FERTIGATION STUDIES IN PAPAYA (*Carica papaya* L.)

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(2017-22-006)

DEPARTMENT OF FRUIT SCIENCE

COLLEGE OF AGRICULTURE

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by

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THESIS

Submitted in partial fulfilment of the requirements for the degree of

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<u>DECLARATION</u>

I hereby declare that the thesis entitled "**Fertigation studies in papaya (*Carica papaya* L.)**" is a bonafide record of research work done by me during the course of research and the thesis has not been previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that thesis entitled **"Fertigation studies in papaya (*Carica papaya* L.)"** is a bonafide record of research work done independently by Ms. Karishma Sebastian (2017-22-006) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship or fellowship to her.

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We, the undersigned members of the advisory committee of Ms. Karishma Sebastian (2017-22-006), a candidate for the degree of **Doctor of Philosophy in Horticulture**, with major field in Fruit Science, agree that the thesis entitled "**Fertigation studies in papaya (*Carica papaya* L.)**" may be submitted by Ms. Karishma Sebastian in partial fulfilment of the requirement for the degree.

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"Commit your works to the Lord

And your plans will be established"

Holy Bible (Proverbs 16:3)

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Karishma Sebastian

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LIST OF ABBREVIATIONS

B : C ratio	Benefit Cost ratio
CD	Critical Difference
cfu	colony forming unit
cm	centimeter
DAP	Days After Planting
EC	Electrical Conductivity
et al.	co –workers/ co-authors
Fig.	Figure
FYM	Farmyard manure
g	gram
ha	hectare
i.e.	That is
K	Potassium
KAU	Kerala Agricultural University
kg	kilogram
kg ha^{-1}	kilogram per hectare
L	Litre
LAI	Leaf Area Index
m	metre
m^2	square metre
MAP	Months After Planting

MOP	Muriate of Potash
N	Nitrogen
NS	Non Significant
P	Phosphorus
POP	Package of Practices
$Plant^{-1}$	per plant
RD	Recommended Dose
RDN	Recommended Dose of Nutrients
RH	Relative Humidity
SEm	Standard Error of mean
t ha^{-1}	tonnes per hectare
TSS	Total Soluble Solids
viz.	Namely

LIST OF SYMBOLS

@	at the rate of
ºC	degree Celsius
%	per cent

Introduction

1. INTRODUCTION

Papaya (*Carica papaya* L.) belonging to Caricaceae family has long been recognized as a wonder fruit of the tropics and grown predominantly for its delicious taste and extraction of its digestive constituent papain. It bestows elevated production of fruits per hectare and an income next to banana. It is a native of tropical America and introduced to India during 16^{th} century. This crop has achieved more significance among farmers on account to its palatability, fruiting ability round the year, early fruiting and highest productivity per unit area and multifold uses like food, medicine and industrial input. The fruit is a rich source of vitamin A, B and C. Green fruit of papaya contains protease enzyme ‘papain’ which has diverse use in pharmaceutical and food industries. Due to neutraceutical properties and multifold uses it is now slowly emerging as a commercial crop in Kerala.

According to data of NHB (2019), India is the leading producer of papaya in the world with an area of 1,39,000 hectares and production of 58,31,000 MT. Nutrient loss and reduction in nutrient use efficiency, leading to situations of decreased productivity, soil health degradation and heightened environmental pollution apart from the wastage of a considerable portion of expensive and scarce inputs are the drawbacks of conventional method of nutrient application followed in papaya. Adoption of fertigation enhances the nutrient uptake efficiency to an extent of 30-40 per cent, deter degradation of soil, deducts fertilizer application cost besides boosting the productivity and produce quality.

According to Kumar *et al*. (2008) supply of requisite amount of nutrients is necessary during the active growth period in papaya, as vegetative growth and flowering is simultaneous in this crop. This is possible through fertigation. Fertigation studies conducted in papaya revealed an increased fruit yield without compromising its fruit qualities over soil application.

For enhancing the productivity of crop, knowledge on correct dose of fertilizers to be provided through fertigation is very crucial. Under Kerala conditions, no ample evidence is available on the correct dose of nutrients for fertigation in papaya. Hence, in this project an endeavor was done to elucidate the impact of fertigation on papaya growth and development.

