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Title of the Thesis: **"Effect of bio-regulators on growth, yield and quality of plum *(Prunus salicina* Lindl.) cv. Santa Rosa"**

ABSTRACT

The present investigation was carried out on 26 years old 'Santa Rosa' plum trees at the Division of Pomology, SKUAST-K, Shalimar Campus, Srinagar during the year 2006 with the objective to improve fruit quality as well as to standardize the concentration of bioregulators for higher yield. The experiment consists of fourteen treatments replicated thrice with a single plot size in a Randomized Block Design (RBD). Three different bioregulators viz., GA_3 (10, 20 and 30 μg ml^{-1}), BA (5, 10 and 15 μg ml^{-1}) and TRIA (5, 10 and 15 μg ml^{-1}) and their different combinations were spread immediately after petal fall. All the bioregulator treatments proved effective in improving plant growth, yield and fruit, physico-chemical characteristics as compared to control. Maximum shoot growth and tree volume was obtained with 30 μg ml^{-1} (T_3). However, highest initial fruit set was recorded with 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{12}). Maximum fruit retention and advancement in harvest maturity was found with 10 μg ml^{-1} TRIA (T_8) application. Among all the treatments, combined application of bioregulators viz., 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) proved to be more effective in improving fruit yield and fruit physical characteristics viz., fruit weight, fruit length, fruit diameter, fruit volume and chemical characteristics viz., TSS, TSS/acid ratio, reducing sugars and total sugars. However fruit acidity was lowest with this treatment. Therefore, combined application of bioregulators at lower concentration i.e.10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) proved effective in

promoting plant growth, enhancing yield and improving fruit physico-chemical characteristics. Hence, represents the best method for improving quality attributes of the fruit and can be advocated to the orchardists for getting better returns.

Key words : GA_3, BA, TRIA, Santa Rosa, Yield, Quality

Signature of Student
Dated : _____

Signature of Major Advisor
Dated : _____

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Effect of bio-regulators on growth, yield and quality of plum *(Prunus salicina* Lindl.) cv. Santa Rosa

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Effect of bio-regulators on growth, yield and quality of plum *(Prunus salicina* Lindl.) cv. Santa Rosa

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Certificate – I

This is to certify that the thesis entitled, **"Effect of bio-regulators on growth, yield and quality of plum *(Prunus salicina* Lindl.) cv. Santa Rosa"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Pomology)**, to the **Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** is a record of bonafide research work carried out by **Ms. Kunzang Wangmo (Registration No. 2005-A-759-M)** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that information received during the course of investigation has duly been acknowledged.

Dr. M. K. Sharma
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Certificate – II

We, the members of the Advisory Committee of **Ms. Kunzang Wangmo (Registration No. 2005-A-759-M),** a candidate for the degree of **Master of Science in Agriculture (Pomology)** have gone through the manuscript of the thesis entitled, "**Effect of bio-regulators on growth, yield and quality of plum *(Prunus salicina* Lindl.) cv. Santa Rosa"** and recommend that it may be submitted by the student in partial fulfillment of the requirements for the award of the degree.

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Certificate – III

This is to certify that the thesis entitled, "**Effect of bio-regulators on growth, yield and quality of plum *(Prunus salicina* Lindl.) cv. Santa Rosa"** submitted by **Ms. Kunzang Wangmo (Registration No. 2005-A-759-M)** to the **Faculty of Post-Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir** in partial fulfillment of the requirements for the award of the degree of **Master of Science in Agriculture (Pomology)** was examined and approved by the Advisory Committee and External Examiner on _____.

(Dr.S.D.Sharma)
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Certificate

This is to certify that all the corrections/ modifications suggested by External Examiner, Dr. S.D. Sharma have been incorporated in the final thesis entitled, "**Effect of bio-regulators on growth, yield and quality of plum *(Prunus salicina* Lindl.) cv. Santa Rosa"** submitted by **Ms. Kunzang Wangmo** (Registration No. 2005-A-759-M) post graduate student of the Division of Pomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar have been taken care of before final binding of the same.

(Dr. M. K. Sharma)
Major Advisor

Chapter-1

INTRODUCTION

The plum (Prunus salicina Lindl.) is one of the most important temperate zone stone fruit. It belongs to genus Prunus of the sub-family Prunoideae and family Rosaceae. This is a delicious juicy fruit prized both for its exquisite fresh fruit flavour, aroma, attractiveness and in fruit preservation industry. Besides having medicinal properties, it is a fairly good source of citric acid, sugars and vitamin A (Westwood, 1993). It thrives well in low hills and in the sub-mountain tracts where high chilling requiring fruits like apple and cherry cannot be grown profitably.

The leading plum producing countries of the world are USSR, Romania, China, Yugoslavia, Germany, United States of America, France and Italy. The world production of plum is estimated to be 9051 metric tonnes (FAO, 2001).

European (Prunus domestica Lindl.) and Japanese (Prunus salicina Lindl.) plum were introduced in Himachal Pradesh for evaluation but only Japanese plum which is a native of China was found promising for cultivation in temperate regions of north-western Himalayas.

Plum is predominantly grown in Jammu and Kashmir, Himachal Pradesh, Uttarakhand, some parts of Punjab (low chilling varieties) and the hilly areas of Tamil Nadu (Kishore et al., 1991). The mid-hills of Himalayas ranging from 1000-1600 m above mean sea level are ideally suited for cultivation of Japanese plum as it requires 700-1000 hours of chilling (below 7.2°C). In India, its area and production are 28369 hectares and 48415 metric tonnes (Dhaliwal and Dhaliwal, 2004), respectively. The state of Jammu and Kashmir occupies an area of 3574 hectares with an annual production of 4121 metric tonnes (Anonymous, 2006). Santa Rosa (Japanese plum) is

the most commercial cultivar of plum grown in the state which is more vigorous, precocious and prolific bearer. It is self fruitful and is used as pollinizer for other cultivars but has got a tendency towards over bearing which results in poor tree growth and production of fruits of smaller size and of inferior quality making it unable to meet the market requirement for better remuneration. Due to its perishable nature, it cannot be stored for longer duration and transported to distant markets. Although soft texture is a genetic character of the cultivar yet it can be modified to some extent by the exogenous application of bio-regulators.

Plant bio-regulators like GA_3 (Gibberellic acid), BA (Benzyl adenine) and TRIA (Triacontanol) play an important role in improving fruit yield, size and quality. They have the potential of increasing the plant productivity through their influence on various metabolic processes. These bioregulators are also reported to enhance ripening of fruits which is effective for early marketing and better price to the orchardists. It was therefore, proposed to explore the possibilities of influencing the yield, quality and growth of plum with the use of these bioregulators.

The present investigations entitled "Effect of bio-regulators on growth, yield and quality of plum (Prunus salicina Lindl.) cv. Santa Rosa" were therefore, carried at the Division of Pomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar during the year 2006 with the following objectives:

i) To determine the influence of bio-regulators on plant growth and yield.

ii) To find out the effect of bio-regulators on fruit size and quality.

iii) To standardize the concentration of bio-regulators for higher yield and quality of Santa Rosa plum.

Chapter-2

REVIEW OF LITERATURE

Plant bioregulators have remained an important component in horticulture from time immemorial because they were effective means of quantitative as well as qualitative improvement in plant growth and development. The available pertinent literature on the effect of different plant bioregulators like Gibberellic acid (GA_3), Benzyl adenine (BA), and Triacontanol (TRIA) on growth, yield and quality of plum cv. Santa Rosa have been reviewed under the following heads:

i. Effect on plant growth

ii. Effect on fruit set and retention

iii. Effect on fruit yield and days taken to maturity (Harvesting date)

iv. Effect on fruit physical characteristics

v. Effect on fruit chemical characteristics

2.1 Effect of Gibberellic acid (GA_3)

2.1.1 Effect on plant growth

Gibberellins play a major role in the control of shoot extension growth and is thought likely that the shoot tip and young leaves are site of gibberellin biosynthesis. Application of 50, 150 or 500 ppm GA once or twice at full bloom and repeated one week later in plums, apricots, cherries, peaches and almonds produce larger shoots compared to untreated control. Shoot length was proportional to the applied GA concentrations (Crane et al.,1960). Exogenous application of gibberellin stimulate the vegetative growth in plants in terms of increase in plant height, girth, internodal length, leaf number and size. The length of shoots in terms of number and length of internodes showed a progressive increase in apple with increase in the concentration of gibberellin like substances (Marcelle, 1963).

Robitaike and Carleon (1971) observed that the injection of 10 ppm GA_3 had stimulating effect on the terminal shoot growth of apple cv. Red Prince Delicious. Teskey and Rajput (1977) recorded that pear trees sprayed with 10 or 100 ppm GA_3 enhanced shoot length at higher concentration. Taylor (1978) recorded that combined application of GA_{4+7} increased shoot extension growth in young Golden Delicious apples. Singh and Phogat (1983) recorded more number of leaves and increased leaf growth in Majestic cultivar of strawberry with the application of 75 ppm GA_3.

Webster and Quinlan (1984) observed that application of gibberellic acid (75 mg L^{-1}) increased shoot growth in 'Groove Late Victoria' plum. Similarly Dwivedi (1987) found maximum leaf area in Sengasengana cultivar of strawberry when plants were treated with 50 ppm GA_3.

Rangelov et al.(1987) found that application of GA_3 at varied concentrations increased shoot growth in plums. Maximum plant height and number of leaves per plant were recorded with the application of 100 ppm GA_3 in strawberry (Anwar et al., 1990).

Xin et al. (1994) recorded that foliar application of GA_3 at 200 ppm significantly increased shoot growth and leaf area by promoting the protein synthesis and increasing transpirational area in apple trees. However, application of GA_3 at 5 to 10 ppm was observed to stimulate shoot elongation and to control apical dominance and enhance lateral growth in apple (Grochowska et al., 1995). Maximum plant height, leaf number and total biomass production was recorded in strawberry cv. Chandler with 100 ppm GA_3 application (Rana, 2001).

Negi and Sharma (2003) in two year field study recorded that application of GA_3 alone at 30 ppm or in different combinations with BA increased shoot elongation, internodal length and average leaf area in Flemish Beauty pear. Verma et al. (2005) concluded that GA_3 at 100 ppm was most beneficial for optimum vegetative growth in low chilling plum cv. Titron. Ou-Yi et al. (2006) recorded that application of GA_3 30

days after harvesting during the previous year, after flowering, and at the early fruiting stage enhanced the number and length of branches in plum var. Qingcuili.

2.1.2 Effect on fruit set and retention

Modlibowska (1966) observed that single spray of gibberellic acid at blossom time doubled the fruit set and yield of four-year old Dr. Jules Guyot pear trees. Srivastava and Agarwal (1968) reported that application of 25, 50 or 100 ppm GA on Red Delicious apples 5 to 6 weeks after petal fall resulted in 87.75, 77.80 and 69.57 per cent fruit retention, respectively compared with 55.54 per cent in control.

Verga (1969) reported that application of 25 ppm GA_{4+7}, 21 days after petal fall in Comise pear and Cox's Orange Pippin apple was more effective in increasing fruit set as compared to GA_3.

An aqueous spray of GA_3+BA and 2-napthoxyacetic acid applied several days after full bloom increased fruit set in Cox's Orange Pippin apple (Schwabe, 1973; Goldwin, 1986). The gibberellin have been used in improving fruit sets with greater promise as compare to auxins in many fruit crops (Turner, 1973; Luckwill, 1976).

Wertheim *et al.* (1973) found that spring application of GA was most effective in improving fruit set in number of apple cultivars. Gibberellins at a concentration of 0.0001 to 0.01 per cent during or after flowering had favourable effect on parthenocarpic fruit set in pear and apple (Gloubinsskii *et al.*,1977; Kazakova, 1978 and Burlak, 1979).

Similarly Webster and Goldwin (1978) recorded large increase in fruit set with application of GA_3 in Victoria plum. Knight (1982) recorded that application of gibberellic acid to blossoms of Conference pear can ensure a very large proportion of set fruits even if pollination conditions were adverse. It was

therefore a potentially useful treatment where the number of blossoms has been drastically reduced by frost.

Webster (1984) observed good flower quality and fruit set with application of GA_3 in 'Victoria' plum. Knight and Browning (1986) observed that fruit set in Conference pear was significantly increased with 11 ppm GA_3 application. Rangelov *et al.* (1987) recorded that application of 100 ppm GA_3 in combination with 10 ppm 2,4,5-TP after 10 days of full bloom increased fruit set in plum.

