EFFECT OF NAPHTHALENE ACETIC ACID ON GROWTH AND POST HARVEST PERFORMANCE OF PLUM

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ABSTRACT

Naphthalene acetic acid (NAA) is a plant hormone in the auxin family that plays a vital role in many aspects of plant development. Plum fruits are perishable and cannot be stored for long periods. Considering the importance of plums in the economy of Pakistan and problems related to the low yield and storage duration, this experiment was conducted.The experiment was carried out in RCBD with three factors replicated three times. The effect of all experimental treatments was found significant for all studied growth attributes. NAA at the rate of 75 ppm increased chlorophyll content (0.0316 mg cm^{-2}), leaf protein content (6.55 %), total number of fruits $plant^{-1}$ (937). Among application stages, NAA sprayed 15 days after fruit set increased chlorophyll content (0.0295 mg cm^{-2}), leaf protein content (6.69 %), total number of fruits $plant^{-1}$ (934). NAA application stages were found non-significant for fruit weight. The analyzed result showed that the attributes studied for storage duration of plum fruit was significantly affected by NAA concentration less non-reducing Sugars(3.75%), while higher reducing Sugars(2.33%) and total flavonoid (4.77mg $100g^{-1}$) were recorded with fruit plant sprayed with 75 ppm. The result for various NAA application stages indicated that less Non-reducing Sugars(3.87%), Reducing Sugars(2.33%) and total flavonoid (4.77 mg $100g^{-1}$) were recorded when NAA applied 15 days after fruit set. Storage duration means showed that freshly harvested plum fruit showed the highest non-reducing Sugars(4.37%)While lowest reducing Sugars(1.57%) respectively. The means for storage durations showed that the lowest non-reducing Sugars(3.85%) and total flavonoid (3.02 mg $100g^{-1}$) plum fruit examined at 75 days of storage. While high total flavonoid (5.33 mg $100g^{-1}$) was found fruit stored for 45 days. Foliar application of NAA 15 days after fruit set at 75 ppm could improve better yield and prolong shelflife of plum up to 45 days under low temperature (10±2 ºCand RH 80-90%).

Keywords: Naphthalene acetic acid (NAA),chlorophyll,leaf protein, flavonoids, Storage

INTRODUCTION

Plum (*Prunus domestica*L.) is a deciduous fruit, usually called drupe or stone fruit. Plum fruit exhibits climacteric behavior as with other types of climacteric fruits, the

quality of plum fruit varies depending on the harvest stage (Valero *et al.,* 2003).Plum fruits is perishable cannot be stored for longer periods as well as transported over long distances under normal circumstances. Post-harvest softening of plums limits its storage periods (Skog *et al.,* 2003).The most effective way to reduce the deterioration of plum fruit after harvest is to apply some Pre-harvest treatments of nutrients (Kader and Mitchell, 2002), to ripening and degradation (Daverynejad *et al.,* 2013).

Naphthalene acetic acid (NAA) is an organic compound having chemical formula ($C_{12}H_{10}O_2$). NAA plays a vital role in many aspects of plant development, including cell division, elongation and differentiation (Woodward and Bartel, 2005). It is a plant hormone in the auxin family and influence fruit yield and quality (Fernandez *et al.,* 2005). It plays important role in fruit formation, cell elongation, apical dominance, photoperiod, and tropism (Haidry *et al.,* 1997). Foliar spraying with NAA improves the fruit quality and physical characteristics of fruits. Growth is greatly affected by most treatments, and fruit weight is one of the parameters that characterize the quality of fruits (Khalil *et al.,* 2012) such as fruit size, weight and pulp seed ratio (El Iraqy, 2001) Application of NAA has been used to improve the fruit quality attributes such as fruit set, size, shape as well as delays fruit maturity (Ramezani and Shekafandeh, 2009).

