (Control)
PS ₂ = After fruit set		G ₂ = 20 ppm
		G ₃ = 30 ppm

Study parameters

The following bio-chemical parameters were studied.

1. Total Soluble Solids (TSS °Brix)

The total soluble solids of 10 fruits randomly selected, were measured by using hand Refractometer, according to method described in [17]. The means were calculated.

2. Fruit pH

Fruit pH was described with the help of electronic pH meter before keeping the electrode of pH meter in plum juice, the pH meter was standardized by pH buffer solution and pH of the plum was determined by taking fruit sample from every treatment in each replication and their average was taken.

3. Total sugars (%)

Sugars content of 10 randomly selected fruits were determined by analyzing the sample in Food Technology lab, according to method described in [17]. The average was counted.

4. Acidity (%)

Acidity of 10 randomly selected fruits were determined by analyzing the sample in Food Technology lab, according to method described in [17]. The average was counted.

5. Sugar acid ratio

The ratio of sugar and acid was determined by sugar contents divided by acid contents of the fruits.

6. Vitamin C (mg/100gm)

Vitamin C content of 10 randomly selected fruits were determined by analyzing their sample in Food Technology lab, according to method described in [17]. The average was counted.

Statistical analysis

All data were tested by the analysis of variance (ANOVA) for treatment effects on analyzed parameters. Means of the

treatments were separated and compared by using the Least Significant Differences at 5% level of significance according to [18]. The statistical analysis was performed by using Statistix 8.1 computer statistical Software.

Results and discussion

The results obtained of different parameters are discussed as below.

Total soluble solids (TSS °Brix)

Mean (Table 1) shows that GA₃ concentrations, phenological stages and interaction between them significantly affected the total soluble solids. Maximum TSS (8.85) was recorded with GA₃ application after fruit set, which was declined to (8.03) with GA₃ at full bloom. The mean data for GA₃ concentrations revealed that the maximum TSS (9.44) was observed with 30 ppm GA₃, followed by (8.65) with 20 ppm GA₃, while minimum TSS (7.23) was observed in control.

The increased in total soluble solids occurred during fruit ripening might be due to the synthesis of sucrose-phosphate, a key enzyme responsible for sucrose biosynthesis [19]. The results are similar with Ingle [20] who revealed that Total Soluble Solids and total yield are significantly increased with the foliar application of GA₃ at 25 ppm compared with control in 'Nagpur' mandarin and yield Rokaya [21] found that TSS are significantly affected by GA₃ application as compared to control in mandarin. Similar evidence were observed by Saleem [22] that application of GA₃ has improved Total soluble solids in 'Blood Red' sweet orange and Wahdan [23] who observed that total soluble solids was significantly increased in fruits harvested from trees sprayed with 40 ppm GA₃ at one month after full bloom in mango as compared to control and other treatments.

Table 1. Mean data for Total Soluble Solids (°Brix) as affected by Gibberellic acid concentrations and Phenological stages

Phenological stages	Gibberellic Acid Concentrations (ppm)			Mean
	Control	20	30	
Full Bloom	7.24	8.15	8.69	8.03b
After Fruit Set	7.22	9.14	10.19	8.85a
Mean	7.23c	8.65b	9.44a	

Fruit pH

Mean (Table 2) shows that effect of GA₃ concentrations, phenological stages and interaction between them was found significant for fruit pH. Maximum fruit pH (4.86) was recorded with GA₃ application at full bloom, which was declined to (4.49) with GA₃ application after fruit set. The mean data for GA₃ concentrations revealed that the maximum fruit pH (5.51) was observed in control, followed by (4.49) with 20 ppm GA₃, while minimum fruit pH (4.03) was observed with 30 ppm GA₃ application.

The fruit pH decreased, as well as the fruit get

matured, this might be due to the conversion of acid to sugars during ripening. According to Davarynejad [24] pH was significantly enhanced during storage, while the GA₃ application retained the pH of the fruit might be due to induction of tinny cover on the fruit surface which inhibit the process of degradation. During respiration the fruit juice pH enhanced due to the alteration of acid to sugars [25]. Results are in harmony with Bhattarai and Gautam [26] discovered that the acids inside the fruit itself utilize by the fruit which leading to enhance the pH of the fruit.