Singh and Chadha (1990) recorded that development of parthenocarpic fruits in apples was considered as a main factor for a higher GA induced fruit set of apples. They further observed that application of GA_3 at 50 or 75 ppm resulted in maximum fruit set and was effective in controlling fruit drop of apples.

Contrary to these reports, Looney *et al.* (1992) when studied the influence of different gibberellins on productivity of Golden Delicious apples, reported that all of them, except GA_3 reduced fruitset. They further reported that GA_4 (7.5 ppm) promoted return bloom, whereas GA_{4+7}; GA_{4+}isomer of GA_7 and GA_4 at 15 ppm each were ineffective. Dai *et al.* (1998) recorded an increased fruit set with GA application in litchi. Kumar and Jindal (2003) recorded high fruit set with GA_3 application in cherry cv. Stella.

2.1.3 Effect on fruit yield and days taken to maturity

Spring application of GA was very effective in improving yield in a number of pear cultivars (Wertheim *et al.,* 1973). Similarly Webster and Goldwin (1978) recorded subsequent increase in yield with GA_3 application in 'Victoria' plum. Treharne and Webster (1982) observed that application of high concentration of GA_3 in Victoria plum could suppress flower bud initiation and development,

however, lower GA_3 concentration affects floral buds much less and increase yield consistently.

Singh and Chadha (1990) recorded that 50 ppm GA_3 application at full bloom significantly increased fruit yield in Delicious apples. Pankov (1992) recorded increased yield of 'Yasna' and 'Sengasengana' cultivars of strawberry with application of GA_3 at 0.006 to 0.10% concentrations. However, Bhautkar (1994) observed that there was not much difference in the yield of strawberry as compared to control when the plants were treated with 50 ppm GA_3. Singh (1995) and Sharma (1998) observed that combined application of auxins (NAA) + gibberellins (GA_3) + Cytokinins (BA or Kinetin) in Delicious apple increased fruit set and yield.

Increase in fruit yield of litchi by GA application was observed by Dai *et al.* (1998). Ozguven *et al.*(2002) also found an increase in yield of strawberry cv. Camarosa with the application of GA_3 at 5, 10 or 20 ppm before flowering. Ou-Yi *et al.* (2006) recorded increased fruit yield and quality with GA_3 spray after flowering and at the early fruiting stage in plum cv. Qingcuili.

Dilley (1969) recorded that 50 and 100 ppm gibberellic acid sprayed during bloom to pears caused the fruit to ripen approximately one week earlier than the control.

2.1.4 Effect on fruit physical characteristics

The size and quality of fruit is greatly influenced by the process of growth and development of plant. The mobilization and partitioning of nutrients and metabolites in the plant play an important role in determining the size and quality of fruit, and since both can be influenced by plant bioregulators, their use offer considerable scope for influencing desirable quality characteristics in fruits.

Proebsting and Mills (1966) observed that 'Early Italian' prune sprayed with 10 ppm GA were firmer at harvest, the fruits had average fruit colour and were less sweet. Williams and Stahly (1969) observed that gibberellins and cytokinins alone or in combination, when applied to 'Delicious' apple after full bloom increased the length-diameter ratio of fruits. Application of GA 250 ppm + 2,4,5-T 12.5 ppm at pit hardening to 'New Castle' apricots resulted in an appreciable increase in fruit diameter, weight and flesh thickness (Sandhu *et al.*,1970). Looney and Lidster (1980) observed an increase in fruit weight in cherry with application of 20 ppm GA_3.

Knight (1980) recorded that application of GA_3 at lower concentration in Conference pear produced crops of good quality fruit but at higher concentration it resulted in the production of many mis-shapen fruits followed by poor flowering in the following year. Comai *et al.* (1982) recorded that gibberellins promote cell elongation in Delicious apple which resulted in elongated fruits.

Hartmann (1984) recorded that application of GA_3 in varied doses increased fruit size and weight in plum. Greene and Lord (1985) recorded that GA_{4+7} in combination with BA consistently increased L/D ratio of 'Delicious' apple. Facteau (1986) observed increase in fruit weight and firmness in 'Bing' and 'Lambert' cherry with 20 ppm GA_3 application. Increase in apple fruit size as a result of gibberellin had also been reported by Singh and Jindal (1986) and Looney *et al*.(1992) in apple.

Similar increase in L/D ratio was reported in Delicious apple with combined application of GA and BA (Kondo, 1989). Thakur *et al.*(1991) observed that application of GA mixture + BA in strawberry produced larger and heavier fruits. Increased fruit length in 'Le-lectier' pear with the application of GA was

observed by Yamada *et al.* (1991). Wani (1995) recorded that application of GA_3 to William pear in Kashmir resulted in increased fruit length, weight and volume. Increase in fruit weight with GA application in litchi cv. Lanzhou was observed by Dai *et al.*(1998). Ozguven *et al.* (2000) recorded that application of 200 ppm GA_3 in strawberry cv. Camarosa resulted in increased fruit weight. Kumar and Jindal (2003) also recorded increased fruit weight with application of GA_3 in cherry cv. Stella.

2.1.5 Effect on fruit chemical characteristics

Increase in ascorbic acid content with GA application was recorded in apple (Srivastava, 1966) and apricot (Srivastava *et al.*, 1971). Srivastava and Agarwal (1968) observed that spray of gibberellic acid (25, 50 or 100 ppm) on Red Delicious apple 5-6 weeks after petal fall increased fruit TSS and total sugars and reduced total acidity.

Sandhu *et al.* (1970) observed that application of GA 250 ppm + 2,4,5-T (12.5 ppm) in 'New Castle' apricot at first hardening stage resulted in slight increase in total soluble solids. An increase in total soluble solids in peach var. Alexander was observed when plants were treated with 25 ppm GA (Srivastava *et al.*,1973).

Dhuria *et al.* (1978) recorded a gradual increase in total soluble solids upto 8 weeks in 'Santa Rosa' plum, after which there was rapid increase till the fruit were fully ripe. However, Facteau and Rowe (1979) concluded that application of 10 ppm GA_3 or GA_{4+7} 3 weeks prior to harvest did not affect the total soluble solids content of 'Bing' and 'Lambert' sweet cherries.

Looney and Lidster (1980) recorded that application of 15 ppm GA_3, 3 weeks prior to harvest in 'Van' cherries resulted in lesser juice soluble solids content of 14.3 per cent compared to 14.7 per cent in untreated control.

Singh and Jindal (1986) recorded that application of 50 ppm GA to 'Royal Delicious' apple resulted in lower fruit acidity. Similarly, application of GA paste, 30 days after flowering to peach ovaries increased fruit soluble solid contents (Hosegawa and Nakazema, 1988). Kondo (1989) recorded from Japan that 'Starking Delicious' fruits sprayed with 100 ppm GA_3 had less acidity. However Lopez *et al.* (1989) recorded high acidity and TSS/acid ratio in strawberry fruits treated with 80 ppm GA_3.

Wani (1995) reported that 150 ppm GA_3 applied to 'William' pear showed higher fruit TSS (12.20%), and total sugars (6.05%) compared with 11.40 and 5.81 per cent respectively in untreated fruits. Kumar *et al.* (1997) observed that foliar spray of 50 ppm GA_3 increased TSS, reducing sugars and non-reducing sugars content of papaya fruit. Ozguven *et al.* (2000) recorded that application of 200 ppm GA_3 in strawberry cv. Camarosa resulted in higher TSS and acidity. Kumar and Jindal (2003) recorded high TSS and total sugars with GA_3 application in cherry cv. Stella. Kour *et al.* (2004) observed that application of GA at 20 and 30 ppm, two weeks after pit hardening decreased acid content and increased TSS content of 'Satluj Purple' plum.

2.2 Effect of Benzyl adenine (BA)

2.2.1 Effect on plant growth

Waithaka and Dana (1978) observed that application of BA had its effect on runner growth. They also found that the foliar spray of 6-Benzyl-amino-9-2-tetrahydropyranyl-9H-purine (PBA) at 600 ppm in 'Sparkle' and 'Ozark Beauty'

cultivars of strawberry increased number of stolons, branch stolons and branch crowns in daughter plants.

Forshey (1982) recorded that BA and GA_{4+7} when applied to young apple trees significantly increased the primary and secondary branching and total shoot growth. Laughlin and Greene (1984) recorded that neither GA_{4+7} nor BA sprays alone influenced leaf area in Golden Delicious apple. Greene and Autio (1990) recorded that application of BA stimulated the lateral branching in young apple trees at a concentration of 100 mg/l and there was reduction of lateral shoot elongation because of inter-shoot competition.

The application of growth promoter activol (GA_3 + BA and GA_{4+7} mixture) at lower concentration (100 ppm) on strawberry cultivar Tioga increased crown height, leaf number and leaf area (Thakur *et al.,* 1991). Dale *et al.* (1996) recorded that application of benzyl adenine (BA) at 1200 mg L^{-1} and GA_3 at 300 mg L^{-1} together as foliar spray increased runner development in day neutral strawberries but not when applied separately.

2.2.2 Effect on fruit set and retention

An initial increase in fruit set on Delicious apple treated during bloom with 500 ppm each of GA_{4+7} and BA was observed by Greene (1980) but the fruits abscised and fruit set was less than control. Similarly, Greene *et al.* (1982) observed that 25, 50 and 100 ppm each of GA_{4+7} and BA can cause fruit thinning and reduce fruit set when applied at bloom to McIntosh apple.

Greene and Lord (1985) recorded that 'Richared' Delicious apple trees sprayed with 25 + 25 ppm GA_{4+7} + BA at full bloom resulted in 31 – 44 fruits/100 blossom cluster, compared to 70 in untreated ones. Archbold and Strang (1986)

observed that application of BA on strawberry cultivar 'Red Chief' at 50, 125 or 250 ppm increased flower number, but extra flowers exhibited poor fruit set.

Emongor and Murr (2000) observed that post bloom application of BA at 100 or 200 mg L^{-1} significantly reduced fruit set of 'Empire' apple.

2.2.3 Effect on fruit yield and days taken to maturity

Archbold and Strang (1986) recorded that application of BA on strawberry cultivar Red Chief at the rate of 50, 125 or 250 ppm significantly increased fruit yield.

Ahn *et al.* (1988) recorded the advanced and higher yield of strawberry fruits when bee pollination was combined with BA at 75 and 100 ppm. Six year old non-bearing Delicious apple trees when treated with 300 ppm BA per year for three consecutive years yielded 177 per cent more than control (Unrath, 1989).

Youn *et al.* (2000) observed that application of BA + $GA_{4+7,}$ 45 days after full bloom advanced fruit maturity by 4 days than untreated fruits in 'Kamcheoabae' and 'Whangkeubae' pear.

2.2.4 Effect on fruit physical characteristics

Application of activol (a mixture of GA_3, BA and GA_{4+7}) on strawberry cultivar Tioga increased fruit length, diameter, weight and volume (Thakur *et al.*,1991). Elfving and Cline (1993) recorded that application of BA at various concentrations as post bloom spray to 8-9 year old Empire apple plants significantly increased fruit weight. Wismer *et al.* (1995) found that application of BA after flowering was most effective in increasing fruit size in apple.

Emongor and Murr (2000) observed increase in fruit length, diameter and weight of 'Empire' apple with 100 or 200 mg L^{-1} BA when applied at post bloom. Ni *et al.* (2000) observed increase in fruit weight with application of 100

to 200 mg L^{-1} BA after fruit setting in *Citrus reticulata* cv. Ponkan. Youn *et al.* (2000) recorded that application of BA + GA_{4+7} 45 days after full bloom increased fruit weight and flesh firmness in 'Kamcheoabae' pear.

2.2.5 Effect on fruit chemical characteristics

Elfving and Laughead (1994) observed that foliar application of BA for fruit thinning of Empire apples produced small and inconsistent effect on flesh firmness, whereas the total soluble solids concentration was consistently increased at harvest. Wismer *et al.* (1995) observed that application of BA after flowering was most effective in increasing total soluble solids and per cent dry weight of Empire apple fruits.

Emonger and Murr (2000) recorded that post bloom application of BA at 100 or 200 mg L^{-1} increased TSS content of 'Empire' apple fruit. Increase in fruit sugar concentration of 'Whangkeubai' pear with BA+GA_{4+7} applied 45 days after full bloom was also observed by Youn *et al.* (2000). Increase in TSS, total sugars, reducing sugars and decreased acidity was observed in *Citrus reticulata* cv. 'Ponkan' with 100 to 200 mg L^{-1} BA application after fruit setting (Ni *et al.*, 2000)

2.3 Effect of Triacontanol

It seems from the available literature that plant bioregulator triacontanol was mostly been used on vegetable and cereal crops and very less work has been done on fruit crops. Therefore, the work done on vegetable, cereals and other crops has also been reviewed here along with fruit crops.