The application of auxin also promotes fruit quality by increasing the total soluble Solids (TSS), total sugar and reducing sugar such as hexose and sucrose content in the fruit (El Otmani *et al.,* 2004) as well as flavonoids in fruits (Vanisree and Tsay 2004).Naphthalene acetic acid can still be used as a physiological molecular structure (Cooke *et al.,* 2002). The application of NAA can regulate respiration, be related to weight loss, and accumulation of TSS, by accelerating the hydrolysis of polysaccharides into simple sugars (Zubair, 2014).The application of plant growth regulator (NAA) helps to increase the sugar content in fruits (Saleem *et al.,* 2008). NAA application can increase the average ascorbic acid content during storage (Singh *et al*., 2008). NAA also plays vital role in secondary metabolites which are attributed to the increase in the total soluble sugar (sucrose, glucose and fructose) (Ibrahim and Jaafar, 2012). NAA also decreases weight loss which may be due to some biochemical changes inside the fruit, which results in the retention of more water relative to the evaporation rate. The application of NAA promotes the storage performance of

different fruits (Singh *et al*., 2008). The usefulness of foliar-applied NAA at different stages to fruit trees is generally accepted for better yield (Ahmad *et al*., 2012). NAA plays a vital role in fruit growth when applied as Pre-harvestfoliar spray to the plants at the fruit development stage (Westwood, 1993).

MATERIALS AND METHODS

The Experiment was conducted at Horticulture Research Farm and postharvest laboratory Department of Horticulture, The University of Agriculture Peshawar. The experiment was conducted in two phases at Ist phase field data were analyzed and then at 2nd phase the fruits were kept for storage performance. Different concentrations of naphthalene acetic acid (NAA) (0, 25, 50, 75 and 100 ppm) their application at different intervals (15, 30 and 45 days after fruit set) and studied various growth parameters and storage duration (0, 15, 30, 45, 60 and 75 days) at a temperature of 10±2 ºCand RH 80-90%. The experiment was carried out inRCBD with three factors replicated three times.

Statistical Analysis

The data were analyzed by Statistix software (Statistix 8.1 Analytical Software, 2000). Means were compared by LSD test when the F test is significant (Jan *et al.*, 2009).

RESULTS AND DISCUSSION

Chlorophyll content (mg cm^{-2})

The analysis of the given data showed a significant effect of NAA concentrations and NAA applications at different stages on the chlorophyll content of plum (Table 1). The interaction was non-significant.

Maximum chlorophyll content (0.0316 mg cm^{-2}) was recorded when NAA was applied at the rate of 75 ppm. Minimum chlorophyll content (0.0161 mg cm^{-2}) was observed in the control.In the case of NAA application at various stages, maximum chlorophyll content (0.0295 mg cm^{-2}) was recorded when NAA was applied 15 days after fruit set. Minimum chlorophyll content (0.0215 mg cm^{-2}) was observed when NAA was applied after 45 days of fruit set, which isat par with 30 days after fruit set.

Chlorophyll is the pigment by which plant photosynthesis occurs. NAA play a vital role in chlorophyll synthesis.NAA application increased photosynthetic pigments, and rate of photosynthesis (Raoofi *et al.,* 2014). The possible reason for more chlorophyll content may be attributed to the involvement of NAA during sun light to chlorophyll molecule thereby transformation of photochemical energy into biochemical energy and increasing utilization of assimilation, which in turn may lead to prolonged chlorophyll synthesis (Lee, 1990). NAA application increased the concentration of chlorophyll a and b. (Guo *et al.,* 2018). Lakshmamma and Rao (1996a) reported that spraying 5-20 ppm NAA at the flowering stage progressively increased the chlorophyll content in plant leaves, with the highest chlorophyll content recorded with 20 ppm NAA. Similar results have also been reported by Sivakumar *et al*. (2002) and Kumar *et al*. (2005).

Leaf protein content (%)

Leaf protein content was significantly affected by NAA concentrations and its application stages. Their interaction was non-significant (Table 1).

