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Strategies for Optimization of Fruit Quality in Temperate Fruits with Special Reference to Pome Fruits

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ABSTRACT

Fruit quality is the major determinant of grower returns without bringing additional land under cultivation and consequently has been studied widely. There are many components of fruit quality such as size, colour, firmness, soluble solids and acidity. In addition there are many factors which may influence fruit quality, some of which are outside of control such as weather, site suitability and varietal genetic potential. But now a days we can improve the fruit quality through modern management practices such as use of dwarf rootstocks, site specific nutrient management, drip irrigation etc. The use of clonal rootstocks regulate the tree size, induce early bearing and high cropping, and helps in adaptation of root system to existing soil and climatic conditions. Fruit Calcium is important in apple fruit quality by delaying cell wall breakdown, maintain firmness, retarding ethylene production and alleviates internal break down. Boron is important in pollen germination and pollen tube growth resulting in successful fruit setting. Bioregulators can have impact on apple fruit quality regardless of the cultivar. Foliar application of gibbberllins have been reported to reduce russeting on Golden Delicious apple and Bartlett pear. The saving of soil water content and improvement of adaptability of plants to periodical insufficient water and use of deficit irrigation technology become more important because of the occurrence of frequently dry periods. Deficit irrigation minimizes water use, decreases vegetative growth and pruning cost may improve fruit quality. The application of different types of mulches conserve the soil moisture during the peak period of plant growth and development and improve quality.

Keywords: Fruit, cultivation, golden delicious apple, bartlett pear

Fruit quality is a concept encompassing sensory properties (appearance, texture, taste and aroma), nutritive value, mechanical properties, safety and defects. Altogether these attributes give the fruit a degree of excellence and economic value (Abbot, 1999). In addition there is now an increasing appreciation that quality of fruit also includes nutritional properties (e.g. vitamins, minerals, dietary fibre) and health benefits (antioxidants); these are now becoming important factors in consumer preferences. Experimental, epidemiological and clinical studies provide evidences that the consumption of fruits plays an important role in the prevention of chronic degenerative diseases such as tumours, cardiovascular diseases and atherosclerosis, It is supposed, in fact, that the consumption of fresh fruits exerts a protective role against the development of such pathologies (Ames *et al*.,1993; Dragsted *et al*.,1993; Doll, 1999; Anderson *et al*., 2000).

Constraints in the optimization of temperate fruit quality

- **Lack of sufficient chilling hours**: Temperature of 7°C and below is effective in meeting the chilling requirements. Sufficient chilling hours are not experienced as there is lack of rainfall and snowfall during the winters especially in the mid-hill areas. This results in erractic and poor flowering, which is responsible for the poor fruit set and low yields.

- **Lack of sufficient soil moisture**: During the winter, spring and summer season sufficient rains are not experienced resulting in drought like conditions, which results in moisture stress and trees do not flower properly which results in poor fruit set and small fruit set and small fruit size.
- **Occurrence of spring frost**: Many times the winters remain warm and dry during spring the weather goes bad and temperature go fairly low and spring frosts are experienced resulting in frost injury and damage to the flowers and poor fruit set
- **Lack of pollinisers**: Delicious group of apples are self unfruitful and need cross pollination for proper fruit set. Therefore, proper provision for pollinisers should be made to get optimum fruit set. At least 33 percent pollinisers should be provided. Suitable pollinisers are Red Gold, Golden Delicious, Tydeman's Early Worcester, Summer Queen, Crab apples and McIntosh. Sometimes pollinisers are also top worked on the individual trees, Provision for honey bees should be made to ensure cross pollination
- **Occurrence of hailstorms**: Due to fluctuating temperature, hail storms are also experienced which cause damage to the flowers and developing fruits at various stages. Use of anti-hail nets, special system of training like hedgerow in semi dwarf plantations can be very useful
- **Occurrence of insect, Pest and diseases**: During the last few years incidence of premature leaf fall and red spider mite infestation has attained epidemic proportions.