High amount of metabolic boron is needed by papaya plant, as it is latex yielding. Zinc and boron deficiencies have been increasingly documented in papaya. Soorianathasundaram (2005) reported that deficiency of boron may cause bumpiness in papaya fruits (tumor like eruptions) along with exudation of latex from fruit skin. To overcome this issue, foliar nutrition of micronutrients will be incredibly beneficial. Also, foliar feeding comes as a boon, under conditions like plant stress or in adverse soil conditions when nutrients become unavailable to plant roots and absorbtion will be at stake. When prompt correction of nutrient deficiencies is required, this is the method of choice as nutrient uptake through leaf stomata is considerably faster than through roots. Micronutrient foliar spray can also help the plant to shield itself from pest attacks by providing extra nutrients to maintain a healthy immune system.

Research on foliar sprays of micronutrients boron (as boric acid) and zinc (as zinc sulphate) on papaya revealed a significant increase in both biometric and yield parameters apart from improved fruit set, fruit retention and also increased latex yield. Raja (2010) observed that papaya fruits with bigger size, smooth skin and healthy seeds where obtained in boron applied treatments whereas, fruits with rough skin and asymmetrically filled fruit cavity was the result of control (no boron treatment) and were unmarketable with small size and few aborted seeds.

Being climacteric, papaya fruits are highly perishable and need to be handled with extreme care from the time they are harvested until they reach the consumer. Post harvest losses of papaya fruits is up to 75%, according to estimates of mainland

USA wholesalers and retailers. Therefore, developing a suitable technology for prolonging the storage life of papaya, which can help both in domestic as well as international trade is the need of the hour. The storage life of fruits can be extended by checking the rate of respiration, transpiration and disease infection through some postharvest treatment like precooling, sanitization, waxing and by the use of ethylene scrubber.

In recent times, a lot of attention has been received for the use of biologically active natural products rather than synthetic fungicides for curbing decay and lengthening the shelf life of fruits (Tripathi and Dubey, 2004). Studies on use of bio-waxes on papaya revealed significant changes in peel colour, firmness, internal CO_2 concentration and respiration rate in all bio-wax coated fruits without affecting its organoleptic characteristics. Also recent researches pointed that chitosan treated fruits registered reduced deterioration index compared to the control without significantly affecting the physicochemical properties of fruits. Hence, use of chitosan, carnauba wax etc. were resorted in the study.

In this view, present study entitled "Fertigation studies in papaya (*Carica papaya* L.)" is proposed with the following objectives:

1. To standardize the nutrient level for yield improvement through fertigation and foliar nutrition in papaya

2. To study the postharvest management practices for extending the shelf life of fruits

Review of literature

2. REVIEW OF LITERATURE

Papaya (*Carica papaya* L.) belongs to the family Caricaceae, is an important fruit crop of tropical world and has long been realized as wonder fruit of the tropics. It occupies limited area for growth, reaches fruiting within a year, is easy to cultivate and contributes more income next to banana. Papaya has a broad spectrum of adaptability and had high monetary return per unit area.

Papaya is a shallow rooted crop and is highly prone to the soil moisture instability. The growth and development of papaya will be affected under extended moisture stress, leading to the production of male flowers which steers to poor fruit set. Irrespective of varieties, papaya fruits produced in high rainfall and humid regions are larger than those grown in low rainfall regions. Singh and Singh, (2002) documented that higher moisture conditions in papaya leads to exorbitant production of unsatisfactory carpelloid types in which the stamens fuse with developing ovary, resulting in deformed fruits whereas, meagre soil moisture level can transform plants towards sterility and male floral characters. Under flood irrigation, the crop is extremely sensitive to collar rot, as water comes in direct contact with the trunk. Hence effective water application to this crop is essential.

Water is the natural resource gifted by nature for sustainability of civilization. Any mishandling of this resource will steer to the devastation of civilization. Spears, (2003) forecasted that there will be an annual global water shortage of 640 billion cubic meters, by the year 2050. Agriculture sector consuming 71 % of the freshwater use across the world is the largest consumptive user of water. Fereres and Soriano (2007) opined that irrigation management practices should be diverted from emphasizing production per unit area towards maximizing the production per unit of water consumed.

Drip irrigation may be considered as one of the latest innovations for applying water to widely spaced crops, especially in the water scarce areas. This technique provides a provision for precise application of water directly into the root zone without wetting the entire area, which aids in saving considerable amount of water (Ahluwalia *et al*., 1993). According to INCID (1994) drip irrigation reduces the requirement of water (45-50 per cent), labour (40-50 per cent) and fertilizer (25-30 per cent).