It is observed from the mean table that leaf protein content of plum fruit increased from 6.02 to 6.55% when NAA concentration was increased from 25 to 75 ppm while further increase in NAA concentration at 100 ppm. While the lowest leaf protein content was observed in control plant (3.79%).Regarding the result for NAA application stages, Maximum leaf protein content (6.71 %) was calculated when NAA applied 15 days after fruit set. While minimum (6.07 %) leaf protein content was observed when NAA was applied 45 days after fruit set. However further delay in NAA application stage (45 days after set) reduced leaf protein content.

Synthetic auxin (NAA) also play important role in protein synthesis (Chaurasiya *et al.*, 2014). Due to impaired structural integrity of the ribosome (protein synthesis site) and activate enzymes involved in protein synthesis. The main reason for leaf protein content increases, NAA promote leaf nitrogen content which increases leaf protein content in plants (Singh and Sharma, 1996). The effects of NAA in the form of a foliar application directly affect on leaves which influenced the leaf protein content in plants leaves (Chaurasiya *et al.*, 2014). Earlier studies are also in line with these findings that synthesis of chlorophyll and leaf protein due to NAA treatment with (Chaurasiya *et al.*,

2014). Kalarani and Jeyakumar (1998) reported that spraying 0.04 % NAA solution caused the soluble protein content of soybean leaves to increase by 9.84, 17.58 and 9.13% over the control. Similar results are reported by Karim (2005) 20 ppm NAA in leaf protein in chickpeas but the protein content in the seeds decreased with the increase in NAA concentration and Sivakumar et al. (2002) in the leaf of pearl millet.

Total number of fruit plant^{-1}

Analysis of the data showed that NAA concentrations and its application at various stages had significantly affected the total number of fruits plant^{-1}. Their interaction was also significant (Table 1).

Trees treated with NAA @ 100 ppm produced the maximum fruits plant^{-1} (937), which are not significantly different from plants treated with NAA @ 50 and 75 ppm. While the minimum total number of fruits plant^{-1}(824) was recorded in the control plants.In case of NAA application stages, the maximum total number of fruits plant^{-1}(941)was observed when NAA was applied 15 days after fruit set. There is no significant difference between NAA applications stage 15 and 30 days after the fruit set. Trees treated with NAA 45 days after fruit setresulted in minimum total number of fruits plant^{-1} (894). Interaction between NAA concentration and application stages indicated that total number of fruits plant^{-1} decreased with delayed NAA application stages and increased with increase NAA concentration. However the total number of fruits plant^{-1} was increased with NAA application up to 75 ppm. Maximum total number of fruits plant^{-1} (975.6) was observed when NAA was applied @ 75 ppm at 15 days after fruit set. While minimum total no. of fruits plant^{-1} (828) was recorded when NAA 25 ppm was applied 45 days after fruit set (Fig 1).

The present result showed that plum tree sprayed with NAA 75 ppm at 15 days after fruit set increased the total number of fruits plant^{-1}. Naphthalene acetic acid plays a key role in chlorophyll content, cell elongation, cell division, fruit setting and flowering thus increasing number of fruits in plants (Raoofi *et al.,* 2014). NAA activate many enzyme that regulates fruit growth which significantly increased the number of fruit plants^{-1} the reason may due to NAA application significantly affected fruit weight which may lead to an increasing number of fruits plants^{-1} (Fernandez *et al.,* 2005).

Foliar application of NAA increases the number of fruits as it helps the formation of fruit set (Choudhary *et al*., 2019). The increase in fruit numbers and production with NAA may be due to high fruit setting (Khanzada *et al.,* 2002). Foliar application of NAA improves as fruit set and numbers of fruits plant^{-1} (Khalil *et al.,* 2012).

Table 1: Chlorophyll content (mg cm^{-2}), leaf protein content (%) and total No. of fruits plant^{-1} of plum fruit as affected by various concentrations of naphthalene acetic acid at different stages.

