Effect of Gibberellic acid, Applin and Calcium foliar sprays on chemo-metric attributes of apple (*Malus* x *domestica* Borkh.)

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(2015-H-85-M)

Division of Fruit Science

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Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir

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Thesis

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in partial fulfillment of requirement for the award of the degree of

Master of Science in Horticulture
(Fruit Science)

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Dedicated

to my

Beloved Parents

'A constant source of inspiration throughout my life'

Sher-e-Kashmir
University of Agricultural Sciences & Technology of Kashmir
Division of Fruit Science,
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Certificate – I

This is to certify that the thesis entitled, **"Effect of Gibberellic acid, Applin and Calcium foliar sprays on chemo-metric attributes of apple (*Malus* x *domestica* Borkh.)"** submitted in partial fulfillment of the requirements for the award of the degree of **Master of Science in Horticulture (Fruit Science)**, to the **Faculty of Horticulture, Sher-e-Kashmir University of Agricultural Sciences & Technology of Kashmir** is a record of bonafide research work carried out by **Mr. Mohsin Ahmad Hajam (Regd. No. 2015-H-85-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.

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We, the members of the Advisory Committee of **Mr. Mohsin Ahmad Hajam (Regd. No. 2015-H-85-M),** a candidate for the degree **Master of Science in Horticulture (Fruit Science)**, have gone through the manuscript of the thesis entitled, **"Effect of Gibberellic acid, Applin and Calcium foliar sprays on chemo-metric attributes of apple (*Malus* x *domestica* Borkh.)"** 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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ABSTRACT

The present investigation entitled ''Effect of gibberellic acid, Applin and calcium foliar sprays on chemo-metric attributes of apple (*Malus x domestica* Borkh.)'' was undertaken during the year 2016-17, at the orchard of progressive farmer from district Kulgam of Kashmir valley. Different treatments of GA_3, $CaCl_2$, chelated calcium and Applin were used to evaluate the response of fruit quality and post harvest attributes of apple *cv.* Red Delicious. Calcium chloride (0.3 %) and chelated calcium (0.1 %) were sprayed one to five times at an interval of 3 week. The first spray started, three weeks after fruit set and at the same time GA_3 (50 ppm and 100 ppm) was sprayed once. Applin (1.5 ml/L and 2.5 ml/L) was sprayed once at walnut stage. Investigation revealed that Applin, GA_3 and Ca sprays had significant effect on fruit size, soluble solids concentrate (SSC), total sugars, fruit and leaf nutritional status. Maximum fruit diameter (7.95 cm), SSC (15.17 ^{0}Brix), total sugars (11.92 %), return bloom (15.71 flower clusters/cm^2 branch cross section area), leaf and fruit N, K, Mg, physiological loss in weight (PLW) at 30 DAS (5.44 %) and at 45 DAS (8.86 %) were observed in Applin at

2.5 ml/L. Whereas maximum fruit length (7.97 cm), shape index (1.02), sweetness index (60.64), PLW at 15 DAS (3.55 %) and minimum acidity (0.24 %), return bloom (12.13 flower clusters/ cm^2 branch cross section area) and anthocyanin (9.12 mg/100 g) were observed by GA_3 spray at 100 ppm. In addition to this all concentrations of Applin and GA_3 increased storage disorders. However Ca sprays were found prominent in improving and maintaining fruit quality and preventing physiological disorders during storage. Calcium in the form of $CaCl_2$ had slightly superior influence to chelated calcium in improving premium grade "A", SSC, total sugars, Vitamin C and storage parameters. The four sprays of either of the calcium sources recorded satisfactory results with regard to fruit quality, whereas fifth spray improved post harvest storage.

Key words: Apple, Applin, calcium, fruit quality, GA_3, sprays.

Signature of Student   Signature of Major Advisor

Dated: ____________   Dated: ________________

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All those who are not mentioned as well as mentioned, I may prefer to employ Rumi's[R.A.] quote to put forth their importance, which says "The Beauty You See In Me Is A Reflection Of You".

Place: Shalimar, Srinagar   Mohsin Ahmad Hajam

Dated : _______________

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Chapter-1

INTRODUCTION

Apple (*Malus x domestica* Borkh.) is an important temperate fruit crop, belonging to family *Rosaceae* and subfamily *pomoideae.* Owing to its great food and medicinal property, it is called as king of temperate fruits. Worldwide; it is grown in all temperate regions, whereas in India its production is confined to Jammu and Kashmir, Himachal Pradesh, Uttrakhand and some regions of Arunachal Pradesh.. It has played an important role in the economic and social life of the people of these regions. Jammu and Kashmir contributes maximum to area and production of apple in India. In Jammu and Kashmir it is mainly grown in Kashmir valley. The apple orchards of Kashmir are mostly comprised of cultivar Red Delicious followed by that of Royal Delicious.

According to FAO statistics (2017), present world production of apples is close to 84.63 million tons and the world's largest apple producing countries include China (40,924,707 metric tons), United States (5,185,078 metric tons), Poland (3,195,299 metric tons), India (2,497,680 metric tons), Turkey (2,480,444 metric tons), Italy (2,473,608 metric tons), Chile (1,757,225 metric tons), Russia (1,624,000 metric tons), Iran 1,572,844 metric tons) and France (1,531,625 metric tons).

Jammu and Kashmir is bestowed with a particularly well-suited climate in the Indian subcontinent for production of temperate fruits particularly apple. Kashmir has for long been called the home of apples. The fruit industry is the backbone of economy in Jammu and Kashmir and has a great potential to ameliorate the living condition of rural people. The area under apple cultivation in Jammu and Kashmir is 161,773 hectare (ha) with the production of 1,966,417 metric tons (MT) and productivity 12.16 MT/ha (Anonymous, 2016).

Despite the fact that Jammu and Kashmir is the leader in apple productivity (12.16 MT/ha) in the country, it is far below the productivity of developed countries. In recent years marvelous increase in yield of apple has been witnessed, but if the harvested fruits are not consumed, high yields are worth little then, compelling focused attention towards good quality apple production to register significant growth in the export of horticulture produce outside the state. It is commonly believed that about 30 percent of 'A' grade, 40 percent of 'B' grade and 30 percent of 'C' grade of pre-falls and culled apples are produced in our state. The reason for low growth in export of fruits outside the state is primarily because of low 'A' grade apple production. Secondly, India is also importing fruits from foreign countries as free trade policy which is in force at the country level. Market price is mostly determined by the demand, supply and quality of the produce as well. In case of apple; some fruit quality attributes like fruit size, shape, firmness and colour peculiar to the variety has profound effect on market value of the fruit as grade 'A' fetches about Rs. 60 per Kg and that of grade 'B' and 'C' Rs. 30 and Rs. 10 respectively. Therefore, increasing percentage of grade 'A' fruits by the way of decreasing percentage of grade 'B' and grade 'C' fruits is going to result in higher income to the growers.

Nutrients play an important role in fruit crops, in increasing the yield, production and productivity, especially apple, pear, cherry and peach. The most commonly used nutrients include calcium (Ca), nitrogen (N), boron (B), Copper (Cu) etc. Nutrient deficiency of Ca, N, B, Cu and Mg particularly at fruit development stage causes poor fruit set, low productivity and inferior fruit quality (Hanson, 1991; Akl *et al.,* 1993; Jozsef and Rehman, 2005; Neilsen and Neilsen, 2006) that ultimately gets reflected by striking drop in economic wellbeing of farmers. Nutrient management plays an important role in fruit production and fruit quality as nutrients are essential for plant life and a plant deprived of any one of these elements would cease to exist (Marschner, 1995). Calcium is among the essential nutrients, found deficit in most of the soils. Ca is considered to be deficit in high rainfall areas and is less mobile in soils (Zatylnyl and St-pierre, 2006).

Humic acid is produced by the decomposition of organic matter, especially those with a plant origin, and can be found in soil, coal and peat resulting in the formation of stable, insoluble complexes with micronutrients. Humic acids have been shown to stimulate plant growth and consequently yield by acting on mechanisms involved in: cell respiration, photosynthesis, protein synthesis, water and nutrient uptake, enzyme activities (Chen, 2004). Under water stress, foliar fertilization with humic molecules increased leaf water retention and the photosynthetic and antioxidant metabolism (Fu Jiu, 1995). Several researchers, David (1991), Neri *et al.* (2002) and El-Desuki (2004) concluded that humic acid as foliar sprays enhanced growth nutrient uptake and yield and improved the quality of the production of some crops. Choline as choline chloride increased photosynthetic rate and thus the yield in Manila grass (Takeuchi *et al.,* 1990) and fig (Teragishi *et al.,* 2000). Thiamine is a B-complex vitamin that is produced in plants and microbes, including brewer's yeast (*Saccharomyces cerevisiae*; Burrows *et al.,* 2000) and *Salmonella typhimurium* (Beck and Downs, 1999). Thiamine functions as an activator of plant disease resistance (Ahn *et al.,* 2005).

Fertilization is the first priority management practice in fruit industry providing optimal conditions for plant growth and yielding. The key to improve fertilization efficiency is to apply preparations enriched with biostimulants (Schmidt *et al.*, 2003). Foliar application of hormones and nutrients can result in their rapid absorption and utilization to correct quantity and to assimilate large amounts of hormones and nutrients and meet the bulk of the hormone and nutrient requirement.

Calcium is an important nutrient in plant nutrition. Where it is abundant in the soil, calcium is abundant in leaves, since it is taken up passively by growing roots (not requiring an energy source). Apparently, only the region just behind the tips of a growing root is capable of calcium uptake (unlike K and P), so factors inhibiting root growth also inhibit its uptake. Calcium moves almost exclusively in the xylem with very small concentrations being found in the phloem. Therefore, once in an organ (such as a mature leaf), calcium is not readily transported out, not even during senescence. Fruit calcium levels are low, since nutrients in fruit tissues are supplied mostly by the phloem. For this reason, fruit and leaf calcium levels are poorly correlated; meaning leaf samples cannot be used to determine the fruit's calcium status. Calcium a relatively large divalent cation has numerous functions in the plant cell. Most of the functions of calcium as a structural component of macro-molecules are related to its capacity for co-ordination by which it provides stable but reversible intermolecular linkages, predominantly in the cell wall at the plasma membrane. Calcium acts as a secondary messenger in the signal conduction between environmental factors and plant response in terms of growth and development (Marschner, 1995). Calcium significantly increased the fruit weight in 'Sharbati' peach when sprayed before harvest (Gautam *et al.,* 1981). Firmness of fruits increases by thickening of middle lamella of fruit cell wall owing to increased formation and deposition of calcium pectate (Gupta *et al.,* 1984; Salehi *et al.,* 2013a). Calcium as nutrient spray to 'Flordasun' peach improved the yield significantly (Koul and Muthoo, 1988). Enhancement of vitamin C by Ca spray was found in pear *cv.* Pathernakh (Prasad *et al*., 2015).

Because calcium moves with the water in the plant, bitter pit; a physiological disorder is more pronounced in dry years when less water moves through the tree, resulting in less calcium in the plant in general which leads to certain physiological disorders including watercore and bitter pit. It relates well to the fact that more than 60 percent orchard areas in Kashmir valley are ranifed. In addition to the developing fruit, the vegetative growth of the leaves and the shoots also require calcium. In this competition for calcium, the developing fruit are very poor competitors when compared with the rapidly growing and developing leaves and shoots, which receive a much larger share of calcium. Excessive levels of nitrogen or light crop loads can often result in more vigorous vegetative growth, which in turn results in less calcium; being available to the developing fruits.

Ca is essential for plant growth, cell division, membrane stability, cell elongation and turgidity (Drake and Proebsting, 1982; Saure, 2005). Calcium promotes the root and fruit growth and quality of fruit (Kadir, 2005). Knowing that nutrients required for fruit growth and development is only one aspect of successful fruit production, but simultaneously optimum yield also requires knowing the rate to apply, the method and time of application, the source of nutrients to use, and how the elements are influenced by soil and climatic conditions (Tucker *et al.,* 1999).

There has been increasing interest in the use of calcium due to the beneficial effects on fruit quality and shelf-life. Lone (2007) reported improvement on yield and quality of Red Delicious due to Ca spray. Calcium is considered as one of the most important nutrient elements in controlling the metabolism of plant cells. Its role in preventing various physiological disorders like bitter pit and watercore in apple is quite evident (Bangerth, 1979; Dris and Niskanen, 1999; Raese and Drake, 2000; Amiri and Fallahi, 2007). Fruits treated with calcium chloride ($CaCl_2$) increased fruit size, weight, volume, organoleptic rating, starch, peel and flesh Ca and firmness of pear *cv.* 'Bartlett' (Bhat *et al.* 2009). Calcium regulates the absorption of nutrients across the cell membranes and plays important role in plant cell elongation and division, structure and permeability of the cell, nitrogen metabolism and carbohydrate metabolism. Calcium is necessary to maintain membrane stability and is an integral part of cell wall where it provides rigidity (Conway *et al.,* 2002).

Although soil application is the most common method of fertilizer application to the fruit trees; however, for quick response, foliar nutrient applications are preferred. Foliar application also entails efficient and economic use of fertilizers; besides, minimising ground water pollution. Further, plants sometime grow at rates that are faster than the ability of the roots to absorb and translocate minerals to the critical leaf, flower and fruit tissues. Foliar sprays can often help to overcome deficiency and maintain optimum nutrient levels of those critical tissues. There are different sources of nutrients for foliar sprays. Calcium can be applied through calcium chloride, calcium nitrate, calcium hydroxide, chelated calcium etc. Foliar fertilizers as chelate are easily absorbed by the plants and rapidly transported to affect the plant physiological processes. Amino acids have a chelating effect on micronutrients when applied together; the absorption and transportation of micronutrients inside the plant is easier, this effect is due to the chelating action, the effect of cell membrane permeability and low molecular weight (Westwood, 1993). Foliar application seems to be effective in ameliorating micronutrient deficiency symptoms (El-Seginy *et al.,* 2003).

The term plant growth regulator (PGR) includes naturally occurring plant growth substances or phytohormones, as well as synthetic compounds which mostly are chemical analogs, materials that alter hormone levels (hormone releasing agents or synthesis inhibitors) and materials that alter hormone sensitivity. The concentrations of hormones required for plant responses are very low (10^{-6} to 10^{-5} mol/L). There are five well established categories of "classical" phytohormones. The chemicals are each grouped together into one of these classes based on their structural similarities and on their effects on plant physiology.

Gibberellic acid and auxin intensifies an organ ability to function as a nutrient sink. Gibberellic acid also increases the biosynthesis of IAA in plant tissues, delays the formation of separation layer, and thus enhances fruit retention (Wally *et al.,* 1999). GA_3 treatment leads to reduce in fruit drop and improving most fruit characteristics of pear trees (Rezk, 1988). Also, the effect of GA_3 has at least three important actions, the first is intensify the ability of organ to be as a nutrient sink; secondly, increasing the synthesis of IAA in plant tissues; the third, it involves synthesis acceleration of hydrolytic enzymes in aleurone cells (Addicott and Addicott, 1982). Growers in British Columbia, the U.S. Pacific

Northwest and increasingly in other regions of the world apply gibberellic acid (GA_3) to increase fruit size, improve fruit firmness and delay maturity of sweet cherries (Kappel and MacDonald, 2007).

The exogenous application of CPPU acts as early and rapid on cell division in the fruitlet and also on subsequent growth and thus the fruit becomes bigger in size due to the increased cells, which are able to attract so much water, minerals and carbohydrates that enable the fruit to expand to large size (Kano, 2003).

Plant growth and development is ultimately the function of all essential elements and five important hormones (gibberellins, auxins, cytokinins, abscisic acid and ethylene). Their desirable effect is manifold when sprayed in combination on the trees. Owing to this importance of plant nutrients and hormones some complex formulations consisting combinations of these (nutrients and hormones) have being launched by some companies. One such formulation being 'Applin' consisting of hormones like gibberellins, cytokinins, auxins; nutrients like nitrogen, boron, copper, magnesium, molybdenum, sulphur; and organic substances like humic acid, choline, thiamine etc.

For increasing the apple production and productivity, it seems to be desirable to have some of technological interventions in the package of practice for apple growers so that we can be able to boost up the productivity and encourage the farmers to grow and earn more. Keeping the above points in view, the present research trail was carried out at a progressive farmer's orchard in Kulgam district of Kashmir valley with following objectives:

1. To study the effects of different chemicals on fruit quality of apple.
2. To identify better source of calcium and optimize the number of calcium sprays on apple.

Chapter – 2

REVIEW OF LITERATURE

The literature available on the present investigation entitled **''Effect of gibberellic acid, Applin and calcium foliar sprays on chemo-metric attributes of apple (*Malus* x *domestica* Borkh.)''** and other related fruit crops in the country and abroad is reviewed under this chapter.

2.1. Fruit physical characteristics

2.1.1. Fruit length

Raese and Drake (2000) studied that the application of $CaCl_2$ @ 0.1 percent increases length (1.5 cm) compared to untreated control (1.2 cm). Gautam *et al.* (1981) reported non-significant effect on size of 'Kanto-5' peach when sprayed with calcium nitrate. Mehta and Jindal (1986) in a trial with 'Santa Rosa' plum found that preharvest nutrient sprays with calcium nitrate, potassium nitrate, calcium chloride and boric acid affected fruit size positively. Koul and Muthoo (1988) reported that application of calcium nitrate improved size of peach fruit *cv.* Flordasun which registered fruit length to the tune of 43.40 cm and was superior in comparison to control (41.00 cm). Robson *et al.* (1989) observed that fruit size of 'Cresthaven' peaches sprayed with higher concentration of calcium chloride i.e. 5.51 kg/ha per season was statistically significant at harvest in comparison to control and low calcium chloride (1.8 kg/ha). Bhat *et al.* (2009) studied the effect of preharvest $CaCl_2$ sprays on physicochemical characteristics of pear *cv.* 'Bartlett' in Kashmir. Fruits treated with 0.50 and 0.75 percent $CaCl_2$ showed increase in length considerably. Kadir (2005) reported that more than six preharvest foliar applications of $CaCl_2$ to Jonathan apple trees increased fruit length and weight. In grape *cv.* 'Thomson Seedless' sprays of $CaCl_2$ @ 1 g/L was found to increase berry L/D ratio as compared to untreated control plants (Marzouk and Kassem, 2011). Wani (1997) in a study revealed that treatment of different cultivars of peach with calcium at flowering exerted a significant positive influence on the length of fruit. Calcium chloride at the rate of 2 percent resulted in 5.16 cm the length of peach *cv.* Shane-i-Punjab and was superior to control (5.04) during first year of study. Calcium chloride at 2 percent recorded 8.78 cm length of fruit and was significantly higher as compared to fruit length of 7.95 cm under control (Rani and Brahamachari, 2004).

Marzouk *et al.* (2002) reported that the application of GA_3 (25 ppm) increased berry length 1.7 cm compared to 1.2 cm in untreated control, whereas berry length of 1.9 cm was observed by cytokinin CPPU (5 ppm) application. Looney and Pharis, (1986) observed that fruit length and length/diameter ratio increased in apples treated with GA_{4+7} at 50-100 ppm. Kano (2003) reported that the application of CPPU on Naval orange increased the length of fruits and same was reported in apple by Curry and Green (1993).

The direct effect of gibberellic acid on stimulating cell division and cell enlargement and increasing fruit size was reported by Liu *et al.* (2006) and Valero (2010). Hossain (2015) reported that the gibberellic acid (GA_3) play a significant role in enlarging the fruit size and quality development. It had been shown that the application of GA_3 @ 50 ppm on bilimbi fruit (*Averrhoa bilimbi*) played major role in developing a bigger sized (length and diameter) fruit as compared to untreated control. Zhuo *et al.* (1996) reported that the application of the Forchlorfenuron (CPPU), a synthetic cytokinin (CPPU) together with the application of GA_3 improves fruit length of loquat.

In a study by Gowda *et al.* (2006), it was revealed that the application of GA_3 had significant effects on bunch length as compared to untreated control. Akinci *et al.* (2014) studied the effect of BA plus GA_{4+7} treatments on fruit setting, quality in 'Fuji' apple varieties and found that the application of BA plus GA_{4+7} (1.8 % BA+1.8% GA_{4+7}; Perlan) at 100 and 150 ppm two times at one-week intervals increased fruit length as compared to untreated control. Choi *et al.*

(2002) revealed that spraying GA_3 at 20, 50 and 100 mg/L increased the fruit size in cherry fruit. Yahata *et al*. (2006) found that the application of GA_3 plus CPPU on loquat fruits produced the largest fruits (51.4 g). Kappel and MacDonald (2007) had seen that fruit size was increased by about 1 g per fruit and fruit size responded linearly to the gibberellin applications with earlier sprays having the largest fruit in 'Sweetheart' sweet cherry and also reported that growers in British Columbia, the U.S. Pacific Northwest and increasingly in other regions of the world apply gibberellic acid (GA_3) to increase fruit size of sweet cherries.

The study of micro nutrients viz zinc, boron and copper in high density orchard of mango *cv.* Dashehari revealed that application of boron significantly improved the fruit length (Singh *et al*., 2003). Mosa *et al.* (2015) carried out an experiment on seven years old 'Anna' apple trees. Results showed that potassium sulphate plus calcium chloride plus boric acid plus humic acid combination was the best treatment with respect to increase in fruit length and average fruit.

Gurung *et al.* (2016) reported that combinations of three growth regulators (GA_3 @ 7.5 ppm and 15 ppm, BA @ 200 ppm and 400 ppm and 2,4-D @ 7.5 ppm and 15 ppm) and two micro nutrients (Zn @ 0.5 % and B @ 0.1 %) increases fruit weight and size in Mandarin. Increase in fruit weight and size is also reported in 'Florida King' peach by spray of hormones like salicylic acid and putrescine and nutrients like $CaCl_2$ (Ali *et al*., 2014). Fruit size improvement is well documented in stone fruits by combined application of hormones and nutrients (Serrano *et al*., 2004; Ali *et al.,* 2010). Wani *et al.* (2017) concluded that sole application of GA_3 and CPPU and two nutrient formulations Solubor and Horticab (Nutrient mixture) as well as combination of these hormones with each other and with the nutrient formulations resulted improvement fruit weight and size with respect to fruit length in 'Red Delicious' apple.

