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Exogenously applied plant growth regulators enhanced the growth, yield, quality and shelf life of phalsa

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Abstract
The study was conducted at Rainfed Research Sub-Station for Subtropical Fruits (RRSS) Raya, of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu, during 2015-2016. The experiment consisted of ten treatments viz., GA3 (100, 150 and 200 ppm), NAA (100, 150 and 200 ppm) and Ethrel (750, 1000 and 1250 ppm) and control (water spray). Results revealed that GA3 150 ppm recorded the longest shoot length (192.50 cm) and Ethrel 1250 ppm resulted in shortest shoot length (162.10 cm). Maximum fruit weight (82.85 g/100 fruits) was recorded with 150 ppm GA3 which was statistically at par with the treatment of 100 ppm GA3 (81.69 g/100 fruits) and 150 ppm NAA (81.58 g/100 fruits and minimum in control (68.80 g/100 fruits). Maximum fruit ascorbic acid (38.30 mg/100 g) was observed with 150 ppm GA3. Application of 1250 ppm ethrel showed significant effect in reducing the harvest span to 22.00 days which was at par with 1000 ppm ethrel (22.40 days) and 750 ppm ethrel (22.60 days) whereas, maximum harvesting span of 31.40 days was recorded in control. Maximum yield of 3.00 kg/ bush was recorded with the application of 150 ppm GA3 followed by 150 ppm NAA, whereas minimum fruit yield of 1.88 kg/bush was recorded in control bushes. Under storage conditions, minimum mean PLW of 8.11% was recorded with 150 ppm GA3 closely followed by 8.79% with 100 ppm GA3 and were statistically at par with each other. Furthermore, the fruit stored under ambient conditions lasted for 48 hours. The lowest mean PLW of 6.23% was recorded after 12 hours of storage and highest mean PLW of 16.88% was observed under control treatment at 48 hour storage interval. Minimum mean PLW of 8.41% was recorded with 150 ppm GA3 closely followed by 8.63% with 100 ppm GA3 and were statistically at par with each other. Further, the fruit stored under refrigerated conditions lasted for 96 hours and there was an increase in PLW with advancing storage intervals. The highest mean PLW of 19.80% was observed at 96 hour storage interval, whereas lowest PLW of 4.80% was recorded after 12 hours of storage. From the mentioned results an overall reduction in PLW was obtained by the application of GA3. Therefore, growth regulators application significantly improves the fruit quality, yield and reduced the harvest duration in phalsa.

Keywords: Growth, yield, quality, shelf-life, Ga3, Ethrel NAA, phalsa cv. Purple Round

Introduction
Phalsa (*Grewia asiatica* L.) is considered as one of the important minor fruit crops. Phalsa is indigenous to Indian sub-continent and South-East Asia (Chundawat and Singh, 1980) [4]. Phalsa is a sub-tropical fruit plant, flowering starts from February- March and fruit ripe in second fortnight of April and continue upto middle of June. Ripe fruit contain 50-60% juice, 10-11% sugar and 2.0-2.5% acid, 14.4% carbohydrates, 1.5% protein, 0.9% fat, 129 mg/100g of pulp..........?, 89 mg phosphorous, 3.1 mg iron, 22 mg/100 g of pulp vitamin-C and 49 IU vitamin. Fruit posses very high antioxidant activity due to presence of vitamin-C, phenolics, flavonoids, tannins and anthocyanins. The berries medicinal properties help in alleviating the inflammations and are also being administered in respiratory, cardiac and blood disorders. Besides being nutritious, it has major bottlenecks in cultivation such as small fruit size, inconsistent fruit yield, non-uniform ripening, prolonged harvesting span involving several pickings and poor shelf-life. Therefore, its cultivation has not been taken up on commercial scale in various regions.

The exogenous application of various plant growth regulators has become an important component of agrotechnical procedures for most of the cultivated plants and especially for fruit crops. Ethylene and gibberellic acid have a great influence on fruit maturity and ripening (Rizk-Alla and Meshrake, 2006; Elfving *et al.*, 2009; Lurie, 2010) [26, 6, 17]. In the meantime, the role of ethylene in uniform fruit ripening of phalsa fruit and hastening the maturity is evident (Parihar *et al.*, 1999 and Kacha *et al.* 2012) [20]. Pre-harvest application of growth regulators was reported to reduce the PLW of the fruits under storage conditions. Further, reduction in fruit weight loss by gibberellic acid is previously reported by Rizk-Alla *et al.* (2011).