Strategies for optimisation of fruit quality of pome fruits

- By rootstocks.
- Mineral Nutrition.
- Growth Regulators.
- Irrigation and temperature.
- Pruning andThining.
- Management of fruit russeting in pear.
- Orchard management practices especially mulches.
- **Rootstocks**. Modern fruit tree is made up of two parts, scion forming tree head and rootstock, which supplies root system. By choosing a suitable rootstock, size of the tree can be influenced, and also also the age at which the tree comes to bearing (Chadha, 2001). The main objective of planting trees on clonal rootstocks are regulation of tree size, growth rate, crown volume, induction of early bearing and high cropping. Baugher *et al*., 1994 studied that the effect of dwarfing rootstocks provides better light penetration and photosynthetic productivity which in turn increases the quality of the fruit.

Table 1: Effect of different rootstocks on the quality of apple (Skrzynski and Gastol, 2006)

Rootstock soluble Solids (%) (mg malate 100 g^{-1})	Flesh firmness titrable acidity Kg Cm^{-2}	Starch index	Total (Scale 1-10)
M.9 635b	8.1b	9.3bc	12.6b
M.26 601ab	7.9a	8.9a	12.0a
P.22 586a	8.6c	9.6d	13.3c
P.59 630b	8.6c	9.4c	13.2c
P.60 603ab	7.1b	9.2b	12.6b

Irrigation and Temperature: The saving of soil water content and the improvement of adaptability of plants to periodical insufficient water and use of deficit irrigation technology become more important because of the occurrence of frequently dry periods. Depletion of soil water resources need to develop efficient irrigation techniques for quality apple production. A new deficit irrigation strategy has been developed that is based on partial water supply of root-zone. This does not result a decrease in the sizes and yield of the fruit. The larger fruit size and lower firmness in frequently irrigated trees can result in excessive internal growth stresses that cause higher rate of fruit splitting. Regulated Deficit

Irrigation has been used to suppress vegetative growth in favour of reproductive growth in apples (Ebel *et al*., 1995). Extensive work has been carried out on the water relations of apple trees (Higgs and Jones, 1991), but there is limited information on effects of reduced irrigation on the quality of the fruit. Apples grown under reduced irrigation can have a lower water content, higher soluble solids concentration (Mills *et al.,* 1994) and be smaller. Mills *et al.* (1994) also reported also that late-season withholding of irrigation enhanced red colour of 'Braeburn' apples. Drake *et al*., (1981) reported no differences in total acidity (TA) levels of apples receiving deficit irrigation throughout the season, but Ebel *et al*., (1993) found that apples from early-season Reduced Deficit Irrigation had a lower total acidity. The differences observed by these workers may have resulted from withholding or reducing irrigation at different times of the season and/or differences in the levels of water stress applied.

There is, therefore, a need to clarify the effects of withholding irrigation at various times of the season on important fruit quality attributes and on yield. Deficit irrigation if applied judiciously conserve soil moisture and reduces leaching of biocides and may increase the fruit quality (Behboudian and Mills, 1997). Deficit Irrigation–No Thinning fruit had a higher SSC at harvest than Full Irrigation–No Thinning fruit. The increased SSC values for DI–NT fruit may indicate partial dehydration of fruit under water stress. The increased SSC values for DI–NT fruit may indicate partial dehydration of fruit under water stress. This is in accordance with the findings on pear (Ramos *et al*., 1994), peach (Li *et al*., 1989; Mercier *et al*., 2009), apple (Mills *et al*., 1994; Mpelasoka *et al*., 2000) and plum (Intrigliolo and Castel, 2010). Significant linear relationships have been found between tree water status and fruit SSC in 'Bartlett' pear (Ramos *et al.*, 1994) and in 'O'Henry' peach (Lopez *et al.*, 2010), with higher levels of water stress leading to higher SSC.

Accordingly, higher fruit dry matter concentration (fruit dryweight /fresh weight) was found in DI–NT (0.20) fruit than in FI–NT (0.18) fruit at harvest. Increased SSC under DI could have a positive impact on fruit taste. For pear, Jackson (2003) reported that fruit taste is mainly related to the sugar concentration in the juice if acidity were low. Since our 'Conference' pear had low levels of acidity (about 2–3 g malic acid l−1) and DI–NT increased SSC values, DI–NT fruit could be perceived positively by consumers. Higher firmness under DI has also been reported for apple (Kilili *et al*., 1996b; Leib *et al*., 2006). Higher fruit firmness under DI might be because of lower fruit size. Water stress reduces fruit size and smaller fruit tend to be firmer than larger fruit. However, Mpelasoka *et al*. (2000) found higher FF in apple fruit produced under DI irrespective of the size. DI had no effect on fruit maturity based on ethylene production.