2.1.2. Fruit diameter

Bhat *et al.* (2009) studied the effect of preharvest $CaCl_2$ sprays on physicochemical characteristics of pear *cv.* 'Bartlett' in Kashmir and reported increase in fruit diameter with 0.50 and 0.75 percent spray of $CaCl_2$. Calcium nitrate gave fruit breadth of 4.42 cm and was statistically significant as compared to control (Koul and Muthoo, 1988). Flowering treatment of peach with calcium chloride at 2 percent resulted in 5.13 cm fruit diameter in cultivar 'Partap' and 5.01 cm in cultivar Shan-i-Punjab compared to 4.85 cm diameter under control respectively (Wani, 1997). Diameter of mango fruit *cv.* Amrapali was affected by preharvest calcium spray, $CaCl_2$ at 2 percent recorded fruit diameter of 6.40 cm and was statistically significant as compared to control which gave fruit diameter of 5.64 cm (Rani and Brahmachari 2004). Kadir (2005) reported that more than six preharvest foliar applications of $CaCl_2$ to 'Jonathan' apple trees increased fruit diameter. Mehta and Jindal (1986) observed that various concentrations of nutrient sprays affected the fruit diameter in plum. Calcium nitrate as preharvest spray resulted in an increase in fruit breadth of peach *cv.* Flordasun. Raese and Drake (2000) tried the application of $CaCl_2$ (1 g/L) and observed increased width to 1.4 cm compared to 1.2 cm in untreated control.

Marzouk *et al.* (2002) reported that the application of GA_3 (25 ppm) increased width to 1.6 cm compared to 1.2 cm in untreated control. They studied that the application of CPPU (5 ppm) increased width to 1.7 cm compared to 1.2 cm in untreated control. Zhuo *et al.* (1996) reported that the application of the CPPU together with the application of GA_3 improve the fruit diameter of loquat. Gowda *et al.* (2006) made the application of GA_3 (20, 25, 30 and 40 mg L^{-1} concentrations) at 45, 50, 55 and 65 days, respectively, after October pruning to the bunches of Thompson Seedless' grapes (*Vitis vinifera* L) and found significant positive effects on bunch breadth as compared to untreated control. Benjawan *et al.* (2006) reported that the application of gibberellins at concentrations of 100-

500 ppm increases the fruit diameter of nubbins in mango as compared to untreated control.

Akinci *et al*. (2014) studied the effect of BA plus GA_{4+7} treatments in 'Fuji' apple and found that the application of BA plus GA_{4+7} (1.8 BA plus 1.8% GA_{4+7}; Perlan) at 100 and 150 ppm two times at one-week intervals increased fruit weight as compared to untreated control. Fruit length: diameter (L/D) ratios generally increased at all doses. Cytokinins have been used together with gibberellins to influence fruit shape in apples by increasing the length: diameter (L/D) ratio (Williams and Stahly, 1969). Singh and Brahamachari (1999) reported that application of potassium, zinc, boron and molybdenum as preharvest spray on guava recorded an increase in diameter and maximum diameter of 6.86 cm was attained with boron than all other treatments.

Mosa *et al.* (2015) showed that potassium sulphate plus calcium chloride plus boric acid plus humic acid combination had the highest positive effect to improve the fruit diameter. Increase in fruit diameter and pulp to stone ratio is also reported in 'Florida King' peach by spray of hormones like salicylic acid and putrescine and nutrients like $CaCl_2$ (Ali *et al*., 2014). Wani *et al.* (2017) reported that sole application of GA_3 and CPPU and two nutrient formulations (Solubor and Horticab; Nutrient mixture) as well as combination of these hormones with each other and with the nutrient formulations resulted improvement fruit diameter in 'Red Delicious' apple. They also reported enhancement in fruit L/D ratio in all the treatments with the maximum L/D ratio (1.05) under GA_3 @ 500 ppm against lowest (1.01) in control.

2.1.3. Colour

Findings of the Mangat (1989) revealed that preharvest application of calcium improved the colour of 'Flordasun' peach from light yellow to orange yellow at low temperature storage. Davenport and Peryea (1990) observed that foliar spray of calcium chloride failed to influence the skin colour of 'Wellspur

Delicious' apple at 19 ºC after five months of controlled atmosphere (CA) storage. Tripathi and Bhargava (1993) sprayed trees of 'Red Delicious' apple at fortnight interval in the month of July with 0.5 percent calcium chloride, 0.05 percent Bavistan (Carbendazin), Difolatan (Captafol) or a combination of 0.5 percent $CaCl_2$ plus 0.05 percent Bavistan plus 0.1 percent boric acid. The results depicted that fruit colour was statistically significant under treatments as compared to control and most attractive fruit colour was associated with combined spray. Simnani (1995) observed improvement in the colour of 'Shan-I-Punjab' fruit with calcium application.

Raese and Drake (2000) in an experiment with apple two cultivars 'Red Delicious' and 'Golden Delicious' found that different calcium spray materials improved fruit quality as measured by an increase in red skin colour than that of control ones. Apple trees which received preharvest spray of calcium were found better coloured when calcium chloride at 0.40 percent was applied (Bhat and Farooqui, 2004). Contrarily to this Crisosto *et al.* (2000) found that foliar calcium sprays applied every 14 days, starting two weeks after full bloom and continuing until one week before harvest, did not reduce surface discoloration of mid or late-season peach and nectarine cultivars.

Martinez *et al.* (1996) revealed that GA_3 retards colour development by delaying chlorophyll degradation and carotenoid synthesis as well as fruit growth rate and reported less colour development by the application of GA_3 in strawberry fruit (*Fragaria* x *ananassa* Duch.). High nitrogen has some negative effect on fruit quality in terms of fruit colour of 'Gala' apple (Neilsen *et al.,* 1999).

Four sprays of Metalosate Potassium during the last 6 weeks before 'Jonagold' apple harvest improved colour in fruits at harvest and after storage (Amiri and Fallahi, 2007). Neilsen and Neilsen (2006) reported that application of KCl, K_2SO_4, $KHSO_4$ and $MgSO_4$ in 'Fuji', 'Spartan' and 'Gala' apple trees increased red coloration of fruit at harvest.

2.1.4. Firmness

Ashoori *et al*. (2013) revealed that application of $CaCl_2$ (2.5g, 10 g/L) and N (5 g/L) increased fruit firmness content of Red Delicious *cv*. apple 9.73 percent as compared to untreated control (8 percent). Calcium salts when used as preharvest spray by Eaves and Leefe (1962) showed a highly significant increase in strawberry firmness with four sprays of 0.4 percent calcium chloride at two days interval starting at blossom time. Calcium hydroxide improved the firmness of apple compared to control when sprayed ten days before harvest and stored at 0 .1 to 0.5 °C (Bulatovic and Tailo, 1981). Quast (1982) observed that calcium sprays in the form of calcium nitrate as well as calcium chloride resulted in delayed ripening and loss of firmness in various apple cultivars. Ben (1986) obtained improved flesh firmness in 'Jonathan' apple with calcium chloride at 0.5 or 0.7 percent and similar results were found on spraying 1 percent solution of chelated calcium at 6, 4 or 2 weeks before harvest.

Raese and Suger (1994) in a study with Bartlett pear concluded that $CaCl_2$ @ 1.79 g/L, six times each season for a time period of four years increased firmness significantly. Increased flesh firmness was also observed by Glenn and Pooviah (1985) upon post harvest infiltration of 'Golden Delicious' apple by $CaCl_2$ and increase in firmness is positively correlated with the concentration of the solution. Contrarily to this Crisosto *et al.* (2000) found that foliar calcium sprays applied every 14 days, starting two weeks after full bloom and continuing until one week before harvest, did not affect fruit firmness of mid or late-season peach and nectarine cultivars.

$CaCl_2$ sprayed at weekly interval increased flesh firmness significantly in 'Red Deliciouis' apple (Baneh, 2003). Bhat and Farooqui (2004) also reported increase in firmness in apple when these trees were sprayed thrice fortnightly by calcium. El-Badawy (2012) studied the effects of chitosan and $CaCl_2$ and their combinations on fruit quality parameters under cold storage. It was found that the fruit firmness was gained by using the treatment of 1 percent chitosan plus 4 percent $CaCl_2$.

Salehi *et al.* (2013a) found the highest amount of fruit firmness was related to apples treated with 7.5 mg/L of amino calcium whereas no effect was found with spray of 2.5 mg/L of amino calcium. The fruit firmness of apples that were not treated with amino calcium (control) reduced drastically after storage. Calcium chloride @ 1.5 percent sprayed thrice sprays sprayed to peach plants at pit hardening stage, 10 and 20 days after pit hardening resulted in maximum fruit firmness in 'Shah-I-Punjab' peach (Raja *et al.,* 2015). Increase in flesh firmness in 6-year-old 'Standard Fuji' trees grafted on 'MM106' rootstock was reported by Ca application from different sources viz $CaCl_2$, Calcicat and Folical (Ghorbani *et al*., 2017).

Choi *et al.* (2002) reported that, spraying GA_3 at 20, 50 and 100 mg/L increased the firmness in cherry fruits. Kappel and MacDonald (2007) had seen that fruit firmness in cherry responded linearly to the gibberellin applications with earlier sprays having the largest and firmest fruit. Ayman (2011) studied that application of gibberellic acid @ 150 ppm on pear 'LeConte' and reported that it increases fruit firmness 13.70 as compared to control 13.00.

Raheem *et al.* (2013) examined that the application of CPPU singly or in combination with GA_3 significantly increased the fruit firmness of 'Washington Navel' orange as compared with control. Similar results were reported in 'McIntosh' (Greene and Autio, 1989); 'Spur Delicious' (Curry and Greene, 1993) and 'Anna' apple (El-Sabagh, 2002). Plant growth substances such as auxins, cytokinins and gibberellins have been shown to reduce or delay various aspects of ripening (softening). They share the ability to delay senescence by reducing the sensitivity of the fruit to ethylene (Abeles *et al.,* 1992). Mosa *et al.* (2015) carried out an experiment on seven years old 'Anna' apple trees. Results showed that potassium sulphate plus calcium chloride plus boric acid plus humic acid combination was the best treatment having high positive effect to improve fruit firmness. Rokaya *et al.* (2016) revealed that the fruits treated with GA_3 at 20 ppm retained more firmness.

Wani *et al.* (2017) reported that sole application of GA_3 and CPPU and two nutrient formulations (Solubor and Horticab) as well as combination of these hormones with each other and with the nutrient formulations resulted improvement fruit firmness in 'Red Delicious' apple.

2.2. Chemical characteristics

2.2.1. Soluble solids concentrate

Gupta *et al.* (1984) reported increased SSC in 'Sharbati' peaches upon calcium chloride sprays. Callan (1978) on sweet cherry has found significantly higher values of TSS content in fruits treated with calcium salt either in the form of calcium chloride or calcium hydroxide. Mehta and Jindal (1986) reported that 250 ppm $CaCl_2$ preharvest spray recorded higher TSS content (10.88 percent) in plum. Meheriuk *et al.* (1991) concluded that preharvest spray of $CaCl_2$ @ 0.35 percent enhances TSS from 16.9 percent in control to 18.4 percent in treated sweet cherry. Crisosto *et al.* (2000) observed that multiple commercial calcium foliar sprays did not affect fruit soluble solids concentration (SSC) of peaches and nectarines.

Singh *et al.* (2007) studied in strawberry (*Fragaria* spp.) that TSS content got significantly decreased 7.1 percent when Ca was sprayed as $CaCl_2$@ 2 kg Ca/ha five times at petal fall and other at weekly intervals over control (water spray) with a value of 7.8 percent. Bhat *et al.* (2009) studied the effect of preharvest $CaCl_2$ sprays on physicochemical characteristics of pear *cv.* Bartlett in Kashmir and reported decreased TSS in fruits treated with 0.50 and 0.75 percent $CaCl_2$ sprays.

Salehi *et al.* (2013b) found that the highest percentage of SSC in 'Red Delicious' was related to fruits treated with 7.5 mg/L chelated calcium than other treatments and the lowest SSC amount was related to a concentration of 2.5 mg/L chelated calcium. Ashoori *et al.* (2013) revealed that application of $CaCl_2$ (2.5 g, 10 g/ L) and N (5 g/L) increased TSS content of 'Red Delicious' apple 15.18 percent as compared to untreated control 15.12 percent. Whereas Ghorbani *et al.* (2017) reported reduction in SSC by Ca sprays from different sources ($CaCl_2$, Calcicat® and Folical®) in all spray programmes evaluated (All-season, Early, Mid and Late season spray).

Mosa *et al.* (2015) reported that calcium chloride alone did not had any remarkable effect on TSS or TSS/acid ratio in 'Anna' apples as compared to the control but potassium sulphate plus calcium chloride plus boric acid plus humic acid combination improved significantly TSS/acid ratio. Metalosate Potassium is effective at increasing soluble solids content as well as improving fruit colour. Four sprays of Metalosate Potassium during the last 6 weeks before 'Jonagold' apple harvest; improved soluble solids concentration in fruits at harvest and after storage (Amiri and Fallahi, 2007).

Hossain (2015) reported that the soluble solids concentrate was higher in GA_3 @ 50 ppm treated fruits as compared to untreated control. Guirguis *et al.* (2010) revealed that spraying GA_3 at 100 ppm was responsible in increasing SSC percent compared to the control. Kaur *et al.* (2004) reported that GA_3 foliar sprays at different concentrations were applied on 'Satluj' and 'Purple' plum. It was found that GA_3 at 500 ppm recorded highest SSC as compared to control. Girish and Ananda (2004) reported that pre-bloom foliar application of GA_3 recorded significantly highest SSC in 'Starking Delicious' apple as compared to untreated control. Application of GA_3 (50- 100 ppm) at full bloom increased the SSC in cherries to the tune of 18.2 percent (Mir *et al.*, 1995). Kupferman (1989) reported that the application of GA_3 at full bloom recorded the highest SSC of 18.1 percent compared to control 17.4 percent.

Gurung *et al.* (2016) reported that combinations of three growth regulators (GA_3 @ 7.5 ppm and 15 ppm, BA @ 200 ppm and 400 ppm and 2,4-D @ 7.5 ppm and 15 ppm) and two micro nutrients (Zn @ 0.5 percent and B @ 0.1 percent) increases fruit TSS in Mandarin.

Davarpanah *et al*. (2016) reported that foliar sprays of nano-Zn chelate fertiliser at three concentrations (0, 60 and120 mg Zn L^{-1}) and nano-B chelate fertiliser (0, 3.25 and 6.5 mg B/L) were applied as a single at a rate of 5.3 L/tree. Fertilization with the highest of the two doses led to significant improvements in fruit quality, including 4.4–7.6 percent increases in TSS. 9.5–29.1 percent in on pomegranate *cv.* Ardestani. Effect of two doses of combination of growth regulators and nutrients (calcium nitrate (2 and 4 percent); boric acid (1.5 and 3 percent) and GA_3 (50 and 75 ppm) on yield, fruit characteristics, cracking and sunburn of pomegranate *cv.* Hicaznar was carried out by Korkmaz *et al.* (2016). They observed that all treatments increased TSS and maximum was under 2 percent calcium nitrate. Wani *et al.* (2017) reported enhancement in fruit SSC in an experiment in Kashmir valley by sole application of GA_3 and CPPU and two nutrient formulations Solubor and Horticab as well as combination of these hormones with each other and with the nutrient formulations on 'Red Delicious' apple.

2.2.2. Acidity and Sweetness index

The acidity of 'Santa Rosa' plum was evaluated and was found to be highest level under control (0.59 percent) and least acidity (0.38 percent) was observed in fruits treated with $CaCl_2$ at 250 ppm (Mehta and Jindal, 1986). Bhat *et al.* (2009) studied the effect of preharvest $CaCl_2$ sprays on physicochemical characteristics of pear *cv.* 'Bartlett' in Kashmir and reported decreased acidity in fruits treated with 0.50 and 0.75 percent $CaCl_2$ sprays. Similar results were noted by Koul and Muthoo (1988) in peach with application of calcium nitrate as preharvest spray. Gupta *et al.* (1980) concluded that calcium nitrate two sprays at

0.5 to 1.0 percent concentration improved the acidity of grapes at harvest and acidity levels were enhanced after three days storage at room temperature. Whereas Gupta *et al.* (1984) reported that calcium compounds applied as preharvest spray did not show any appreciable increase in the acidity of the peaches.

Kadir (2005) reported that more than six preharvest foliar applications of $CaCl_2$ to Jonathan apple trees did not affect soluble solid concentration, but SSC/TA was increased by $CaCl_2$ applications. Ghorbani *et al.* (2017) in their study on 6-year-old 'Standard Fuji' trees grafted on 'MM106' rootstock to assess the effect of calcium chloride ($CaCl_2$) and two organic calcium compounds including Calcicat® and Folical® and water (as control) at four different spray programs (All-season, Early, Mid and Late season spray) reported increment in titrable acidity by Folical all season sprays and Calcicat early season sprays.

Application of GA_3 (100 mg/L) during flowering in 'Flemekirt' nectarines, recorded reduction of acidity resulting in less acidic fruits at harvest (Zilkah *et al.,* 1997). Yahata *et al.* (2006) reported reduction in titratable acidity by GA_3 and CPPU in pear fruits.

Higher level of titratable acidity also reported in 'Florida King' peach by spray of hormones like salicylic acid and putrescine and nutrients like $CaCl_2$ (Ali *et al*., 2014). Kirmani *et al.* (2015) studied the influence of preharvest application of some chemicals viz $CaCl_2$ (0.1, 0.3 and 0.5 percent), GA_3 (20, 40 and 60 ppm) and NAA (20, 40 and 60 ppm) applied 20 and 10 days before the expected date of harvest of plum (*Prunus salicina* L.) *cv.* Santa Rosa. TSS (12.63%) at the harvest time was reported maximum in response to GA_3 (60 ppm). Mosa *et al.* (2015) reported that calcium chloride alone did not had any remarkable effect on acidity but combination of potassium sulphate plus calcium chloride plus boric acid plus humic acid combination significantly decreased the acidity in Anna apple. Neilsen and Neilsen (2006) reported that application of KCl, K_2SO_4, $KHSO_4$ and $MgSO_4$

in 'Fuji', 'Spartan' and 'Gala' apple trees increased titrable acidity. Gurung *et al.* (2016) reported that combinations of three growth regulators (GA_3 @ 7.5 ppm and 15 ppm, BA @ 200 ppm and 400 ppm and 2,4-D @ 7.5 ppm and 15 ppm) and two micro nutrients (Zn @ 0.5 % and B @ 0.1%) reduced acidity and increased sweetness index in Mandarin.

Rokaya *et al.* (2016) conducted an experiment to assess the effect of gibberellic acid on quality and shelf life of the mandarin fruit. GA_3 at 10, 20, and 30 ppm as against of control were evaluated. It was revealed that all treatments enhanced TSS/acid ratio and the highest (21.24) value was found under 20 ppm of GA_3. Davarpanah *et al.* (2016) carried out a study to assess the effects of the foliar application of nano-fertilizers of zinc (Zn) and boron (B) on pomegranate (*Punica granatum cv.* Ardestani) fruit yield and quality with nine treatments. Foliar sprays of nano-Zn chelate fertiliser at three concentrations (0, 60 and120 mg Zn/L) and nano-B chelate fertiliser (0, 3.25 and 6.5 mg B/L) were applied as a single spray before full bloom at a rate of 5.3 L/tree The effect was not as large with Zn as with B. Fertilization with the highest of the two doses led to significant improvements in TSS and 9.5–29.1 percent decreases in titrable acidity and hence increase in TSS/acid ratio. Wani *et al.* (2017) reported decrease in fruit acidity and increase in TSS/acid ratio by sole application of GA_3 and CPPU and two nutrient formulations Solubor and Horticab (Nutrient mixture) as well as combination of these hormones with each other and with the nutrient formulations on 'Red Delicious' apple.

2.2.3. Total sugars

The chemical constituents of mango fruit improved by calcium chloride spray and maximum total sugars was attained with 2 percent spray which recorded total sugars of 15.29 percent in comparison to control where total sugars was 14.96 percent (Singh and Rajput, 1991). Treatment of 'Partap' peach with $CaNO_3$ and $CaCl_2$ each at 1 and 2 percent resulted in significantly higher total sugars than the untreated one (Wani, 1997). Bhat *et al.* (2009) studied the effect of preharvest $CaCl_2$ sprays on physicochemical characteristics of pear *cv.* Bartlett in Kashmir and reported decreased total sugars in fruits treated with 0.50 and 0.75 percent $CaCl_2$ sprays.

Girish and Ananda (2004) revealed that pre-bloom foliar application of GA_3 at 150 ppm in apple recorded significantly highest total sugars (8.83 %) as compared to untreated control. Application of GA_3 (50-125 ppm) increased the total sugars content in peaches as compared to control (Guerriero *et al.*, 1970). Mehta and Jindal (1986) revealed that the boric acid significantly affected the total sugars content of plum i.e. 8.51 percent was recorded as compared to control 6.70 percent.

Rizk-Alla and Meshrake (2006) reported that the application of GA_3 at 100 ppm, CPPU at 6 ppm and $CaCl_2$ at 2 percent increases the total sugars in grape berry.

Bora *et al.* (2015) revealed that application of potassium nitrate (1.5 %) along with calcium chloride (2 %) on pear *cv.* Pathernakh increases total sugars (7.62 %), reducing sugars (6.10 %) and non-reducing sugars (1.51 %). Kirmani *et al.* (2015) studied the influence of preharvest application of some chemicals viz $CaCl_2$ (0.1, 0.3 and 0.5%), GA_3 (20, 40 and 60 ppm) and NAA (20, 40 and 60ppm) applied 20 and 10 days before the expected date of harvest of plum (*Prunus salicina* L.) *cv.* Santa Rosa. A total sugar (8.80 %) at the harvest time was reported maximum in response to GA_3 (60 ppm). Davarpanah *et al.* (2016) reported minor changes in total sugars in pomegranate by foliar sprays of nano-Zn chelate fertiliser and nano-B chelate fertiliser were applied as a single spray before full bloom at a rate of 5.3 L/tree.

Gurung *et al.* (2016) reported that combinations of three growth regulators (GA_3 @ 7.5 ppm and 15 ppm, BA @ 200 ppm and 400 ppm and 2,4-D @ 7.5 ppm and 15 ppm) and two micro nutrients (Zn @ 0.5 % and B @ 0.1 %) enhanced total sugars in 'Darjeeling' Mandarin. Wani *et al.* (2017) concluded that sole application of GA_3 and CPPU and two nutrient formulations (Solubor and Horticab) as well as combination of these hormones with each other and with the nutrient formulations resulted improvement total sugars in 'Red Delicious' apple.