Therefore, any efforts that could be done to maintain the phalsa fruits with high yield, better quality, reduce the production cost by reducing the number of pickings and harvesting and extending the shelf-life would be very important for the phalsa growers in order to obtain higher monetary return.

Materials and Methods

The present investigation was carried out at Rainfed Research Sub-Station for Subtropical Fruits (RRSS) Raya, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. During the year 2015-16 on thirty years old healthy phalsa bushes already established in the field.The experiment was design as randomised block design (RBD) and the following ten spray treatments were obtained with three replicates for each treatment.

There were ten treatments comprised of T_1= 100 ppm GA_3, T_2= 150 ppm GA_3, T_3= 200 ppm GA_3, T_4= 100 ppm NAA, T_5= 150 ppm NAA, T_6= 200 ppm NAA, T_7= 750 ppm Ethrel, T_8= 1000 ppm Ethrel, T_9= 1250 ppm Ethrel and T_{10}= control (water spray). All the growth regulators were sprayed twice-first at pre flowering stage and second at pre-harvest stage of the plant development. The growth regulators were applied directly to the bushes with a Knapsack sprayer in the early morning. The observations were recorded for length of the longest shoots at the time of final harvest was measured with a tape from the base of the shoot to the tip of the longest selected shoot of each bush, average number of leaves counted from shoots tagged in four directions (east, west, north and south), chlorophyll content of leaves was determined with the help of chlorophyll meter SPAD-502 manufactured by KONICA MINALTA SENSING, INC. in Japan. Average number of fruits per shoot was determine by tagging four shoots in different directions (east, west, north and south), number of pickings was calculated by counting total pickings required for each bushes, from start of harvest till the end of harvest, harvesting span was calculated from the date of first harvest and counting the number of days taken to complete the harvest for each bushes, yield was calculated by weighing harvested fruits and expressed in kg/ bush. Fruit size was calculated with the help of digital vernier calliper, fruit weight was measured by using electronic balance, total soluble solids (TSS) of the fruit juice was recorded with the help of Erma hand refractometer, sugar content in fruit was calculated by the procedure described in A.O.A.C. (1995) [1].

Titratable acidity was determined by titration alkali (A.O.A.C, 1994)

$$\text{Acidity (\%)} = \frac{\text{Titre value x normality of alkali x volume made x equivalent wt. of acid}}{\text{Volume of sample taken x wt. of sample x 1000}} \times 100$$

Ascorbic acid was estimated by the method of A.O.A.C (1994)

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre x dye equivalent x dilution}}{\text{Weight of sample (g)}} \times 100$$

Fruit weight loss was observed under both the fruit storage conditions i.e. at ambient (40 ± 2^0C) and refrigerated temperature (4-6^0C) for 96 hrs. The physiological loss in weight (PLW) was calculated on initial weight basis and results were expressed as the percentage loss of initial weight as per the standard method of AOAC (1995) [1].

Statistical Analysis: The data obtained were subjected to standard analysis of variance procedure according to Panse and Sukhatme, 1985 [19].

Results and Discussion

i. Pre-harvest observation

Vegetative growth

The effect growth regulators on vegetative growth characteristics of phalsa cv. Purple Round is presented in Table 1. A significant increase in length of longest shoot was obtained by different plant growth regulator treatments compared to the control. Additionally, longest shoot length of 192.50 cm was recorded with the application of 150 ppm GA_3, closely followed by 188.00 cm with 100 ppm GA_3 and were statistically at par with each other. However, application of 1250 ppm ethrel resulted in shorter shoot length of 162.10 cm. The role of exogenously applied GA_3 for increasing bush yield was previously stated in phalsa by Kumar *et al.* (2014) [12] and Singh *et al.* (2017) [31]. Moreover, Singh *et al.* (2011) [32] reported an increase in the shoot length of phalsa by application of GA_3. The increase in shoot growth obtained by the GA_3 might pertain to the fact that gibberellins promote cell division and expansion causing significant elongation of stems in intact plants. However, shorter shoot length by the application of ethrel could be attributed to their influence on inhibiting the cell division, cell expansion and transport of gibberellins in the meristems of shoots and axillary buds.