	Parameters		
NAA concentrations (ppm)	**Chlorophyll content (mg cm^{-2})**	**Leaf protein content (%)**	**Total No. of fruits plant^{-1}**
0	0.0161 c	3.79 d	824 c
25	0.0228 b	6.02 c	883 b
50	0.0223 b	6.29 b	916 a
75	0.0316 a	6.55 a	936 a
100	0.0233 b	6.62 a	937 a
LSD (P≤0.05)	0.0047	0.202	29.4
NAA application stages (days after fruit set)			
15	0.0295 a	6.71 a	941 a
30	0.0240 b	6.34 b	919 a
45	0.0215 b	6.07 c	894 b
LSD (P≤0.05)	0.0041	0.175	25.4
Interaction at LSD (P≤0.05)			
NAA × Stages	---	---	Fig. 1
Significance	NS	NS	*

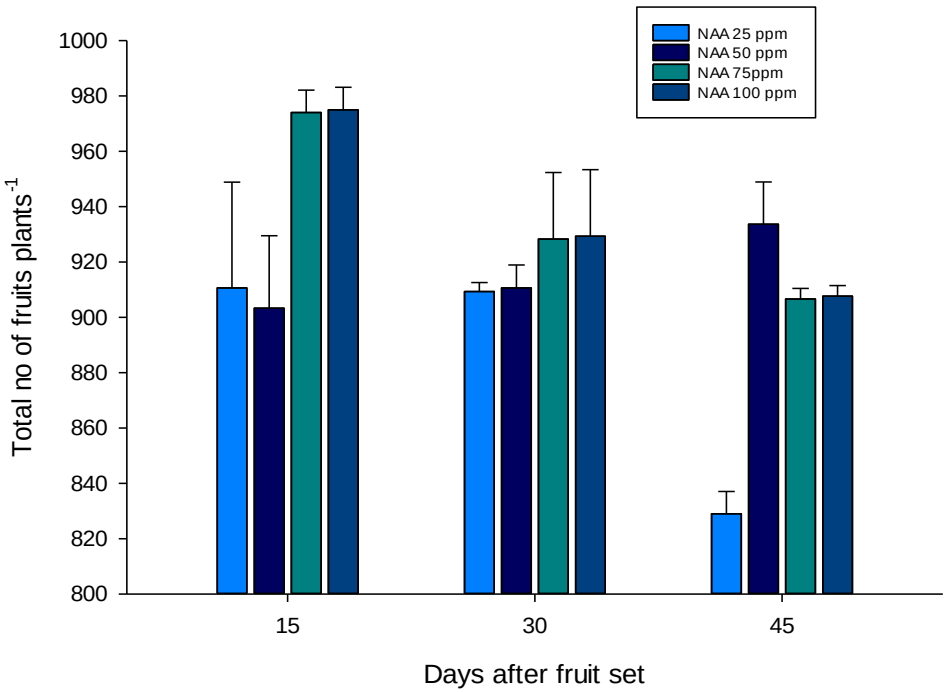

Figure 1: Interaction between NAA concentrations and days after fruit set for total no of fruits plant^{-1}of plum

Reducing Sugars (%)

The data revealed a significant variation for NAA concentrations and application stagesfor reducing Sugarsof plum fruits during storage. All the interactions were non-significant exceptNAA ×Application stage (Table 2).

Data regarding reducing Sugarsof plum fruit showed maximum reducing sugars(2.33%) was observed with the application of NAA @ 75 ppm which is at par with 100 ppm. While minimum Reducing Sugars(1.87%) was observed in control. Increased with NAA application concentration showed an increased in reducing sugarsof plum fruit.Maximum reducing sugars(2.33%) were obtained when NAA was applied 15 days after fruit set. Decreased in reducing sugarswas observed by delaying the application stages. Minimum reducing sugars(1.96%) were observed when NAA was applied 45 days after fruit set. In case of storage duration minimum reducing sugars(1.57%) was recorded in at 0-day storage. While reducing sugarswas increased with storage duration, (2.71%) was found fruit stored for 75 days.Interaction between NAA concentration and NAA application stage indicated that reducing sugars(%) decreased

with delayed NAA application stage and increased with NAA concentration, however maximum reducing sugars(2.65%) was observed when NAA 75 ppm was applied 15 days after fruit set. While minimum reducing sugars(1.83%) were observed NAA was applied 45 days after fruit set (Fig 2).