Hence, any effect of DI on fruit quality may be with water stress and not mediated through ethylene production. Weight loss in 'Conference' pear increases with time in storage (Nguyen *et al*., 2007). However, lower weight loss was observed in DI–NT fruit than in FI–NT fruit. This has not been reported form pear but our finding is consistent with those observed in apple (Kilili *et al*., 1996a; Mpelasoka *et al*., 2000), apricot (Perez-Pastor *et al*., 2007) and peach (Mercier *et al*., 2009). The difference in weight loss between DI–NT and FI–NT fruit could be due to differences in the structure and/or composition of the skin or the cuticular waxes covering the skin. Cuticle modification by water stress has been reported by Crisosto *et al*. (1994) in peach fruit where the lower rate of water loss under DI was explained by a thicker cuticle and a higher density of trichomes on the skin surface. A possible reason here could be the lower water content of DI pear. Differences in weight loss in 'Conference' pear are function of differences in the original water content (Nguyen *et al*., 2006). Irrespective of the mechanism involved, DI fruit could have better quality after cold storage than FI fruit due to a reduction in weight loss. The reduction in weight loss in DI fruit could prolong the cold storage life, facilitating marketing for a longer period of time.

The precipitation of July and August months have the most crucial effect on the fruit crops. During this period the water use efficiency of apple trees is affected by their water demands. Dragoni *et al.* (2004) published that the daily water use per tree showed peak values around 35–40 L.day^{-1}. tree-1 from middle of June to middle of July, then gradually declining after mid-July. Green *et al.* (2003) revealed that the apple trees consumed 70 L of water per day during the middle of summer. The optimum ideal conditions for red colour development of apples is found in climates with clear bright days (20–25 °C) and cool nights (below 18 °C) during the pre-harvest period (Chalmers *et al.*, 1973, Williams 1989, Iglesias 2001). The influence of temperature on colour development also depends on the cultivars (Saure, 1990) because the highly coloured strains produce better coloured fruit under high temperature, low-light or shaded conditions (Iglesias *et al.*, 2000). The combined effects of larger fruit size and lower firmness in frequently irrigated trees may result in excessive internal growth stresses that caused higher rate of fruit splitting (Opara *et al.*, 1997).

However the lenticel cracks on fruit skin are due to microclimatic changes. The lenticel cracking is localized to the fruit epidermis (that is the cuticle and underlying 2 to 3 layers of cells) while the fruit splitting due to the moving of layers of cells inside the fruit flesh. Water stress in pear occurs when they are in their cell-expansion growth period (Stage II). Water stress in Stage II reduces the potential of achieving commercial fruit size at harvest (Marsal *et al.*, 2010). Size is an important quality attribute for fresh-market pear. Irrigation season began at bud-break (late March) and finished before leaf fall was complete (late October). When the cell division phase finishes, pome fruit growth occurs almost entirely by cellular enlargement, due to carbohydrate accumulation and water uptake (Pavel and DeJong, 1995) and it is the average cortical cell size that determines fruit size at maturity. The rate and duration of the cell division phase are important, because they determine the number of cells within the fruit at harvest.

Table 2: Effect of different nutrients on the quality of Jonagold apple (Bennewitz *et al.*, 2011)

Treatment	Internal browning (%)				
	2002	2003	2004	2006	2008
Two spray of $CaCl_2$	5.2b	4.5b	0.9b	2.2b	2.5b
Four spray of $CaCl_2$	6.1b	4.8b	0.8b	1.8b	3.1b
Six spray of $CaCl_2$	1.2a	0.8a	0a	0a	0a
Control	6.5b	5.2b	1.2b	2.1b	3.2b

The number of cells within a fruit, and their size, are likely to affect the mechanical properties of the cortical tissue, and thus the textural quality as perceived by consumers and the susceptibility of the fruit to physiological disorders during storage (Sharple, 1994). In some apple growing regions of the world, water supply is limited. Reducing the timing and frequency of irrigation could lower costs of production and also decrease nutrient and pesticide leaching into the ground water (Kabashima, 1993).