Table 1: Effect of growth regulators on vegetative growth characteristics of phalsa cv. Purple Round

Treatments	Length of the longest shoot (cm)	Average number of leaves per shoot
T_1 (100 ppm GA_3)	188.00	23.58
T_2 (150 ppm GA_3)	192.50	24.90
T_3 (200 ppm GA_3)	181.30	23.00
T_4 (100 ppm NAA)	179.00	22.83
T_5 (150 ppm NAA)	185.50	23.50
T_6 (200 ppm NAA)	176.00	21.58
T_7 (750 ppm Ethrel)	165.00	19.85
T_8 (1000 ppm Ethrel)	163.00	19.00
T_9 (1250 ppm Ethrel)	162.10	18.54
T_{10} (Control)	167.00	20.20
C.D. ($p \le 0.05$)	6.04	1.86

Number of leaves per shoot
Furthermore, the presented data showed significantly more number of leaves (24.90) per shoot were obtained by spraying 150 ppm GA_3 followed by 150 ppm NAA (Table 1). On the other hand, number of leaves per shoot was significantly reduced to 18.54 in plants sprayed with 1250 ppm ethrel. Gibberellins and naphthalene acetic acid has been reported to stimulate cell division, cell elongation, tissue differentiation that resulted in the initiation of more number of leaves, better photosynthetic activity and translocation of photosynthates to developing organs in turn promote better vegetative growth in phalsa (Singh *et al.*, 2011; Kumar *et al.*, 2014; Singh *et al.*, 2014 and Karole and Tiwari, 2016) [7, 12]. Similar increase in number of leaves was recorded with the application of GA_3 in mango (Wahdan *et al.*, 2011). The reduced number of leaves as a result of ethrel might be due to accelerating process of senescence and it is in agreement to the findings of Grozeff *et al.* (2010) [7] in date.

Leaves chlorophyll content
A significant increase in leaf chlorophyll content of 55.67 SPAD value was recorded with 150 ppm NAA, followed by 54.00 SPAD value with 100 ppm NAA (Fig.1). On the other hand, ethrel recorded low value of chlorophyll content upto 43.20 SPAD value. The increase in chlorophyll content by NAA and GA_3 application could be explained by the positive influence of these growth regulators in increasing cell elongation as well as enhancement of metabolite accumulation in leaves.

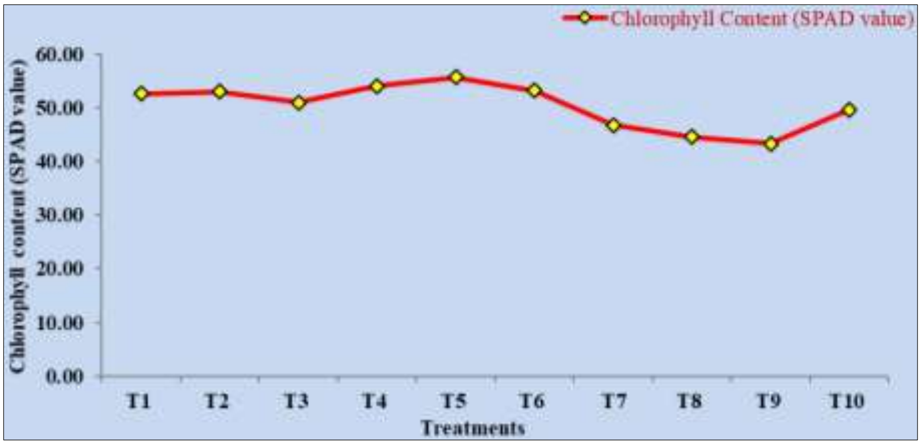

Fig 1: Effect of plant growth regulators on Leaf chlorophyll content of phalsa cv. Purple Round

These results are supported with those obtained by Khandaker *et al.* (2015) in peach. However, the lowest chlorophyll content of 43.20 SPAD value was obtained with 1250 ppm ethrel application. The exposure of plant to ethylene induces premature senescence symptoms such as leaf yellowing and abscission due to chlorophyll degradation (Lewington *et al*., 1967).