2.1 FERTIGATION AND FOLIAR NUTRITION STUDIES IN PAPAYA

Fertilizers supplied at planting time and in split doses at critical growth periods to the plant root zone mostly offer lesser efficiency, as most of the conventionally applied nutrients will leach and become unavailable to the plant roots.

By the technique of fertigation, accurate quantities of both water and fertilizer can be supplied to growing crops at the root zone. Roots develop vastly in a limited volume of soil moistened by drip irrigation and application of fertilizers through the irrigation system can significantly provide nutrients in that wetted zone, where the roots are present at highest concentration in the soil. The advantage of drip irrigation over conventional method includes reduced water requirement, enhanced yield and improved quality of produce. Goldberg and Shmuli (1970) reported that drip irrigation aids in controlled placement and acurate supply of water soluble fertilizers apart from providing highly efficient water application.

As surface evaporation and deep percolation are reduced by drip fertigation, high water use efficiency and nitrogen use efficiency are the results (Darwish *et al*., 2006). Chaudhri *et al.* (2001) documented that fertigation in papaya provides a substantial increase in yield along with 50 per cent and 53 per cent saving of fertilizer and water respectively. Deshmukh and Hardaha (2014) reported that drip irrigation is beneficial over conventional method of irrigation in saving water and increasing yield of papaya to the tune of 45 to 66 per cent and 21 to 36 per cent respectively. However, expensive investment of fertilizer injection system and safety devices are the limiting factors for fertigation (Imas, 1999).

Foliar nutrition is a widely used environmental friendly method for providing supplemental dose of major and minor nutrients, plant hormones, stimulants and other beneficial substances on the canopy. It aims at improving the yield and quality of crops with reduced environmental impacts associated with soil fertilization. Kuepper (2003) reported that foliar application of major nutrients was beneficial for promoting vegetative growth and size of fruits.

As nutrients applied through foliar spray are readily absorbed through the leaf surface it gives a quicker response than application of nutrients to soil. Foliar sprays are also a boon in cases of immobilization processes, which make application to the soils ineffective. Apart from this foliar nutrition has multiple advantages like low cost, use of limited quantity of fertilizers and ability to combine with other agrochemicals in a single application (Oosterhuis, 2009). Studies have shown that micronutrient application to plants is highly effective since it can tremendously upgrade yield of crop and enhance fruit quality and shelf life of produce. Role of micronutrients as enzyme activators and its function in lignin biosynthesis gives disease resistance to plants upon its application (Raja, 2009).

Kavitha *et al*. (2001) reported improvement in yield and fruit quality in papaya variety CO.5 upon foliar sprays with micronutrients, 0.1% boric acid and 0.5% zinc sulphate at 4^{th} and 8^{th} month after planting. Hada (2013) documented that foliar application of boron reduces the fruit drop, as it plays a crucial role in carbohydrate translocation, auxin synthesis and augmenting pollen viability and fertilization.

Application of micronutrient boron as pre-harvest foliar sprays was useful in strawberry cv. Chandler for ensuring elevated marketable fruit yield with better firmness and enhanced quality parameters (Singh *et al*., 2007), which was achieved by lowering the incidence of physiological disorders. Similar conclusions were also reported by Sajid *et al*. (2010) in sweet orange cv. Blood Orange. They concluded that foliar sprays of 0.05% zinc and 0.04% boron significantly reduced the incidence of die back (13.77%), whereas, control treatment succumbs to higher percentage of die back incidence (25.56%).

Low levels of zinc in soil affect the fruit yield in many tropical and subtropical fruits, as this micronutrient is a constituent of several enzymes required for metabolic reactions in the plant and also crucial for auxin and protein synthesis. Small leaves, shortened internodes giving a stunted appearance to plant are the zinc deficiency symptoms. Boron is a constituent of cell membrane and important for cell division. According to Trivedi *et al.* (2012) boron plays a role in absorption of nitrogen and translocation of sugars and acts as a regulator of potassium/calcium ratio in the plant.

In the following pages review of literature on impact of fertigation and foliar spraying with micronutrients on various fruit crops are described.

2.1.1 Biometric parameters

2.1.1.1 *Plant height*

In banana cv. Grand Naine, increase in plant height (185 cm) upon application of 100 % RD of N and K through drip was reported by Bhalerao *et al*. (2009), whereas supply of 100 % RD of N and K through soil resulted in a plant height of 180 cm. Least plant height (170 cm) was observed in plants receiving 50 % RD of N and K through soil.