2.2.4. Ascorbic acid

Bangerth (1976) obtained increased ascorbic acid content in the fruits of apple, pear and tomato by increasing their calcium content. Kadir (2005) reported that the application of $CaCl_2$ @ 1.5 percent on apple at pink bud stage increased the vitamin C content in comparison to control. Prasad *et al.* (2015) examined that ascorbic acid were found maximum (6.42 mg/100 g) with $CaCl_2$ at 2.0 percent concentration in pear *cv.* Pathernakh. Foliar spray of $CaNO_3$ and $CaCl_2$ on 'Shan-I-Punjab' peach trees at different concentrations (1-3 %) significantly maintained the higher levels of ascorbic acid in comparison to untreated fruits, both at harvest and after 45 days of cold storage (Singh, 1994). Bhat *et al.* (1997) noted that full bloom application of calcium increases the ascorbic acid content as compared to control. All the concentration of calcium ($CaCl_2$) significantly improved the ascorbic acid level of peach over control. The mean ascorbic acid (4.75 mg/100 g) was obtained at 2.5 percent $CaCl_2$ concentration. The decrease in calcium concentration showed a corresponding increase in loss of ascorbic acid and consequently, the lowest mean ascorbic acid to the level of 4.33 mg/100 g was noticed under control (Simnani, 1995).

Sofi (2001) reported that the application of GA_3 (25 and 50 ppm) on strawberry was found to increase the ascorbic acid content of fruits as compared to control. Application of GA_3 (250 ppm) in 'Kansha' apricots increased ascorbic acid content as compared to control (Shrivastava *et al.*, 1971). Solution containing different nutrients when sprayed on apple, registered higher content of vitamin C compared to control (Kumar and Chauhan, 1990). Ghosh *et al.* (2012) found that the application of GA_3 @ 250 ppm to sweet orange resulted in increase in ascorbic acid content of 10.23/100 g compared to 8.14 mg/100 g in untreated control.

Kirmani *et al.* (2015) studied the influence of preharvest application of some chemicals viz $CaCl_2$ (0.1, 0.3 and 0.5 %), GA_3 (20, 40 and 60 ppm) and NAA (20, 40 and 60ppm) applied 20 and 10 days before the expected date of harvest of plum (*Prunus salicina* L.) *cv.* Santa Rosa and reported that 0.5 percent $CaCl_2$ resulted in highest ascorbic acid (7.18 mg/100 g).

Ali *et al.* (2014) reported ascorbic acid improvement in 'Florida King' peach by spray of hormones like salicylic acid and putrescine and nutrients like $CaCl_2$. Improvement of fruit firmness at the time of harvest was already reported in other fruits like apricot and apple (Ali *et al*., 2010; Asgharzade *et al*., 2012).

Enhancement in ascorbic acid was also reported in 'Darjeeling' mandarin by spraying combinations of three growth regulators (GA_3 @ 7.5 ppm and 15 ppm, BA @ 200 ppm and 400 ppm and 2,4-D @ 7.5 ppm and 15 ppm) and two micro nutrients viz Zn @ 0.5 % and B @ 0.1% (Gurung *et al.*, 2016). Wani *et al.* (2017) revealed that application of phytohormones and nutrients alone or in combination significantly improved ascorbic acid of apple fruits *cv.* Red Delicious.

2.2.5. Anthocyanin

Mature apple fruit skin consists of waxy cuticle and four to eight layers of cells beneath which containing the epidermal and sub epidermal layers which are cultivar dependent. The anthocyanin pigment may be located in outer four to six or even eleven epidermal and sub epidermal layers and the thickness of the skin depends on these layers of cells (Dayton, 1959; Pratt *et al.,* 1975). Increased skin darkness in apple has been reported due to increased concentration of the anthocyanins in darker red vacuoles, larger vacuoles and several layers of red cells (Lancaster *et al*., 1994). Many endogenous and exogenous factors affect the concentration of anthocyanins such as genetic, intensity and types of light, temperatures and agronomic factors including irrigation, pruning, plant growth regulators and fertilization (Saure, 1990).

Increasing evidence indicates that calcium plays an import role in fruit anthocyanin biosynthesis. The calcium signaling pathway was implicated in sucrose-induced anthocyanin accumulation in grapes by activating flavonoid pathway genes (Gollop *et al.,* 2002; Vitrac *et al.,* 2000; Xu, 2014). Cyanidin 3-O-galactoside is a major anthocyanins compounds present in the fruit skin, which plays a vital role in apple skin reddening and formed from the glycosylation of cyanidin (Lancaster, 1992). Different concentrations of calcium salts enhanced fruit anthocyanin in cherry and application of $CaCl_2$ @ 2.0 percent caused enhancement of anthocyanin by 19.9 percent as compared to control (Bhat *et al.,* 1997). Ganai (2006) reported increase in anthocyanin under $CaCl_2$ sprays in 'Red delicious' apple under Kashmir conditions.

Siatoh (1995) in a study to find the influence of heavy application of nitrogen on tree growth, yield and fruit quality in apples reported that fruit colour was poorly developed (anthocyanin concentrations were lower) in all the treatments where higher doses of nitrogen was applied. Awasthi *et al.* (1995) reported that trees sprayed with 00, 1 or 2 foliar sprays of 0.5 percent potassium chloride with 500, 600 and 700 g potassium sulphate per tree increased anthocyanin content. Li *et al.* (2004) reported that anthocyanin accumulation in 'Fuji' apple was enhanced with potassium sulphate but subsequently decreased with higher concentrations of potassium sulphate. They further observed that lower concentration of nitrogen application slightly enhanced anthocyanin accumulation but decreased it with higher concentrations.

Mosa *et al.,* 2015, carried out an experiment on seven years old 'Anna' apple trees (Malus domestica L.) and showed that potassium sulphate plus calcium chloride plus boric acid plus humic acid combination was the best treatment. This combination improved significantly anthocyanin concentration in fruit. Davarpanah *et al.* (2016) reported minor changes in phenolic compounds; whereas the antioxidant activity and total anthocyanins was unaffected pomegranate by foliar sprays of nano-Zn chelate fertiliser and nano-B chelate fertiliser were applied as a single spray before full bloom at a rate of 5.3 L/tree.

2.2.6. Fruit nutritional status

Application of calcium chloride resulted in an increase in nitrogen and calcium but did not influence P, K, Mg and B content of fruit in apple (Martin *et al.,* 1976). Dipping of fruit in calcium solution slightly increased the calcium content and reduced the levels of K, Mg and the K plus Mg/ Ca ratio (Ichiki *et al.,* 1980).

Greene and Smith (1980) used high calcium chloride rates and reported that foliar sprays failed to increase whole fruit calcium concentration of 'York Imperial' apples. The increase of cell wall calcium with $CaCl_2$ and chelated calcium treatments were found in peach *cv.* Andross (Manganaris, 2005). Kapoor (1988) used calcium chloride at the rate of 0.5, 0.75 and 1.0 percent as preharvest spray in 'Red Delicious'. He found that nitrogen content of fruit was lowest under all calcium treatments of fruit compared to control. The nitrogen content of fruit was 140 mg/100 g with 1.0 percent calcium chloride as compared to control (150 mg/100 g). Application of calcium chloride significantly affected the phosphorous and potassium contents of apple fruits. The phosphorous content of fruit was found maximum with calcium chloride at 0.75 percent (74.6 mg/100 g) and 1.0 percent (73.6 mg/100 g) compared to 70.6 g/100 g phosphorus under control. Potassium content with 0.75 percent calcium chloride was found to be 7.l0 mg/100 g as compared to 680 mg/100 g under control. Similarly, magnesium content was also found maximum in fruits treated with calcium chloride. Well Spur Delicious apple was sprayed with calcium chloride at the rates of 0, 5.9 or 19.6 kg/ha. The calcium chloride sprays failed to influence fruit mineral element composition with respect to N, P, K, Ca and Mg or N/Ca ratio (Kapoor, 1988). The preharvest spray of calcium chloride and calcium nitrate increased nitrogen content in peel and flesh of 'Pathamakh' pear fruit and the N/Ca ration in peel and flesh reduced by calcium chloride spray at all concentrations compared to control (Bhat, 1993).

Raese and Suger (1994) revealed calcium chloride spray (1.79 g/L) applied six times each season for four years from mid-May to late July increased the fruit calcium concentration in 'Bartlett' pear on the other hand Crisosto *et al.* (2000) found that foliar calcium sprays applied every 14 days, starting two weeks after full bloom and continuing until one week before harvesting in mid- or late-season peach and nectarine cultivars did not affect fruit flesh calcium concentration at harvest.

The analysis of peel, pulp and core portion of apple revealed that fruits treated with various concentrations of calcium chloride whether singly or in combination with DPA (diphenylamine) significantly have higher calcium levels than the untreated ones. Fruits treated with 4 percent calcium had an average calcium percentage of 0.17 in peel as compared to 0.10 in untreated fruits. Similarly, calcium content of pulp and core was higher under 4.0 percent calcium chloride. The fruits treated with calcium chloride had significantly lower Mg and K levels in peel, pulp and core of apple (Sofi and Dhillon, 1998). Raese and Drake (2000) reported increase in Ca concentrations in the fruit cortex and peel and reduction in the incidence of bitter pit and scald in Red Delicious and Golden Delicious apple trees sprayed with up to 12 calcium (Ca) spray materials over five years. Kadir (2005) reported that more than six preharvest foliar applications of $CaCl_2$ to 'Jonathan' apple trees Ca concentrations increased Ca concentrations in which coincided with increases in K, Mg, N, and P in fruit tissues contributing to the quality of fruit. Benavides *et al.* (2002) applied pre- harvest calcium treatment, 6 or 12 times at rate of 1 percent (w/v) beginning 60 days after full bloom. The results showed that the calcium applications were equally effective on increasing the calcium content in the fruit. Increases in calcium concentration both in fruit flesh and skin have been found in ‘Jonathan’ apples (Kadir, 2005) and always, the increase in concentration in the peel was far greater than in the pulp.

To increase the calcium content in apple fruit a trial was carried out for two years, spraying commercial crystalline calcium chloride and two other calcium products. Further, two Prohexadione calcium treatments after full bloom were combined with later calcium chloride spray. All calcium chloride sprays increased calcium content in ‘Boskoop’ and ‘Elstar’ apples compared to unsprayed control. The best treatment in both cultivars during two years was 10 kg calcium chloride in 500 ml/ha sprayed every two weeks after June drop until harvest and this treatment increased the calcium content in ‘Boskoop’ or ‘Elstar’ apples on an average by 29 percent or 18 percent respectively (Mayr *et al.*, 2002). Bhat *et al.* (2009) studied the effect of preharvest $CaCl_2$ sprays on physicochemical characteristics of pear *cv.* Bartlett in Kashmir and reported increase in flesh Ca in fruits treated with 0.50 and 0.75 percent $CaCl_2$ sprays. Three sprays of 1.5 percent of $CaCl_2$ resulted in maximum Ca content in peach *cv.* Shah-I-Punjab (Raja *et al.,* 2015).

Ghorbani *et al.* (2017) in their study on 6-year-old 'Standard Fuji' trees grafted on ‘MM106’ rootstock to assess the effect of calcium chloride ($CaCl_2$) and two organic calcium compounds including Calcicat® and Folical® and water (as control) at four different spray programs (All-season, Early, Mid and Late season spray) reported all treated fruits which received late season $CaCl_2$ had higher Ca content, lower K/Ca and (K+Mg)/Ca ratios, and fruits treated with Folical Mid season had lower Ca, higher K/Ca and (K+Mg)/Ca ratios.

Effects were assessed for five orchards in which sprays of calcium nitrate alone or together with NAA, Phloridizin, $MgCl_2$ or DPA were tried on fruit composition. The calcium content was increased by all calcium treatments except Ca plus Phloridizin and total and soluble N, P and Mg contents were increased by

Ca plus NAA (Martin *et al*., 1971). Singh *et al.* (2000) investigated the effect of various plant growth regulators and boric acid on nutrient contents of apple fruit at commercial maturity. The results depicted that K and Mg content of fruit were highest with the spray of GA_3 plus boric acid.

2.3. Grading

The red colour of apple skin is one of the important grading standards set for marketing. Poor skin colour at commercial harvest often causes serious economic losses to apple growers. The other parameters which determine different grades are fruit size, fruit finish, bruising and incidence of fruit diseases and disorders which reflects to the overall appearance and hence to grading. Widmer *et al*. (2006) found that combined application of urea and boron or separate application of urea and born for five years did not cause any significant improvement in the fruit grade of apple cultivar ‘ Red Delicious’.

Nutrients in association of plant growth regulators increase better graded yield. The use of growth elicitors and minerals in this respect have been reported on apricot, pear and apple (Eissa *et al.,* 2008; Ali *et al*., 2010; Abd- El-Messeih *et al*., 2010). Ali *et al.* (2014) also reported increase in market yield in ‘Florida King’ peach by application of combination of hormones (salicylic acid and putrescine) and nutrients ($CaCl_2$), which resulted in greater price in the market, since large size fruits are more appreciated in the market.

2.4. Physiological disorders

2.4.1. Watercore and bitter pit

Casero *et al.* (2004) reported that fruit firmness shows a positive correlation with fruit Ca content and bitter pit incidence correlate negatively with this nutrient content. Calcium has a very important role in increasing fruit storability. It is reported that apple fruits have good storability if their Ca levels are above 4.5 mg/100 g fresh fruit (Dris and Niskanen, 1999). If the amount of Ca falls below this value, there is a high risk of damage to the skin, and consequently internal parts of the fruit. Namely, calcium is vital for fruit firmness, being involved in the formation of calcium pectinates and oxalates which provide firmness to the outer parts of cell membranes. When the membranes are weakened, there is an uncontrollable loss of water which contributes to the decay of the surface layer and consequently the inner layer of the tissue. Visual manifestations include the occurrence of dark brown or black bitter pits. Given the damage of the layer, these areas become susceptible to different pathogens (Freitas *et al.*, 2010). Bitter pit incidence can be prevented by the supply of sufficient amounts of calcium to apple fruits (Poovaiah, 1986). Raese and Drake (2000) reported increase in Ca concentrations in the fruit cortex and peel and reduction in the incidence of bitter pit and scald in 'Red Delicious' and 'Golden Delicious' apple trees sprayed with up to 12 calcium (Ca) spray materials over five years. Metalosate calcium is effective at reducing bitter pit (Amiri and Fallahi, 2007). Kadir (2005) reported that more than six preharvest foliar applications of $CaCl_2$ to 'Jonathan' apple trees enhanced appearance and decreased scald. Pre and post-harvest application of calcium for improvement of quality and minimizing the disorders have been reported in various fruits like strawberry, peaches, nectarines and apples (Dunn and Able, 2006; Hernandez-Munoz *et al*., 2006).

Kirmani *et al.* (2015) studied the influence of preharvest application of some chemicals viz $CaCl_2$ (0.1, 0.3 and 0.5%), GA_3 (20, 40 and 60 ppm) and NAA (20, 40 and 60ppm) applied 20 and 10 days before the expected date of harvest of plum (*Prunus salicina* L.) *cv.* Santa Rosa. $CaCl_2$ at higher concentration of 0.5 percent proved to be the most effective treatment in retaining the fruit quality during the entire storage period. Neilsen and Neilsen (2006) reported that application of KCl, K_2SO_4, $KHSO_4$ and $MgSO_4$ in 'Fuji', 'Spartan' and 'Gala' apple trees increased incidence of bitter pit.

Effect of two doses of combination of growth regulators and nutrients (calcium nitrate at 2 and 4 %); boric acid (1.5 and 3 %) and GA_3 (50 and 75 ppm) on yield, fruit characteristics, cracking and sunburn of pomegranate *cv.* Hicaznar was carried out by Korkmaz *et al.* (2016). They observed that all treatments reduced the rate of cracking of the fruits in first year and in the second year all treatments reduced cracking and sunburn in the pomegranate fruits. Rokaya *et al.* (2016) assessed the effect of gibberellic acid on quality and shelf life of the mandarin fruit. GA_3 at 10, 20, and 30 ppm as against of control were evaluated. The PLW was found less with GA_3 at 30 ppm in both ambient (5.17 %) and cellar (6.69 %) condition as against untreated fruits (9.52 % and 11.76 %). Similarly, the decay loss was less in fruits treated with GA_3 at 30 ppm both with ambient (1.02 %) and cellar condition (8.21 %) as against control with ambient (5.54 %) and cellar (21.58 %).

The storability of apple fruits is dependent not only upon calcium levels, but also upon the content of other elements, including primarily phosphorus, potassium, magnesium and nitrogen (Perring and Preston., 1974). If phosphorus levels in apple fruits are below 9 mg/100 g fruit, there is a great risk of bitter pit occurrence, particularly at a very low Ca concentration in apple fruits (Johnson *et al.*, 1983). Gago *et al.* (2016) reported that $CaCl_2$ alone and $CaCl_2$ plus 1-MCP reduced bitter pit intensity by reducing moderate and severe incidence, maintained higher lightness and had firmer fruit than control and suggested that postharvest dips of 'Golden Delicious' apples in $CaCl_2$ before 1-MCP application (CA plus MCP), may be a good solution to prevent scald, and reducing the bitter pit which is enhanced by 1-MCP alone.

The efficient use of foliar feeding with phosphate fertilizers in preventing bitter pit occurrence and increasing fruit quality in general has been reported by many scientists (Yogaratnam and Johnson, 1982; Wojcik and Wojcik, 2007). The high concentration of potassium in apple fruit is not desirable, or more precisely it is not desirable to have high ratio between potassium and calcium content in apple fruit. It is noteworthy that the foliar feeding of apple trees with macronutrients, including nitrogen, potassium and phosphorus, is not easily achievable, mostly due to the inability of foliar feeding to satisfy the large fruit demand for these elements. Bakeer (2016) studied the effect of four rates of ammonium nitrate fertilizer (600, 900, 1200 and 1500 g/tree) and three concentrations of calcium chloride spray at (0, 1 and 2 percent) on vegetative growth parameters, yield and fruit quality (especially fruit cracking and sunburn damage) of pomegranate trees. Obtained results showed that ammonium nitrate fertilizer and/or calcium chloride alone or in combination enhanced vegetative growth parameters, yield, fruit quality traits and reducing fruit cracking and sunburn damage through increasing vegetative development and thereby improve protection of the fruits from direct sunlight and the role of Ca in controlling physiological disorders of fruit.

2.4.2. Physiological loss in weight

Beric (1972) observed that weight loss in apple was highly related to skin characteristics like thickness of epidermis, the surface wax and the number of lenticels. Reduction in physiological loss in weight (PLW) of fruits treated with calcium compounds might be due to retardation of respiration (Bangerth *et al.,* 1972). Bulatovic and Tarailo (1977) studied the change in fruit weight and composition in apples of three size grades (60, 70 and 80 mm in diameter) stored immediately in four or ten days after harvest at 0-0.5 °C and 85 percent relative humidity for five months. He further reported that weight losses in storage increased proportionately with fruit size being 8.76 percent in 60 mm, 9.28 percent in 70 mm and 11.68 percent in 90 mm.

Preharvest sprays of different concentrations of calcium nitrate (Singh *et al.,* 1982) and calcium nitrate or calcium hydroxide (Gupta *et al.,* 1984) reduced physiological loss in weight of ‘Sharbati’ peaches during ambient storage. Bhullar *et al.* (1981) reported that physiological loss in weight of ‘Flordasun’ peach was reduced by calcium nitrate spray at both ambient as well at low temperature storage up to five and forty two days respectively. Baneh *et al.* (2003) studied the effect of different concentrations of calcium chloride (0, 0.5, 1.0 and 1.5 percent) sprayed at weekly intervals in apple. The highest weight loss was observed under control and the least with 1.5 percent calcium chloride. Calcium chloride @ 1.5 percent (three sprays sprayed to peach plants at pit hardening stage, 10 and 20 days after pit hardening) resulted in minimum PLW in 'Shah-I-Punjab' peach (Raja et al., 2015).

Physiological loss in weight was reduced by 30 percent compared with control during storage in 'Red Delicious' by 1 percent calcium chloride spray (Tabatabaie and Malakouti, 1998). Ramakrishna *et al.* (2001) sprayed papaya trees with calcium chloride and calcium nitrate both at 0.5, 1.0, 1.5 and 2.0 percent fifteen days before harvest. They reported that physiological loss in weight (5.82 percent) was observed in fruits sprayed with 2 percent calcium chloride followed by 2 percent calcium nitrate (7.02 percent) whereas control fruits observed physiological loss in weight up to 9.97 percent. The physiological loss in weight among treatments increased as storage period advanced.

In two year trail with the pear *cv.* LeConte, twenty six years old trees were sprayed with B, Zn, B plus Zn or B plus Zn plus Ca, three weeks after petal fall and again shortly before harvest. The findings showed that fruits which received combined application of B plus Zn plus Ca had least storage weight loss of 11.8-20.2 percent as compared with 13.6-26.3 percent in the control (Badani 1981).

Plant growth substances such as cytokinins and gibberellins have been shown to reduce or delay various aspects of ripening (softening). They share the ability to delay senescence by reducing the sensitivity of the fruit to ethylene (Abeles *et al.*, 1992). Also, in most cases exogenous application of cytokinins counteract the promoting effects of ethylene on the senescence process (Arteca, 1990). Salehi *et al.,* (2013a) found that fruits that were sprayed with concentrations of 5 and 7.5 mg/L of amino calcium experienced lower weight loss and was highest in case of fruits that were not treated with amino calcium. El-Badawy (2012) studied the effects of chitosan and $CaCl_2$ and their combinations on fruit quality parameters under cold storage. It was found that the lower values of weight loss (percent) by using the treatment of 1 percent chitosan plus 4 percent $CaCl_2$.

2.5. Leaf nutritional status

Increase in leaf nitrogen was reported by Mukherji (1994) in peach whereas decrease in potassium level with calcium spray has been seen by Upreti (1988) and Mukherji (1994). Calcium nitrate at higher concentration i.e. 2.0 percent resulted in 2.75, 0.46 and 0.74 percent N, P and Mg, respectively, the corresponding leaf nutrient content was of the order of 1.57, 0.32 and 0.55 percent of N, P, and Mg in untreated control. The amount of potassium was found maximum under control (0.97 %) and decreased with the application of calcium which recorded 0.73 % at 2.0 percent calcium nitrate (Singh, 1994). Foliar spray of calcium chloride has been reported to reduce foliar K content in apple (Wooldridge *et al.,* 1998). Azad (1999) reported increase in leaf nitrogen and phosphorus in apple whereas potassium and magnesium was non-significant by preharvest spray of calcium chloride at 0.5 percent. Kadir (2005) reported that more than six preharvest foliar applications of $CaCl_2$ to Jonathan apple trees increased Ca concentrations in leaf tissues as the result of $CaCl_2$ applications coincided with increases in K, Mg, N, and P in leaf tissues.