ii. Post harvest observation
Fruit physical characteristics
Fruit size (cm)
The effect of the different treatments on fruit physical characteristics at harvest date is presented in Tables 2. The maximum increase in fruit length of 1.15 cm and a significant increased in fruit width of 1.30 cm were obtained with 150 ppm GA_3. The increase in fruit size goes on line with Singh *et al*. (2011) and Alam and Kumar (2017) in phalsa. Similar result was previously mentioned by Ranjan *et al.* (2003), Usenik *et al*. (2005) in sweet cherry (*Prunus avium* L.) and in grapes (*Vitis vinifera* L.) Zahra (2013). Gibberellic acid has been reported to promote fruit growth by increasing plasticity of the cell wall followed by the hydrolysis of starch into sugars resulting in the entry of water into the cell and causing elongation (Richard, 2006). The fruit weight was influenced by different growth regulator treatments, maximum weight of 82.85 g/100 fruits was recorded with 150 ppm GA_3 application which was statistically at par with the treatment of 100 ppm GA_3 (81.69 g/100 fruits) and 150 ppm NAA (81.58 g/100 fruits and minimum in control (68.80 g/100 fruits).

Table 2: Effect of growth regulators on physical characteristics of phalsa cv. Purple Round

Treatments	Fruit Length (cm)	Fruit Breadth (cm)	Fruit weight (g/100 fruits)	Pulp weight (g/100fruits)	Stone weight (g/100 fruits)	Pulp: Stone ratio	Specific gravity
T_1 (100 ppm GA_3)	1.13	1.28	81.69	70.00	10.89	6.43	1.00
T_2 (150 ppm GA_3)	1.15	1.30	82.85	71.57	9.75	7.67	1.01
T_3 (200 ppm GA_3)	1.10	1.21	79.03	66.98	11.62	5.76	0.96
T_4 (100 ppm NAA)	1.09	1.19	78.55	64.56	12.67	6.10	0.93
T_5 (150 ppm NAA)	1.12	1.24	81.58	68.68	11.74	5.85	0.95
T_6 (200 ppm NAA)	1.07	1.17	75.27	61.65	12.99	4.75	0.90
T_7 (750 ppm Ethrel)	1.04	1.16	72.40	58.20	13.18	4.42	0.96
T_8 (1000 ppm Ethrel)	1.00	1.14	71.88	56.85	13.23	4.30	0.97
T_9 (1250 ppm Ethrel)	0.99	1.12	70.90	55.52	13.87	4.00	0.99
T_{10} (Control)	0.94	1.09	68.80	53.27	14.00	3.81	0.92
C.D. ($p \leq 0.05$)	0.04	0.08	1.62	0.85	0.87	0.83	0.02

Fruit weight (g/100 fruits)

From the mentioned results in Table 2 an overall enhancement in the fruit weight was obtained by the different spayed growth regulators. These result agreed with those obtained by Singh and Singh (2015) [30] in phalsa and Shah *et al.*, (2015) [28] in grapes. The increase in fruit weight might be due to rapid cell division, cell enlargement, lengthen the meristematic cells, increase fruit size and results in increment of fruit weight. Maximum pulp weight (71.57 g/100 fruits) was recorded with the application of 150 ppm GA_3. Whereas, minimum pulp weight (53.27 g/100 fruits) was recorded in fruits in control. The results are in agreement with the findings in grapes (*Vitis vinifera* L.) (Khan *et al.*, 1976; Singh and Lal, 1980; Zahedi *et al.*, 2013) [10, 33, 36]. Debnath *et al.* (2011) [5] reported that GA_3 resulted in maximum pulp weight while working with phalsa. The increment in the pulp weight may be due to the enhanced uptake of water and accumulation of sugar and other food reserves in greater amount and increased volume of intercellular spaces in the pulp of fruits. The effect of various plant growth regulators on stone weight was observed to be significant. However, lowest stone weight of 9.75 g/100 fruits was recorded with the application of 150 ppm GA_3 which was statistically at par with 100 ppm GA_3 (10.89 g/100 fruits). The control resulted in maximum stone weight (14.00 g/100 fruits). The decrease in stone weight was contributed to the role of gibberellic acid in stimulating the growth of fruit flesh and effect in parthenocarpic fruits in multiseeded fruits but in single seeded fruits it reduced the size and weight of the fruits. The results are in conformity with the findings of (Rao and Rao, 1963; Reddy, 1977; Debnath *et al.*, 2011) [23, 24, 5] in phalsa.