Growth regulators

Table 3: Effect of plant growth regulators on the quality of Leconte pear (Stino *et al.*, 2011)

Treatment	Fruit set (%)	Fruit drop (%)	Fruit retention (%)	Seed number
GA_3 10 ppm	4.78	37.01	62.91	2.23
GA_3 20 ppm	6.56	30.05	69.94	2.00
GA_3 30 ppm	5.85	36.40	63.67	2.39
Sucrose 5%	5.09	48.59	51.37	4.30
Sucrose 10%	5.97	40.95	59.06	4.77
Sucrose 15%	7.29	35.99	64.04	4.77
Boric acid 100	6.10	42.27	57.46	4.67
Boric acid 200	5.16	43.92	57.52	4.70
Boric acid 300	4.61	44.47	55.58	5.17
Control	3.13	61.6	38.32	5.17
$CD_{0.05}$				
Stage	0.02	0.63	NS	0.10
Treatment	0.05	1.42	4.58	0.22
Interaction	0.07	2.01	6.48	0.31

Sucrose at 15 per cent significantly enhanced fruit set when compared with other chemicals. It is well documented that fruit set is the resultant of gibberellins produced by immature seeds following pollination and fertilization, while GA, if applied to unfertilized flowers induced parthenocarpic fruit set. The general desirable effects of sucrose and boric acid applications could be attributed to enhanced pollen germination and pollen tube growth which increases fruit set and yield. The application of boron reported to improve the fruit set in Le Conte pear (Badawi *et al*., 2005). Thus, exogenous application of GA3 and sucrose on pear trees has shown good response. Significantly lower fruit drop was obtained with GA3 20 ppm. This was followed by sucrose 15 per cent and GA3 30 ppm, which reduced fruit drop significantly as compared to the control. Sucrose and boric acid treatments had no effect on seed numbers in the fruits. The minimum seed number was recorded with GA3 20 ppm both at full bloom and petal fall stages.

Prunning and Thinning: Young trees should be pruned as lightly as possible to promote rapid growth and early bearing. It is more hazardous to prune in early winter than later in the dormant season, because evidences has shown that extremely cold temperature following the pruning operation are likely to result in serious freezing injury to trees. Tree yield and apple fruit quality have been shown to strongly depend on pruning and thinning, since light distribution within the tree canopy can affect flowering, fruit size, fruit colour and fruit quality (Hampson *et al*., 2002). Fruit thinning has generally resulted in higher firmness, soluble solids concentration (SSC) and acidity in apple (Wünsche and Ferguson, 2005) and in higher SSC in peach (Crisosto *et al.,* 1994) and plum (Intrigliolo and Castel, 2010). Removing unnecessary shoots during during summer provides better fruit distribution within the tree, higher fruit calcium content and better fruit colour compared to winter pruning (Warrington *et al*., 1995).

On the other hand, summer pruning can decrease yield and SSC and may negatively affect fruit storability in comparison with winter pruning (Katzler and wurm, 1998). Tahir *et al.* (2006) while studying the effect of pruning time on yield, fruit colour, resistance to bruising and storage decay. He observed increasing fruit weight of apple by summer pruning due to the result of better light penetration. Fruit quality and storability depends on the activity of photosynthesis, use of photosynthetic products. Better light availability in July and August might encourage photosynthesis process and positive effect on cell enlargement. Winter or Spring pruning negatively affected fruit weight, colour and storage potential as a result of a disproportional increase in shading within the canopy (Tomala,1999). The increased light penetration during to july improved fruit weight and storability, it has less effectiveness on colouration perhaps because several heading cut shoots during July started growth again making more shade during august, thus apple trees should be pruned 5-6 weeks before harvesting to achieve better photosynthetic processes and anthocyanin synthesis, resulting in best fruit colour and storage potential. The fact that September pruning did not affect fruit quality might be due to this pruning time being time being late, as fruits has already matured.