Several reporters have reported an increased amount of N, K, Ca and Mg in leaves of both seedling and maturity apple trees by gibberellic acid (GA_3) or naphthalene acetic acid (NAA) or naptheyl acetamide (NAAm) or boric acid (BO_3) (Stahley and Benson, 1976 and Steenkamp and De Vellier, 1979) whereas others have reported reduction or no effect by these substances (Lysenko and Gordienko, 1970 and Granger and Looney, 1983).

Shin *et al.* (1989) recorded data on foliar macro and micro nutrient levels and fertilizer rates used in numerous orchards and observed that the application of calcium increased N, P and Mg content in guava leaves.

Foliar spray of nutrients to full bearing apple trees showed significant differences in nutrient status of leaves. Level of phosphorus, potassium and magnesium in leaves was found to be highest with the treatment of NAA plus Kinetin plus Miracl plus H_3BO_3 (2.5 +0.5 + 0.5% + 25 ppm) with their respective values of 0.26, 1.83 and 0.43 percent (Singh, 2004). Shahin *et al.* (2010) have seen positive effect of Fertifol Misr (N, P, K, Mg Zn, Fe, Mn, Cu, Mo & B) and gibberellic acid on fruit leaf chemical composition of 'Anna' apple trees during 2007 and 2008. Mosa *et al.,* 2015, showed that potassium sulphate plus calcium chloride plus boric acid plus humic acid combination increased N, K and Ca concentration in leaves.

2.6. Organoleptic rating

Gupta and Mehta (1988) observed that calcium application as preharvest spray had a significant effect on organoleptic rating of ber *cv.* Gola. Calcium application at 1.0 percent improved organoleptic rating which attained the score of 70.0 in comparison to 60.0 under control. The organoleptic scoring of 'Flordasun' peach was higher at two percent calcium nitrate as preharvest spray. The overall acceptability was significantly higher in two and three calcium nitrate sprays in comparison to one spray and the fruits remained acceptable up to 28 days of cold storage. Bhat *et al.* (2009) reported increase in organoleptic rating with 0.50 and 0.75 percent $CaCl_2$ sprays on pear *cv.* 'Bartlett' in Kashmir. Singh *et al*. (1984) conducted an experiment to study the effectiveness of calcium as pre-harvest treatment on 'Amrapali' mango. The study indicated that organoleptic rating was high in treated fruits for a period of twelve days as against four days in control. Three sprays of 1.5 percent $CaCl_2$ resulted in maximum sensory score in peach *cv.* Shah-I-Punjab (Raja *et al.,* 2015).

Raffo *et al.* (2014) observed the effect of the application of different organic and conventional fertilizers on some flavor quality attributes of *cv.* Golden Delicious apples. Fertilisation treatments significantly affected the level in fruits of several flavor related compounds (aroma volatiles, sugars and organic acids). The different organic fertilisation treatments weakly affected the considered fruit quality attributes. Significant differences were observed for several sensory attributes between apples coming from different fertilization treatments.

2.7. Return bloom

Curry and Greene (1993) reported that the application of gibberellic acid on apples influence fruit quality and return bloom. McLaughlin and Greene (1991) observed that GA_{4+7} @ 150 mg/L at fruit bud plus 42 days reduced appendage formation and percentage of flowering spurs but was less effective in reducing the return bloom as compared to early spray that is fruit bud plus 5, plus14, and plus 22 days. GA_3 at l00, 500, or 1000 mg/L was applied at the beginning of spring (at full bloom) and at the highest concentration, GA_3 reduced flower bud formation in the following spring and produced the lowest yields (Maksymiuk *et al.*, 1986). Dennis *et al.* (1970) demonstrated decreased levels of flowering in the pome fruit 'Bartlett' pear (*Pyrus communis*) with 20-100 mg/L of GA_3 in following spring. In 'Kosui' Japanese pear (*Pyrus pyrifolia* Nakai), application of GA_3 at 200 ppm during flowering decreased flower bud formation, while August sprays of the same material increased flowering in coming spring (Ito *et al.,* 2000). Unrath and Whitworth (1991) studied that the application of GA_3 @ 250 and 500 ppm on 'Red chief Delicious'/M 7 apple which resulted in reduction in return bloom of 0.4 and 0.1 as compared to untreated control (7.8).

Greene and Curry (1989) found that CPPU at 10 or 100 mg/L and gibberellic acid or Promalin (50 or 300 mg/L) at full bloom reduced 'McIntosh' return bloom similar results were also reported in 'Spur Delicious' apple after application of CPPU @ 5 ppm at full bloom was recorded as 5.7 as compared to untreated control (12.0). Ramirez (2014) reported that the exogenous application of cytokinins to apple spurs at the time of fruit bud initiation increased return bloom in the following spring. McArtney and Wargo, (2012) also reported that Promalin (6-BA+GA_{4+7}) increases cropping of apples after a freeze by promoting parthenocarpic fruit set. Gurung *et al.* (2016) reported that combinations of three growth regulators (GA_3 @ 7.5 ppm and 15 ppm, BA @ 200 ppm and 400 ppm and 2,4-D @ 7.5 ppm and 15 ppm) and two micro nutrients (Zn @ 0.5 % and B @ 0.1%) improved flowering intensity the next year in Mandarin. Ghorbani *et al.* (2017) in their study on 6-year-old 'Standard Fuji' trees grafted on 'MM106' rootstock to assess the effect of calcium chloride ($CaCl_2$) and two organic calcium compounds including Calcicat® and Folical® and water (as control) at four different spray programs (All-season, Early, Mid and Late season spray) reported increase in return bloom and hence yield efficiency (Number of fruits per cm^2 trunk cross-sectional area) by all sprays. Wani *et al.* (2017) revealed that application of phyto-hormones and nutrients alone or in combination in apple *cv.* 'Red Delicious' had significant influence on return bloom which recorded highest (16.73 %) under the treatment of nutrient mixture (Ca + B + N) @ 2 ml/L but both the hormones (GA_3 and CPPU) and their combinations with nutrients proved unsatisfactory due to reduced return bloom in the succeeding year.

Chapter – 3

MATERIALS AND METHODS

The present investigation was carried out during the year 2016-2017 in the orchard of a progressive farmer Mr. Abdul Ahad Dar of district Kulgam in Kashmir valley. The details of the materials used and the techniques followed during the course of investigation are described in this chapter.

3.1. Plant material

Healthy trees of apple *cv.* Red Delicious were selected on the basis of uniform size, vigour and bearing capacity. The plant material was 26 years old grafted on seedling rootstock. All the trees received uniform cultural practices during the year under study as per the package of practices of SKUAST-Kashmir. The initial soil status of the experimental orchard was examined and the readings were as under.

S. No.	Nutrient	Concentration
1	N	295 kg/ha
2	P	16.5 kg/ha
3	K	220 kg/ha
4	Ca	1850 ppm
5	Mg	320 ppm
6	Zn	0.90 ppm

3.2. Spray material

GA_3 used was Progibb® of Valent agricultural products containing 90 percent GA_3. For chelated calcium the spray material used was ca in the form of Ca-EDTA with trade name Chelcal® of Aries agro chemicals ltd. The calcium chloride used was calcium chloride dihydrate from Merck life sciences. The Applin® is a hormone nutrient mixture developed by Crystal crop protection containing GA_{4+7} (1.8 % w/w), 6-BAP (1.8 % w/w), Auxin (40 ppm), N (7.0 %), B (0.0024 %), Cu (0.0013 %), Mg (0.036 %), Mo (0.003 %), S (0.5 %), Humic acid (3.76 %), Choline (750 ppb) and Thiamine (150 ppb).

3.3. Treatment details

Codes	Variants	Time of spray
T_1	Control (water spray)	3 WAFS
T_2	GA_3 @ 50 ppm	3 WAFS
T_3	GA_3 @ 100 ppm	3 WAFS
T_4	Chelated Ca @ 0.1 %,1 spray	3 WAFS
T_5	Chelated Ca @ 0.1 %, 2 sprays	3 and 6 WAFS
T_6	Chelated Ca @ 0.1 %, 3 sprays	3, 6 and 9 WAFS
T_7	Chelated Ca @ 0.1 %, 4 sprays	3, 6, 9 and 12 WAFS
T_8	Chelated Ca @ 0.1 %, 5 sprays	3, 6, 9, 12 and 15 WAFS
T_9	$CaCl_2$ @ 0.3 %, 1 spray	3 WAFS
T_{10}	$CaCl_2$ @ 0.3 %, 2 sprays	3 and 6 WAFS
T_{11}	$CaCl_2$ @ 0.3 %, 3 sprays	3, 6 and 9 WAFS
T_{12}	$CaCl_2$ @ 0.3 %, 4 sprays	3, 6, 9 and 12 WAFS
T_{13}	$CaCl_2$ @ 0.3 %, 5 sprays	3, 6, 9, 12 and 15 WAFS
T_{14}	Applin @ 1.5 ml/L	Walnut Stage
T_{15}	Applin @ 2.5 ml/L	Walnut Stage

*WAFS = Weeks after fruit set

The experiment was laid in Randomized Complete Block Design (RCBD) with four replications in each treatment.

3.4. Method of preparation

Spray solutions of gibberellic acid (GA_3), calcium chloride ($CaCl_2$), chelated calcium and Applin were prepared just before being used. For preparing 50 ppm GA_3, 5 g of GA_3 were first dissolved in 100 ml ethyl alcohol then 200-300 ml of water was added and magnetic stirrer was used for complete dissolution; finally volume was raised to 100 L with water. Similar procedure was fallowed for the preparation of 100 ppm of GA_3. Calcium chloride dihydrated (0.3 %) solution was prepared by dissolving 300 g in small quantity of water and final volume was made to 100 L by adding water. Similarly 0.1 percent of chelated calcium was prepared by dissolving 100 g of EDTA chelated calcium in small quantity of water and final volume was made 100 L with water. Applin @ 1.5 ml/L was made by dissolving 150 ml of Applin in small quantity of water then more water was added to make it 100 L. Similarly spray solution of Applin 2.5 ml/L was prepared. The solutions thus made were allowed to rest for some time so that heat dissipation occurred and the pH of the spray solution was maintained 7.0 with NaOH or HCl; measured by portable electronic pH meter. Finally the selected plants were thoroughly sprayed at respective times with power sprayer.

3.5. Time of application and Number of sprays

GA_3, calcium chloride dihydrated and chelated calcium were sprayed three weeks after fruit set (WAFS) as per treatment. The remaining sprays of calcium chloride and chelated calcium were conducted after 6, 9, 12 and 15 WAFS as per the treatment. Single spray of Applin @ 1.5 ml/L and 2.5 ml/L were conducted at walnut stage when the fruit size was about 4 cm in diameter.

3.6. Collection and preparation of leaf samples

Leaf samples were collected from current season's growth around periphery of tree in the middle of August.

After collection, the leaf samples were washed with tap water and later dipped in dilute hydrochloric acid. Further, washings were repeated with single and double distilled water. The samples were then air dried on a filter paper and oven dried at 60 ± 5 ºC until constant weight was obtained. The samples were then crushed in a stainless steel blender to pass through 2 mm mesh and stored in polythene bags for chemical analysis.

3.7. Collection and preparation of fruit sample

Fruit sample was collected as per procedure suggested by Waller (1980). After collecting the fruits these were washed with tap water and later dipped in dilute hydrochloric acid. Further, washings were given with single and double distilled water. The moisture was wiped with filter paper and muslin cloth. The fruits were cut into thin slices, the central core along with seeds were removed. The samples were dried in an oven at a temperature of 60 to 85 ºC until constant weight was obtained, and then crushed to pass through 2 mm mesh and stored in polythene bags for subsequent chemical analysis.

3.8. Time at which observations were recorded

The observations like fruit length, fruit diameter, fruit shape index (L/D ratio), colour, soluble solids concentrate, ascorbic acid, anthocyanin, fruit nutritional status, total sugars, acidity, grading, watercore and sensory evaluation were recorded at harvest whereas bitter pit incidence and physiological loss in weight were recorded after every 15 days starting from the date of harvest (i.e., 0 day after storage or 0 DAS) upto 45 days after storage (45 DAS). Fruit firmness was recorded at harvest as well as fifteen, thirty and forty-five days after storage

(DAS) under ambient storage conditions.

3.9. Observations recorded

3.9.1. Fruit physical characteristics

i. Fruit length

The length of randomly selected ten fruits from each treatment in each replication were measured with the help of a Vernier Caliper, averaged and expressed in centimeters.

ii. Fruit diameter

The diameter of randomly selected ten fruits from each treatment in each replication were measured with the help of a Vernier Caliper and averaged.

iii. Fruit shape index (L/D)

L/D ratio was calculated to determine the shape of fruits by dividing the length of fruit with the diameter of corresponding fruit.

iv. Colour

A random sample of ten fruits from each replicate of each treatment was taken and observed for colour scores. Individual fruits were scored for the colour of the skin 1-4 scale (Blanpied *et al.,* 1979) as under:

Percentage of red colour	Score
a) 0-25 % red skin colour	1
b) 26-50 % red skin colour	2
c) 51-75 % red skin colour	3
d) 76-100 % red skin colour	4

v. Firmness

Fruit firmness was measured at harvest and after every fifteen days upto forty five days of storage under ambient conditions with the help of Effegi penetrometer model, Ft-3-27 having 7/16 inch diameter. In each treatment, fruits were punched at three different places on its surface after removing about two square centimeter of peel and firmness was recorded as kg/cm^2.

3.9.2. Chemical characteristics

i. Soluble solids concentrate

Soluble solids concentrate was measured by a hand refractometer ranging from 0-33 (^{0}Brix Erma make Japan) and values were corrected at 20 ^{0}C (Ranganna, 1997).

ii. Acidity

Acidity was determined by taking a known weight of fruit sample (25 g) which was crushed and added to 100 ml distilled water and then filtered through Whatman's No. 1 filter paper. 10 ml of aliquot was titrated against N/10 NaOH using phenolphthalin indicator and end point was determined by pink colouration. The total titrable acidity was calculated in terms of malic acid on the basis of 1ml of 0.1 N NaOH solution equivalent to 0.0067 and expressed in terms of percent acidity (A.O.A.C., 1990). Acidity was calculated as malic acid by using the following formula:

$$\text{Acidity (\%)} = \frac{\text{Titre value} \times \text{normality of alkali} \times \text{dilution factor} \times 67}{\text{Weight of sample} \times \text{volume of aliquot taken} \times 1000} \times 100$$

iii. Sweetness index. (SSC/Acid ratio)

The SSC/Acid ratio simply gives the sweetness index of fruit in terms of sugar- acid blend and is calculated by dividing the soluble solids concentrate (^{0}Brix) with acidity (%) of corresponding treatments.

iv. Total sugars

Twenty-five grams of fruit pulp thoroughly mixed with distilled water in a beaker and 25 ml of lead acetate was added to extract the juice from filtrate. To this 25 ml of potassium oxalate was also added for removing excess lead and volume was made upto 250 ml by adding distilled water. The solution was filtered through Whatman filter paper No. 1. From the above aliquot 100 ml of solution was taken and hydrolysed by adding 10 ml of concentrated hydrochloric acid and left for overnight. The excess of HCl was neutralized by saturated sodium hydroxide solution. Total sugar content was estimated by titrating a solution against mixture containing 5 ml each of Fehling's solution A and B using methylene blue as indicator. The titration was continued till brick red colour appeared (A.O.A.C., 1990). The total sugars content was calculated by using the following formula:

$$\text{Total sugars (\%)} = \frac{\text{Fehling factor} \times \text{volume made up}}{\text{Titre value} \times \text{weight of sample}} \times 100$$

v. Ascorbic acid

Ascorbic acid was determined by 2, 6-Dichlorophenol-Indophenol visual titration method (Ranganna, 1997), for this 10 ml of juice was taken in a 100 ml volumetric flask and the volume was made with 3 percent metaphosphoric acid (H_3PO_4). Then 10 ml of aliquot was taken in a beaker and titrated against standardized solution of 2, 6-Dichlorophenol-Indophenol dye, till light and distinct rose pink colour appeared that remains for more than five seconds and the reading was noted. Titration was repeated thrice and the average value was recorded and ascorbic acid content was calculated by the formula.

$$\text{Ascorbic acid (mg/100 g)} = \frac{\text{Titre value} \times \text{dye factor} \times \text{volume made}}{\text{Volume of filtrate taken} \times \text{weight of sample}} \times 100$$

vi. Anthocyanin

Anthocyanin content is based upon the principle that it is extracted with ethanolic hydrochloride and the intensity of the colour appeared is measured colorimetrically (Kaur and Dhillon, 2007). From the reading, the amount of the pigment present is determined. For extraction three reagents were made. Reagent-1:95 percent ethanol was made. Reagent-2:1.5 N hydrochloric acid (HCl) was made. Reagent-3: ethanol-hydrochloric acid mixture was made by mixing 85 parts of reagent 1 and 15 parts of reagent 2 by volume.

Anthocyanins were calculated by the method as described by Ranganna (1997). 10 ml of fruit sample was taken and diluted to 100ml with ethanolic HCl (95% Ethanol-1.5 N HCl) and then kept in refrigerator overnight at 4^{o}C. Then it was filtered using Whatman Paper No. 1. Filtrate was taken in a cuvet and its O.D was taken at 535 nm using spectrophotometer against 95 percent alcohol as blank. Total anthocyanins were calculated using following equations:

$$Total\ O.D. = \frac{O.D.\ at\ 535\ nm}{weight\ of\ sample} \times 100$$

$$Total\ Anthocyanin\ (mg/100\ g) = \frac{Total\ O.D.}{98.2}$$

3.10 Market acceptability

3.10.1. Grading

Fruit grading was performed as per orchardists practice and allotted grades were ‘A’ for excellent, ‘B’ for good and ‘C’ for poor and low quality apples and accordingly their percentages were calculated.

3.10.2. Organoleptic rating

To assess the consumer acceptability with regard to quality (physical appearance, colour, taste, flavour, texture, firmness), the fruits were rated on a scale of 1-5 by a panel of five members as:

1 = Poor
2 = Fair
3 = Good
4 = Very Good
5 = Excellent

3.11. Physiological disorders

The fruits were stored for 45 days under ambient conditions and observations were recorded at fifteen days interval.

i. Watercore

At random 10 fruits from each treatment were cut and examined visually. The number of fruits having watercore incidence were counted and expressed in percentage.

ii. Bitter pit incidence

Bitter pit incidence was examined by cutting 10 fruits from each replication of every treatment and the incidence of bitter pit was out and expressed in percentage.

iii. Physiological loss in weight

For physiological loss in weight, at random 10 fruits from each replication of each treatment were labeled and periodically weighed after 15 days interval and loss was worked.

$$\text{PLW (\%)} = \frac{\text{Intial weight} - \text{Final weight}}{\text{Intial weight}} \times 100$$

3.12 Fruit nutritional status

Nitrogen (N) content in fruit samples was estimated by modified Kjeldhal's method (Jackson, 1973). Fruit potassium (K) content from fruit samples was estimated by digestion of plant samples with diacid (HNO_3:$HClO_4$ in ratio of 9:4) and subsequent analysis on flame photometer (Jackson, 1973). Fruit calcium (Ca) and magnesium (mg) were estimated by versenate titration method given by Jackson (1973). All of these parameters were expressed in percentage to fruit dry weight.

3.13 Leaf nutritional status

Nitrogen (N) content in leaf samples was estimated by modified Kjeldhal's method (Jackson, 1973). Leaf potassium (K) content from leaf samples was estimated by digestion of plant samples with diacid (HNO_3:$HClO_4$ in ratio of 9:4) and subsequent analysis on flame photometer (Jackson, 1973). Leaf calcium (Ca) and magnesium (mg) were estimated by versenate titration method given by Jackson (1973). All of these parameters were expressed in percentage to leaf dry weight

3.14 Return bloom

Six year old branches (two for each replication) were selected and marked with paint to record braches diameter, number of flower buds and number of vegetative buds before blooming and was taken in the year 2016 and also in 2017. The values were put for calculations as:

$$\text{Return bloom} = \frac{\text{No. of Flower clusters}}{\text{cm}^2\,\text{BCSA}}$$

$$\text{Branch cross sectional area (BCSA)} = \frac{(\text{Girth})^2}{4\pi}$$

3.15 Statistical analysis

The observations recorded during the course of investigation were subjected to statistical analysis as per the method of 'Analysis of Variance' (Fisher, 1950). The significance and non-significance of treatment effects were judged with the help of software OP stat. The significant difference on the means was tested against the critical difference at 5% level.

Chapter-4

EXPERIMENTAL FINDINGS

The experimental findings of present investigations conducted on the ''Effect of Gibberellic acid, Applin and Calcium foliar sprays on chemo-metric attributes of apple (*Malus* x *domestica* Borkh.)'' are presented here under:

4.1. Physical characteristics

4.1.1. Fruit length

The data pertaining to fruit length presented in Table 1 reveals that varied foliar sprays either of GA_3, Applin, $CaCl_2$ or chelated-Ca exhibited a significant effect on fruit length. The maximum fruit length (7.97 cm) was recorded in T_3 [GA_3 @ 100 ppm sprayed once], which was statistically at par with T_{15} (7.88 cm) and T_{14} (7.84 cm) treatments. The minimum fruit length (6.22 cm) was observed in T_1 [Control] which was at par with T_4 [chelated calcium sprayed once (6.26 cm)] and T_9 [$CaCl_2$ sprayed once (6.30 cm)] treatments.

Among the calcium sprays, $CaCl_2$ resulted more increase in fruit length as compared to chelated calcium sprays. The data in Table 1 also indicates that fruit length was increased with increase in number of sprays of Ca upto four numbers of sprays then tends to decrease. Among $CaCl_{2,}$ the four times spray [T_{12}] resulted in maximum fruit length (7.36 cm) which was followed in 0.3 percent calcium chloride sprayed five times [T_{13} (7.33 cm)]. These treatments were statistically at par with each other but significantly higher than control. Among chelated calcium sprays the maximum fruit length (7.23 cm) was recorded in chelated calcium applied four times [T_7] followed by chelated calcium applied five times [T_8 (7.18 cm)] and were statistically at par with each other but significantly higher than control and that of other treatments of chelated calcium.

Table-1 Effect of gibberellic acid, Applin and calcium foliar sprays on fruit length, fruit diameter, fruit shape index (L/D ratio) and colour score of apple.