Table 2. Mean data for fruit pH as affected by Gibberellic acid concentrations and Phenological stages

Phenological stages	Gibberellic Acid Concentrations (ppm)			Mean
	Control	20	30	
Full Bloom	5.49	4.64	4.44	4.86a
After Fruit Set	5.52	4.34	3.61	4.49b
Mean	5.51a	4.49b	4.03c	

Sugars (%)

Mean (Table 3) shows that effect of GA₃ concentration and phenological stages was found significant for percent sugars while interaction between them was found non-significant. Maximum sugars (9.12%) was recorded with GA₃ application after fruit set, which was declined to (8.98%) with GA₃ at full bloom. The mean data for GA₃ concentrations revealed that the maximum sugars (9.16%) was observed with 30 ppm GA₃, followed by (9.10%) with 20 ppm GA₃, while minimum sugars (8.88%) was observed in control.

Sugars are the primary source of energy and is an important part of human diet [27] and includes in fruit parameters for quality

measurement. The main sugars found in fresh plums are glucose, fructose and sucrose, although sorbitol, a sugar alcohol, are also present [28]. The results are in uniformity with the Moneruzzaman [29] and Moneruzzaman [30] they found that application of GA₃ increased total sugar (%) in the wax apple fruits compared with the control treatment. According to Saleem [22] application of GA₃ in 'Blood Red' sweet orange has improved reducing sugar, non-reducing sugar and total sugar. Similarly, Sattar [31] applied gibberellic acid on Hollywood plum and observed a significant increase in reducing, non-reducing and total sugars contents.

Table 3. Mean data for sugars (%) as affected by Gibberellic acid concentrations and Phenological stages

Phenological stages	Gibberellic Acid Concentrations (ppm)			Mean
	Control	20	30	
Full Bloom	8.81	9.04	9.09	8.98b
After Fruit Set	8.94	9.17	9.24	9.12a
Mean	8.88c	9.10b	9.16a	

Acidity (%)

Mean (Table 4) shows that different Gibberellic acid concentrations, phenological stages and interaction between them affected the acidity significantly. Highest acidity (0.21%) was measured from the trees sprayed with Gibberellic acid, at full bloom while the lowest acidity (0.18%) was recorded at spray practiced after fruit set. Data regarding GA₃ concentrations shows that fruits of maximum acidity (0.22%) were recorded in untreated control trees pursued by acidity (0.19%) at 20 ppm Gibberellic acid concentration while, trees treated with 30 ppm GA₃ produced the fruits of minimum acidity (0.17%).

The main acid present in plum is malic acid and its level decreases during ripening [32]. The results shows that gibberellic acid

application had an extreme reducing effect on the acidity. The results are in line with Li and Sun [33] who revealed that GA₃ treatments decreased acidity percentage in pineapple compared with control treatment, Mastuane [34] who observed that the percent acidity decreased in strawberry with the increasing concentrations of Gibberellic acid while, Tuan and Chung-Ruey [10] who observed that GA₃ applications at 30 ppm greatly decreased the acidity as compared to control treatment. Due to normal respiration and conversion to other metabolites the loss in acidity was observed [35]. Plant Growth Regulators convert the organic acids to sugar during fruit ripening and thus the reduction in titratable acidity occur Tuan and Chung-Ruey [10].

Table 4. Mean data for acidity (%) as affected by Gibberellic acid concentrations and Phenological stages

Phenological stages	Gibberellic Acid Concentrations (ppm)			Mean
	Control	20	30	
Full Bloom	0.22	0.21	0.19	0.21a
After Fruit Set	0.22	0.17	0.15	0.18b
Mean	0.22a	0.19b	0.17c	

Sugar:Acid ratio

Mean (Table 5) revealed that different phenological stages and Gibberellic acid concentrations and their interaction affected the sugar: acid ratio significantly. Highest sugar: acid ratio (52.01%) was measured from the trees sprayed with Gibberellic acid after fruit set, while the lowest sugar: acid ratio (43.43%) was recorded at spray practiced at full bloom. Data regarding GA₃ concentrations shows that fruits of maximum sugar: acid ratio (54.40%) were recorded in trees treated with 30 ppm GA₃, followed by

(48.34%) with Gibberellic acid at 20 ppm concentration, while the minimum sugar: acid ratio (40.41%) were noted in untreated control treatment.