Table 4: Effect of crop load on the fruit quality (Dennis Katuuramu, (2008)

Treatment Soluble-solids	Crop load (%)	Increase in TCSA (cm^2)	Yield per tree (lbs)	Avg. fruitwt. (g)	Fruit-firmness
Cultivar Redfree					
11.2	3	5.5x	40.6	159.6	110.2
10.9	6	5.1	50.5	142.5	114.3
10.6	9	4.6	60.2	125.3	118.4
10.2	12	4.2	70.1	108.2	122.5
*	*	NS	*	*	*
Liberty					
13.8	3	7.6	36.2	160.8	91.3
13.4	6	5.9	43.9	152.1	90.3
12.9	9	4.3	51.8	143.4	89.4
12.5	12	2.7	59.7	134.7	88.4
NS	*	*	*	*	*
Gold Rush					
14.4	3	8.3	50.5	182.2	133.2
13.6	6	7.2	66.4	165.3	132.4
12.8	9	5.9	81.8	148.4	131.6
12.1	12	4.8	97.2	131.5	130.8
*	*	*	*	*	NS

Fruits from summer pruned tress, which were well coloured, showed more resistance to bruising (Tahir, 2006). The apple is a biennial bearing fruit where full cropping is finally realized every other year. Characteristically, fruit are small and poor quality in the on year because of over cropping. Application of chemical thinners to reduce crop load is the primary way to improve fruit quality and increase fruit size the examples of chemical thinners includes Carbaryl, napthalenic acetic acid, napthleneacetamide, benzyladenine and ethophon.

The thinners are applied during the blossom period or they can be applied at post blossom period Fruit Size is increased commercially by crop load reduction with chemical thinners.

Thus, although the total yield is reduced, the remaining fruits have larger value because of increased fruit size. The synthetic cytokinin Benzyladenine (BA) has considered to be a best thinner for fruit crops, but it also increases fruit size by stimulating cell division within the fruit. Cell division during the early stages of fruit development has a major influence on final fruit size . with the heavy crop nearly all the products of leaves were used in fruit growth and little was left for flower bud initiation for the following crop. The immediate effect of fruit thinning is an increase in fruit size. There is a strong inverse relationship between number of fruits on an apple tree and size of those fruits, and an increase in fruit size can reasonably be expected from a significant reduction in fruit numbers

Management of physiological disorders. Fruit production is a major agricultural industry in many parts of the world. Temperate fruits play an important role in boosting the economy o the orchardists. The state of J&K is a leading producer of temperate fruits in country. However the marketability and consumer acceptability of such fruits is much below in comparison to horticulturally advanced countries. This is due to various physiological disorders during the pre and post-harvest period.

- Preharvest disorders
- Water core
- Cork spot
- Black end
- Sunburn (sunscald)
- Russet
- Post harvest disorders
- Bitter pit
- Low chilling breakdown
- Soft scald
- Jonathan soft
- Superficial scald
- Internal breakdown

Among the above listed disorders russeting in pome fruits is a major concern to the fruit growers worldwide. The russet-affected fruits fetch low market price. It is particularly a common problem in golden delicious and bartlett pear. Russet of fruit results from damage to the epidermal cells that occur within 30 to 40 days after petal fall, during this time the epidermal cells of fruit undergo rapid cell division and elongation, apparently predisposing them to chemical and environmental stress.

Once the epidermal cells are damaged a brown layer of suberized cells is formed in the lower epidermal region. As the cork cells develop, they push outward and become exposed on fruit surface; and as the fruit matures the cuticle is sloughed off (Gil *et al*., 1993). The specific factor(s) responsible for russeting still unknown, although it has been attributed to the caustic effects of spray materials, unfavorable weather conditions such as cold, frost, cold winds, heavy rains, cloudy weather, etc. during blossoming period. Cultivars having thin cuticle are more susceptible to russeting than those with cuticles arranged in free platelets whereas the cultivars with oily and thin cuticles are reportedly russet-resistant (Faust and Shear, 1972). Russeting develops in areas where night temperature is high (15-20°C). High turgor pressure in epidermal cells due to diffusion of rain or dew through the cuticular cracks on fruits exposed to sun may cause bursting of skin, and thus russeting is more commonly noticed on exposed fruits than on the fruits in shade (Yuri *et al.*, 1998).