Treatments	Length (cm)	Diameter (cm)	Shape index	Colour score (1-4)
T_1 Control	6.22	6.34	0.98	2.39
T_2 GA_3 @ 50 ppm	7.53	7.48	1.01	2.34
T_3 GA_3 @ 100 ppm	7.97	7.84	1.02	2.27
T_4 Chelated Ca @ 0.1 %,1 spray	6.26	6.37	0.98	2.41
T_5 Chelated Ca @ 0.1 %, 2 sprays	6.43	6.54	0.98	2.56
T_6 Chelated Ca @ 0.1 %, 3 sprays	6.93	6.98	0.99	2.93
T_7 Chelated Ca @ 0.1 %, 4 sprays	7.23	7.21	1.00	3.36
T_8 Chelated Ca @ 0.1 %, 5 sprays	7.18	7.16	1.00	3.59
T_9 $CaCl_2$ @ 0.3 %, 1 spray	6.30	6.42	0.98	2.39
T_{10} $CaCl_2$ @ 0.3 %, 2 sprays	6.65	6.71	0.99	2.78
T_{11} $CaCl_2$ @ 0.3 %, 3 sprays	7.09	7.18	0.99	3.04
T_{12} $CaCl_2$ @ 0.3 %, 4 sprays	7.36	7.38	1.00	3.62
T_{13} $CaCl_2$ @ 0.3 %, 5 sprays	7.33	7.30	1.00	3.58
T_{14} Applin @ 1.5 ml/L	7.84	7.92	0.99	2.39
T_{15} Applin @ 2.5 ml/L	7.88	7.95	0.99	2.31
C.D. ($p \leq 0.05$)	**0.18**	**0.16**	**0.01**	**0.11**

4.1.2. Fruit breadth

Examination of Table 1 reveals that different foliar sprays of GA_3, Applin, $CaCl_2$ or chelated-Ca presented a significant effect on fruit breadth. The maximum fruit breadth (7.95 cm) was recorded in T_{15} [Applin @ 2.5 ml/L] which was statistically at par with T_{14} [Applin @ 1.5 ml/L (7.92 cm)] and T_3 [GA_3 @100 ppm (7.84)] treatments. The minimum fruit breadth (6.34 cm) was observed in T_1 [Control] which was at par with T_4 [chelated calcium sprayed once (6.37 cm)] and T_9 [$CaCl_2$ sprayed once (6.42)] treatments.

Among the calcium sprays, $CaCl_2$ resulted more increase in fruit breadth as compared to chelated calcium sprays. The data also indicates that fruit breadth was increased with increase in number of sprays upto four numbers of sprays then tends to decrease. Among $CaCl_{2,}$ the four times spray [T_{12}] resulted in maximum fruit breadth (7.38 cm), which was very close to 7.30 cm of calcium chloride sprayed five times [T_{13}]. These treatments were statistically at par with each other but significantly higher than control and other treatments of $CaCl_2$. Among chelated calcium sprays the maximum fruit breadth (7.21 cm) was recorded in chelated calcium applied four times [T_7] which was statistically at par with chelated calcium applied five times [T_8 (7.16 cm)] but significantly higher than control.

4.1.3. Fruit L/D ratio

Perusal of data in Table 1 reveals that different and separate foliar sprays of GA_3, Applin, $CaCl_2$ or chelated-Ca displayed significant effect on fruit L/D ratio which was minimum under control [T_1 (0.98)] and maximum under GA_3 @ 100 ppm [T_{12} (1.02)].

The calcium sprays also improved fruit L/D ratio and both the sources responded similarly with respect to fruit shape improvement. Three, four and five chelated calcium sprays improved fruit L/D ratio with values of 0.99, 1.00 and

1.00 respectively. Whereas in $CaCl_2$ sprays; fruit L/D ratio showed significant improvement from two sprays onwards with maximum same value of 1.00 under T_{12} and T_{13}.

4.1.4. Colour (Score: 1-4)

From the Table 1, it is clear that the various treatments under study differed significantly with respect to colour. The treatment of four sprays of $CaCl_2$ [T_{12}] scored the maximum value for colour (3.62) which was statistically at par with chelated-Ca sprayed five times [T_8] (3.59) and 3.58 of five sprays of $CaCl_2$ [T_{13}]. The lowest value of 2.27 was found under T_3 [GA_3 @ 100 ppm]. Applin showed non-significant response to colour development. The treatments T_1, T_2, T_4, T_9, T_{14}, and T_{15} were statistically at par with scores of 2.39, 2.34, 2.39, 2.39 and 2.31 respectively.

4.2. Fruit grading

It is evident from the data presented in Table 2 and Fig. 1 that unlike foliar sprays of GA_3, Applin, $CaCl_2$ and chelated-Ca marked a considerable effect on different conventional fruit grades of apple i.e., grade “A”, “B” and “C”.

4.2.1. Grade A

The maximum (75.21 %) premium grade “A” fruit production was obtained from trees sprayed with $CaCl_2$ five times [T_{13}] which was at par with $CaCl_2$ four times [T_{12} (73.99 %)] and chelated-Ca five times [T_8 (74.00 %)]. The minimum of this grade was recorded in control [T_1 (58.07 %)]. Thus five sprays of either $CaCl_2$ or chelated-Ca have enhanced the percentage of grade “A” fruits by over 15 percent compared to control.

Table -2 Effect of gibberellic acid, Applin and calcium foliar sprays on fruit grading of apple.

Treatments	Grade 'A' (%)	Grade 'B' (%)	Grade 'C' (%)
T_1 Control	58.07	17.80	24.14
T_2 GA_3 @ 50 ppm	68.43	18.08	13.49
T_3 GA_3 @ 100 ppm	71.48	18.34	10.18
T_4 Chelated Ca @ 0.1 %,1 spray	60.42	19.98	19.60
T_5 Chelated Ca @ 0.1 %, 2 sprays	61.14	20.56	18.30
T_6 Chelated Ca @ 0.1 %, 3 sprays	65.81	20.05	14.15
T_7 Chelated Ca @ 0.1 %, 4 sprays	72.48	19.59	7.94
T_8 Chelated Ca @ 0.1 %, 5 sprays	74.00	19.03	6.98
T_9 $CaCl_2$ @ 0.3 %, 1 spray	64.50	18.33	17.17
T_{10} $CaCl_2$ @ 0.3 %, 2 sprays	67.15	18.50	14.36
T_{11} $CaCl_2$ @ 0.3 %, 3 sprays	68.64	20.58	10.78
T_{12} $CaCl_2$ @ 0.3 %, 4 sprays	73.99	18.85	7.16
T_{13} $CaCl_2$ @ 0.3 %, 5 sprays	75.21	18.27	6.53
T_{14} Applin @ 1.5 ml/L	70.86	17.50	11.64
T_{15} Applin @ 2.5 ml/L	72.11	18.32	9.58
C.D. ($p \leq 0.05$)	**1.46**	**1.31**	**2.15**

4.2.2. Grade B and Grade C

In case of grade "B" fruits, the highest value of 20.58 percent was recorded in treatment T_{11} [$CaCl_2$ applied thrice] very near to that of T_5 [Chelated-Ca applied twice (20.56)] and statistically at par with T_6 [Chelated-Ca applied thrice (20.05 %)] but higher than T_1 (17.80 %).

The minimum of 17.50 percent was found under Applin @ 1.5 ml/L [T_{14}] which was at par with T_1 (17.80 %), T_2 (18.08 %), T_3 (18.34 %), T_9 (18.33 %), T_{10} (18.50 %), T_{13} (18.27 %) and T_{15} (18.32 %).

Grade "C" was reduced by all the chemical treatments. The highest value of grade "C" of 23.72 percent was observed in control [T_1] and the lowest (3.47 %) in T_{15} [$CaCl_2$ applied five times].

4.3. Chemical characteristics

4.3.1. Soluble solids concentrate (SSC)

The perusal of data (Table 3) reveals that soluble solid concentrate was significantly affected by various foliar treatments of GA_3, Applin, $CaCl_2$ and chelated-Ca. It was found that maximum content of total soluble solids of 15.17 ^{o}Brix was under T_{15} [Applin @ 2.5 ml/L] which was at par with Applin @ 1.5 ml/L [T_{14} (15.08)]. SCC was also improved by GA_3 with values of 13.61 ^{o}Brix and 14.56 ^{o}Brix under GA_3 @ 50 ppm and GA_3 @ 100 ppm respectively. Control treatment recorded minimum content of soluble solids concentrate (12.89 ^{o}Brix).

Among the calcium sprays, $CaCl_2$ resulted more increase in SSC as compared to chelated calcium sprays. The data also indicates that SSC was statistically increased with increase in number of sprays upto four but not then after. Among $CaCl_2$, the four times spray [T_{12}] resulted in maximum SSC (14.50 ^{o}Brix), which was statistically at par with calcium chloride sprayed five times treatment [T_{13} (14.36 ^{o}Brix)] but both the treatments were significantly higher than control. Among chelated calcium sprays the maximum SSC (14.11 ^{o}Brix) was recorded in chelated calcium applied four times [T_7] followed by chelated calcium applied five times [T_8 (13.89 ^{o}Brix)] and chelated calcium applied thrice [T_6 (13.37 ^{o}Brix)]. These treatments were statistically and significantly higher than control.

4.3.2. Acidity

Data on acidity as depicted in Table 3 shows a significant difference among all the treatments. The acidity of fruits varied from 0.24-0.32 percent among the treatments under study. It is obvious from the noted observations that treatment T_{15} [$CaCl_2$ sprayed five times] recorded maximum acidity of 0.32 percent followed by 0.31 percent in T_{12} [$CaCl_2$ sprayed four times]. The minimum acidity of 0.24 percent was observed in T_3 [GA_3 @ 100 ppm].

An increasing trend of acidity was found in the calcium treatments and decreasing in case of GA_3 and Applin. Among the two calcium chemicals, $CaCl_2$ resulted in higher increase in titratable acidity as compared to chelated-Ca. The data also indicates that acidity increased with the increase in number of sprays. Among $CaCl_{2,}$ the spray at 0.3 percent, five times resulted in highest acid content (0.32 %). Among chelated-Ca the highest acidity (0.30 %) was recorded in 0.1 percent concentration applied five times which was significantly more than the control.

4.3.3. Total sugars

Table 3 reveals that all the treatments of GA_3, Applin, $CaCl_2$ and chelated-Ca affected total sugars content. It was observed that maximum content of total sugars (12.65 %) was recorded with treatments T_{15} [Applin @ 2.5 ml/L] which was at par with that of T_{14} [Applin @ 1.5 ml/L]. The lowest total sugars content was (10.55 %) recorded in treatment T_1 (control).

Table-3 Effect of gibberellic acid, Applin and calcium foliar sprays on SSC, acidity, total sugars and sweetness index of apple.

Treatments	SSC (°Brix)	Acidity (%)	Total sugars (%)	Sweetness index
T_1 Control	12.89	0.27	9.70	47.70
T_2 GA_3 @50 ppm	13.61	0.25	10.31	54.45
T_3 GA_3 @100 ppm	14.56	0.24	10.99	60.64
T_4 Chelated Ca @0.1 %,1 spray	12.85	0.27	9.71	47.57
T_5 Chelated Ca@0.1 %, 2 sprays	13.20	0.28	10.02	47.12
T_6 Chelated Ca @0.1 %, 3 sprays	13.37	0.29	10.31	46.09
T_7 Chelated Ca @0.1 %, 4 sprays	14.11	0.30	10.84	46.98
T_8 Chelated Ca @0.1 %, 5 sprays	13.89	0.30	10.37	46.34
T_9 $CaCl_2$ @ 0.3%, 1 spray	12.86	0.28	9.80	45.19
T_{10} $CaCl_2$ @ 0.3%, 2 sprays	13.10	0.29	10.11	45.97
T_{11} $CaCl_2$ @ 0.3%, 3 sprays	14.05	0.29	10.66	48.46
T_{12} $CaCl_2$ @ 0.3%, 4 sprays	14.50	0.31	11.44	46.85
T_{13} $CaCl_2$ @ 0.3%, 5 sprays	14.36	0.32	10.80	44.84
T_{14} Applin @ 1.5ml/L	15.08	0.27	11.84	55.84
T_{15} Applin @ 2.5 l/L	15.17	0.26	11.92	58.40
C.D. ($p \leq 0.05$)	**0.40**	**0.01**	**0.36**	**2.60**

Among the calcium sprays, $CaCl_2$ resulted more increase in total sugars as compared to chelated calcium sprays. The data also indicates that total sugars content was increased with increase in number of sprays upto four numbers of sprays then tends to decrease. Among $CaCl_2$, the four times spray [T_{12}] resulted in maximum total sugars (11.44 %) which was followed by 10.66 percent under calcium chloride sprayed five times treatment [T_{13}]. Among chelated calcium sprays the maximum total sugars (10.84 %) was recorded in chelated calcium applied four times [T_7] followed by chelated calcium applied five times [T_8 (10.37 %)] and chelated calcium applied thrice [T_6 (10.31 %)]. These treatments were significantly higher than control.

4.3.4. Sweetness index (SSC/Acid ratio)

Table 3 shows that significant differences were recorded with respect to sweetness index of apple fruits by chemical treatments. It was found that maximum sweetness index of 60.64 was recorded in treatment T_3 [GA_3 @ 100 ppm] which was at par with T_{15} [Applin @ 2.5 ml/L (58.40)]. These were followed by 55.84 and 54.45 under treatments T_{14} [Applin @ 1.5 ml/L] and T_3 [GA_3 @ 100 ppm] respectively; which were significantly higher than control (47.70). The minimum sweetness index 44.84 was found in treatment T_{13} [$CaCl_2$ sprayed five times].

Fruits from trees receiving calcium treatments showed significantly less sugar:acid blend as compared to other treatments and the effect was more pronounced in case of $CaCl_2$ sprays than those of chelated-Ca ones. 48.46 was the highest value of sweetness index found in $CaCl_2$ applied thrice [T_{11}] and minimum value of (44.84) was found in case of T_{13} [$CaCl_2$ sprayed five times] among these treatments.

4.3.5. Ascorbic acid

The data pertaining to ascorbic acid presented in Table 4 reveals that individual foliar sprays of GA_3, Applin, $CaCl_2$ and chelated-Ca at different concentrations or different number of sprays showed a significant effect on

Table-4 Effect of gibberellic acid, Applin and calcium foliar sprays on ascorbic acid, anthocyanin and organoleptic rating of apple.

Treatments		Ascorbic acid (mg/100g)	Anthocyanin (mg/100g)	Organoleptic rating (1-5)
T_1	Control	4.85	9.48	3.24
T_2	GA_3 @50 ppm	5.11	9.37	3.53
T_3	GA_3 @100 ppm	5.45	9.12	3.7
T_4	Chelated Ca @ 0.1%,1 spray	4.96	9.63	3.47
T_5	Chelated Ca @ 0.1%, 2 sprays	5.15	9.82	3.61
T_6	Chelated Ca @ 0.1%, 3 sprays	5.61	10.08	3.85
T_7	Chelated Ca @ 0.1%, 4 sprays	6.53	11.16	4.23
T_8	Chelated Ca @ 0.1%, 5 sprays	7.01	11.03	4.47
T_9	$CaCl_2$ @ 0.3%, 1 spray	5.21	9.46	3.5
T_{10}	$CaCl_2$ @ 0.3%, 2 sprays	5.75	9.50	3.7
T_{11}	$CaCl_2$ @ 0.3%, 3 sprays	6.66	9.99	3.8
T_{12}	$CaCl_2$ @ 0.3%, 4 sprays	7.17	11.21	4.43
T_{13}	$CaCl_2$ @ 0.3%, 5 sprays	7.34	11.15	4.27
T_{14}	Applin @ 1.5ml/L	6.37	9.75	4.17
T_{15}	Applin @ 2.5ml/L	6.63	9.40	3.81
C.D. ($p \leq 0.05$)		**0.27**	**0.30**	**0.16**

ascorbic acid. The maximum ascorbic acid (7.34 mg/100 g) was recorded in calcium chloride sprayed five times [T_{13}] which was statistically at par with 7.17 mg/100 g of fresh weight under calcium chloride sprayed four times [T_{12}] but higher than all other treatments. The minimum ascorbic acid (4.85 mg/100 g) was observed in T_1 [Control] which was at par with T_4 [chelated calcium sprayed once (4.96 mg/100 g)] and T_2 [GA_3 @ 50 ppm (5.11 mg/100 g)]. Applin also enhanced vitamin C content having figures of 6.37 and 6.63 mg/100 g under lower and higher concentration respectively.

Among the calcium sprays, $CaCl_2$ resulted more increase in ascorbic acid as compared to chelated calcium sprays. The data also indicates that ascorbic acid was increased with increase in number of sprays. Among $CaCl_2$, sprayed five times [T_{13}] resulted in maximum ascorbic acid (7.34 mg/100 g) fallowed by four sprays [T_{12} (7.17 mg/100 g)]. Among chelated calcium sprays the maximum ascorbic acid (7.01 mg/100 g) was recorded in five times spray [T_8] followed by 6.53 mg/100 g in four times spray [T_7] and in three times spray [T_6 (5.61 mg/100 g)]. These treatments were significantly higher than control.

4.3.6. Anthocyanin content

From the Table 4, it is clear that the various treatments under study differed significantly with respect to their effect on anthocyanin content. The treatment of four sprays of $CaCl_2$ [T_{12}] scored the maximum value for anthocyanin content (11.21 mg/100 g) which was statistically at par with chelated-Ca sprayed four times [T_7 (11.16 mg/100 g)], five sprays of $CaCl_2$ [T_{13} (11.15 mg/100 g)] and chelated-Ca sprayed five times [T_8 (11.03 mg/100 g)]. The lowest value of 9.12 mg/100 g was found in T_3 [GA_3 @ 100ppm] which was statistically lower than values of 9.40, 9.46, 9.48 and 9.50 of T_2, T_9, T_1, and T_{10} treatments respectively.

4.3.7. Organoleptic rating

The data pertaining to organoleptic rating for overall acceptability with respect to colour, taste, flavour and aroma in Table 4 reveals that foliar sprays of GA_3, Applin, $CaCl_2$ and chelated-Ca at different concentrations or different number of sprays resulted in significant effect on sensory evaluation score. Maximum score was recorded in T_8 [chelated calcium sprayed five times] with an overall score of 4.47 which was at par with (4.40) T_{12} [$CaCl_2$ sprayed four times]. All treatments have shown better acceptability than control [T_1 (3.24)]. With chelated-Ca the organoleptic rating kept on increasing with increasing in number of sprays whereas $CaCl_2$ decreased organoleptic score under five sprays over four sprays.

4.4. Nutrients status of leaves

4.4.1. Nitrogen

It is evident from the data presented in Table 5 that foliar sprays of GA_3 and Applin at different concentrations enhanced leaf nitrogen content and the increase was found linear with the concentration, whereas calcium sprays showed insignificant decrease in leaf nitrogen. The highest nitrogen status (2.490 %) was recorded in treatment T_{15} [Applin @ 2.5 ml/L] which was significantly higher than control [T_1 (1.939 %)] and the lowest value (1.919 %) in T_{13} [$CaCl_2$ sprayed five times] was at par with the control.

4.4.2. Potassium

It is evident from the data presented in Table 5 that leaf potassium content was significantly increased by foliar sprays of GA_3 and Applin. $CaCl_2$ at higher number of sprays (3 sprays onward) decreased leaf K significantly whereas less number of sprays and all sprays of chelated-Ca decreased leaf K insignificantly. The highest potassium (1.783 %) was recorded in treatment T_{15} [Applin @ 2.5 ml/L] followed by T_{14} [Applin @ 1.5ml/L (1.652 %)]. The lowest leaf potassium (1.115 %) was observed in $CaCl_2$ applied thrice [T_{11}] which was at par with all

Table-5 Effect of gibberellic acid, Applin and calcium foliar sprays on leaf nutritional status of apple.

Treatments		N (%)	K (%)	Ca (%)	Mg (%)
T_1	Control	1.939	1.225	1.030	0.230
T_2	GA_3 @ 50 ppm	2.040	1.428	1.014	0.250
T_3	GA_3 @ 100 ppm	2.103	1.595	0.995	0.281
T_4	Chelated Ca @ 0.1 %,1 spray	1.979	1.223	1.029	0.236
T_5	Chelated Ca @ 0.1 %, 2 sprays	1.964	1.196	1.049	0.233
T_6	Chelated Ca @ 0.1 %, 3 sprays	1.959	1.197	1.189	0.222
T_7	Chelated Ca @ 0.1 %, 4 sprays	1.935	1.192	1.169	0.223
T_8	Chelated Ca @ 0.1 %, 5 sprays	1.930	1.194	1.179	0.222
T_9	$CaCl_2$ @ 0.3 %, 1 spray	1.923	1.228	1.039	0.231
T_{10}	$CaCl_2$ @ 0.3 %, 2 sprays	1.930	1.205	1.109	0.226
T_{11}	$CaCl_2$ @ 0.3 %, 3 sprays	1.928	1.115	1.201	0.216
T_{12}	$CaCl_2$ @ 0.3 %, 4 sprays	1.926	1.117	1.198	0.217
T_{13}	$CaCl_2$ @ 0.3 %, 5 sprays	1.919	1.116	1.206	0.215
T_{14}	Applin @ 1.5 ml/L	2.381	1.652	1.089	0.343
T_{15}	Applin @ 2.5 ml/L	2.490	1.783	1.109	0.387
C.D. ($p \leq 0.05$)		**0.050**	**0.107**	**0.060**	**0.009**

sprays except for single spray of either of the calcium formulation that is chelated-Ca applied once [T_4 (1.223 %)] and $CaCl_2$ applied once [T_9 (1.228 %)].

4.4.3. Calcium

It is evident from the data presented in Table 5 that foliar sprays of GA_3 or Applin at different concentrations or different number of sprays of $CaCl_2$ and chelated-Ca showed a significant effect on calcium content of the leaves. The highest calcium (1.206 %) was recorded in treatment $CaCl_2$ sprayed five times [T_{13}] which was statistically at par with 1.089 percent under Applin @ 1.5 ml/L [T_{14}] and 1.109 percent under Applin 2.5 ml/L [T_{15}].

Among $CaCl_2$ sprays the maximum calcium content (1.206 %) was recorded in treatment T_{13} [$CaCl_2$ sprayed five times] which was statistically at par with $CaCl_2$ sprayed four times [T_{12} (1.198 %)] and $CaCl_2$ sprayed thrice [T_{11} (1.201)]. Among chelated-Ca sprays the highest value of 1.189 percent was recorded in T_6 [chelated-Ca sprayed thrice] which was statistically at par under chelated-Ca sprayed four times [T_7 (1.169)] and chelated-Ca sprayed five times [T_{13} (1.179 %)]. This data also represents non-significant difference by the two sources of calcium on leaf calcium content.