The increase and decrease in sugar content depends on metabolic activities in the fruit. Reducing sugars is vital to fruit quality.Application of NAA increase reducing sugars during refrigeration may be due to the conversion of polysaccharides (starch or sucrose) to monosaccharides (glucose and fructose) or through the conversion of organic acids to sugars (Kumar *et al.,* 2011). Reducing sugar increased in NAA-treated fruits due to induction of invertase synthesis (Rao *et al.,* 2015). Which breaking down of sucrose into fructose and glucose, causing reduced sugars (Tymowska, 1998). The application of NAA enhances the utilization of carbohydrates, and results in increased hexose and sucrose content in the fruit which regulate reducing sugars (El Otmani *et al.,* 2004). NAA application also reduces acidity and increase reducing sugars in different fruit species (Ahmad *et al.,* 2009). Reducing sugar content will increase as the NAA concentration increases. Generally, sugar content increases with increasing maturity, while NAA acts as a biological regulator, delaying maturity and increasing the sugar content of fruits (Saleem *et al.,* 2008). Previous research are also is in line with these findings that the application of NAA increasesthe reducing sugars and non-reducing sugars in date palm (Kassem *et al.,* 2010) and fruit quality (Nawaz *et al.,* 2008) such as higher reducing sugars, acidity and lower non reducing sugars, TSS (Amiri *et al.,* 2012).

Non-Reducing Sugars (%)

Naphthalene acetic acid concentration and NAA application stages had significant effect on non-reducing sugarsof plum during storage. All the interactions were non-significant except NAA ×Application stage (Table 2).

Result regarding non-reducing Sugarsof plum fruit observed that minimum non-reducing Sugars(3.75%) was observed with the application of NAA @ 75 followed by 100 ppm. While maximum non-reducing Sugars(4.37%) was observed in control. Increased NAA application concentrations showed decreased in non-reducing Sugarsof

plum fruit.Minimum non-reducing sugars(3.87%) were obtained in plum fruit when NAA was applied 15 days after the fruit set. An increased in reducing sugarswas observed with delaying NAA application stages. Maximum non-reducing Sugars(4.26%) was observed when NAA applied 45 days after fruit set. In case of storage duration maximum non-reducing Sugars(4.21%) was recorded in at 0-day storage. A decreased in non-reducing Sugarswas observed with storage duration increased, (3.85%) was found in fruit stored for 75 days.Interaction between NAA concentration and NAA application stage indicated that non-reducing sugars(%) increased with delayed NAA application stage and decreased with NAA concentration, however minimum non-reducing sugars(3.71%) was observed when NAA 75 ppm was applied 15 days after fruit set. While maximum non-reducing sugars(4.77%) was observed NAA applied 45 days after fruit set (Fig 3).

The effect of plant growth regulator (NAA) on non-reducing sugars was significantly lower (Ahmed *et al.,* 2012). Non-reducing sugar decrease in NAA treated fruits this may be due to the auxin induction of invertase synthesis (Rao *et al.,* 2015). Because NAA is known to regulate gene expression, invertase is synthesized (Wang and Ruan, 2013). Invertase is responsible for breaking down sucrose into fructose and glucose, this result were significant in reducing and non-reducing sugars (Tymowska and Kreis, 1998).It was observed in previous result that after foliar application of NAA, inwhich sugar content in mangoes was higher while the non-reducing sugars were lowest (Haidry *et al.,* 1997). Application of plant growth regulators, especially NAA, will reduce fruit acidity and non-reducing sugars in different fruit species (Ahmad *et al.,* 2009; Yildirim*et al.,* 2011).The application of NAA helps to increase and decrease the sugar content in fruits. Generally, sugar content increases with increasing maturity, while NAA acts as a biological regulator, regulating sugar content of fruits (Saleem *et al.,* 2008). The effect of NAA on the sugar content of fruit was significantly higher and the content of non-reducing sugars was lower (Ahmed *et al.,* 2012).