Spraying the fruits with chemicals like gibberellic acid and pesticides (Skuarai and Watanabe, 1994; Yuri *et al*., 1998) reportedly controlled fruit russeting to some extent. Wettable sulphur has been used as a russet control chemical (Greene, 1993). The sulphur based fungicides have a tendency to forms mall aggregates which may be overcome by the addition of small amount of inert material such as kaolin. Peer *et al*., 2010 studied the effect of GA_3, wettable sulphur + boric acid on length, breadth and L/D ratio of pearfruits cv. 'Bartlett'. They observed that highest fruit length of 6.22 cm was observed in fruits treated with 0.5% wettable sulphur + 0.05% boric acid + 0.2% kaolin because boron is responsible for pollen germination and pollen tube growth and lowest fruit length of 6.06cm in untreated control fruits. they also observed that the spray of 0.7% wettable sulphur + 0.1% boric acid + 0.2% kaolin

Table 5: Effect of GA_3, wettable sulphur + boric acid on length, breadth and L/D ratio of pear fruits cv. 'Bartlett'
Peer *et al.*, 2010

Treatment	Fruit length (cm)			Fruit diameter (cm)			Fruit L:D ratio		
	2006	2007	Mean	2006	2007	Mean	2006	2007	Mean
Control (water sprayed)	6.17	5.95	6.06	5.76	5.66	5.71	1.07	1.05	1.06
GA3 @ 12 ppm	6.24	6.13	6.18	5.72	5.70	5.71	1.09	1.07	1.08
GA3 @ 24 ppm	6.27	6.16	6.21	5.7	5.72	5.71	1.10	1.08	1.09
GA3 @ 36 ppm	6.26	6.15	6.20	5.70	5.71	5.70	1.10	1.08	1.09
*Wettable sulphur 0.5% + boric acid 0.05%	6.16	6.28	6.22	5.65	5.65	5.65	1.09	1.11	1.10
*Wettable sulphur 0.7% + boric acid 0.10%	6.18	5.97	6.07	5.73	5.69	5.71	1.08	1.05	1.06
*Wettable sulphur 0.9% + boric acid 0.15%	6.19	5.97	6.08	5.63	5.64	5.63	1.10	1.06	1.08
CD0.05	ns	ns	ns	ns	ns	ns	ns	ns	ns

proved most effective in controlling russeting because Nene and Thapliyal (2002) reported that sulphur based fungicides emit vapours to prevent the growth of fungal spores at a distance several mm from deposition leaf and fruit surface. This vapour may possibly ensure the protection of gaps on leaf and fruit surface resulting from weathering or expansion of leaf and fruit area.

Mulching

In Kashmir valley the orchards are mostly rainfed and during the peak period of plum fruit growth and development scarcity of water erupts. As such conservation of soil moisture is imperative due to meagre and costly irrigation facilities. Mulching is known to play an important role in the conservation of soil moisture during dry periods besides offering the advantages like suppression of weed growth, water runoff and soil erosion. various mulches are used to conserve soil moisture (Sharma and Kathiravan, 2009., Kumar *et al*., 2008., Raina, 1991), and reduce the weed growth (Kaur and Kaundal, 2009) and may improve fruit quality. Available potassium and certain other necessary elements including phosphorus, magnesium, calcium, and boron are found to be higher in the soil beneath mulched trees (Kim *et al*. 2008, Sheikh mehraj, 2013).The reflective mulches increasing anthocyanin formation and accumulation in two ways: increased canopy photosynthesis and assimilation to the fruit, and thus indirectly stimulated anthocyanin synthesis by providing substrate/carbohydrates (Lancaster, 1992; Williams,1993) without affecting SSC or fruit size .The increase in light intensity accelerates the PAL activity and UFGalT activity and consequently stimulate anthocyanin synthesis (Ju *et al.,* 1995).

CONCLUSION

Fruit quality is the major determinant of grower returns without bringing additional land under cultivation and consequently has been studied widely. There are many components of fruit quality such as size, colour, firmness, soluble solids and acidity. In addition there are many factors which may influence fruit quality, some of which are outside of control such as weather, site suitability and varietal genetic potential. Fruit quality can be improved through use of dwarf rootstocks, nutrient management practices, growth regulators, irrigation scheduling technologies and proper orchard management

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