Pulp: Stone ratio

In Table 2 the maximum pulp: stone ratio of 7.67 was recorded with 150 ppm GA_3. It may be ascribed to the higher pulp weight of fruits. These findings are supported by the results of (Kacha *et al.*, 2014; Singh *et al.*, 2015; Meena, 2017) [8, 30, 18] in phalsa.

Specific gravity

The maximum specific gravity of 1.01 was recorded in 150 ppm GA_3 followed by 100 ppm GA_3 of 1.00 as compared to control Table 2. The increase in specific gravity of the fruits might be due to increase in flesh weight of the fruit. Gibberellins are mainly involved in the subsequent phases of cell expansion of fruits after cell division. The change in specific gravity of fruits during growth is due to increase in intercellular, capillary air spaces and is a function of both weight and volume. The results are in consonance with the findings in guava (Rajput and Singh, 1977; Kumar *et al.*, 1998) [22, 13], in phalsa (Zora *et al.*, 2000) [37], in ber (*Zizyphus mauritiana* Lamk.) (Yadav and Chaturvedi, 2005) [35] and in aonla (*Emblica officinalis* Gaertn.) (Chandra *et al*., 2015).

TSS (^{0}Brix) and sugar content (%)

The effect of different growth regulators on bio-chemical characteristics of phalsa cv. Purple Round is presented in Table 3. Data showed that ethrel, GA_3 and NAA increased the TSS, sugars and reduces the titratable acidity compared control. Maximum TSS content of 24.62^0 B was obtained by spraying 1250 ppm ethrel.

Table 3: Effect of growth regulators on bio-chemical characteristics of phalsa cv. Purple Round

Treatments	TSS (^{0}Brix)	Total sugar (%)	Reducing Sugar (%)	Non reducing sugar (%)	Titratable acidity (%)	Ascorbic Acid (mg/100g)
T_1 (100 ppm GA_3)	23.68	11.05	8.85	2.09	2.54	37.62
T_2 (150 ppm GA_3)	24.00	11.13	8.90	2.12	2.52	38.30
T_3 (200 ppm GA_3)	22.51	10.45	8.60	1.76	2.71	35.80
T_4 (100 ppm NAA)	22.46	10.62	8.52	1.96	2.75	34.50
T_5 (150 ppm NAA)	23.23	10.96	8.74	1.99	2.72	37.00
T_6 (200 ppm NAA)	22.42	10.55	8.17	1.92	2.79	33.43
T_7 (750 ppm Ethrel)	23.73	11.33	8.97	2.24	2.59	31.70
T_8 (1000 ppm Ethrel)	24.06	11.76	9.13	2.41	2.64	31.43
T_9 (1250 ppm Ethrel)	24.62	11.95	9.30	2.52	2.69	31.29
T_{10} (Control)	19.77	10.00	7.78	1.47	2.90	30.00
C.D. ($p \leq 0.05$)	1.10	1.03	0.60	0.48	0.18	1.08

However, minimum value was recorded in control. Furthermore, the significantly higher total sugar (11.95%), reducing sugar (9.30%) and non-reducing sugar (2.52%) were recorded by application of 1250 ppm ethrel followed by GA_3 and NAA (Table 3). In addition to that, significantly lowest titratable acidity was recorded by application of 150 ppm GA_3 followed by ethrel and NAA. Singh *et al.* (2006) reported the similar result while working on growth regulators spray in phalsa. The improvement in TSS with ethrel, might be due to quick metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from the leaves to the developing fruits (Tripathi and Sukhla, 2007).

Ascorbic acid content (mg/100 g)

Significant variations in ascorbic acid content of phalsa fruit was observed during the course of investigation. Maximum fruit ascorbic acid (38.30 mg/100 g) was observed by application of 150 ppm GA_3 Table 3. The increase in ascorbic acid of fruit by GA_3 treatment might be due to perpetual synthesis of glucose-6- phosphate throughout the growth and development of fruit which is thought to be the precursor of ascorbic acid in phalsa (Kumar and Singh, 1993; Meena *et al*., 2017) [18].

Average number of fruits per shoot

Application of growth regulators showed significant effect in increasing number of fruits per shoot as compared to control Table 4. Application of 150 ppm GA_3 resulted in maximum number of fruits per shoot of 113.58 which was at par with 100 ppm GA_3 (112.22) and 150 ppm NAA (111.47). Kumar *et al.* (2014) and Alam *et al.* (2017) in phalsa and Shah *et al*. (2015) [28] in grapes reported similar results. Gibberellic acid has been reported to enhance more vegetative growth for development of fruiting nodes and increase the number of fruits per shoot.