Total flavonoid (mg $100g^{-1}$)

Naphthalene acetic acid concentrations and NAA application stages had significant effect on total flavonoid of plum fruits during storage. All the interactions were non-significant exceptNAA ×Application stage (Table 2).

The total flavonoid of plum fruit, the maximum total flavonoid (4.77mg $100g^{-1}$) was observed with the application of NAA @ 75 ppm which was at par with 100 ppm. While minimum total flavonoid (4.32 mg $100g^{-1}$) was observed in control. Increased NAA application concentrations showed an increased in the total flavonoid of plum fruit.Maximum total flavonoids (4.77 mg $100g^{-1}$) were obtained when NAA was applied 15 days after the fruit set. Decrease in total flavonoid was observed in delaying application stages. Minimum total flavonoid (4.41 mg $100g^{-1}$) was observed when NAA was applied 45 days after fruit set. In case of storage duration maximum flavonoid (5.33 mg $100g^{-1}$) was recorded at 45 days of storage. While total flavonoid was found to decrease with storage duration and was the least, (3.02 mg $100g^{-1}$) in fruit stored for 75 days.Interaction between NAA concentration and NAA application stage indicated that total flavonoid (mg $100g^{-1}$) decreased with delayed NAA application stage and increased with NAA concentration, however, maximum total flavonoid (5.10 mg $100g^{-1}$) was observed when NAA 75 ppm was applied 15 days after fruit set. While minimum total flavonoid (4.27 mg $100g^{-1}$) was observed NAA was applied 45 days after fruit set (Fig 4).

The application of NAA increased the flavonoid content significantly (Zhou *et al.*,2011). Naphthalene acetic acid plays a major role in the production of large amounts of flavonoids.NAA also plays a vital role in secondary metabolites which is attributed to the increase in the total soluble sugar (sucrose, glucose and fructose), which is related to the increase inflavonoids and polyphenol (Ibrahim and Jaafar, 2012). Fructose shows a higher flavonoid content than other tested sugars, and this accumulation of total flavonoids is related when plants treated with NAA application. This may indicate that fructose may be a signaling molecule that regulates flavonoid content and cell metabolism in fruit plants (Rolland *et al*., 2006). Flavonoid content is highest with an application of NAA which supplementation on the synthesis of biologically active products and may be related to the flavonoid content of plant (Das *et al*., 2013). Flavonoids are one of the largest categories of plant phenols which are abundant polyphenolic compounds in nature. Some previous results are the same as our study that the use of growth regulator(NAA) at the fruit development stage induces the production of secondary metabolites and increases the anthocyanin content, and flavonoid content (Winkel, 2001). NAA, as a metabolically stable auxin, has a

significant effect on the production of flavonoids compared to other plant growth regulators (Bello *et al*., 2004).

Table 2: Reducing sugars (%), non-reducing sugars (%)and total flavonoid (mg 100g^{-1}) of plum as affected by NAA concentrations and stages during storage.

NAA concentrations (ppm)	Parameters		
	Reducing sugars (%)	Non-reducing sugars (%)	Total flavonoid (mg 100g^{-1})
0	1.87d	4.37a	4.32d
25	1.99c	4.21b	4.43c
50	2.13b	4.01c	4.57b
75	2.33a	3.75e	4.77a
100	2.31a	3.87d	4.76a
LSD (P≤0.01)	0.040	0.052	0.040
NAA application stages (days after fruit set)			
15	2.33a	3.87c	4.77a
30	2.08b	3.99b	4.53b
45	1.96c	4.26a	4.41c
LSD (P≤0.01)	0.031	0.040	0.031
Storage durations (days)			
0	1.57f	4.21a	4.77d
15	1.80e	4.14b	4.99c
30	2.02d	4.08c	5.21b
45	2.22c	4.02d	5.33a
60	2.45b	3.94e	4.13e
75	2.71a	3.85f	3.02f
LSD (P≤0.01)	0.044	0.057	0.044
Interactions (LSD at (P≤0.01)			
Storage × NAA			
Significance	NS	NS	NS
Storage × Stage			
Significance	NS	NS	NS
NAA × Stage	Fig. 2	Fig. 3	Fig 4
Significance	***	***	***
Storage × NAA × Stage			
Significance	NS	NS	NS