The results are in line with the Mohsen [36] who reported that GA₃ at 30 mg/L recorded the higher most percentages of sugar: acid ratio in grapes, Wahdan [23] who reported that sugar: acid ratio was significantly decreased in fruits harvested from trees sprayed with GA₃ at full bloom in mango, and Moneruzzaman [30] observed significant changes in the sugar acid ratio due to

different Gibberellic acid concentrations in wax apple fruits as compared to control treatments. Similarly, Sattar [31] observed a significant enhancement in sugar: acid ratio that was obtained by spraying Gibberellic acid in Hollywood plum. According to Li and Sun [33] the ratio of soluble sugar and titratable acidity was affected significantly

with the application of Gibberellic acid in pineapple. According to Rokaya [21] Gibberellic acid application significantly increased the Sugar/acid ratio compared to control treatment. When the sugars content increased and juice acidity decreased, the sugar/acid ratio will be increased during holding of fruit on the tree.

Table 5. Mean data for sugar: acid ratio as affected by Gibberellic acid concentrations and Phenological stages

Phenological stages	Gibberellic Acid Concentrations (ppm)			Mean
	Control	20	30	
Full Bloom	39.48	43.76	47.04	43.43b
After Fruit Set	41.34	52.92	61.76	52.01a
Mean	40.41c	48.34b	54.40a	

Vitamin C (mg/100gm)

Mean (Table 6) revealed that different Gibberellic acid concentrations and phenological stages affected the Vitamin C significantly while their interaction was non-significant. Highest Vitamin C (5.54 mg/100g) was measured from the trees sprayed with Gibberellic acid, after fruit set while the lowest Vitamin C (5.34 mg/100g) was recorded at GA₃ spray practiced at full bloom. In case of GA₃ concentrations the fruits of maximum Vitamin C (5.63 mg/100g) were observed in trees sprayed with Gibberellic acid concentration at 30 ppm followed by (5.48 mg/100g) at 20 ppm concentration while, in control treatment fruits of minimum Vitamin C (5.22 mg/100g) were produced.

Vitamin C is an important part of human diet

Table 6. Mean data for vitamin C (mg/100gm) as affected by Gibberellic acid concentrations and Phenological stages

Phenological stages	Gibberellic Acid Concentrations (ppm)			Mean
	Control	20	30	
Full Bloom	5.16	5.37	5.49	5.34b
After Fruit Set	5.27	5.58	5.76	5.54a
Mean	5.22c	5.48b	5.63a	

Conclusion

Majority of parameters are positively affected by phenological stages and had significant variation

which helps to save the human from many serious diseases as it is a powerful antioxidant [27]. Vitamin C was significantly influence by the GA₃ concentrations and phenological stages as compared to control. According to Ingle [20] vitamin C increases in 'Nagpur' mandarin with the foliar application of GA₃ at 25 ppm compared to control treatment. The results are similar to Saleem [22] who observed that application of GA₃ in 'Blood Red' sweet orange has improved Vitamin C contents, and Wahdan [23] who observed that GA₃ at 40 ppm after full bloom significantly increased vitamin C contents in mango fruits. Moneruzzaman [30] also reported that Vitamin C contents was significantly increased by GA₃ application as compared to control in wax apple.

towards GA₃ application. The application of Gibberellic acid at full bloom resulted significantly in maximum total soluble solids,

sugars, low acidity and high vitamin C contents. All bio-chemical parameters of plum studied were improved by the application of 30 ppm GA₃ than control treatments including maximum total soluble solids, sugars, low acidity, sugar: acid ratio and high vitamin C contents. Gibberellic acid application at 30 ppm concentration, after fruit set was found better in most of bio-chemical parameters of plum as compared to control. Therefore, Gibberellic acid at 30 ppm concentrations, after fruit set is recommended for the best quality production of plum under agro-climatic conditions of Peshawar valley. Further research should be conducted beyond 30 ppm to study the effect of foliar application of GA₃ on quality attributes of plum.

Authors' contributions

Conceived and designed the experiments: W Khan, Performed the experiments: W Khan, Analyzed the data: S Khan & M Ghaffar, Contributed materials/ analysis/ tools: W Khan, Wrote the paper: W Khan, S Khan & M Ghaffar.

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