Number of pickings and Harvest span (days)

The application of 1250 ppm ethrel showed significant effect in reducing the harvest span to 22.00 days which was at par with 1000 ppm ethrel (22.40 days) and 750 ppm ethrel (22.60

days) whereas, maximum harvesting span of 31.40 days was recorded in control Table 4. In addition to that, data of Table 4 showed that ethrel had positive result in reducing the number of pickings to 4.50 by application of 1250 ppm ethrel followed by 1000 ppm ethrel (4.90) and 750 ppm ethrel (5.00). The results are in consonance with the findings of (Parihar *et al.*, 1999 and Kacha *et al.*, 2012) [20, 8] in phalsa. Ethylene is known as the ripening hormone and its effects are well known in grapes, which are classified as non climacteric fruit, however, they respond to exogenous ethylene preharvest treatments (Becatti *et al*., 2010) [3]. Therefore, spraying ethrel would increase ethylene content in the fruit by autocatalytic stimulation as a result it accelerates fruit maturing, ripening processes and more uniform, ultimately advances the harvest date.

Table 4: Effect of growth regulators on yield characteristics of phalsa cv. Purple Round

Treatments	Average number of fruits per shoot	Number of Pickings	Harvesting span (days)	Yield (kg/bush)
T_1 (100 ppm GA_3)	112.22	5.90	23.50	2.90
T_2 (150 ppm GA_3)	113.58	6.00	24.75	3.00
T_3 (200 ppm GA_3)	108.23	6.50	25.50	2.78
T_4 (100 ppm NAA)	109.64	6.80	27.20	2.75
T_5 (150 ppm NAA)	111.47	7.00	28.90	2.86
T_6 (200 ppm NAA)	107.32	7.50	29.40	2.50
T_7 (750 ppm Ethrel)	105.58	5.00	22.60	2.18
T_8 (1000 ppm Ethrel)	103.50	4.90	22.40	2.02
T_9 (1250 ppm Ethrel)	102.17	4.50	22.00	1.94
T_{10} (Control)	98.67	7.90	31.40	1.88
C.D. ($p \leq 0.05$)	2.38	1.07	0.66	0.21

Yield (kg/bush)

Data in Table 4 showed that GA_3 and NAA had similar and significantly higher yield value than ethrel and control, which did not significantly differ among each other. However, maximum yield of 3.00 kg/ bush was recorded with the application of 150 ppm GA_3 followed by 150 ppm NAA, whereas minimum fruit yield of 1.88 kg/bush was recorded in control bushes. Similar increase in yield by gibberellic acid sprays was recorded in phalsa (Debnath *et al.*, 2011; Singh *et al.*, 2011 and Singh *et al.*, 2017) [5]. The increase in yield is obtained by the growth regulators might be due to increase in large number of fruits, better physiology of developing fruits in turn increased fruit size, and fruit weight in the present study.

iii. Post harvest Shelf life

Physiological loss in weight (%) at ambient conditions

Data presented in Table 5 showed that under ambient storage conditions, application of different plant growth regulator treatments significantly reduced the physiological loss in weight. However, minimum mean PLW of 8.11% was recorded with 150 ppm GA_3 closely followed by 8.79% with 100 ppm GA_3 and were statistically at par with each other. Furthermore, the fruit stored under ambient conditions lasted for 48 hours and there was an increase in PLW with advancing storage intervals. The highest mean PLW of 16.88% was observed under control treatment at 48 hour storage interval, whereas lowest mean PLW of 6.23% was recorded after 12 hours of storage.