4.4.4. Magnesium

Significant effect on leaf magnesium (Mg) was obtained by different chemical sprays (Table 5). The highest leaf magnesium (0.387 %) was recorded in treatment T_{15} [Applin @ 2.5 ml/L] fallowed by T_{14} [Applin @ 1.5 ml/L (0.343 %)]. The lowest leaf magnesium (0.215 %) was observed in $CaCl_2$ sprayed five times [T_{13}] which was very close to 0.216 percent and 0.217 percent under T_{11} [$CaCl_2$ sprayed thrice] and T_{12} [$CaCl_2$ sprayed four times] respectively. Chelated calcium sprays did not affect leaf Mg level significantly.

4.5. Nutrients status of fruits

4.5.1. Nitrogen

The data presented in Table 6 reveals that only higher concentration of foliar sprays of GA_3 and both concentration of Applin had significant effect on fruit nitrogen. The highest value was for T_{15} [Applin @ 2.5 ml/L (0.474 %)] and the lowest (0.341 %) in T_{13} [$CaCl_2$ sprayed five times] which was statistically at par with T_1 [control]. The data also reveals that all the calcium sprays had insignificant effect on fruit nitrogen, however the fruit nitrogen showed a decreasing trend with the number of sprays but was statistically non significant.

4.5.2. Potassium

It is evident from the data presented in Table 6 that fruit potassium content was significantly affected by foliar sprays of GA_3, Applin, $CaCl_2$ and chelated-Ca. The highest fruit potassium (0.788 %) was recorded in treatment T_{15} [Applin @ 2.5 ml/L] which was statistically at par with T_3 [GA_3 @ 100 ppm] and both were significantly higher than control [T_1 (0.653 %)]. The lowest fruit potassium (0.551 %) was observed in $CaCl_2$ sprayed five times [T_{13}].

Among the calcium sprays, $CaCl_2$ resulted more decrease in fruit potassium as compared to chelated calcium sprays. The data also indicates that fruit potassium decreased with increase in number of sprays. Among $CaCl_2$ sprays, $CaCl_2$ sprayed five times [T_{13}] resulted in minimum fruit potassium (0.521 %) fallowed by four sprays [T_{12}] (0.585 %). Among chelated calcium sprays the minimum fruit potassium (0.608 %) was recorded in chelated calcium applied five times [T_8] followed by chelated calcium applied four times [T_7 (0.623 %)] and chelated calcium applied thrice [T_6] (0.635 %). These treatments were significantly lower than control.

Table-6 Effect of gibberellic acid, Applin and calcium foliar sprays on fruit nutritional status of apple.

Treatments	N (%)	K (%)	Ca (%)	Mg (%)
T_1 Control	0.354	0.653	0.026	0.028
T_2 GA_3 @ 50 ppm	0.364	0.751	0.024	0.030
T_3 GA_3 @ 100 ppm	0.386	0.778	0.023	0.028
T_4 Chelated Ca @ 0.1 %,1 spray	0.354	0.648	0.028	0.030
T_5 Chelated Ca @ 0.1 %, 2 sprays	0.356	0.650	0.032	0.028
T_6 Chelated Ca @ 0.1 %, 3 sprays	0.353	0.635	0.037	0.027
T_7 Chelated Ca @ 0.1 %, 4 sprays	0.350	0.623	0.038	0.025
T_8 Chelated Ca @ 0.1 %, 5 sprays	0.349	0.608	0.040	0.024
T_9 $CaCl_2$ @ 0.3 %, 1 spray	0.354	0.656	0.029	0.029
T_{10} $CaCl_2$ @ 0.3 %, 2 sprays	0.358	0.648	0.033	0.028
T_{11} $CaCl_2$ @ 0.3 %, 3 sprays	0.351	0.608	0.035	0.025
T_{12} $CaCl_2$ @ 0.3 %, 4 sprays	0.349	0.585	0.040	0.022
T_{13} $CaCl_2$ @ 0.3 %, 5 sprays	0.348	0.551	0.044	0.021
T_{14} Applin @ 1.5 ml/L	0.436	0.765	0.030	0.034
T_{15} Applin @ 2.5 ml/L	0.474	0.788	0.032	0.037
C.D. ($p \leq 0.05$)	**0.013**	**0.017**	**0.003**	**0.003**

4.5.3. Calcium

It is obvious from the data presented in Table 6 that fruit calcium content was significantly affected by foliar sprays of GA_3, Applin, $CaCl_2$ and chelated-Ca. The highest fruit calcium (0.044 %) was witnessed in $CaCl_2$ sprayed five times [T_{13}] and the lowest fruit calcium (0.023 %) was observed in GA_3 @ 100 ppm [T_3].

Among the calcium sprays, $CaCl_2$ sprays resulted more increase in fruit calcium as compared to chelated calcium sprays. The data also indicates that fruit calcium increased with increase in number of sprays. Among $CaCl_{2,}$ sprayed five times [T_{13}] resulted in highest fruit calcium (0.044 %) and was followed by four sprays [T_{12}] (0.040 %). Among chelated calcium sprays the maximum value of fruit calcium (0.040 %) was recorded in chelated calcium applied five times [T_8] followed by (0.038 %) chelated calcium applied four times [T_7] and then by chelated calcium applied thrice [T_6 (0.037 %)]. These treatments were considerably higher than control [T_1 (0.026)].

4.5.4. Magnesium

As clear from the data presented in Table 6 that fruit magnesium content was only enhanced significantly by Applin sprays and decreased by higher number of Ca sprays. The highest fruit magnesium (0.037 %) was witnessed in T_{15} [Applin @ 2.5 ml/L] and the lowest (0.021 %) in T_{13} [$CaCl_2$ sprayed five times] which was at par with (0.022 %) in T_{12} [$CaCl_2$ sprayed four times]. Among the calcium sprays, $CaCl_2$ sprays resulted decrease in fruit magnesium by three, four or five sprays whereas chelated calcium sprays decreased fruit Mg by either four or five sprays.

4.6. Fruit firmness

4.6.1. Firmness at harvest

Foliar sprays of GA_3, Applin, $CaCl_2$ and chelated-Ca at different concentrations or different number of sprays exhibited significant effect on fruit firmness as shown in Table 7. The trees sprayed with $CaCl_2$ five times [T_{13}] produced more firm fruits with a fruit firmness of 8.65 kg/cm^2. This treatment was significantly superior to control. The lowest fruit firmness (6.94 kg/cm^2) was observed in T_4 [chelated-Ca sprayed once] which was very close to 6.95 kg/cm^2 under T_1 [control] and 6.99 kg/cm^2 under T_9 [$CaCl_2$ sprayed once].

The data also indicates that firmness increased with the increase in concentration of Applin and GA_3 and number of sprays of chelated-Ca and $CaCl_2$. Among $CaCl_2$, the spray at 0.3 percent, five times resulted in highest fruit firmness (8.65 kg/cm^2), which was followed in 0.3 percent $CaCl_2$ sprayed four times (8.43 kg/cm^2). These treatments were significantly superior over control. Among chelated-Ca, the highest fruit firmness (8.23 kg/cm^2) was recorded by 0.1 percent concentration applied five times, followed in 0.1 percent chelated-Ca applied four times (7.81 kg/cm^2), which were significantly more than the control.

4.6.2. Firmness at 15 DAS

With the advancement of storage period the fruit firmness of all the treatments decreased (Fig. 2). Fruit firmnesses recorded fifteen days after storage (15 DAS) as affected by foliar sprays of GA_3, Applin, $CaCl_2$ and chelated-Ca at different concentrations or numbers of sprays are presented in Table 7. The trees sprayed with $CaCl_2$ five times (T_{13}) retained highest firmness (8.16 kg/cm^2) which was significantly higher than control (6.08 kg/cm^2) and all other treatments. The lowest fruit firmness of 6.08 kg/cm^2 was observed in control which was statistically at par with T_4 (6.16 kg/cm^2) and T_9 (6.26 kg/cm^2) but significantly lower than any other treatments.

Table-7 Effect of gibberellic acid, Applin and calcium foliar sprays on fruit firmness (kg/cm^2) under ambient conditions of storage of apple.

Treatments		At harvest	At 15 DAS	At 30 DAS	At 45 DAS
T_1	Control	6.95	6.08	4.96	3.52
T_2	GA_3 @ 50 ppm	7.20	6.40	5.27	3.60
T_3	GA_3 @ 100 ppm	7.33	6.49	5.32	3.64
T_4	Chelated Ca @ 0.1 %,1 spray	6.94	6.16	5.10	3.68
T_5	Chelated Ca @ 0.1 %, 2 sprays	7.06	6.36	5.28	3.92
T_6	Chelated Ca @ 0.1 %, 3 sprays	7.20	6.57	5.56	4.23
T_7	Chelated Ca @ 0.1 %, 4 sprays	7.81	7.21	6.27	4.97
T_8	Chelated Ca @ 0.1 %, 5 sprays	8.23	7.68	6.78	5.53
T_9	$CaCl_2$ @ 0.3 %, 1 spray	6.99	6.26	5.16	3.75
T_{10}	$CaCl_2$ @ 0.3 %, 2 sprays	7.13	6.49	5.41	4.04
T_{11}	$CaCl_2$ @ 0.3 %, 3 sprays	7.69	7.09	6.08	4.77
T_{12}	$CaCl_2$ @ 0.3 %, 4 sprays	8.43	7.87	6.95	5.67
T_{13}	$CaCl_2$ @ 0.3 %, 5 sprays	8.65	8.16	7.29	6.06
T_{14}	Applin @ 1.5 ml/L	7.23	6.39	5.22	3.78
T_{15}	Applin @ 2.5 ml/L	7.44	6.63	5.43	3.93
C.D. ($p \leq 0.05$)		**0.13**	**0.14**	**0.11**	**0.10**

It is also been observed that among the two calcium sources, $CaCl_2$ retained higher fruit firmness as compared to chelated-Ca. The data also tells that after fifteen days of storage higher fruit firmness was retained with the increase in number of Ca sprays.

4.6.3. Firmness at 30 DAS

Further decline of firmness was found with the advancement of storage period. It is clear from the data presented in Table 7 that fruit firmness was significantly affected at thirty DAS, by foliar sprays of GA_3, Applin, $CaCl_2$ and chelated-Ca. The firmest fruits (7.29 kg/cm^2) were witnessed in calcium chloride sprayed five times [T_{13}] and the softest ones (4.96 kg/cm^2) in T_1 [control]. T_{14} [Applin @ 1.5 ml/L] which was at par with (5.10 kg/cm^2) in T_4 [chelated-Ca sprayed once] and (5.16 kg/cm^2) in T_9 [$CaCl_2$ sprayed once]. Among the calcium sprays, $CaCl_2$ sprays exhibited good retention of fruit firmness as compared to chelated calcium sprays.

4.6.3. Firmness at 45 DAS

The data pertaining to firmness presented in Table 7 reveals that all the chemicals offered significant resistance against deterioration of firmness after forty five days of storage at ambient conditions. The maximum fruit firmness of 6.06 kg/cm^2 was recorded in the fruits of calcium chloride sprayed five times [T_{13}] which was statistically higher than all other treatments. The minimum (3.52 kg/cm^2) fruit firmness was observed under T_1 [control]. The table also discloses that among the calcium sprays, $CaCl_2$ sprays resisted better to the deterioration of firmness in fruits as compared to chelated calcium sprays.

4.7. Physiological weight loss

It is noticeable from the data presented in Table 8 and Fig. 3 that the foliar sprays of GA_3, Applin, $CaCl_2$ and chelated-Ca expressed significant effect on physiological weight loss of fruits during the storage.

After fifteen days of storage (15 DAS) the maximum weight loss (3.55 %) was recorded under the treatment of GA_3 @ 100 ppm which was significantly higher than any other treatments including control (3.09 %). Treatments T_2 (3.17 %), T_4 (2.81 %), T_9 (2.70 %), T_{14} (2.95 %) and T_{15} (3.14 %) were statistically at par with the control and with one another. The minimum weight loss of fruits at fifteen DAS (0.82 %) was observed in T_{13} [$CaCl_2$ applied five times], which was significantly lower than any other treatments.

Calcium sprays were found instrumental in depressing physiological loss in weight. Fruits treated with calcium chloride five times, [T_{13}] resulted in minimum loss in weight, to the tune of 0.82 percent in comparison to 3.09 percent when no hormone/nutrient/hormone nutrient mixture (control) was used. The treatment T_{13} was followed by chelated calcium sprayed five times which restricted physiological loss in weight upto 1.32 percent after fifteen DAS. Chelated calcium sprayed once [T_4] or twice [T_5] were statistically at par with each other. The data also indicates that weight loss of fruits at 15 DAS decreased with the increase in number of calcium sprays.

With the advancement of storage period, there was an increase in weight loss of fruit under all the treatments. After thirty days of storage the treatment consisting five sprays of calcium chloride was found best in reducing physiological loss in weight which recorded 1.50 percent followed by $CaCl_2$ four time spray treatment which recorded 2.23 percent weight loss. The maximum fruit loss (5.44 %) was found in T_{15} [Applin @ 2.5 ml/L] followed by GA_3 @ 100 ppm [T_3 (5.11 %)] both were statistically higher than control (4.16 %).

Table-8 Effect of gibberellic acid, Applin and calcium foliar sprays on physiological loss in weight (%) of apple under ambient conditions of storage.

Treatments		15 DAS	30 DAS	45 DAS
T_1	Control	3.09	4.16	7.78
T_2	GA_3 @ 50 ppm	3.17	4.74	8.02
T_3	GA_3 @ 100 ppm	3.55	5.11	8.20
T_4	Chelated Ca @ 0.1 %,1 spray	2.81	3.98	7.77
T_5	Chelated Ca @ 0.1 %, 2 sprays	2.50	3.19	7.50
T_6	Chelated Ca @ 0.1 %, 3 sprays	2.51	3.21	6.59
T_7	Chelated Ca @ 0.1 %, 4 sprays	2.07	3.44	6.19
T_8	Chelated Ca @ 0.1 %, 5 sprays	1.32	2.98	6.05
T_9	$CaCl_2$ @ 0.3 %, 1 spray	2.70	4.35	7.73
T_{10}	$CaCl_2$ @ 0.3 %, 2 sprays	2.18	3.70	6.96
T_{11}	$CaCl_2$ @ 0.3 %, 3 sprays	2.22	3.12	6.38
T_{12}	$CaCl_2$ @ 0.3 %, 4 sprays	1.20	2.23	4.95
T_{13}	$CaCl_2$ @ 0.3 %, 5 sprays	0.82	1.50	3.94
T_{14}	Applin @ 1.5 ml/L	2.95	5.05	8.76
T_{15}	Applin @ 2.5 ml/L	3.14	5.44	8.86
C.D. ($p \leq 0.05$)		**0.36**	**0.27**	**0.34**

After forty five days of storage (45 DAS) there was an increase in weight loss of fruit under all the treatments and again calcium chloride at five sprays served as best treatment in reducing physiological loss in weight which recorded with cumulative physiological loss in weight (CPLW) value of 3.94 percent followed by four time $CaCl_2$ spray treatment which recorded 4.95 percent CPLW. The data also reveals that the fruits of the chelated-Ca sprayed treatments showed dramatic increase in loss of weight. Among the chelated calcium sprays the maximum CPLW was noticed (7.77 %) in T_4 [chelated-Ca sprayed once] which was at par with (7.50 %) T_5 [chelated-Ca sprayed twice] and the minimum loss of weight was noticed (6.05 %) in T_8 [chelated-Ca sprayed five times] which was at par with (6.19 %) T_7 [chelated-Ca sprayed four times]. The maximum CPLW after 45 DAS, (8.86 %) was found in Applin @ 2.5 ml/L [T_{15}] which was at par with (8.76 %) found in Applin @ 1.5 ml/L [T_{14}] followed by GA_3 @ 100 ppm [T_3 (8.20 %)] and these were statistically higher than control [T_1 (7.78 %)].

4.8. Physiological disorders

Visual examination of fruits at harvest for watercore; a disorder in which water soaked areas (plate. 2) of cortex become translucent revealed that the disorder was significantly eliminated with calcium sprays whereas GA_3 and Applin had increased the same insignificantly to significantly with lower to higher concentrations (Table 9). The maximum watercore was found in T_{15} [Applin at 2.5 ml/L (10.00 %)] followed by T_{14} [Applin at 1.5 ml/L (7.50 %)], GA_3 at 100 ppm [T_3 (7.50 %)], GA_3 at 50 ppm [T_3 (5.00 %)] and control [T_1 (5.00 %)].

Examination of stored fruits after every fifteen days for depressed brown lesions (Bitter pit) in the skin of the fruit (plate. 3) shows that the applications of calcium chloride and chelated calcium significantly eliminated the disorder whereas GA_3 and Applin increased and the increase was linear with their concentration applied. Bitter pit incidence was insignificant at fifteen days after storage (15 DAS) and showed significant enhancement only after 30 DAS with

Table- 9 Effect of gibberellic acid, Applin and calcium foliar sprays on physiological disorders of apple.

Treatments	Water core (%) (0 DAS)	Bitter pit (%) at 15 DAS	Bitter pit (%) at 30 DAS	Bitter pit (%) at 45 DAS
T_1	5.00 (2.16)	2.50 (1.58)	7.50 (2.74)	10.00 (3.05)
T_2	5.00 (2.16)	2.50 (1.58)	2.50 (1.58)	12.50 (3.63)
T_3	7.50 (2.74)	2.50 (1.58)	7.50 (2.74)	15.00 (3.95)
T_4	5.00 (2.16)	2.50 (1.58)	2.50 (1.58)	7.50 (2.74)
T_5	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	2.50 (1.58)
T_6	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_7	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_8	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_9	0.00 (1.00)	0.00 (1.00)	2.50 (1.58)	7.50 (2.74)
T_{10}	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_{11}	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_{12}	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_{13}	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)
T_{14}	7.50 (2.74)	0.00 (1.00)	5.00 (2.16)	12.50 (3.63)
T_{15}	10.00 (3.05)	2.50 (1.58)	5.00 (2.16)	15.00 (3.95)
C.D. ($p \leq 0.05$)	**4.81 (1.11)**	**NS (NS)**	**5.02 (1.16)**	**6.69 (1.23)**

***Values in parenthesis are square root transformed values.**

maximum percentage value of 7.50 in case of control and Applin applied at 2.5 ml/L. With the advent of storage period upto 45 DAS the disorder was greatly increased. The maximum percentage (15.00 %) of fruits affected by bitter pit were in T_{15} [Applin @ 2.5 ml/L] at forty five days after storage and same was the value in case of GA_3 @ 100 ppm. The single sprays of the calcium sources didn't resist well after 45 DAS for the disorder whereas other number of sprays of calcium (2-5 sprays of either Ca source) significantly eliminated the disorder.

4.9. Return bloom

Data (Table 10) regarding flowering density of 2016, shows insignificant difference in the trees with an average of 13.35 FC/cm^2 BCSA (flower clusters/ cm^2 branch cross section area) which were to be sprayed with chemicals. Table 10 also signifies that return bloom was affected by varied foliar applications of GA_3, Applin, $CaCl_2$ and chelated-Ca. Taking control as reference the return bloom of 2017 (year after sprays) was decreased compared to the previous year return bloom.

It was found that the highest return bloom after the year of spray was recorded in trees under T_{15} [Applin at 2.5 ml/L (15.71 FC/cm^2 BCSA)] and lowest was recorded in trees under T_3 [GA_3 at 100 ppm (12.13 FC/cm^2 BCSA)]. Among the calcium sprays, $CaCl_2$ resulted more increase in return bloom as compared to chelated calcium sprays. The data also indicates that return bloom was increased with increase in number of sprays. Among $CaCl_2$, trees sprayed $CaCl_2$ five times [T_{13}] resulted in maximum return bloom (14.06 FC/cm^2 BCSA) followed by four sprays [T_{12}] (13.98 FC/cm^2 BCSA). These two treatments were statistically at par with each other but higher than control. Among chelated calcium sprays the maximum return bloom (13.86 FC/cm^2 BCSA) was recorded in chelated calcium applied five times [T_8] which was at par with 13.78 FC/cm^2 BCSA under chelated calcium applied four times [T_7] but significantly higher than control.

Table-10 Effect of gibberellic acid, Applin and calcium foliar sprays on return bloom (flower clusters/cm^2 BCSA).

Treatments		FC/ cm^2 BCSA in 2016	Return bloom (FC/ cm^2 BCSA) in 2017
T_1	Control	13.34	12.86
T_2	GA_3 @ 50 ppm	13.43	12.66
T_3	GA_3 @ 100 ppm	13.34	12.13
T_4	Chelated Ca @ 0.1%,1 spray	13.47	13.00
T_5	Chelated Ca @ 0.1%, 2 sprays	13.31	13.20
T_6	Chelated Ca @ 0.1%, 3 sprays	13.35	13.45
T_7	Chelated Ca @ 0.1%, 4 sprays	13.33	13.78
T_8	Chelated Ca @ 0.1%, 5 sprays	13.31	13.86
T_9	$CaCl_2$ @ 0.3%, 1 spray	13.35	12.88
T_{10}	$CaCl_2$ @ 0.3%, 2 sprays	13.27	12.90
T_{11}	$CaCl_2$ @ 0.3%, 3 sprays	13.38	13.61
T_{12}	$CaCl_2$ @ 0.3%, 4 sprays	13.33	13.98
T_{13}	$CaCl_2$ @ 0.3%, 5 sprays	13.27	14.06
T_{14}	Applin @ 1.5ml/L	13.39	15.36
T_{15}	Applin @ 2.5ml/L	13.41	15.71
C.D. ($p \leq 0.05$)		**NS**	**0.30**

***FC= flower clusters**

***BCSA= Brach cross section area= (Girth)^2/4π**

Chapter-5

DISCUSSION

The scientific interpretations of the results obtained in the present investigations entitled 'Effect of gibberellic acid, Applin and calcium foliar sprays on chemo-metric attributes of apple (*Malus* x *domestica* Borkh.)' are given below under the following heads.

5.1. Physical characteristics

5.1.1. Fruit size (length, diameter and L/D ratio)

Perusal of the data presented in Table 1 shows that the application of different concentrations gibberellic acid and Applin and different number of sprays of chelated calcium and of calcium chloride have significant effect on fruit length, diameter and fruit shape index that is ratio between fruit length and fruit diameter.