2.3.1 Effect on plant growth

Triacontanol (TRIA), a straight chain 30 carbon alcohol i.e

primary alcohol is an endogenous hormone which is active at very low concentration on the cell membranes and acts in combination with other long chain alcohols to regulate the formation of TRIM, a secondary messenger(s) of TRIA. TRIM, the putative secondary messenger elicited by TRIA, move rapidly throughout the plant resulting in dry matter increase (Ries and Wert, 1988).

The growth regulatory effect of triacontanol was first reported by Ries *et al*. in 1977 when they observed increase in dry weight and water uptake of rice seedlings treated with a crystalline substance isolated from the active fraction of alfalfa meal. An increase in the growth of several vegetable and field crops including carrot, cucumber, dry bean, radish, sweet corn, soybean and tomato in the green house has been observed by Ries *et al.* (1978) with the application of triacontanol to the seed, soil or foliage.

Growth promoting effects of triacontanol on cell cultures of several plant species have been reported by Hangarter *et al.* (1978) who concluded that the increase in growth and dry weight of callus tissue was due to an increase in cell division. Ries *et al.* (1983) postulated that triacontanol treatment increased hydrolysis and/or mobilization of starch and sucrose in the plant resulting in increased growth.

Jadhav *et al.* (1984) had also confirmed the growth promoting effects of triacontanol and alfalfa meal on rice. Chandel (1985) recorded increase in growth of ‘Santa Rosa’ plum with triacontanol alone or in combination with paclobutrazol. Improved growth with triacontanol has also been observed in ‘New Castle’ apricot by Mahajan *et al.* (1988).

Mandal *et al.* (1989) observed higher plant growth in guava with 0.6 ml L^{-1} Mixtalol (triacontanol). Sharma (1990) obtained markedly higher annual shoot growth in Red Delicious apple with 0.75 ml L^{-1} Miraculan (triacontanol). Barua (1998) observed markedly higher annual shoot growth in Santa Rosa plum with 10 ppm triacontanol.

Kumar *et al.* (1996) observed that application of triacontanol (5 ppm) before the flower emergence in the month of March on the strawberry cultivar 'Tioga' produced highest leaf area, number of leaves per plant and number of runners. Joolka and Sharma (2003) in two year field study recorded maximum increase in shoot growth with application of 5 ppm triacontanol when applied 15 days before flowering in 'New Castle' apricot.

2.3.2 Effect on fruit set and retention

Chen *et al*. (1982) have shown that the use of 0.1 ppm triacontanol in cotton delayed the bud shedding and reduced abscission of young bolls by 20 per cent. The fruit set in litchi with triacontanol was reported to be improved by Zhuang *et al.* (1983) and reduced by Zhang *et al.*(1988). Chandel (1985) obtained enhanced fruit set in Santa Rosa plum with triacontanol alone or in combination with paclobutrazol. Premature fruit drop in Bendizao mandarin *(Citrus succosa)* was prevented by triacontanol through inhibition of pre-abscission pectinase and cellulase activities (Hu *et al*., 1985).

Miniraj and Shanmugavelu (1987) observed that triacontanol enhanced the number of flowers and per cent fruit set in chillies. Setia *et al.* (1988) reported that mixtalol treatment decreased pod abscission in lentil from 63 per cent (control) to 6.8 per cent. Barua (1998) recorded highest fruit set (23.80 per cent) and fruit

retention (14.59 per cent) with triacontanol when applied at a concentration of 2.5 ppm in Santa Rosa plum.

Increased fruitset in 'Santa Rosa' plum with 20 ppm triacontanol application was also observed by Jindal and Chandel (1996). Mandal *et al.* (1999) observed that application of mixtalol (triacontanol) 6 ml L^{-1}, 3-weeks before fruit set resulted in the highest fruit set per cent (92%) in guava. Joolka and Sharma (2003) recorded maximum number of fruit set (30.86 and 36.44 per cent) with application of 5 ppm triacontanol, 15 days before flowering in 'New Castle' apricot.

2.3.3 Effect on fruit yield and days taken to maturity

The increased grain yield of maize on treatment with triacontanol was observed by Ohlrogge and Fulk-Bringman (1980). Increased yield of tomato and pepper with application of 10 μg L^{-1} was observed by Lim (1981). Significant increased in the yield of Chinese radish, cucumber, rice and tomato on treatment with triacontanol had been observed by Lim (1982).

Triacontanol increased the yield of tomato at 1 ppm (Eriksen *et al.*, 1982) and at 0.5 to 10 ppm (Gunasekaran and Shanmugavelu, 1983) as foliar spray. Mamat *et al.* (1983) observed taller plants of tobasco pepper with higher yield and more number of fruits with triacontanol application.

Yield increase to the tune of 17 to 21 per cent in rice, 6 to 18 per cent in different cereal crops, 20 per cent in sugar beets and 13.3 per cent in wheat, rice and soybean due to triacontanol application was reported from Japan and China (Ries and Houtz, 1983). Stanley and Robert (1983) concluded that triacontanol can increase the yield of crops, but the results were not sufficiently consistent in U.S.A. to recommend its use commercially.

Triacontanol at 2 ppm increased the yield and quality of brinjal (Jyothi and Shanmugavelu, 1985) and chillies (Miniraj and Shanmugavelu, 1987). Szita and Parliscsak (1986) enhanced the yield of winter wheat by spraying Ankorn (triacontanol) during the late tillering stage. Zheng *et al.*(1986) recorded 10 per cent increase in bean yield with 10 ppm triacontanol as foliar spray.

Similarly 5 to 10 ppm of triacontanol improved the pod yield of pea along with increased nodulation and fresh weight of plant (Saimbhai and Gill, 1988). Mahadevappa *et al.* (1989) obtained higher biomass and grain yield of rice with triacontanol treatment.

Triacontanol at 2.5 ppm was the most effective to promote the growth and yield of 'Santa Rosa' plum trees and its commercial formulations, viz., Miraculan at 5 ppm and Paras at 7.5 ppm were also effective to enhance yield without having any adverse effect on the fruit quality (Barua, 1990). Joolka and Sharma (2003) recorded that application of 5 ppm TRIA before flowering increased the total soluble solids content of 'New Castle' apricot fruit.

2.3.4 Effect on fruit physical characteristics

Jindal and Dwivedi (1984) observed that triacontanol sprayed 10 days before harvest to Santa Rosa plum significantly increased the length and diameter of fruits. The highest fruit length was observed with 4 ppm and lowest with 16 ppm triacontanol. Fruit weight and volume was also increased when triacontanol was applied at a concentration of 4 and 8 ppm.

Jindal and Dwivedi (1984) reported that triacontanol treatment had no effect on fruit firmness in 'Santa Rosa' plum. The beneficial effects of triacontanol on fruit weight and enhancement of fruit quality have also been observed in 'New

Castle' apricot by Chander (1987) when triacontanol was used in two commercial formulations, e.g., Miraculan and Vipul.

Sud and Parmar (1990) observed that the application of triacontanol at 1.5 – 6 ppm at pea stage and just after the pit hardening in 'New Castle' apricot, had a profound effect on the fruit size. Significantly higher weight was recorded in fruits treated with 6 ppm triacontanol at pea stage.

Jindal and Chandel (1996) observed increased fruit size and weight with triacontanol application in Santa Rosa plum. Barua (1998) also recorded increased fruit size in terms of weight, volume, diameter and length with 2.5 ppm triacontanol application. The maximum increase in fruit weight and volume was 36.49 and 35.84 per cent, respectively over the control as a result of 2.5 ppm triacontanol. Sud and Thakur (1998) recorded an increase in fruit length, diameter, weight and volume by 7.5 ppm TRIA application in peach cv. 'July Elberta'.

Mandal *et al.* (1999) recorded an increase in fruit weight and diameter with application of Mixtalol (triacontanol) 3 weeks before and after fruitset in guava. Mahajan and Sharma (1999) also recorded increased fruit size and fruit weight with 10 ppm triacontanol in Satluj Purple plum.

Joolka and Sharma (2003) observed increase in fruit weight with application of 5 ppm triacontanol 15 days before flowering in 'New Castle' apricot. Increase in fruit length, diameter, volume and weight with application of triacontanol at flowering stage was also recorded in mango (Patil *et al.*, 2005).

2.3.5 Effect on fruit chemical characteristics

Application of triacontanol at 4 ppm increased fruit TSS whereas 16 ppm decreased TSS in 'Santa Rosa' plum (Jindal and Dwivedi, 1984). However,

maximum sugars were recorded in fruits treated with 2 ppm triacontanol followed by 4 ppm and 8 ppm. In respect of non-reducing sugars, maximum content was found in 2 ppm treated fruits and minimum with 10 ppm treatment. Ascorbic acid content was not significantly influenced by all the triacontanol treatments.

Barua (1990) recorded that application of 7.5 ppm triacontanol significantly increased the fruit total soluble solids and total sugars, but this treatment had no significant effect on the level of fruit titratable acidity in 'Santa Rosa' plum.

Sud and Parmar (1990) observed that application of triacontanol to apricot plants do not alter fruit quality in terms of total soluble solids and total sugars content, but the percentage of total acid content decreased considerably in the treated fruits.

Jindal and Chandel (1996) observed that application of triacontanol increased the fruit TSS, total sugars, reducing sugars and non-reducing sugars significantly in 'Santa Rosa' plum. Maximum TSS was recorded with 10 ppm triacontanol. However, maximum total sugars and reducing sugars were found with application of 20 ppm triacontanol. The highest non-reducing sugars were observed in fruits, those received treatment of 5 ppm triacontanol. Singh *et al.* (1996) observed an increase in fruit sugar content, acidity, sugar : acid ratio and ascorbic acid by application of Mixtalol, Miraculan and Vipul (all triacontanol formulations) in litchi cv. 'Purbi'.

The use of triacontanol (1.25 ppm) on the strawberry cultivar 'Tioga' just before flower emergence lowered fruit TSS content (Kumar *et al.*, 1996). Thakur *et al.* (1998) observed an increase in soluble sugars with 40 ppm triacontanol in olive. Significant increase in TSS and total sugar was observed in 'July Elberta'

peach with the application of 7.5 ppm triacontanol when applied at pea stage and after pit hardening stage (Sud and Thakur, 1998).

Mahajan and Sharma (1999) recorded that 10 ppm triacontanol was the most effective for increasing TSS content of ‘Satluj Purple’ plum fruits. Mandal *et al.*(1999) observed that application of 6 ml L^{-1} Mixtalol increased reducing sugars content and lowers the fruit acidity in guava when applied at pea stage. Joolka and Sharma (2003) observed increase in fruit TSS and decrease in acidity with application of 5 ppm triacontanol 15 days before flowering in ‘New Castle’ apricot.. Patil *et al.* (2005) observed highest per cent of TSS and ascorbic acid content in mango with triacontanol applied at flowering stage.

Chapter 3

MATERIALS AND METHODS

3.1 General

The present investigations on the "**Effect of bio-regulators on growth, yield and quality of plum *(Prunus salicina* Lindl.) cv. Santa Rosa**" were carried out in the experimental field of Division of Pomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar during the year 2006. The details of material used and the methods followed during the course of investigations are given below:

3.1.1 Geographical features of experimental site

Srinagar is situated at an altitude of 1390 meters about mean sea level and between 34^{o} 75' North latitude and 74^{o} 50' East longitude. The University campus is at a distance of 15 kilometers from main city towards the Northeast side.

3.1.2 Climate

The climate in general is of typical temperate type. Winters are severe extending from December to March and the temperature often goes below freezing point during this period. The valley is mostly covered with snow during the winter months. The meteorological data at the main campus of SKUAST(K), recorded during 2006 is shown in Appendix-I.

3.2 Materials

The present experiment was conducted on 26 years old plants of plum cv. 'Santa Rosa' of uniform size and vigour which received uniform cultural operations. Treatments and replications were randomly assigned with a single plot size.