Table 5: Effect of growth regulators on physiological loss in weight (%) of phalsa cv. Purple Round at different storage intervals under ambient conditions

Treatments	Storage intervals (Hours)					
	12	24	36	48	60	Mean
T_1	4.97	5.99	9.30	14.90	F.N.A.	8.79
T_2	4.55	5.64	8.26	13.98	F.N.A.	8.11
T_3	5.32	6.48	9.85	15.35	F.N.A.	9.25
T_4	5.50	6.75	10.80	16.83	F.N.A.	9.97
T_5	5.10	6.26	10.01	15.51	F.N.A.	9.22
T_6	5.90	7.07	11.19	16.88	F.N.A.	10.25
T_7	6.84	7.99	11.98	17.99	F.N.A.	11.22
T_8	7.26	8.56	12.32	18.32	F.N.A.	11.62
T_9	7.85	8.84	12.95	18.86	F.N.A.	12.13
T_{10} (Control)	8.92	9.96	14.10	20.15	F.N.A.	13.28
Mean	6.23	7.35	11.08	16.88		
C.D. ($p \leq 0.05$) Storage intervals (S)= 0.65 Treatments (T)= 1.03 S×T=N.S. *F.N.A.: Fruit Not Acceptable						

Physiological loss in weight (%) at refrigerated conditions

A significant reduction in physiological loss in weight was observed by application of growth regulators as compared to control. Minimum mean PLW of 8.41% was recorded with 150 ppm GA_3 closely followed by 8.63% with 100 ppm GA_3 and were statistically at par with eachother Table 6. Further, the fruit stored under refrigerated conditions lasted for 96 hours and there was an increase in PLW with advancing storage intervals. The highest mean PLW of 19.80% was observed at 96 hour storage interval, whereas lowest PLW of 4.80% was recorded after 12 hours of storage. From the mentioned results an overall reduction in PLW was obtained by the application of GA_3. These results agreed with those obtained in grapes (*Vitis vinifera* L.) (Singh *et al*., 2003; Rizk -Alla and Meshreki, 2006) [26], in guava (*Psidium guajava* L.) (Brahmachari and Rani, 2005), in mandarin (*Citrus reticulata* Blanco) (Kirmani *et al*., 2013; Rokaya *et al*., 2016).

Table 6: Effect of growth regulators on physiological loss in weight (%) of phalsa cv. Purple Round at different storage intervals under refrigerated conditions

Treatments	Storage intervals (Hours)									
	12	24	36	48	60	72	84	96	108	Mean
T_1	2.75	3.84	5.14	6.74	8.54	10.66	13.67	17.68	F.N.A.	8.63
T_2	2.56	3.61	4.90	6.50	8.33	10.39	13.49	17.50	F.N.A.	8.41
T_3	3.25	4.30	5.60	7.20	9.00	11.11	14.21	18.23	F.N.A.	9.11
T_4	4.68	5.69	6.99	8.59	10.40	12.42	15.42	19.43	F.N.A.	10.45
T_5	3.86	4.92	6.23	7.82	9.72	11.83	14.83	18.84	F.N.A.	9.76
T_6	5.00	6.12	7.48	8.96	10.92	12.98	15.98	19.99	F.N.A.	10.93
T_7	5.75	6.84	8.14	9.74	11.54	13.66	16.76	20.78	F.N.A.	11.65
T_8	5.86	6.92	8.22	9.82	11.73	13.84	16.95	20.95	F.N.A.	11.79
T_9	6.48	7.54	8.84	10.44	12.34	14.52	17.62	21.62	F.N.A.	12.43
T_{10} (Control)	7.84	8.30	9.76	11.60	13.74	15.86	18.96	22.97	F.N.A.	13.63
Mean	4.80	5.81	7.13	8.74	10.63	12.73	15.79	19.80		
C.D. ($p \leq 0.05$) Storage intervals (S)= 0.53 Treatments (T)= 0.59 S×T=N.S. *F.N.A.: Fruit Not Acceptable										

Increase in fruit shelf life by GA_3 could be due to its ability to retain more water against force of evaporation and it act as antisenescent and antirespirant, which inhibited catabolic activities and consequently reduced the weight loss during storage. Under refrigerated storage conditions berries could be stored for longer due to lower physiological activity at low temperature as compared to the ambient conditions.

Conclusion

The present study concluded that pre flowering and pre harvest treatment T_2 (150 ppm GA_3) had a positive influence in increasing the shoot length, yield kg per bush, fruit size, weight, pulp weight, TSS, sugar content, ascorbic acid content span as well as extending the shelf life of phalsa. In addition, treatment T_9 (1250 ppm Ethrel) resulted in minimum number of pickings and harvesting. The application of growth regulators *viz*. GA_3, NAA and ethrel at two stages of growth in phalsa is an effective under sub-tropic regions.

Competing Interests: There is no competing interest exist

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