Increase in fruit size by GA_3 is attributed to the reason that GA_3 is involved in cell division and cell elongation that leads to increase in fruit size (Liu *et al.,* 2006 and Valero, 2010). GA_3 is reported to provide growth by escalating plasticity of the cell wall followed by the hydrolysis of starch into sugars which reduces the cell wall potential, resulting in the entry of water into the cell and causes cell elongation (Valero, 2010). Whereas the fruit size increment by Applin application could be attributed directly to the auxins, cytokinins and gibberellic acids present in it which act as early and rapid cell division in the fruitlet and also on subsequent growth and the nutrients present within it quest the nutrients requirement. Thus, the fruit becomes bigger in size due to the increased cells, which are able to attract so much water, minerals and carbohydrates that enable the fruit to expand to large size (Kano, 2003). Results in hand are in line with those found by Curry and Green (1993) on apples, Mervet *et al.* (2001) on

‘Thompson Seedless’ grapes and Fathi *et al.* (2011) on ‘Costata’ persimmon. CPPU a cytokinin, also helps in activating the biosynthesis of proteins, RNA and DNA, leading to the increase in fruit weight, length and diameter (El-Gendy *et al.,* 2006). These results are in harmony with those obtained by Benjawan *et al.* (2006), Ahmad *et al*. (2012), Navarro *et al.* (2001), Akinci *et al.* (2014), Hossainn (2015) and Wani *et al*. (2017).

The increase in fruit size due to calcium sprays could be attributed directly to the fact that calcium is required for cell elongation and cell division (Burstrom, 1968). There is evidence that auxin induced H^+ secretion of meristematic cells is related to the presence of Ca^{2+} (Mamie, 1983). Kadir (2005) observed improvement in terms of fruit size, weight and appearance of apple fruits with foliar sprays of calcium chloride and reported that increase in fruit weight and size was attributed to a linear increase in calcium concentrations of fruits and leaves due to calcium applications. Mursec (2004) noted that foliar sprays of Ca had a significant effect on the Ca content of the fruit, which in turn significantly affected fruit weight and size. Similar results were obtained by Bhat *et al.* (2009) due to $CaCl_2$ sprays in pear *cv.* Bartlett in Kashmir, Raese and Drake (1993 & 2002) and Hagag *et al.* (2011) in different fruit crops. Scarcity of Ca decreases plant height by declining mitotic activity in the terminal meristem (Nelson and Niedziela, 1998). Accumulation of Ca in leaves enhances the Ca and other minerals content of leaves and may have contributed for improved cell division and promoting root growth, which boosts nutrient absorption (Sathya *et al.,* 2010). Thus, the application of calcium increases tree growth (Dole and Wilkins, 2005). However, non significant effect on fruit size by fifth spray over four sprays of chelated- Ca and $CaCl_2$ might be because in case of more sprays of calcium increasing higher levels of calcium in fruit and cell wall becomes too rigid thereby, inhibiting cell elongation (Ushrom, 1969) and the timing of spray at latter stages of growth might have made unfruitful effect with regard to size improvement and the usefulness of calcium is not always consistent (Rosen *et al.,* 2006).

The perusal of data in Table 1 also reveals that foliar sprays of GA_3, Applin, $CaCl_2$ and chelated-Ca at different concentrations or different number of sprays exhibited significant effect on fruit L/D ratio which was minimum under control [T_1 (0.98)] and maximum under GA_3 @ 100 ppm [T_3 (1.02)]. Among Ca sprays fruit maximum L/D ratio of 1.00 was under four or five sprays of either of the Ca sources. The shape of the fruit is mainly affected by plant genotype, than the environment or nutritional status. Gibberellins have long been known to increase typeness. The results are in harmony with Williams and Stahly (1969) who reported that cytokinins together with gibberellins influence fruit shape in apples by increasing the L/D ratio. The increased L/D ratio was also found by Akinci *et al*. (2014) in 'Fuji' apple by application of BA+GA_{4+7} and Wani *et al.* (2017) in ''Red Delicious' apple by varied applications of growth hormones and nutrients as well as the combinations of growth hormones and nutrients. Kadir (2005) reported improvement of fruit L/D ratio by foliar applications of $CaCl_2$ in 'Jonathan' apple and Marzouk and Kassem (2011) in 'Thomson Seedless' grape by sprays of $CaCl_2$.

5.1.2. Colour

The applications of calcium chloride, chelated-Ca and GA_3 significantly influenced the fruit colour, whereas Applin did not influence colour score. GA_3 retards colour development by delaying chlorophyll degradation and carotenoid synthesis as well as fruit growth rate (Martinez *et al*., 1996).The stimulating effect on development of fruit colour with the use of chelated calcium and calcium chloride as preharvest sprays is apparently opposite to its general role in preservation of cellular organization and is not well understood. High Ca content might have counteracted the detrimental effect of high nitrogen to colour formation (Shear and Faust, 1975; Sharma, 1976; Neilsen *et al.,* 1999; Saure, 1990) and colour development may be an attendant physiological manifestation of this relationship. The better reason might be that calcium can upregulate the entire flavonoid pathway, particularly anthocyanin and proanthocyanidin biosynthetic genes (Xu *et al.,* 2014). Increasing evidence indicates that calcium plays an import role in fruit anthocyanin biosynthesis and hence to colour development (Vitrac *et al*., 2000; Gollop *et al*., 2002; DeFalco *et al*., 2010; Kudla *et al*., 2010; Xu *et al*., 2014). An indirect involvement of calcium in colour development has been shown by Weis *et al.* (1980) with 'McIntosh' apple. They reported that massive calcium chloride spray caused marginal necrosis and cupping of leaves which in turn increased light penetration into tree canopy and greatly increased red colouration of the fruit. Bhat and Farooqui (2004) obtained better coloured fruits of apple *cv.* Red Delicious with preharvest spray of $CaCl_2$. Colour improvement by Ca sprays was also reported in peach (Mangat, 1989: Simnani, 1995) and in 'Red Delicious' apple (Tripathi and Bhargava, 1993; Raese and Drake, 2000).

5.2. Market acceptability

5.2.1. Fruit grading

It is evident from the data presented in Table 2 that foliar sprays of GA_3, Applin, $CaCl_2$ and chelated-Ca at different concentrations or at different number of sprays exhibited a significant effect on different conventional fruit grades of apple. The maximum (75.21 %) premium grade 'A' fruit production was obtained from trees sprayed with $CaCl_2$ five times [T_{13}] which was at par with those sprayed with chelated-Ca five times. The minimum of this grade was recorded in control [T_1]. In case of grade 'B' fruits, the highest value of 20.58 percent was recorded in treatment T_{11} [$CaCl_2$ applied thrice] close to 20.56 percent with T_5 [Chelated-Ca applied twice] but higher than control (17.80 %). However, the highest value of grade 'C' was observed in control [T_1] and the lowest in T_{15} [$CaCl_2$ applied five times].

The red colour of apple skin is one of the important grading standards set for marketing. Poor skin colour at commercial harvest often causes serious economic losses to apple growers. The other parameters which determine different grades are fruit size, fruit finish, bruising, disorders and incidence of fruit diseases which reflects the overall appearance and hence grading. The observed data is well in accordance to these points. Nutrients in association of plant growth regulators increase better graded yield and the use of growth elicitors and minerals in this respect have been reported on apricot, pear and apple (Eissa *et al.,* 2008; Ali *et al*., 2010; Abd- El-Messeih *et al*., 2010). Widmer *et al.* (2006) found that combined application of urea and boron or separate application of urea and born for five years did not cause any significant improvement in the fruit grade of apple cultivar ‘ Red Delicious’. Ali *et al.* (2014) also reported increase in market yield in ‘Florida King’ peach by application of combination of hormones (salicylic acid and putrescine) and nutrients ($CaCl_2$), which resulted in greater price in the market, since large size fruits are more appreciated in the market.

5.2.2. Organoleptic rating

Organoleptic rating was significantly influenced by various treatments. Maximum organoleptic rating was achieved by chelated calcium sprayed five times and the fruits were marked ‘Excellent’ and minimum was recorded in control. The increase in organoleptic rating with GA_3 and Applin may be attributed to the increase in their TSS, total sugars, size and sweetness index. Improved fruit typeness may have played role in case of GA_3 spray. Gill and Bal (2009) reported that the palatability rating of fruits was increased by various foliar sprays of NAA (40 ppm), KNO_3 (1.5 %), $ZnSO_4$ (0.4 %) and $ZnSO_4$ (0.5 %) treatments as compared to control. Singh *et al.* (1984) reported the effectiveness of calcium as pre- harvest treatment on ‘Amrapali’ mango in enhancing organoleptic rating. Raja *et al.* (2015) reported three sprays of 1.5 percent $CaCl_2$ resulted in maximum sensory score in peach *cv.* Shah-I-Punjab. The findings are in agreement with those of Gupta and Mehta (1988), Ganai (2006), Bhat *et al.* (2009), Simnani (2012) and Raffo *et al*. (2014).

5.3. Chemical characteristics

5.3.1. Soluble solids concentrate

The results of the present study indicate that GA_3, Applin, chelated calcium and calcium chloride sprays resulted in significantly higher soluble solids concentrate (SSC) than control. The increase in SSC by GA_3 and Applin might be attributed to the enhanced photosynthetic efficiency of the leaves and a possible increase in the translocation of assimilates with the application of bioregulators (Brahmachari and Rani, 2001). Wani *et al*. (2017) reported enhancement in fruit SSC by sole application of GA_3 and CPPU and two nutrient formulations Solubor and Horticab as well as combination of these hormones with each other and with the nutrient formulations on 'Red Delicious' apple. These findings are in conformity with Singh (1994), Fallahi *et al.* (1995), Liu *et al.* (2006), Warusavitharana *et al.* (2008), Hossain (2015), Guirguis *et al*. (2010), Kaur *et al.* (2004), Girish and Ananda (2004), Mir *et al*. (1995) and Kupferman (1989).

Higher SSC encouraged by calcium treatments might be owing to lesser utilization of sugars in metabolic processes as an outcome of retarded respiration (Gupta *et al*., 1980). The reduced pace of respiration could also cause accumulation of organic acids which have oxidized at slower rate. Increase in SSC content with calcium chloride sprays have been also reported by Raese and Drake (1993) in apple and pear fruits and Robson *et al.* (1989) in peaches. Similarly, Randhawa *et al.* (1980) and Banday (1996) recorded higher SSC in 'Le Conte' pears with 6 and 8 percent calcium chloride respectively. Kondo and Suthhiwal, (2005) reported that foliar Ca treatment in apple decreased the internal ethylene concentration, while bound Ca concentration in the cell wall of Ca-treated fruits was higher than that of the untreated control contributing for maintain higher SSC content in the Ca treated fruits. Korkmaz *et al*. (2016) also observed that TSS was maximised under 2 percent calcium nitrate in pomegranate *cv.* Hicaznar. These results are in line with those obtained in different fruit crops by Meheriuk *et al.* (1991), Singh *et al.* (2007), Mehta and Jindal (1986) and Gupta *et al.* (1984).

5.3.2. Total sugars

The result reveals that the total sugars was significantly influenced by foliar sprays of GA_3, Applin, chelated- Ca and $CaCl_2$. Maximum content of total sugars (11.92 %) was recorded with treatments T_{15} [Applin @ 2.5ml/L] followed by T_{14} [Applin @ 1.5ml/L (11.82 %)]. The lowest (9.70 %) total sugars content was recorded in T_1 [Control] very close to that of treatment T_4 [Chelated calcium sprayed once].

The increase in sugars may be due to the stimulated translocation of assimilates from leaves through vascular system, facilitation of carbohydrates movement towards sink, stimulation of rate of photosynthesis and activation of enzyme system capable of transformation of organic acids into sugars by gibberellins, auxins and cytokinins (Warusavitharana *et al.,* 2008). Valero (2010) reported that GA_3 also promoted the growth by increasing plasticity of the cell wall followed by the hydrolysis of starch into sugars. The increase in sugar by GA_3 was directly related to the decrease in acidity as well. Increase in sugar content may also be ascribed to translocation of sugars which is enhanced with B, Cu, Mg, S and other nutrients present in Applin (Davenport and Peryea, 1990). These findings are in close consistency with those of Fransisco and Gomez (2000). The findings of Moneruzzaman *et al.* (2013) are also supportive, who reported that GA_3 is the stimulator of invertase enzyme which leads to sugar accumulation in fruits. Enhancement of total sugars by sole as well as combined applications of hormones and nutrients has been also reported in different fruit crops by Kirmani *et al.* (2015), Gurung *et al.* (2016) and Wani *et al.* (2017).

Preharvest calcium treated fruits resulted in significantly elevated levels of total sugars than the fruits of control ones. Both the calcium formulations applied as four sprays during the season recorded significantly superior values for total sugars characteristic of the fruits whereas fifth one increased total sugars insignificantly. Increase in total sugars content with the application of calcium was also reported by Sachdeva (1985); Pant and Tewari (1987) in apple; Singh and Rajput (1991) in mango; Wani (1997) in peach and Bhat *et al.* (2009) in pear. Kondo and Suthhiwal, (2005) reported that foliar Ca treatment helps in maintaining higher total sugars content in the treated fruits. The results are in harmony with Bora *et al.* (2015) and Davarpanah *et al.* (2016)

5.3.3. Acidity and Sweetness index

Table 3 showed that GA_3, Applin and calcium foliar sprays have produced significant differences with respect to acidity and sweetness index. Acidity in apple fruit showed significant decrease with increased concentration of either GA_3 or Applin. The lowest fruit acidity of 0.24 percent was observed with T_3 [GA_3 @ 100 ppm] whereas the highest fruit acidity of 0.32 percent was recorded in $CaCl_2$ applied five times (T_{13}) treatment. The increase in sweetness index in GA_3 and Applin is due to increasing SSC and decrease in the same parameter is due to increase in acidity.

The reduction in acidity percentage of juice accompanied by increased accumulation of total soluble solids content clearly suggests increased catabolisation of organic acids into sugars which also has been suggested earlier by Singh and Sharma (1996). The increase in TSS and decrease in acidity due to GA_3 application may be due to chemical mediated degradation of starch and metabolism of organic acids into soluble sugars. Moti (1971) reported that GA_3 resulted in reduced acid content in 'Perlette', 'Himrod' and 'Gulabi' grapes. These findings are in conformity with those of Marivel and Sundararaj (1968) and Singh (1994).

The applications of calcium chloride and chelated calcium significantly enhanced titratable acidity of the fruits in comparison to control (Table 3). Both the calcium formulations applied as foliar sprays during the growing season recorded significantly superior values for acidity. Increase in number of sprays resulted in increased acidity percent of the fruits and most striking effects for acidity were produced in the treatment comprising 0.3 percent calcium chloride applied five times. This may be credited to the ability of calcium to maintain cellular integrity by controlling membrane permeability as a result of which H^+ ions cannot seep out from the cytosol, thus maintaining elevated levels of acidity. This is in conformity with the findings of Singh (1994); Raese and Drake (1993) in 'D Anjou' pears and Gupta *et al.* (1980) in grapes.

5.3.4. Ascorbic acid

The data presented in Table 4 showed that all the chemicals sprayed have significant effect on ascorbic acid content of apple fruit. Maximum ascorbic acid content (7.34 mg/100 g) was recorded with $CaCl_2$ sprayed five times. Control recorded minimum content of ascorbic acid (4.85 mg/100 g).

The augmented values in ascorbic acid content with Applin and GA_3 can be attributed to the reason that gibberellic acid increased ascorbic acid biosynthesis or to protection of synthesized ascorbic acid from oxidation through inhibition of the action of ascorbic acid oxidase (Kassem *et al.,* 2011). Brahmachari and Rani (2001) also stated that perspective rise in ascorbic acid content of fruit may be due to catalytic activity of GA_3 on its biosynthesis from its precursor glucose-6-phosphte or inhibition of its conversion into dehydroascorbate by enzyme ascorbic acid oxidase or both**.** This is in harmony with those results obtained by Moneruzzaman *et al.* (2013), Ghosh *et al.* (2012), Sofi (2001), Shrivastava *et al.* (1971), Kumar and Chauhan (1990), Sharma *et al.* (2014) and Kirmani *et al.* (2015).

Calcium chloride significantly increased the ascorbic acid (Vitamin C) content of apple fruit. The maximum vitamin C content was obtained with calcium chloride at 0.3 percent sprayed five times. With the increase in number of sprays from either of the sources of Ca ascorbic acid have shown increasing trend. Xie *et al.* (1992) showed a significant positive correlation of vitamin C content in orange *cv.* 'Jinchen' with calcium concentrations in fruit juice. These findings were in harmony with those reported earlier by Pant and Tewari (1987); Bhat *et al.* (1997) in cherry and Kadir (2005); Gyulakhimedov and Gasanova (1990) in apple. Bangerth (1976) obtained increased ascorbic acid content in the fruits of apple, pear and tomato by increasing their calcium content during growth season or even by post harvest application. Prasad *et al.* (2015) showed that ascorbic acid was found maximum with $CaCl_2$ at 2.0 percent concentration in pear *cv.* 'Pathernakh'.

5.3.5. Anthocyanin content

Anthocyanins are phenolic pigments in fruits and vegetables that impart from red to blue coloration. Anthocyanins play a role in fruit and vegetable tolerance to environmental stresses and disease resistance, and promote postharvest quality and shelf-life. Furthermore, anthocyanins are recognized as compounds with potential human health-benefits against oxidative stress mediated diseases (He and Giusti, 2010). Anthocyanin and phenolic compound contents in fruit are affected by genetic, developmental and environmental factors. The expression of anthocyanin biosynthesis structural genes is regulated by internal and external factors including sugar concentration, light, hormones, chilling stress, and nutrient status (Carbone *et al.,* 2009). The results of the present study indicate that maximum content of anthocyanins (11.21mg/100 g) was recorded with treatments T_{12} [$CaCl_2$ sprayed five times] that was very close to that of T_7 [chelate calcium sprayed four times (11.16 mg/100 g)] and T_{13} [$CaCl_2$ sprayed four times

(11.15 mg/100 g)]. The lowest anthocyanin content (9.12 mg/100 g) was recorded in treatment T_3 [GA_3 @ 100 ppm].

The lower content of anthocyanin due to GA_3 and Applin may be because anthocyanin formation appears to be subdued probably by gibberellins. Most external factors and cultural practices appear to modify the sensitivity to light by reducing or increasing, the repression of anthocyanin formation. Because of this Saure (1990) suggested that anthocyanin formation may be promoted directly by reducing GA activity, or indirectly by raising the level of ethylene and/or ABA, which are GA antagonists. Anthocyanin usually coincides with a reduction in chlorophyll and increased concentration of carotenoid (Lancaster, 1992; Reay *et al*., 1998).

The preharvest spray of calcium treatments markedly influenced the anthocyanin content and was found more pronounced with four sprays of calcium chloride and chelated calcium. High nitrogen fertilization seems to be most disadvantageous to color formation if applied late in the season (Saure, 1990). High Ca content might have counteracted the detrimental effect of high nitrogen to colour formation and thus improves anthocyanin formation (Shear and Faust, 1975; Sharma, 1976; Neilsen *et al.,* 1999; Saure, 1990). Calcium is a universal second messenger in the signal transduction pathways of hormones and environmental stimuli (touch, wind, chilling, light, and elicitors) (DeFalco *et al*., 2010; Kudla *et al*., 2010). Increasing evidence indicates that calcium plays an import role in fruit anthocyanin biosynthesis. The calcium signaling pathway was implicated in sucrose-induced anthocyanin accumulation in grapes by activating flavonoid pathway genes (Gollop *et al*., 2002; Vitrac *et al*., 2000). Another reason could be that calcium causes translocation of carbohydrates from leaves to fruits (Simnani, 2012) which might have increased anthocyanin formation. These findings are in accordance with those of Wojcik *et al.* (1999), Pant and Tewari

(1987), Bhat *et al.* (1997), Vitrac *et al.* (2000), Gollop *et al.* (2002) and Xu, (2014).

5.4. Leaf nutritional status

Table 5 indicates leaf nutritional status was influenced by different chemical sprays and leaf nutritional status for T_6, T_7 and T_8 and similarly for T_{11}, T_{12} and T_{13} were at par which could be ascribed to the fact that leaf sampling was done before fourth and fifth sprays for treatments T_7 and, T_{12} and T_8 & T_{13} respectively.

5.4.1. Leaf nitrogen (N)

Foliar nutrient content as influenced by different foliar sprays of GA_3, Applin and Ca shows that leaf nitrogen content increased significantly by GA_3 and Applin whereas the highest leaf nitrogen was recorded when Applin was applied at 2.5 ml/L. The significant increase in leaf nitrogen content in T_{14} and T_{15} can be attributed due to assimilation of nitrogen through N, gibberellins, cytokinins and other nutrients present in Applin. Gibberellins and cytokinins might have intensified leaf ability as nutrient sink (Addicott and Addicott, 1982). The second reason could be the synergetic effect of Mn, Zn, Cu and B present in it (Amiri *et al.,* 2008; Malvi, 2011). The present findings led credence to those of Hasani *et al.* (2012), who concluded that applied Mn increases the concentration of N in pomegranate leaves. Robinson (2006) and Amiri *et al.* (2008) reported significant improvement in nitrogen concentration in leaves with zinc and boron application, singly or in combination.

There was non-significant decrease in fruit nitrogen with calcium sprays this is in accordance with Kapoor (1988) who reported that calcium chloride sprays failed to influence fruit mineral element composition with respect to N.

5.4.2. Leaf potassium (K)

Foliar application of nutrients had a significant influence on leaf potassium content. Significantly higher leaf K content (1.783 %) was noticed in T_{15} and the minimum (1.115 %) was observed under T_{11}. The control recorded 1.225 percent of K which was at par all the sprays of chelated calcium as well as with one, two and three sprays of $CaCl_2$. The significant increase in leaf potassium content under treatments T_{14} and T_{15} can be attributed to the fact that plant growth regulators intensify nutrient sink and enhance protein and nutrient content with respect to nitrogen, phosphorous and potassium (Ptiwari, 2015). Hasani *et al.* (2012) also recorded increase in leaf K content with the application of micronutrients as foliar sprays on Pomegranate. Whereas the decrease in K content was recorded only after three sprays of $CaCl_2$ which can be attributed to the antagonistic effect of Ca. Similar observations were recorded by Koutinas *et al.* (2010) in kiwifruit and the decrease in K content of leaves was attributed to the application of high levels of commercial substances containing Ca.