3.3 Experimental details

3.3.1 Treatments:

i)	Growth regulators		Concentrations
	T_1	GA_3 (Gibberellic acid)	10 ($\mu g\ ml^{-1}$)
	T_2	GA_3	20 ($\mu g\ ml^{-1}$)
	T_3	GA_3	30 ($\mu g\ ml^{-1}$)
	T_4	BA (Benzyl adenine)	05 ($\mu g\ ml^{-1}$)
	T_5	BA	10 ($\mu g\ ml^{-1}$)
	T_6	BA	15 ($\mu g\ ml^{-1}$)
	T_7	TRIA (Triacontanol)	05 ($\mu g\ ml^{-1}$)
	T_8	TRIA	10 ($\mu g\ ml^{-1}$)
	T_9	TRIA	15 ($\mu g\ ml^{-1}$)
	T_{10}	GA_3 + BA	10 ($\mu g\ ml^{-1}$)+5($\mu g\ ml^{-1}$)
	T_{11}	GA_3 + TRIA	10 ($\mu g\ ml^{-1}$)+5($\mu g\ ml^{-1}$)
	T_{12}	BA + TRIA	05 ($\mu g\ ml^{-1}$)+5($\mu g\ ml^{-1}$)
	T_{13}	GA_3 + BA + TRIA	10 ($\mu g\ ml^{-1}$)+5($\mu g\ ml^{-1}$) + 5 ($\mu g\ ml^{-1}$)
	T_{14}	Control	Water spray
ii)	Number of replications	:	03
iii)	Design	:	Randomized Block Design (RBD)
iv)	Stage of spray treatment	:	Immediately after petalfall

3.4 Preparation of spray solutions and method of spray

The required amount of GA_3 and BA was weighed on an electronic digital balance and dissolved in 10 ml of 50 per cent absolute alcohol. When fully dissolved, the volume was made to one litre with distilled water

to serve as stock solution, from which further dilutions to desired concentrations were made before use. The stock solutions were prepared one day before use in the laboratory while dilutions were done on the date of application in the orchard itself.

The stock solution of triacontanol were directly made in distilled water. The required amount was taken with pipette and final volume was made to one litre with distilled water to serve as stock solution, from these further dilutions of desired concentrations were made before use. Spraying was done on the scheduled day in the morning with a foot sprayer equipped with a long handle and microfine nozzle to ensure mist spray. Each experimental tree was sprayed thoroughly with five litres of solution.

3.5 Observations recorded

Procedure followed for recording the observations are given below:

3.5.1 Growth parameters

3.5.1.1 Annual shoot extension growth (cm)

Ten shoots of the current season growth were randomly selected all over the periphery of each tree. The length of these shoots were recorded with a measuring tape during the last week of November and expressed in centimeters..

3.5.1.2 Tree volume (m^3)

Volume of tree was worked out by using the formula given by Westwood (1993).

i) For a tree that was taller than wide (prolate spheroid):

Tree volume = $4/3\ \pi\ ab^2$

ii) For a tree that was wider than tall:

Tree volume = $4/3\ \pi\ a^2\ b$

Where,

a = ½ of the major axis (height)

b = ½ of the minor axis (spread)

π = 3.142

3.6 Phenological studies

3.6.1 Fruitset (%)

Three branches on different sides of the tree were tagged for counting flowers and number of fruitlets after petal fall and per cent fruitset was calculated by the formula given by Westwood (1993)

$$\text{Per cent fruit set} = \frac{\text{Number of fruitlets}}{\text{Number of flowers}} \times 100$$

3.6.2 Fruit retention (%)

The total number of fruits retained on the tagged branches were counted at the time of harvest and percentage of fruit retained was calculated on the basis of total number of fruits at the time of fruitset and expressed in per cent.

3.6.3 Fruit yield (kg/tree)

The total yield of the fruits under different treatments were determined by taking weight of all the fruits harvested from the tree under each treatment and expressed in kg/tree.

3.6.4 Days taken to maturity (Harvesting date)

Days taken to maturity (date of harvesting) was recorded by recording the no. of days from full bloom (when more than 80% flowers opened) till maturity of the fruits.

3.7 Physical characteristics of fruit

3.7.1 Fruit weight (g)

The weight of 15 randomly selected fruits from each treatment in each replication was taken on a top pan balance and the average weight per fruit was expressed in grams (g).

3.7.2 Fruit length (cm)

The length of 15 randomly selected fruits from each treatment in each replication was measured with the help of digital Vernier calliper. The fruit length was measured between calyx and styles ends and the average was expressed in cm.

3.7.3 Fruit diameter (cm)

The diameter between cheeks of 15 randomly selected fruits was measured with the help of digital Vernier calliper and the average was expressed in cm.

3.7.4 Fruit volume (cm^3)

Volume of the fruit was measured by water displacement method using two litre measuring cylinder. A measuring cylinder was filled with water upto certain graduation and same five fruits, whose weight was recorded were fully immersed in it. The difference between initial and final volume of water represented the total volume of fruits and the average fruit volume was expressed in cubic centimeter (cm^3) per fruit.

3.7.5 Fruit firmness (kg/cm^2)

The fruit firmness was determined by a pressure tester (penetrometer) which recorded the pressure necessary for the plunger to penetrate the peeled flesh of plum fruit. The two readings were taken at

shoulder of the fruit at sides and the average reading was expressed in kg/cm^2.

3.7.6 Pulp/stone ratio

A sample of 15 randomly selected fruits was selected from each treatment and was divided into pulp and stone. The weight of each fraction was determined and the ratio was worked out.

3.8 Chemical characteristics of fruit

3.8.1 Titratable acidity (%)

Ten gram of fruit pulp was thoroughly homogenized with distilled water in an electric blender and volume was made upto 100 ml. The mixture was then filtered through Whatman No.1 filter paper. 10 ml of this extract was titrated against 0.1 N NaOH solution using phenolphthalein as an indicator and end point was determined by pink coloration. The total titratable acidity was calculated in terms of malic acid and the result were expressed as per cent acidity.

3.8.2 Total soluble solids (%)

The TSS content in fruits were determined by Erma hand refractometer. The refractometer was calibrated with distilled water before use and then a few drops of fruit juice were placed on the prism and the reading was recorded. The total soluble solids were expressed as percentage of fresh fruit juice.

3.8.3 TSS/ acid ratio

TSS/ acid ratio was obtained from dividing the TSS value (%) of a sample by its respective acid content (%).

3.8.4 Total sugars (%)

The method suggested in A.O.A.C. (1984) was followed as given below:

Twenty five grams of fruit pulp was taken and it was homogenized with distilled water and final volume was made to 250 ml. Five ml of 10 per cent lead acetate was added. After 10 minutes, 10 per cent potassium oxalate was added with the purpose to precipitate the excess of lead acetate and then filtered the solution with Whatman No. 1 filter paper. 100 ml of titrate was taken and hydrolyzed by adding concentrated HCl and allowing it to stand overnight. The excess amount of HCl was neutralized by adding 10 per cent NaOH solution.

The hydrolysed solution was taken in a burette and titrated against the boiling mixture of 5 ml each of Fehlings A and B solutions, using methylene blue as an indicator. The end point was indicated by the appearance of brick red colour and total sugars were worked out as per cent of fresh weight of the fruit pulp.

3.8.5 Reducing sugars (%)

The remaining fruit extract was titrated against the boiling mixture containing five ml of Fehling solution A and B each using methylene blue as an indicator. The results were expressed as per cent of reducing sugars.

3.8.6 Non-reducing sugars (%)

The amount of non-reducing sugars was calculated by subtracting reducing sugars from total sugars and multiplying the differences by a constant value, 0.95 as suggested in (A.O.A.C., 1984).

3.9 Statistical analysis

The data generated from the present investigations were subjected to statistical analysis as per the procedures described by Cochran and Cox (1963).

Chapter-4

EXPERIMENTAL FINDINGS

The present investigation aimed at studying the "**Effect of bio-regulators on growth, yield and quality of plum cv. Santa Rosa**" was carried out in the experimental field of Division of Pomology, SKUAST-K, Shalimar during the year 2006.

The experimental results obtained have been presented below:

4.1 Growth parameters

The observations on the effect of bioregulators on growth parameters viz., annual shoot extension growth and plant volume are summarized in Table 1.

4.1.1 Annual shoot extension growth

It is evident from Table 1 that annual shoot extension growth was significantly influenced by bioregulator treatments. Plants treated with T_3 (30 μg ml^{-1} GA_3) produced maximum shoot growth of 56.41 cm followed by 55.83 cm with 10 μg ml^{-1} GA_3+ 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}). The minimum annual shoot growth (43.86 cm) was recorded in control plants.

4.1.2 Tree volume

The perusal of data presented in Table 1 and Figure 1 indicate that plant volume was markedly influenced by bioregulator treatments. Highest volume of 3.98 m^3 was attained by the plants treated with 30 μg ml^{-1} GA_3 (T_3) which was statistically at par (3.93 m^3) with the plants treated with 10 μg ml^{-1} GA_3+5 μg ml^{-1} BA+5 μg ml^{-1} TRIA (T_{13}). However, the minimum volume (2.82 m^3) was attained by control plants.

4.2.2 Phenological studies

4.2.1 Initial per cent fruit set

The flowers under different treatments were sprayed with bioregulators of different concentration immediately after petal fall and observations on initial fruit set were recorded 10 days from the date of treatment. It is apparent from Table 2 that all the bioregulator treatments appreciably increased the initial fruit set per cent. The highest initial fruit set (53.86%) was recorded in T_{12} (5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA), whereas, the control plants had the lowest initial fruit set (50.38%).

4.2.2 Per cent fruit retention at harvest

Data presented in Table 2 revealed that bioregulator treatments significantly affected the per cent fruit retention at harvest. Plants treated with 10 μg ml^{-1} TRIA (T_8) had highest per cent fruit retention (26.26%) followed by T_9 (15 μg ml^{-1} TRIA) (25.05%). Fruit retention was found lowest (18.26%) in the plants treated with 30 μg ml^{-1} GA_3 (T_3). Fruit retention at harvest ranged from 18.26% to 19.97% with GA_3 (10-30 μg ml^{-1}), 21.28% to 24.93% with BA (5-15 μg ml^{-1}) and 24.96 to 26.26% with TRIA (5-15 μg ml^{-1}) application. Fruit retention of 19.55% was recorded in control plants.

4.2.3 Fruit yield

It is apparent from data (Table 3 and Figure 3) that fruit yield was significantly improved by the bioregulator treatments in comparison to control. Maximum fruit yield (22.42 kg/tree) was recorded with 10 μg ml^{-1} GA_3+ 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) followed by (20.98 kg/tree) with 10 μg ml^{-1} TRIA (T_8) and minimum fruit yield (12.01 kg/tree) in control plants.

Increase in fruit yield over control was highest (86.67%) with 10 μg ml^{-1} GA_3+ 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) and lowest (45.71%) with 10 μg ml^{-1} GA_3 (T_1) (Table 3 and Figure 2). Different bioregulator treatments increased fruit

yield over control ranging from 45.71 to 59.37 per cent with GA_3 (10 - 30 μg ml^{-1}), 53.29 to 56.87 per cent with BA (5-15 μg ml^{-1}) and 63.19 to 74.68 per cent with TRIA (5-15 μg ml^{-1}) application.

4.2.4 Days taken to maturity (Harvesting date)

It is evident from Table 3 that plants treated with TRIA at a concentration of 10 μg ml^{-1} (T_8) and 15 μg ml^{-1} (T_9) resulted into early harvest as compared to other treatments. With these treatments fruit maturity was advanced by nearly six days. Fruits of control plants took a maximum period of 107 days after full bloom (DAFB) for harvesting.

4.3 Physical characteristics of fruit

4.3.1 Fruit weight

Data presented in Table 4 and Figure 3 revealed that all the bioregulator treatments significantly increased the fruit weight in comparison to control. Plants treated with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) had the heaviest fruits (54.41 g) followed by 53.86 g with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} TRIA (T_{11}). However, control plants had the smallest fruits (31.82 g).

Increase in fruit weight over control was maximum (70.99%) with 10 μg ml^{-1} GA_3+ 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) and minimum (43.09%) with 5 μg ml^{-1} BA (T_4) (Figure 4). Bioregulator treatments increased fruit weight over control ranging from 43.75 to 53.39 per cent with GA_3 (10-30 μg ml^{-1}) 43.09 to 50.47 per cent with BA (5-15 μg ml^{-1}) and 50.94 to 59.08 per cent with TRIA (5-15 μg ml^{-1}) application, respectively.

4.3.2 Fruit length

The data recorded on fruit length revealed the significance of various bioregulator treatments over control (Table 4). Maximum fruit length (4.73 cm) was observed

with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) which was statistically at par (4.70 cm) with T_{11} (10 μg ml^{-1} GA_3 + 5 μg ml^{-1} TRIA) and T_{12} (5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA) (4.71 cm). The minimum fruit length (3.90 cm) was recorded in control.