Means followed by different letters are significantly different at 1% level of Significance

NS = Non-significant

***= Significant at 1% level of Significance

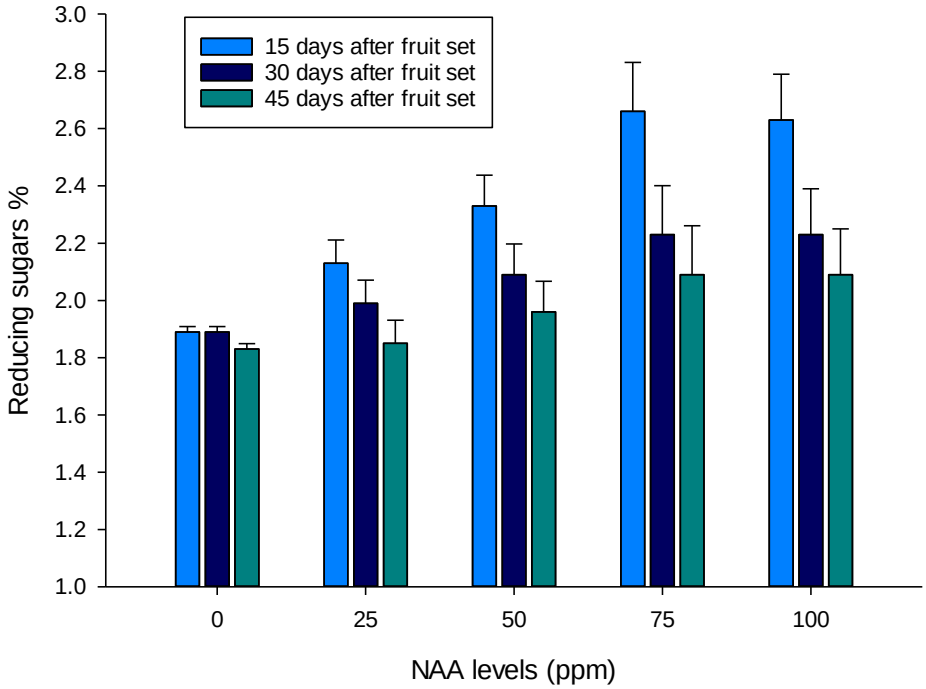

Figure 2: Interaction between NAA concentration and stage (days after fruit set) for reducing sugars (%) of plum