5.4.3. Leaf calcium (Ca)

The present investigation revealed that leaf calcium concentration was enhanced with foliar application of $CaCl_2$, chelated calcium and Applin whereas minimum Ca was recorded in GA_3 sprays. $CaCl_2$ (0.3 %) sprayed five times recorded maximum leaf calcium content which was at par with three and four sprays of $CaCl_2$ and three four and five sprays of chelated calcium. Sathya *et al.* (2010) also reported accumulation of calcium in leaves with calcium sprays. Haji (2014) reported highest leaf Ca (1.14 %) with combined application of macro and micro-nutrients and attributed it to sugar polyalcohols, facilitating the transportation of Ca within the plant.

5.4.4. Leaf magnesium (Mg)

All chelated calcium sprays; one and two sprays of $CaCl_2$ and both the concentrations of GA_3 did not show any significant effect on leaf Mg content. However, there was decrease of leaf Mg with three, four and five sprays of $CaCl_2$ and increase in leaf Mg content with both concentrations of Applin when compared to control. Gibberellins and cytokinins might have intensified leaf ability as nutrient sink (Addicott and Addicott, 1982). The physiological manifestation of the interaction of different nutrients including Mg present in Applin also might be the cause for Mg enhancement. Haji (2014) reported enhanced leaf Mg with combined application of macro and micro-nutrients. Excessive supply of Ca may inhibit the uptake of other cations such as K and Mg lowering leaf K and Mg concentration. The basis for this argument is the antagonism at a cellular level between Ca and Mg (Cooper and Bangerth, 1976).

5.5. Fruit nutritional status

Nutritional status with respect to N, K, Ca and Mg of fruits were altered with preharvest GA_3, Applin and calcium foliar sprays.

5.5.1. Fruit nitrogen (N)

Effect of GA_3, Applin and calcium foliar sprays on fruit nutritional status of apple shows that fruit nitrogen content increased significantly by GA_3 and Applin sprays wheras calcium sprays had no significant effect on fruit nitrogen. Higher fruit nitrogen content in T_{14} and T_{15} can be attributed due to assimilation of nitrogen present in Applin and could be the outcome of synergetic effect of Mn, Zn, Cu and B present in it (Amiri *et al.,* 2008; Malvi, 2011). The increase in N content by nutrient sprays was also reported by Robinson (2006) and Amiri *et al.* (2008). Fruit nitrogen was found minimum in calcium sprayed fruits but was statically at par with control. Casero *et al.* (2004) found a negative relationship between fruit N concentration and fruit Ca concentration in 'Golden Delicious Smoothee' apple. The results were in accordance with Kapoor (1988).

5.5.2. Fruit potassium (K)

Fruit potassium (K) was found maximum in T_{15} [Applin @ 2.5 ml/L] and minimum in T_{13} [$CaCl_2$ sprayed five times]. The significant increase in fruit K content in GA_3 and Applin treated fruits can be attributed due to plant growth regulators which enhance protein and nutrient content with respect to nitrogen, phosphorous and potassium (Ptiwari, 2015). Whereas the decrease in fruit K content by Ca sprays can be attributed to the antagonistic effect of Ca. Dipping of apple cultivar ‘Ralls’ fruits in calcium solution reduced the levels of K (Ichiki *et al.,* 1980). Similar observations were recorded by Koutinas *et al*. (2010) in Kiwifruit. Singh *et al*. (2000) investigated the effect of various plant growth regulators and boric acid on nutrient contents of apple fruit at commercial maturity. The results depicted that K content of fruit was highest with the spray of GA_3 plus boric acid.

5.5.3. Fruit calcium (Ca)

Ca content increases due to higher absorption and deposition of Ca in fruit. The increase of cell calcium with $CaCl_2$ and chelated calcium treatments were found in peach *cv.* Andross by Manganaris (2005). Ichiki *et al.* (1980) revealed that dipping of ‘Ralls’ apple fruits in calcium solution slightly increased the calcium content. Casero *et al.,* (2002) reported more calcium accumulation in ‘Golden Smoothee’ apple with calcium treatments. Similar results with regard to calcium were observed by Nijjar (1996) and Sathya *et al.* (2010). The enhancement of Ca by Applin could be the outcome of the effect of other nutrients in it. Haji (2014) reported enhanced values of fruit Ca with combined application of macro and micro-nutrients and attributed it to sugar polyalcohols, facilitating the transportation of Ca within the plant. Applin might have also increased Ca due to the fact that calcium in stalks and leaves was excessively transported into fruits following application of auxins to the fruit surface (Wei *et al.,* 1999).

5.5.4. Fruit magnesium (Mg)

The fruit Mg content showed a non-significant effect with the application of GA_3 and calcium. However, significant increase in fruit Mg with Applin was found which could be due to Mg present in it and also could be by complementary effect of other nutrients present in it. Dipping of 'Ralls' apple fruits in calcium solution slightly increased the calcium content and reduced the levels of Mg and Mg/ Ca ratio (Ichiki *et al.,* 1980). These results are in accordance with Martin *et al*. (1971) and Ghorbani *et al*. (2017).

5.6. Storage studies

5.6.1. Fruit firmness

Table 7 showed that the application of gibberellic acid, Applin, different sprays of chelated calcium and of calcium chloride produced significant differences with respect to fruit firmness. The most remarkable effect of foliar applications of calcium at different sprays was shown in maintenance of higher fruit firmness during the storage.

The high fruit firmness than control by application of Applin and GA_3 could be attributed to the fact that auxins, cytokinins, gibberellins and nitrogen the constituents of Applin, delay various aspects of ripening (softening) by inhibiting the action of polygalacturonase and pectin methyl esterase involved in softening and also cross-links pectic substances in the cell wall, producing rigidification and increasing fruit firmness (Romero *et. al*., 2000). Zilkah *et al*. (2008) reported that CPPU significantly increased the fruit firmness of 'Late Fuyu Mutant' persimmon. GA_3 has the ability to delay senescence by reducing the sensitivity of the fruit to ethylene i.e., counteracts the promoting effects of ethylene on the senescence process (El-Gendy *et. al.,* 2006). The larger fruit size GA_3 treatments may cause greater percentage of 50.34 percent of firmness loss after forty five days of storage over 49.35 percent of control and 29.94 percent of $CaCl_2$ applied five times. The results are in accordance with the Arteca (1990), Raheem *et al.* (2013), El-Sabagh (2002), Curry and Greene (1993), Mosa *et al.* (2015), and Abeles (1992).

The maximum fruit firmness of 8.65 kg/cm^2 at harvest was recorded in fruits sprayed with $CaCl_2$ five times (Table 7). Increase in the number of Ca sprays of both the calcium sources consistently maintained higher firmness. $CaCl_2$ had more pronounced effect than chelated calcium. The minimum weight loss along with highest fruit firmness was recorded in fruits sprayed five times with 0.3 percent calcium chloride. This may be attributed to the role of calcium in maintaining membrane integrity of cells and its importance in maintaining structural integrity of cell walls. Moreover, calcium is needed for the synthesis of pectic substances which enhance fruit firmness. Rabiei *et al.* (2011) stated that calcium treatments influenced peroxidase and catalase enzyme activity in the apple fruits in support of delayed breakdown of cells and hence maintained the higher firmness during storage. Higher calcium fertilizer density in foliar applications can keep firmness of the fruit according to Zhao *et al.* (2011). These results are in agreement with the findings of Wojcik *et al.* (2009), Benavides *et al.* (2002), Casero *et al.* (2004), Conway *et al.* (2002), Ernani *et al.* (2002), Ferguson and Watkins (1992), Val *et al.* (2008) and Ashoori *et al.* (2013).

5.6.2. Physiological weight loss

Physiological loss in weight is a noteworthy physiological problem during postharvest management of fruits that affect fruit quality. The outstanding effect of foliar applications of gibberellic acid, Applin, different sprays of chelated calcium and of calcium chloride has shown in reducing the physiological weight loss of fruits during the ambient storage condition (Table 8). The minimum weight loss along with highest fruit firmness was recorded in fruits sprayed five times with 0.3 percent calcium chloride.

The maximum weight loss in fruits at fifteen days after storage (DAS) was recorded GA_3 applied at 100 ppm. After 30 DAS and 45 DAS physiological weight loss was found to be maximum in case of fruits applied with Applin at 2.5 ml/L. The larger fruit size with Applin and GA_3 treatments may have caused greater percentage of weight loss. The increased loss in weight might be further attributed to the fact that at the stage of harvest the fruits were not fully ripe as the application of hormones (GA_3 and Cytokinins) and nutrients like nitrogen delay repining so the ripening process continues in storage as well which in turn causes severe reduction of fruit weight during storage. Another reason could be that low Ca and higher concentration of N and K content in fruits of GA_3 generally has been found to accelerate the ripening process by stimulating the production of ethylene and by increasing the activity of enzymes which are responsible for increased weight loss (Pooviah, 1986).

The minimum loss of weight under ambient storage conditions was found in case of fruits treated Ca from either source. The increase in number of sprays of both the chemicals (calcium sources) consistently reduced the weight loss. Ca retards the rate of respiration and transpiration by possibly by reducing rate of degradation of proteins and nucleic acids (Bangerth *et al.,* 1972). Rabiei *et al.* (2011) stated that calcium treatments influenced peroxidase and catalase enzyme activity in the apple fruits in favour of postponed breakdown of cells and hence maintained the firmer fruits and reduced weight losses percentages during storage. The reduction in physiological weight loss during storage with application of calcium formulations might be ascribed to their influence on maintaining the integrity of the plasma membrane since calcium unite to the polar head group of the phospholipid units of that membrane which reflect on retarding the cell deterioration and delaying senescence. Furthermore, calcium plays an imperative role in preserving the cell wall structure which lead again to delaying senescence and reflect on lesser water loss (Farag and Nagy, 2012). The reduced weight loss of fruits during storage has also been reported by Baneh *et al.* (2003), Ramakrishna *et al.* (2001), Salehi, *et al.* (2013a), El-Badawy (2012), Conway *et al.* (2002), Ernani *et al.* (2002), Ferguson and Watkins (1992), Val *et al.* (2008), Zhao *et al.* (2011) and Bhat *et al.* (2012).

5.7. Physiological disorders

Apple encounters different physiological disorders; worth to mention are watercore and bitter pit being common and thought to be related with nutrient calcium. Bitter pit usually appears postharvest as depressed brown lesions in the skin of the fruit, located mainly on the calyx end of the fruit (Ferguson and Watkins, 1992) and watercore is disorder in which water soaked areas of cortex become translucent. The applications of calcium chloride and chelated calcium significantly eliminated disorders like bitter pit and watercore whereas GA_3 and Applin increased and the increase was linear with their concentration applied (Table 9). Neilsen and Neilsen (2006) reported that application of KCl, K_2SO_4, $KHSO_4$ and $MgSO_4$ in ‘Fuji’, ‘Spartan’ and ‘Gala’ apple trees increased incidence of bitter pit.

The increase in bitter pit and watercore by GA_3 and Applin may be due to the fact that gibberellins inhibit calcium translocation. Saure (2005) observed differences in the calcium content in fruit between different years and different regions by varying levels of gibberellic acid. The important factor could be low levels of fruit Ca and high levels of N, K and Mg as research done in the last 50 years has shown that the incidence of the bitter pit is inversely related to the Ca concentration of the fruit and, in general, is directly related to Mg, potassium (K) and nitrogen (N) levels in fruit tissues (Garman and Mathis, 1956; Fallahi *et al.,* 1997). A high source-to-sink ratio can also accelerate maturation, which is associated with increased watercore incidence (Beaudry, 2014). Evidence suggests that when the tree produces elevated amounts of photosynthate (which is typically in the form of sorbitol) at a time when the capacity of the fruit cells to take up the sorbitol is diminishing (as it is during the latter stages of development), then the stage is conducive for symptom development. Thus, membranes could change their relative permeability, resulting in bitter pit and other disorders. Frequently, bitter pit incidence as well as other calcium-related disorders has been associated with high fruit K/Ca ratios; however, Ca concentration appears to be the critical factor (Neilsen and Neilsen, 2003).

The application of calcium had a significant impact on watercore incidence which may be due to slowing the aging process in leaves and thus preventing the rapid export of sorbitol associated with the latter stages of life stages of leaves. Interestingly, it was observed in watercore affected fruits that core breakdown and alcoholic off-flavours arise during storage. The prevention of bitter pit with Ca treatments could be attributed to high Ca levels in treated fruits which reduce the susceptibility to senescence disorders such as bitter pit, watercore, and senescence breakdown, and strengthen the resistance to fungal decays. These findings were in accordance with Yogaratnam and Johnson (1982), Wojcik and Wojcik (2007), Johnson *et al.* (1983), Perring and Preston (1974) and Amiri and Fallahi (2007). Low fruit Ca levels probably favour the binding of other cations like K and Mg on exchange sites on membrane surfaces, under a competitive environment. Sharpies (1970) obtained that bitter pit was prevalent and increased in severity with fruit size. Disorders like bitter pit, cork spot and internal breakdown are associated with high rate of respiration and occur due to deficiency of calcium (Thakur and Xu, 2004).

5.8. Return bloom

The perusal of data in Table 10 regarding return bloom indicates that it was negatively affected by the application GA_3 only at 100 ppm whereas Applin at both concentrations resulted in its improvement while comparing with control. It was found that the highest return bloom after the year of spray was recorded in trees under T_{15} [Applin at 2.5 ml/L (15.71 FC/cm^2 BCSA)] and lowest was recorded in trees under T_3 [GA_3 at 100 ppm (12.13 FC/cm^2 BCSA)].

The reduction in return bloom in the following spring can be due to the reason that gibberellins cause flower bud inhibition and there is more vegetative growth (Curry and Green, 1993). Also gibberellin postpones plastichron i.e., initiation of vegetative bud to flower bud with the result critical node number does not reach at particular period due to which there occurs limit of reserves, minerals and hence there do not take place flower bud formation. Also GA_3 lengthens plastichron and bud never reaches the receptive stage, thereby indirectly inhibiting flowering (Zahoor and Dhillon, 2011). These lines are in close agreement with those of Prang *et al.* (1998) and Unrath and Whitworth (1991). Other reasons could be larger sized fruits, higher yield and higher number of seeds. Robinson *et al.* (2009) who showed a strong suppressive effect of increasing yield on return bloom the next year. Applin enhanced return bloom over control trees. This may be attributed to the fact that cytokinins and nutrients present within overpower the negative effects of gibberellins. Stiles (1999) reveals N, K and other nutrients have both direct and indirect effect on regularity of cropping by increasing photosynthetic efficiency of the plant; as a result some of the photosynthates are utilized for the next year's flower bud differentiation. Wani *et al.* (2017) revealed that application of phytohormones and nutrients alone or in combination had significant influence on return bloom which recorded highest (16.73 %) under the treatment of nutrient mixture (Ca + B + N) @ 2 ml/L but both the hormones (GA_3 and CPPU) and their combinations with nutrients proved unsatisfactory due to reduced return bloom in the succeeding year.

Ca sprays marginally improved return bloom in the following year of spray. Improvement of return bloom by these chemicals can be possibly due to their role in flower development (Galston *et al.,* 1997). The role of Ca^{2+} in plant fertilization has been recently investigated in brown algae (Roberts *et al*., 1994; Roberts and Brownlee, 1995). Nutrients have both direct and indirect effect on regularity of cropping by increasing photosynthetic efficiency of plant or any other process that helps enhancement of the photosynthates which are utilized for the subsequent year's flower bud differentiation (Stiles, 1999).

Chapter-6

SUMMARY AND CONCLUSION

The present investigation entitled ''Effect of Gibberellic acid, Applin and Calcium foliar sprays on chemo-metric attributes of apple (*Malus x domestica* Borkh.)'' was carried out during the year 2016-2017 at the orchard of a progressive farmer of district Kulgam in Kashmir valley. The salient features of the results obtained during the course of investigation are summarised and concluded as under:

1. The foliar application of gibberellic acid, Applin, calcium chloride and chelated calcium in different concentrations and frequency, significantly improved the size and shape of the fruits. In terms of length (7.97 cm) and L/D ratio (1.02) highest values were recorded from the trees receiving one spray of 100 ppm GA_3 whereas maximum (7.95 cm) mean diameter was observed under treatment of Applin @ 2.5 ml/L. However, the minimum length (6.22 cm), diameter (6.34 cm) and L/D ratio (0.98) were recorded in control.

2. Colour and anthocyanin content were significantly improved by calcium sprays and decreased by GA_3 spray. Colour and anthocyanin improvement showed least difference between the two sources of calcium. The maximum (90.5 %) colour was observed in $CaCl_2$ @ 0.3 percent sprayed four times and the minimum (56.75 %) under GA_3 applied at 100 ppm. On the other hand the maximum (11.21 mg/100 g) and minimum (9.12 mg/100 g) anthocyanin contents were recorded in $CaCl_2$ sprayed four times and GA_3 @ 100 ppm respectively.

3. The maximum grade 'A' fruit (75.21 %) production was obtained from trees sprayed with $CaCl_2$ five times and the minimum of this grade was recorded in control (58.07 %).

4. Soluble solids concentrate and total sugars were enhanced by all treatments. Whereas GA_3 and Applin showed more marked effect than calcium sprays. Maximum SSC (15.17 ^{0}Brix) and total sugars (11.92 %) were recorded under Applin @ 2.5 ml/L and minimum in control.

5. Calcium sprays increased acidity and the maximum value of 0.32 percent was observed under five sprays of $CaCl_2$. The minimum acidity (0.24 %) and maximum sweetness index (60.64) were recorded under the influence of GA_3 @ 100 ppm.

6. Increment in ascorbic acid and organoleptic rating were observed in all chemical sprays over control. The maximum value (7.31 mg/100 g) of vitamin C was recorded in $CaCl_2$ sprayed five times whereas maximum value (4.47 score out of 5) for organoleptic rating was observed in chelated calcium sprayed five times.

7. Leaf nitrogen increased significantly with GA_3 and Applin whereas the same parameter decreased insignificantly with Ca sprays. The maximum (2.490 %) and minimum (1.919 %) figures were recorded under Applin at 2.5 ml/L and $CaCl_2$ five sprays respectively.

8. Potassium (1.783 %) and magnesium (0.387 %) contents of leaves were recorded highest in trees receiving 2.5 ml/L Applin, whereas leaf Ca (1.206 %) content was found highest under five sprays of 0.3 percent calcium chloride.

9. Nitrogen (2.17%), potassium (1.783 %) and magnesium (0.387 %) contents of fruits were recorded highest in trees receiving Applin @ 2.5 ml/L.

10. Calcium content in fruits was found highest (0.44 %) by the application of 0.3 percent calcium chloride five times, whereas lowest values of fruit N (0.348 %), K (0.551 %) and Mg (0.021 %) were also recorded in this

treatment.

11. Five applications of calcium chloride resulted in highest (8.65 kg/cm^2) fruit firmness and maintained firmer fruits (6.06 kg/cm^2) upto forty five DAS, on the other side, the least firmnesses of 6.95 and 3.52 kg/cm^2 were observed in control fruits at harvest and 45 DAS respectively.

12. The highest physiological weight loss (8.86 %) of fruits after forty five days of storage under ambient conditions occurred in Applin sprayed fruits at 2.5 ml/L; whereas lowest (3.94 %) was observed in fruits treated with 0.3 percent calcium chloride sprayed five times.

13. The maximum watercore was found in Applin at 2.5 ml/L (10.00 %) followed by (7.50 %) in Applin @ 1.5 ml/L and T_3 GA_3 @ 100 ppm.

14. The maximum percentage (15.00 %) of fruits affected by bitter pit were in Applin @ 2.5 ml/L at forty five days after storage and same was the value in case of GA_3 @ 100 ppm.

15. Return bloom was positively affected by Applin and Ca sprays but negatively by gibberellic acid (GA_3).

The summation and critical observations on the results led to conclusion, that all the folairly applied chemicals brought into limelight, had their effect on the chemometric attributes of apple *cv.* Red Delicious. Accordingly, soluble solids concentrate, total sugars, sweetness index, size related parameters, fruit and leaf nutritional status were efficiently improved by Applin and GA_3 with a little but bearable compromise on colour, watercore and bitter pit. However, four sprays of Ca from either of the sources ($CaCl_2$ @ 0.3 % or chelated Ca @ 0.1 %) could be employed for the improvement in fruit colour, anthocyanin, ascorbic acid, soluble solids concentrate, total sugars, firmness, organoleptic ratings, watercore, farmer's grade 'A' fruit. It also lend a hand for the maintenance of acceptable fruit quality, forty five days after ambient storage in terms of least bitter pit incidence, physiological loss in weight and losses in firmness. Even though the $CaCl_2$ or chelated Ca had very similar influence on the said parameters with slight edge towards $CaCl_2$ and economy should decide which one should be applied.

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<u>**Appendix - 1**</u>

Meteorological data of the year 2016 (April- November)

Meteorological weeks 2016	Temperature (^0C)		Rainfall (mm)	Relative humidity (%)	
	Max.	Min.		Max.	Min.
14	15.14	6.50	41.30	91.14	82.43
15	19.57	6.76	15.20	89.43	66.86
16	19.00	6.13	48.10	88.86	73.43
17	23.51	8.64	0.00	82.86	57.71
18	23.91	4.51	11.40	77.57	47.57
19	23.51	8.64	19.50	82.86	57.71
20	24.71	9.93	4.00	82.71	57.29
21	30.21	10.29	26.80	74.57	42.57
22	26.50	11.14	2.10	79.29	53.00
23	28.64	11.47	3.40	72.29	47.29
24	29.29	12.77	0.60	75.14	42.71
25	29.93	14.20	0.00	76.71	45.86
26	31.43	15.06	0.00	69.00	51.14
27	32.36	17.27	11.60	75.00	48.71
28	31.21	15.46	0.00	76.86	43.86
29	30.00	18.16	34.60	78.29	52.43
30	30.79	15.50	61.20	81.86	44.71
31	28.29	16.96	1.60	88.00	60.29
32	29.39	17.71	30.80	86.14	56.43
33	27.10	16.41	0.40	85.71	48.14
34	29.86	13.79	43.40	82.57	49.71
35	25.29	14.71	31.00	88.29	72.43
36	25.00	13.27	0.00	86.43	60.00
37	30.07	12.94	3.10	79.71	55.14
38	28.29	10.57	0.00	85.14	44.57
39	28.71	9.93	0.00	89.14	42.71
40	29.93	9.66	6.40	90.29	36.71
41	26.21	7.21	0.00	83.86	38.00
42	25.71	3.17	0.00	78.00	32.00
43	23.71	3.03	0.00	81.71	42.14
44	22.64	-0.29	0.00	83.29	41.00
45	20.57	-0.87	0.00	86.86	45.71
46	17.79	-2.56	0.00	89.14	35.43
47	14.79	-4.10	0.00	93.57	44.14
48	13.36	1.29	0.00	85.57	52.71