4.3.3 Fruit diameter

The perusal of data (Table 5) revealed that combined spray of different bioregulators at varied concentrations appreciably increased the fruit diameter over control. Maximum fruit diameter (4.54 cm) was recorded with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} TRIA (T_{11}) and 10 μg ml^{-1} TRIA (T_8) followed by T_{10}, T_{12} and T_{13} treatments. However, the lowest fruit diameter (3.78 cm) was observed in control.

4.3.4 Fruit volume

The data in Table 5 and Figure 6 indicate that fruit volume was significantly improved by all the treatments as compared to control. T_{13} (10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA) was superior among all the treatments in increasing fruit volume (52.33 cm^3), whereas, minimum fruit volume (30.88 cm^3) was recorded in control.

4.3.5 Fruit firmness

The perusal of data in Table 6 revealed that various bioregulator treatments did not have significant influence on the fruit firmness over control. However higher fruit firmness (2.41 kg/cm^2) was recorded with 10 μg ml^{-1} TRIA (T_8), whereas minimum fruit firmness (2.34 kg/cm^2) was recorded with T_2 (20 μg ml^{-1} GA_3) and control.

4.3.6 Pulp/ stone ratio

It is evident from the data (Table 6) that all the bioregulator treatments significantly improved pulp/ stone ratio over control. Highest pulp/stone ratio (33.66) was recorded with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} TRIA (T_{11}) which was statistically at par (32.70 cm) with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}). However, the fruits from control plants had the minimum (21.60) pulp/stone ratio.

4.4 Chemical characteristics of fruit

4.4.1 Titratable acidity

The data on the effect of bioregulators on titratable acidity is given in Table 7. It is apparent from the data that acidity was significantly reduced in all the bioregulator treated fruits in comparison to control. Lowest acidity (1.40%) was recorded with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) followed by 1.41 per cent with 10 μg ml^{-1} TRIA (T_8). However highest titratable acidity of (1.52%) was recorded in control.

4.4.2 Total soluble solids

The perusal of data (Table 7) revealed that TSS were slightly affected by bioregulator treatments. This ranged between 15.74 to 15.91 per cent with GA_3 application (10-30 μg ml^{-1}), 15.64 to 15.93 per cent with BA application (5-15 μg ml^{-1}) and 16.01 to 16.25 per cent with TRIA application (5-15 μg ml^{-1}). Combined application of bioregulators at different concentrations increased the TSS over control. Maximum TSS (16.35%) was observed with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) followed by 16.25 per cent with 10 μg ml^{-1} TRIA (T_8). The minimum TSS (15.01%) was recorded in control.

4.4.3 TSS/ acid ratio

It is evident from the data presented in Table 8 that all the bioregulator treatments significantly improved TSS/ acid ratio in comparison to control. Maximum TSS/ acid ratio (11.65) was recorded with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) which was statistically at par (11.47) with 10 μg ml^{-1} TRIA (T_8) whereas, minimum TSS/ acid ratio of 9.84 was obtained in control.

4.4.4 Reducing sugars

It is apparent from the data (Table 8) that all the treatments appreciably increased the reducing sugars content. The maximum reducing sugars (5.81%) was recorded with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) which was statistically at par (5.76%) with 10 μg ml^{-1} TRIA (T_8). Minimum level of reducing sugars (4.37%) was recorded in control.

4.4.5 Non-reducing sugars

The data on the effect of bioregulators on non-reducing sugars is given in Table 9. It was observed that non-reducing sugars in the fruit ranged between 0.62 to 1.28 per cent. Maximum percentage of non-reducing sugars (1.28%) was observed with 10 μg ml^{-1} TRIA (T_8) and T_9 (15 μg ml^{-1} TRIA), however minimum amount of reducing sugars (0.62%) was recorded in control.

4.4.6 Total sugars

It is evident from the data presented in Table 9 that total sugars was significantly increased by bioregulator treatments. Plants treated with T_{13} (10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA) had significantly higher total sugars content (7.14%) closely followed by 7.11 per cent in T_8 (10 μg ml^{-1} TRIA), while the lowest sugars content (5.03%) was recorded in control.

Chapter-5

DISCUSSION

5.1 General

Santa Rosa (a Japanese plum) is the most commercial cultivar of plum grown in Jammu and Kashmir, and is known for its fair quality and characteristic flavour. It is self fruitful and is used as pollinizer for other cultivars but has got a tendency towards over bearing which results in poor tree growth and production of fruits of smaller size and of inferior quality. With a view to improve its fruit size and quality an investigation entitled "Effect of bio-regulators on growth, yield and quality of plum cv. Santa Rosa**"** was undertaken. The results obtained in the present investigations are discussed in this chapter in the light of available literature under the appropriate heads:

5.2 Effect of bio-regulators on growth parameters

5.2.1 Effect on annual shoot extension growth and tree volume

The results of the present studies revealed that all the bioregulators viz., GA_3, BA and TRIA alone and in combination were effective in increasing the shoot extension growth and tree volume. The application of 30 µg ml $^{-1}$ GA_3 (T_3) immediately after petal fall resulted in maximum shoot extension growth (56.41 cm), followed by 55.83 cm with 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA (T_{13}). Plants treated with 30 µg ml^{-1} GA_3 (T_3) had highest tree volume (3.98 m^3), which was statistically at par (3.93 m^3) with 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA (T_{13}) and 3.69 m^3 with 10 µg ml^{-1} TRIA (T_8). The increase in shoot growth and plant volume might be due to promotion of cell growth because of increased hydrolysis of starch, fructans and sucrose into glucose and

fructose molecules with GA_3 application. Exogenous application of gibberellins moves into the shoot apex, increased cell division and cell growth apparently which lead to increased elongation of the stem (Salisbury and Ross, 2004).

The results of the present studies are in conformity with the findings of Crane *et al.* (1960); Webster and Quinlan (1984); Rangelov *et al.* (1987) in plum and Xin *et al.* (1994) in apple, who observed that foliar application of GA_3 increased shoot growth by stimulating cell division and cell elongation as it is thought likely that the shoot tip and young leaves are sites of gibberellin biosynthesis. Minimum annual shoot extension growth (43.86 cm) and plant volume (2.82 m^3) were observed under control.

5.3 Effect of bioregulators on phenological characteristics

5.3.1 Effect on initial fruitset (%)

Combined application of bioregulators viz., GA_3, BA and TRIA markedly increased the per cent fruitset in comparison to individual application. The percentage of fruit set ranged from 50.48 to 51.75 with GA_3, 50.41 to 51.80 with BA and 51.38 to 52.56 with TRIA applications.

Maximum fruitset (53.86 %) was recorded with 5 µg ml^{-1} BA +5 µg ml^{-1} TRIA (T_{12}) and it was minimum (50.38%) under control. Increase in fruitset with combined application of bioregulators might be due to increased rate of photosynthesis, which may influence the number of flowers that reach the pollination stage of development (Naylor, 1984). The present investigation are in agreement with the findings of Schwabe (1973) in apple and Jindal and Chandel (1996) in plum. Application of GA_3 alone inhibited the fruitset in plum but it was superior to control. The results of

the present studies are in conformity with the findings of Luckwill and Silva (1979); Tromp (1982) in apple and Webster (1984) in plum, who reported reduced flowering in fruit crops with gibberellins application.

5.3.2 Effect on fruit retention (%) at harvest

Observations on the percentage of the fruit retention at harvest indicate that the per cent fruit retention ranged from 18.26 to 19.97 with GA_3, 21.28 to 24.93 with BA and 24.96 to 26.26 with TRIA application. Maximum fruit retention (26.26%) was observed with application of 10 µg ml^{-1} TRIA (T_8), however it was minimum (18.26%) with 30 µg ml^{-1} GA_3 (T_3). The fruit retention was less than control in the plants treated with higher concentration (20 and 30 µg ml^{-1}) of GA_3. Increase in fruit retention with TRIA might be due to higher carbohydrate supply, water uptake and prevention of premature abscission of fruits, occurring mostly as a result of competition for assimilates or water with TRIA application (Naylor, 1984). The results are in accordance with the findings of Hu *et al.* (1985) in mandarin and Konhar and Mech (1988) in cashew who also reported higher fruit retention with TRIA application.

5.4 Effect of bioregulators on fruit yield

The application of bioregulators exerted a significant influence on the yield of 'Santa Rosa' plum. The maximum fruit yield (22.42 kg/ha) was obtained with 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA (T_{13}), whereas the minimum yield (12.01 kg/tree) was recorded under control. A yield range between 17.50 to 19.14, 18.41 to 18.84 and 19.60 to 20.98 kg/tree was observed with GA_3, BA and TRIA application, respectively.

These yields were significantly higher than control. This higher yield might be due to higher no. of fruit, greater fruit size and weight with these treatments. Increased fruit size due to enhanced photosynthesis, increase uptake of nutrients, translocation of sugars and metabolites, faster cell expansion and production of larger cells, with the application of GA_3, BA and TRIA might be the other reasons for higher fruit yield. The results are in conformity with those of Singh and Chadha (1990) in apple and Kokate *et al.*(1992) in grapes.

Plant yield also depends upon an adequate production of photosynthetic assimilates and an adequate storage capacity to contain the photosynthetic product. The enhanced photosynthesis might have a direct influence on the fruit size and yield. Application of GA_3 increased the mobilization of carbohydrates to the developing fruit and increased berry size (Sidahmed and Kliewer, 1980). Malik *et al.* (1987) observed that triacontanol has an immediate effect on the photosynthetic rate due to the regulation of various processes relating to photosynthesis and photorespiration. The present findings are in accordance with Seeley (1978) in apple, Staples and Kuhr (1980); Gifford and Evans (1981); Christy and Porter (1982); and Barua (1990) in plum.

5.5 Effect of bioregulators on days taken to maturity

The harvesting date of plum exhibited a decreasing trend with bioregulator treatment as compared to control. All the concentration of TRIA significantly advanced the harvest maturity as compared to GA_3 and BA application. Minimum number of days after full bloom for maturation (101.33) were taken by the plants treated with 10 and 15 µg ml^{-1} TRIA,

however maximum number of days (107) were taken by the fruits of control. This advancement in harvest maturity might have occurred due to stimulated ethylene production as a result of TRIA treatments. The rate of photosynthesis gradually increased with the advancement of growth and this may be explained in the light of several reports by Ries *et al.* (1983); Ries and Houtz (1983) and Ries and Wert (1988) indicating that the presence of fruit leads to higher rates of photosynthesis which become maximum near harvest hence advancing maturity. Chandler and Heinicke (1926) in apple; Hansen (1969); Hansen (1970); Chalmer *et al.* (1975) in peach and Avery (1975) have also recorded an increase in rate of photosynthesis with triacontanol application and this enhanced photosynthetic efficiency of triacontanol treated leaves might have provided the rapidly developing fruits with sufficient amount of assimilates. These findings are in accordance with Hansen and Ryugo (1979) who observed that the rate of export of soluble sugars and sorbitol and mobilization of starch from leaves were proportional to the rate of fruit growth in French prune.

5.6 Effect of bioregulator on physical characteristics of fruit

In the present study, application of bioregulators markedly improved weight and size of the fruits over control. Significantly higher fruit weight (54.41 g) was obtained with 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA (T_{13}), however minimum fruit weight (31.82 g) was recorded in control. It was observed that maximum benefit could however be achieved when the bioregulators were sprayed in combination at different concentrations. Fruit weight obtained with 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA

+ 5 µg ml^{-1} TRIA (T_{13}) was 70.99 per cent higher than control plants. This increase in fruit weight may be attributed to increased fruit size as a result of flesh thickness due to increase in cell division with BA application (Salisbury and Ross, 2004), cell elongation/expansion with GA_3 application (Facteau, 1986) and enhancement of photosynthetic activity, higher production of carbohydrates and increased translocation of assimilates as a result of triacontanol application (Ries *et al.*,1977). Similar findings have been reported by Jindal and Dwivedi (1984) and Chandel (1985) in plum; Hashim and Lundergan (1985) in strawberry and Sud and Parmar (1990) in apricot. Increase in fruit weight with GA_3 was also observed by Facteau (1986) and Gutzwiler (1988) in 'Bing' and 'Lambert' cherries. They attributed this increase to the improved cell expansion, resulting in more cell volume. Similar findings with regard to GA in increasing fruit weight have been reported by Singh and Randhawa (1959) and Anwar *et al.* (1990) in strawberry. Increased fruit weight with GA_{4+7} application 3 days to 5 weeks after first petal fall was recorded by Looney (1979) in apple.