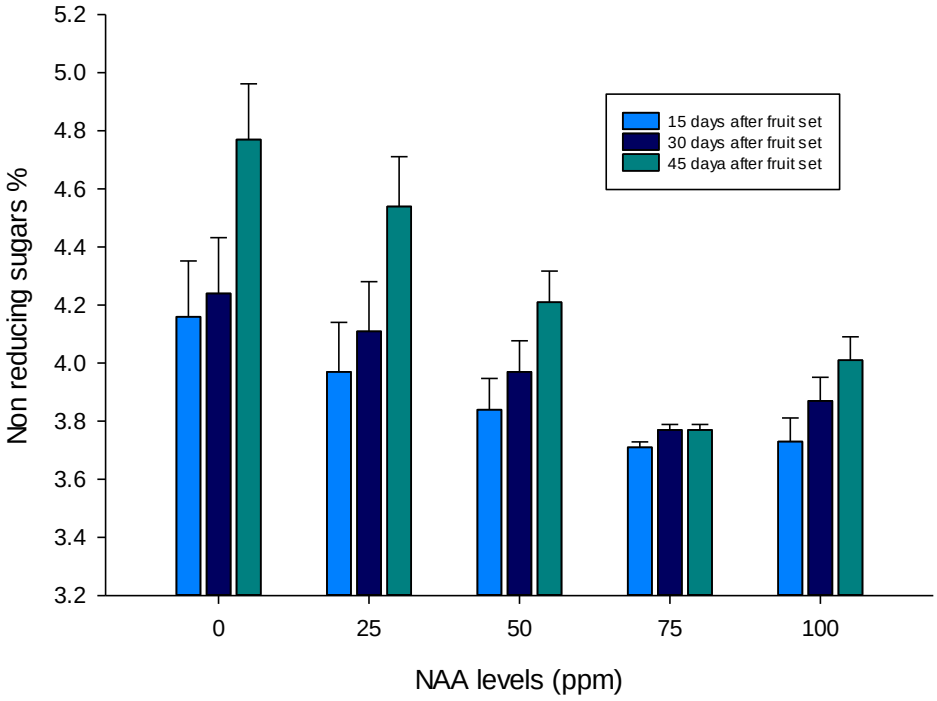

Figure 3: Interaction between NAA concentrations and stage (days after fruit set) for non-reducing sugars (%) of plum

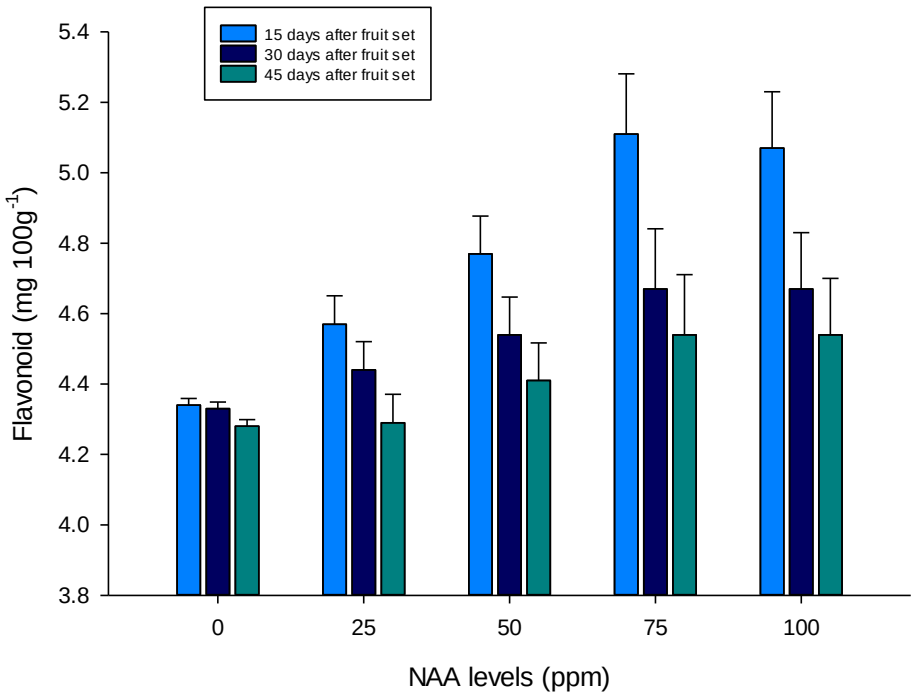

Figure 4: Interaction between NAA concentration and stage (days after fruit set) for total flavonoid (mg $100g^{-1}$) of plum

CONCLUSION

Naphthalene acetic acid is an organic compound plays a vital role in many aspects of plant development.Plum fruits are perishable and cannot be stored for longer periods and cannot be transported over long distances under normal circumstances. Therefore the best treatment in this study was Naphthalene acetic acid75 ppm when it was applied 15 days after the fruit set which maximize chlorophyll content, leaf protein content, total no of fruits $plant^{-1}$and also retained reducing and non-reducing sugars andflavonoid content up to 45 days of storage.

Conflicts of Interest: The authors declare no conflict of interest

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