Different bio-regulators viz., GA_3 BA and TRIA appreciably enhanced fruit size in terms of length, diameter and volume in comparison to control. Maximum fruit length (4.73 cm) was obtained with 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA +5 µg ml^{-1} TRIA (T_{13}) and a minimum fruit length (3.90 cm) were recorded in control. Similarly, highest fruit diameter (4.54 cm) was observed with 10 µg ml^{-1} GA_3 +5 µg ml^{-1} TRIA (T_{11}) and 10 µg ml^{-1} TRIA (T_8). The increased fruit size in response to GA_3 may presumably be due to auxins which are believed to increased cell elongation while gibberellic acid increased cell size isodiametrically (Kondo, 1989).

Increase in fruit size with the application of TRIA may be due to an enlargement of the cells in the fleshy part of the fruits as has been reported by Tukey and Young (1939) in strawberry. Skogen *et al.*(1982) concluded that increased fruit growth in response to triacontanol may be mediated through its effect on growth stimulation due to its potential ability to enhance the process of photosynthesis. As overall growth requires cell expansion and growth promotion by cytokinins involves faster cell expansion and production of larger no. of cells as reported by Salisbury and Ross (2004). These results are in conformity with Kondo (1989) and Mohammad *et al.* (1996) who reported increase in fruit size in 'Starking Delicious' apple and 'Red Haven' peach with bioregulator treatments.

All the treatments significantly increased fruit volume over control. As the volume of fruit is highly correlated with fruit size and a stimulation of growth by bioregulators might have increased the fruit volume. Maximum fruit volume (52.33 cm^3) was observed with 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA (T_{13}). This increase in fruit volume can be attributed to the increased fruit size as a result of increase in cell size due to enhanced cell division and cell elongation with GA_3 and BA application. Increase in fruit volume with TRIA are in agreement with Hansen (1967) in apple; Sud and Parmar (1990) in apricot and Jindal and Chandel (1996) in plum. Increase in fruit volume is the output of increased photosynthetic activity as a result of triacontanol application which enhanced the accumulation of carbohydrates (Ries *et al.*, 1977). However, the increase in fruit volume with GA_3 is in accordance with the observations of Richards

(1957) in apricot, Yamada *et al.* (1991) in pear, Thakur *et al.* (1991) in strawberry, Khan (1994) in apricot and Wani (1995) in pear.

The data on fruit firmness revealed that fruit firmness was not significantly influenced by bio-regulators application. However the fruit firmness was higher (2.41 kg/cm^2) when treated with 10 µg ml^{-1} TRIA (T_8). Minimum fruit firmness (2.34 kg/ cm^2) was recorded with 20 µg ml^{-1} GA_3 (T_2) and control. T_5, T_6, T_9, T_{12} and T_{13} had the similar fruit firmness (2.40 kg/ cm^2). Jindal and Chandel (1996) also observed an increase in fruit firmness of plum with TRIA application which was due to its potential ability to enhance the process of photosynthesis. Increased flesh firmness by TRIA application indicates extended shelf life of the fruit and more desirable eating quality.

The pulp/stone ratio was significantly increased by the combined application of bioregulators viz., GA_3, BA and TRIA at different concentrations. Maximum pulp/stone ratio of 33.66 was observed when the plants were treated with 10 µg ml^{-1} GA_3 + 5µg ml^{-1} TRIA (T_{11}) however minimum pulp/stone ratio (21.60) was observed in control. The increase in pulp/stone ratio may be due to increase in fruit size by bioregulators treatment and therefore, be attributed entirely to cell enlargement in the mesocarp as has been reported by Crane (1964). Increase in pulp/stone ratio with different bioregulators application was also observed by Bal *et al.* (1981) and Jindal and Chandel (1996).

5.7 Effect of bioregulators on chemical characteristics of fruit

Fruit chemical characteristics viz., acidity, TSS, TSS/ acid ratio, reducing sugars, non-reducing sugars and total sugars were markedly affected by bioregulators application. Fruit acidity was significantly reduced by all the bioregulator treatments as compared to control. Minimum acidity (1.40 %) was found in the plants treated with 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA (T_{13}) whereas maximum acidity (1.52 %) was recorded in control. The reduction in acidity percentage indicate that fruits were at a higher stage of maturity due to increased rate of respiration with bioregulators application as has been reported by Ries *et al.* (1977). Similar reduction in fruit acidity with application of TRIA has been observed by Chandel (1985) in plum, Chander (1987) and Sud and Parmar (1990) in apricot. Srivastava (1966); Singh and Jindal (1986) and Mitra (1991) in apple also reported reduced fruit acidity with GA_3 application due to mark increased in the utilization of malic acid in peel as well as in pulp, initiated during the period of climacteric.

Observations on TSS indicate that bioregulator treatments were effective in improving TSS and TSS/acid ratio as compared to control. Maximum TSS (16.35%) and TSS/acid ratio (11.65) was observed with 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA (T_{13}), whereas minimum TSS (15.01%) and TSS/acid ratio (9.84) were recorded in control. The increase in TSS may be attributed to the enhanced photosynthetic efficiency of the leaves and a possible increase in the translocation of assimilates with the application of bioregulators. Hosegawa and Nakazema (1988) also recorded an increased TSS with the application of GA_3 in peach. Similar

findings have also been reported by Carolene (1962) in peach and Sandhu *et al.* (1970) in 'New Castle' apricot.

An increase in TSS was also reported in Santa Rosa plum with triacontanol by Jindal and Dwivedi (1984), in apricot with Miraculan and Vipul (Chander, 1987) and in grape with Mixtalol (Gupta *et al.*,1987). Hansen (1967) also reported that increase in fruit TSS may be associated with increased translocation of organic assimilates from leaves in response to hormonal stimulation.

Present study reveal that the sugar content of fruits was positively influenced by bioregulators spray. Application of bioregulators in combination proved to have increased the sugar content of the fruits appreciably. Maximum reducing (5.81%) and total sugars content (7.14%) were observed with 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA (T_{13}) application, however minimum sugars were recorded in control. Monselise (1986) attributed the increase in fruit sugars to the appreciably higher growth, photosynthesis, more uptake of nutrients as well as rapid translocation of metabolites which helps in sugar translocation as the developing fruit have higher demand for photosynthates. The increase in sugars in the present study may also be attributed to a stimulated translocation of assimilates from leaf through vascular system (Booth *et al.*, 1962), facilitation of carbohydrate movement towards stronger sink and stimulation of rate of photosynthesis and activation of enzyme system capable of degrading reserve polysaccharides into smaller units as a result of bioregulators application (Luckwill, 1973). Hulme (1970) also observed

that a growing fruit constitutes a very active metabolic centre towards which large amount of nutrients flow and starch hydrolysis and the formation of soluble sugars may be initiated in the ripening fruits by ethylene. Increase in sugars content due to bioregulators application has also been observed by Jindal and Dwivedi (1984) and Chandel (1985) in plum and Chander (1987) in apricot.

Chapter-6

SUMMARY AND CONCLUSION

The present investigation entitled "**Effect of bio-regulators on growth, yield and quality of plum *(Prunus salicina* Lindl.) cv. Santa Rosa**" was carried out at Division of Pomology, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Shalimar, Srinagar during 2006. In the present investigation, different bioregulators viz., GA_3, BA and TRIA were applied immediately after petal fall at different concentrations and in combination for improving yield and quality of Santa Rosa plum. The results obtained during the course of investigations are summarized below:

1. Annual shoot extension growth was significantly improved by all the bioregulator treatments. Among different the treatments, maximum shoot growth was recorded with 30 μg ml^{-1} GA_3 (T_3) followed by 10 μg ml^{-1} GA_3+ 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) application.
2. Tree volume was increased by all the bioregulator treatments and maximum volume was recorded with 30 μg ml^{-1} GA_3 (T_3) which was statistically at par with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) application.
3. Initial fruitset was improved by all the bioregulator treatments. Among various treatments, highest fruitset was recorded with 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{12}) application.
4. Observations on fruit retention at harvest indicated that maximum per cent retention was recorded with 10 μg ml^{-1} TRIA (T_8) followed by 15 μg ml^{-1} TRIA (T_9) application.

5. Fruit yield was appreciably enhanced by bio-regulator treatments. Maximum fruit yield was obtained with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) followed by 10 μg ml^{-1} TRIA (T_8) application.
6. Application of 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) exhibited maximum per cent increase in fruit yield over control.
7. Maturity date was advanced by nearly 6 days with 10 and 15 μg ml^{-1} TRIA application.
8. Fruit weight was significantly increased by bioregulators application. Highest fruit weight was obtained with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) followed by 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} TRIA (T_{11}) application.
9. Application of 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) exhibited maximum per cent increase in fruit weight over control.
10. Fruit length was increased with all the bioregulator treatments and maximum fruit length was recorded with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) which was statistically at par with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} TRIA (T_{11}) and 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{12}) application.
11. Fruit diameter was significantly improved by bioregulators application. Maximum diameter was obtained with 10 μg ml^{-1} TRIA (T_8) and 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} TRIA (T_{11}) applications.
12. Fruit volume was also improved by different bioregulator treatments. Fruits treated with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) attained highest volume.

13. The firmness was higher in the fruits treated with 10 μg ml^{-1} TRIA (T_8). However, this parameter was not significantly influenced by different bioregulators application.
14. The highest pulp/stone ratio was obtained with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} TRIA (T_{11}) followed by 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) application.
15. Fruit acidity was decreased with all the bioregulator treatments. Lowest acidity was recorded with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) closely followed by 10 μg ml^{-1} TRIA (T_8) application.
16. Total soluble solids and TSS : acid ratio were found to be highest with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) application.
17. Maximum reducing sugars was recorded with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) application while the minimum was recorded in control.
18. Maximum percentage of non-reducing sugars was observed with 10 and 15 μg ml^{-1} TRIA application however minimum amount was recorded in control.
19. Application of bioregulators increased the total sugars content of fruits as compared to control. Maximum percentage of total sugars was recorded with 10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA (T_{13}) closely followed by 10 μg ml^{-1} TRIA (T_8) application.

Thus, it may be concluded that application of bioregulators viz., GA_3, BA and TRIA immediately after petal fall resulted in improved growth, yield and quality of Santa Rosa plum. The combined application of these bioregulators at lower concentration (10 μg ml^{-1} GA_3 + 5 μg ml^{-1} BA + 5 μg ml^{-1} TRIA) proved

more effective in promoting plant growth and fruit physico-chemical characteristics. The fruit yield was also superior with this treatment Hence it represents the best treatment for promoting plant growth and getting higher yield of better quality ‘Santa Rosa’ plums for better remuneration to the orchardist.

Table 1. Effect of bioregulators on annual shoot extension growth and tree volume in plum cv. Santa Rosa

Treatments	Annual shoot extension growth (cm)	Tree volume (m^3)
T_1 10 µg ml^{-1} GA_3	52.26	2.88
T_2 20 µg ml^{-1} GA_3	53.19	3.35
T_3 30 µg ml^{-1} GA_3	56.41	3.98
T_4 5 µg ml^{-1} BA	50.86	2.87
T_5 10 µg ml^{-1} BA	52.75	2.84
T_6 15 µg ml^{-1} BA	50.81	2.86
T_7 5 µg ml^{-1} TRIA	52.64	2.92
T_8 10 µg ml^{-1} TRIA	55.17	3.69
T_9 15 µg ml^{-1} TRIA	52.84	3.27
T_{10} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA	52.91	3.32
T_{11} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} TRIA	54.39	3.49
T_{12} 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	52.46	2.93
T_{13} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	55.83	3.93
T_{14} Control (water spray)	43.86	2.82
LSD (0.05)	**0.55**	**0.44**
±S.E. of mean difference	**0.26**	**0.21**

Table 2. Effect of bioregulators on initial fruit set and fruit retention at harvest in plum cv. Santa Rosa

Treatments	Initial fruit set (%)	Fruit retention at harvest (%)
T_1 10 µg ml^{-1} GA_3	50.99	19.97
T_2 20 µg ml^{-1} GA_3	51.75	19.31
T_3 30 µg ml^{-1} GA_3	50.48	18.26
T_4 5 µg ml^{-1} BA	50.91	24.93
T_5 10 µg ml^{-1} BA	51.80	22.26
T_6 15 µg ml^{-1} BA	50.41	21.28
T_7 5 µg ml^{-1} TRIA	51.38	24.96
T_8 10 µg ml^{-1} TRIA	52.56	26.26
T_9 15 µg ml^{-1} TRIA	51.06	25.05
T_{10} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA	51.12	20.26
T_{11} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} TRIA	52.86	21.11
T_{12} 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	53.86	22.33
T_{13} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	52.79	22.17
T_{14} Control (water spray)	50.38	19.55
LSD (0.05)	**0.014**	**0.05**
±S.E. of mean difference	**0.006**	**0.02**

Table 3. Effect of bioregulators on fruit yield and days taken to maturity (Harvesting date) in plum cv. Santa Rosa

Treatments	Fruit yield (kg/tree)	Days taken to maturity (Harvesting date) (DAFB)*
T_1 10 µg ml^{-1} GA_3	17.50	106.33
T_2 20 µg ml^{-1} GA_3	19.14	104.66
T_3 30 µg ml^{-1} GA_3	17.91	105.33
T_4 5 µg ml^{-1} BA	18.41	105.33
T_5 10 µg ml^{-1} BA	18.84	105.33
T_6 15 µg ml^{-1} BA	18.71	105.33
T_7 5 µg ml^{-1} TRIA	19.60	102.33
T_8 10 µg ml^{-1} TRIA	20.98	101.33
T_9 15 µg ml^{-1} TRIA	19.81	101.33
T_{10} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA	19.42	106.33
T_{11} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} TRIA	20.75	103.00
T_{12} 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	20.53	103.33
T_{13} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1}TRIA	22.42	102.66
T_{14} Control (water spray)	12.01	107.00
LSD (0.05)	**0.12**	**2.24**
±S.E. of mean difference	**0.06**	**1.09**

* Days after full bloom.

Table 4. Effect of bioregulators on fruit weight and fruit length in plum cv. Santa Rosa

Treatments	Fruit weight (g/fruit)	Fruit length (cm)
T_1 10 µg ml^{-1} GA_3	45.74	4.52
T_2 20 µg ml^{-1} GA_3	48.81	4.62
T_3 30 µg ml^{-1} GA	47.39	4.60
T_4 5 µg ml^{-1} BA	45.53	4.58
T_5 10 µg ml^{-1} BA	47.88	4.63
T_6 15 µg ml^{-1} BA	46.25	4.66
T_7 5 µg ml^{-1} TRIA	48.03	4.60
T_8 10 µg ml^{-1} TRIA	50.62	4.64
T_9 15 µg ml^{-1} TRIA	49.19	4.63
T_{10} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA	52.27	4.72
T_{11} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} TRIA	53.86	4.70
T_{12} 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	53.39	4.71
T_{13} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	54.41	4.73
T_{14} Control (water spray)	31.82	3.90
LSD (0.05)	**0.08**	**0.07**

±S.E. of mean difference	**0.03**	**0.03**

Table 5. Effect of bioregulators on fruit diameter and fruit volume in plum cv. Santa Rosa

Treatments	Fruit diameter (cm)	Fruit volume (cm^3)
T_1 10 µg ml^{-1} GA_3	4.41	45.55
T_2 20 µg ml^{-1} GA_3	4.52	47.10
T_3 30 µg ml^{-1} GA_3	4.48	46.55
T_4 5 µg ml^{-1} BA	4.33	44.55
T_5 10 µg ml^{-1} BA	4.50	48.44
T_6 15 µg ml^{-1} BA	4.38	45.55
T_7 5 µg ml^{-1} TRIA	4.51	47.77
T_8 10 µg ml^{-1} TRIA	4.54	48.68
T_9 15 µg ml^{-1} TRIA	4.52	48.44
T_{10} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA	4.53	50.21
T_{11} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} TRIA	4.54	50.77
T_{12} 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	4.53	50.08
T_{13} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	4.53	52.33
T_{14} Control (water spray)	3.78	30.88

LSD (0.05)	**0.02**	**1.15**
±S.E. of mean difference	**0.01**	**0.56**

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Table 6. Effect of bioregulators on fruit firmness and pulp/ stone ratio in plum cv. Santa Rosa

Treatments	**Fruit firmness (kg/cm^2)**	Pulp/stone **Ratio**
T_1 10 µg ml^{-1} GA_3	2.36	29.59
T_2 20 µg ml^{-1} GA_3	2.34	30.63
T_3 30 µg ml^{-1} GA_3	2.38	31.38
T_4 5 µg ml^{-1} BA	2.39	30.02
T_5 10 µg ml^{-1} BA	2.40	30.89
T_6 15 µg ml^{-1} BA	2.40	30.87
T_7 5 µg ml^{-1} TRIA	2.39	29.64
T_8 10 µg ml^{-1} TRIA	2.41	31.08
T_9 15 µg ml^{-1} TRIA	2.40	31.99
T_{10} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA	2.38	32.64
T_{11} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} TRIA	2.39	33.66
T_{12} 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	2.40	32.07
T_{13} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	2.40	32.70

T_{14} Control (water spray)	2.34	21.60
LSD (0.05)	**NS**	**0.96**
±S.E. of mean difference	**-**	**0.47**

Table 7. Effect of bioregulators on fruit titratable acidity and fruit total soluble solids in plum cv. Santa Rosa

Treatments	**Titratable acidity (%)**	TSS **(%)**
T_1 10 µg ml^{-1} GA_3	1.49	15.80
T_2 20 µg ml^{-1} GA_3	1.45	15.91
T_3 30 µg ml^{-1} GA_3	1.48	15.74
T_4 5 µg ml^{-1} BA	1.50	15.64
T_5 10 µg ml^{-1} BA	1.46	15.88
T_6 15 µg ml^{-1} BA	1.45	15.93
T_7 5 µg ml^{-1} TRIA	1.44	16.01
T_8 10 µg ml^{-1} TRIA	1.41	16.25
T_9 15 µg ml^{-1} TRIA	1.42	16.18
T_{10} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA	1.48	15.71
T_{11} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} TRIA	1.46	15.90
T_{12} 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	1.45	16.07

T_{13} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	1.40	16.35
T_{14} Control (water spray)	1.52	15.01
LSD (0.05)	**0.03**	**0.03**
±S.E. of mean difference	**0.01**	**0.01**

Table 8. Effect of bioregulators on fruit TSS/ acid ratio and reducing sugars in plum cv. Santa Rosa

Treatments	TSS/ Acid ratio	Reducing sugars (%)
T_1 10 µg ml^{-1} GA_3	10.60	4.46
T_2 20 µg ml^{-1} GA_3	10.97	5.08
T_3 30 µg ml^{-1} GA_3	10.63	4.79
T_4 5 µg ml^{-1} BA	10.38	4.56
T_5 10 µg ml^{-1} BA	10.85	4.81
T_6 15 µg ml^{-1} BA	10.93	5.12
T_7 5 µg ml^{-1} TRIA	11.11	5.64
T_8 10 µg ml^{-1} TRIA	11.47	5.76
T_9 15 µg ml^{-1} TRIA	11.39	5.70
T_{10} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA	10.61	4.70

T_{11} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} TRIA	10.86	4.76
T_{12} 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	11.03	5.66
T_{13} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	11.65	5.81
T_{14} Control (water spray)	9.84	4.37
LSD (0.05)	**0.27**	**0.05**
±S.E. of mean difference	**0.13**	**0.02**

Table 9. Effect of bioregulators on fruit non-reducing sugars and fruit total sugars in plum cv. Santa Rosa

Treatments	Non-reducing sugars (%)	Total sugars (%)
T_1 10 µg ml^{-1} GA_3	1.09	5.61
T_2 20 µg ml^{-1} GA_3	1.04	6.18
T_3 30 µg ml^{-1} GA_3	1.01	5.86
T_4 5 µg ml^{-1} BA	1.07	5.69
T_5 10 µg ml^{-1} BA	1.18	6.06
T_6 15 µg ml^{-1} BA	1.08	6.26
T_7 5 µg ml^{-1} TRIA	1.12	6.82
T_8 10 µg ml^{-1} TRIA	1.28	7.11

T_9 15 µg ml^{-1} TRIA	1.28	7.05
T_{10} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA	1.03	5.79
T_{11} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} TRIA	1.03	5.85
T_{12} 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	1.25	6.98
T_{13} 10 µg ml^{-1} GA_3 + 5 µg ml^{-1} BA + 5 µg ml^{-1} TRIA	1.26	7.14
T_{14} Control (water spray)	0.62	5.03
LSD (0.05)	**0.06**	**0.02**
±S.E. of mean difference	**0.03**	**0.01**

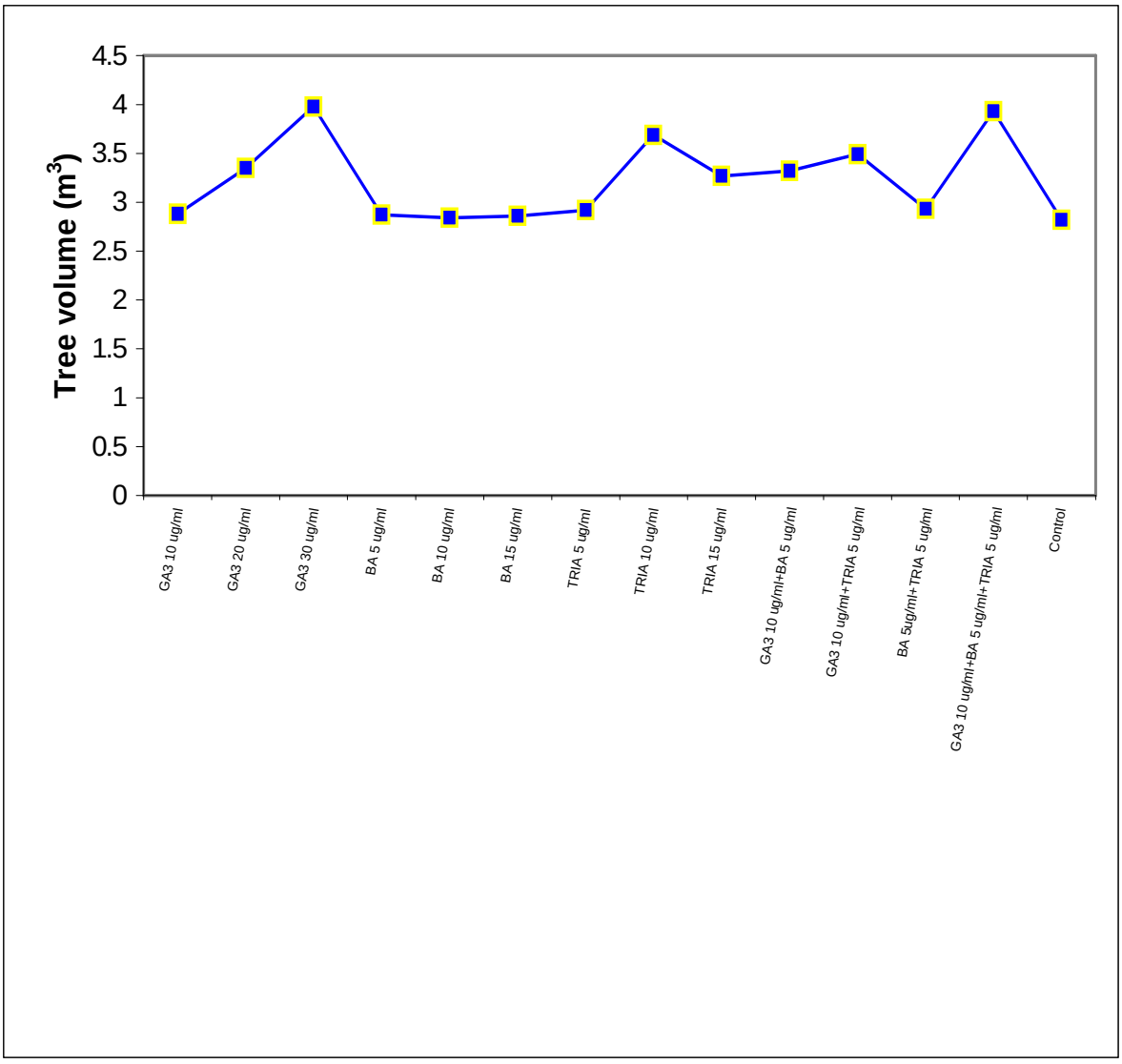

Figure 1. Effect of bioregulators on tree volume (m^3) in plum cv. Santa Rosa

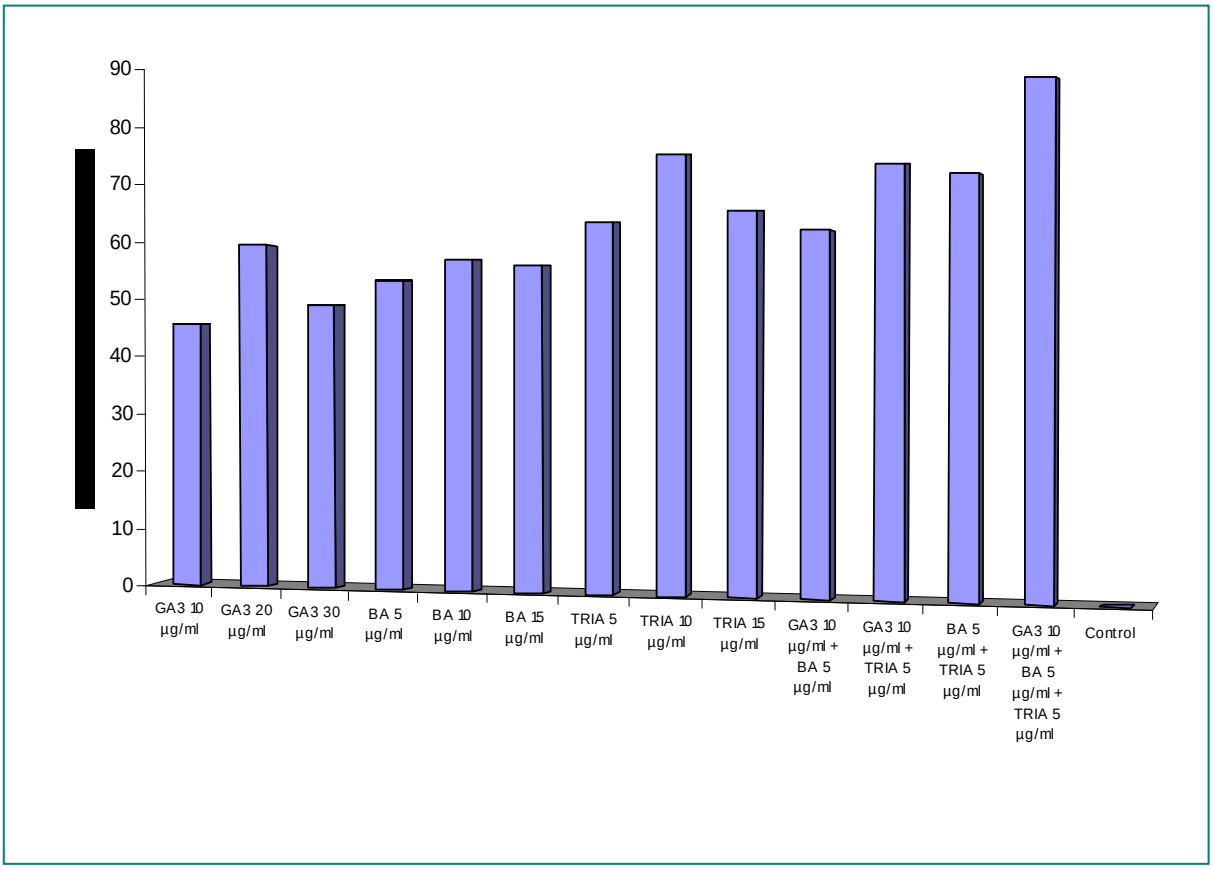

Figure 2. Effect of bioregulators on increase in fruit yield over control (%) in plum cv. Santa Rosa

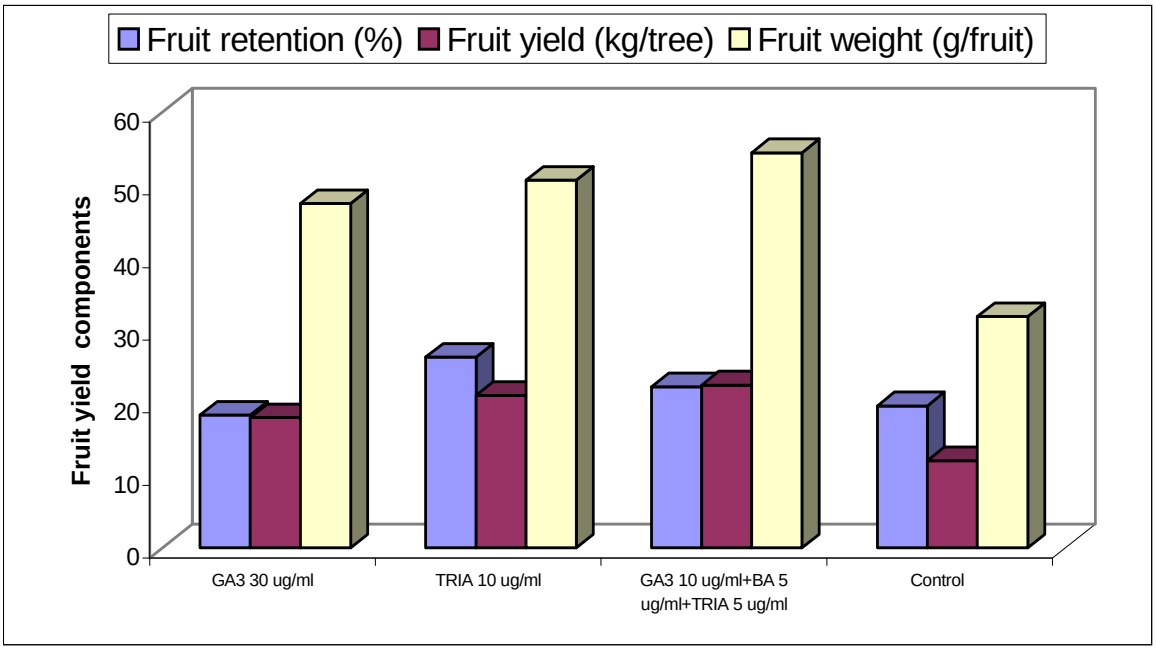

Figure 3. Comparative influence of bioregulators on fruit yield components in plum cv. Santa Rosa

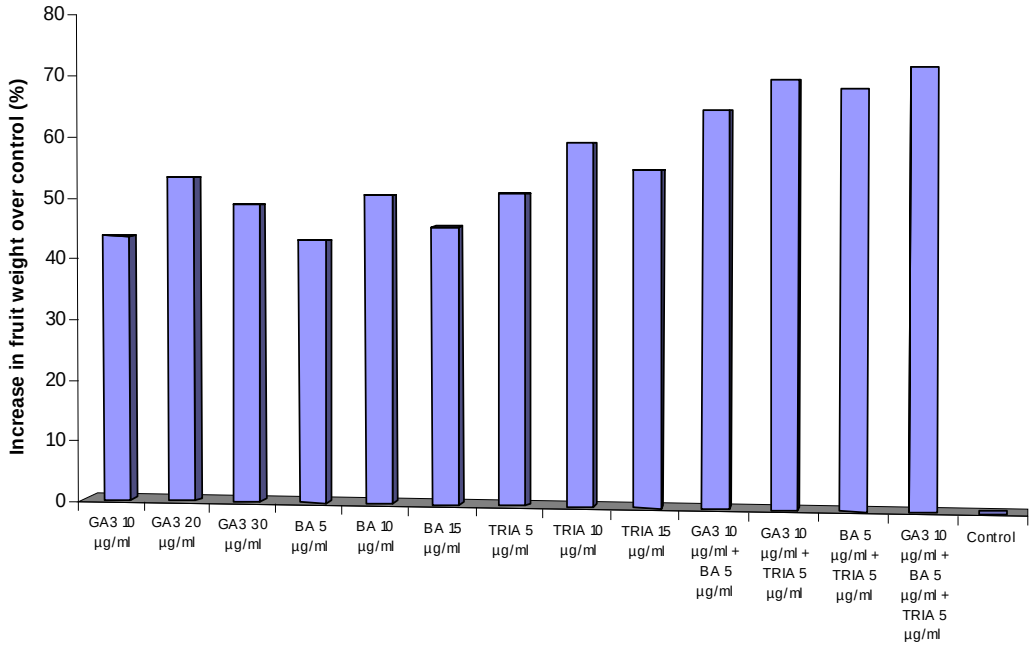

Figure 4. Effect of bioregulators on increase in fruit weight over control (%) in plum cv. Santa Rosa

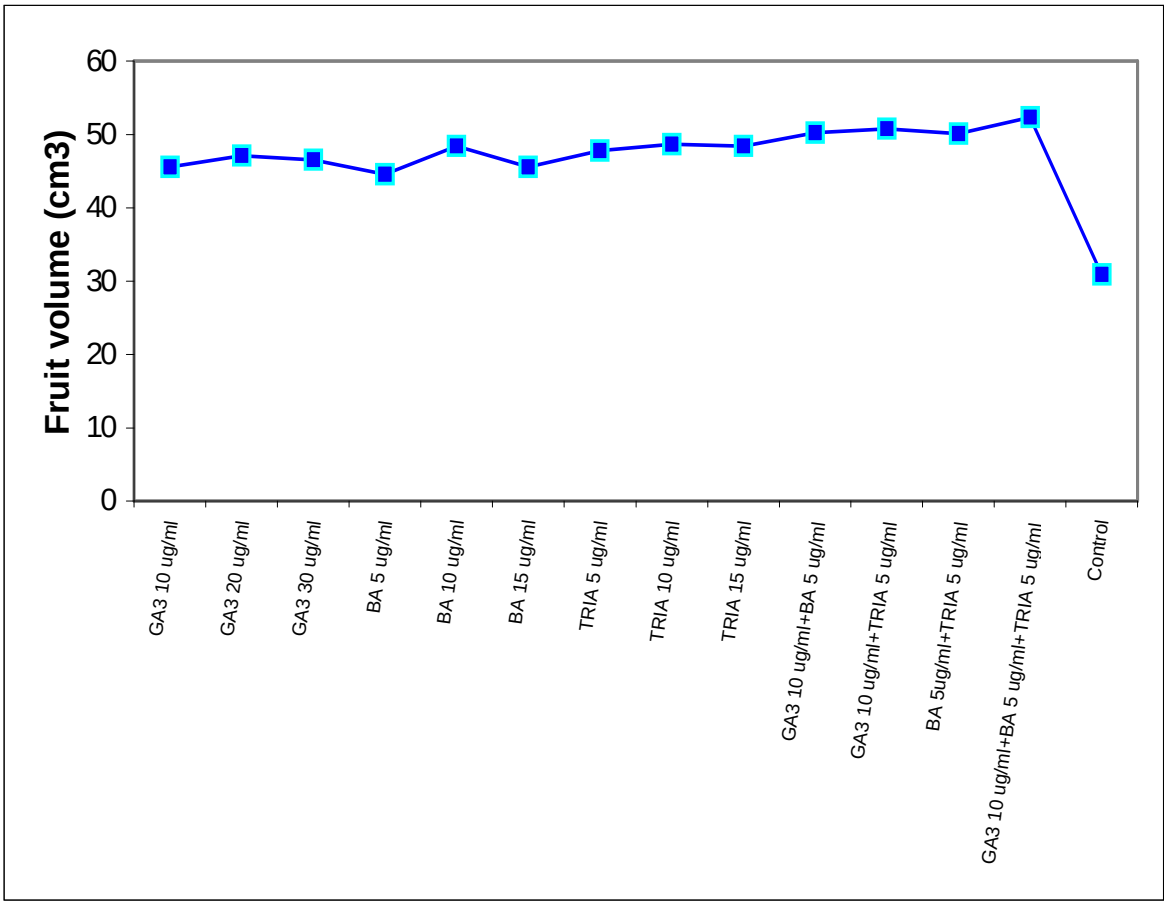

Figure 5. Effect of bioregulators on fruit volume (cm^3) in plum cv. Santa Rosa

Appendix-I

Climatological table: Weather parameters of the year 2006

Station : SKUAST-K, Shalimar, Srinagar

Altitude: 1587 m

Month	Weather parameters of the year 2006			
	Maximum temperature (^{o}C)	**Minimum temperature (^{o}C)**	*Relative humidity* **(%)**	**Rainfall (mm)**
March	14.52	3.57	79.03	65.02
April	20.94	5.47	71.03	55.00
May	27.72	11.45	74.29	38.06
June	27.96	13.42	79.43	35.08
July	31.12	17.92	77.35	151.06

Division of Agronomy,
SKUAST-K, Shalimar

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* **Original not seen.**