According to Singh *et al.* (2010) application of 0.50% borax along with 0.25% $ZnSO_4$ gave maximum plant height (171.62 cm) in papaya cv. Ranchi and least plant height was recorded in control (153.58 cm).

Impact of fertigation on plant height of Sapota cv. Kalipatti (*Achras sapota* Mill) was studied by Patel *et al*. (2017b). They reported that plant which received 100

% RD of NPK gave a maximum plant height of 618 cm which was followed by plants which received 75 % RD of NPK (602 cm). Lowest plant height was reported in control (572 cm).

2.1.1.2 *Plant girth*

Application of borax 0.50% along with 0.25% $ZnSO_4$ was found to be best which gave maximum plant girth (39.74 cm) in papaya cv. Ranchi (Singh *et al.*, 2010), whereas control registered a girth of 34.29 cm.

Babaji (2013) reported that application of N and K_2O at 100 % RD resulted in highest stem girth of 28.33 cm, 42.21 cm and 48.15 cm respectively at 180 DAP, 270 DAP and 360 DAP in papaya cv. Red Lady. Plants receiving 60 % RD of N and K_2O recorded lowest stem girth of 22.39 cm, 36.50 cm and 42.09 cm respectively at 180 DAP, 270 DAP and 360 DAP.

Influence of different levels of fertigation (50, 60 and 80% of recommended NPK fertilizers) on growth attributes of banana cv. Martaman (AAB), Silk at shooting stage was studied by Pramanik and Patra (2016). Highest pseudostem girth of 75.48 cm was recorded in plants receiving 80 per cent RDN through fertigation and plants receiving 50 per cent RDN through fertigation recorded a shortest pseudostem girth of 66.22 cm in banana.

2.1.1.3 *Number of leaves*

In strawberry cv. Chandler, improvement in number of leaves per plant (24.93) upon foliar sprays of $ZnSO_4$ (0.4%) was reported by Chaturvedi *et al*. (2005). Control plants recorded lowest number of leaves per plant (19.21).

Jeyakumar *et al*. (2010) reported that application of 100 % RD of N and K_2O through drip resulted in maximum number of leaves (34.20) in papaya cv. Co.7.

Plants receiving 50 % RD of N and K_2O through drip recorded lowest number of leaves per plant (28.00).

Application of $ZnSO_4$ (0.25%) along with Borax (0.1%) recorded maximum number of leaves (39.11) in papaya cv. Red Lady compared to untreated control (31.67) (Manjunatha, 2012).

According to Babaji (2013), papaya cv. Red Lady receiving 100 % RD of N and K_2O registered highest number of leaves per plant of 24.25, 34.80 and 44.97 respectively on 180, 270 and 360 days after transplanting whereas, plants receiving 60 % RD of N and K_2O recorded minimum number of leaves per plant (21.28, 30.89 and 39.62 on 180, 270 and 360 days after transplanting).

Maneesha *et al*. (2019) opined that application of 100 % RD of N and K_2O as weekly fertigation improved the number of leaves per plant (17.82) in pineapple variety 'Giant Kew' during crop establishment stage. It was found to be on par (17.46) with plants receiving fertigation with 125 % RDN. Lowest number of leaves (11.16) was recorded in plants provided with surface irrigation and conventional application of 100 % RDN.

2.1.1.4 *Leaf Area Index*

Valji (2011) reported that leaf area increased linearly with level of fertigation (60 %, 80 % and 100 % RDN) in papaya var. Madhu Bindu. Maximum leaf area of 6.88 m^2 was noted by the plants receiving drip irrigation at 0.8 PEF along with N and K_2O at 100 % RD. Control (surface irrigation at IW/CPE ratio of 1.0 along with 100 % RDN of N, P_2O_5 and K_2O through soil) registered a leaf area of 5.28 m^2. Minimum total leaf area of 4.49 m^2 was measured in plants receiving drip irrigation at 0.4 PEF along with N and K_2O at 60 % RD.

Greatest leaf area of 628.21 cm^2 was recorded in guava cv. L-49 receiving foliar application of 0.8% $ZnSO_4$ and 0.4% borax, while the lowest leaf area (528.88 cm^2) was noted in control (Hada, 2013).

Kachwaya and Chandel (2015) studied the impact of fertigation on leaf area of strawberry cv. Chandler. They opined that supply of 100 % and 75 % RD of NPK through drip increased the leaf area (129.2 and 128.2 cm^2 respectively) whereas soil application of recommended dose of NPK gave a lesser leaf area of 122.5 cm^2.

Pramanik and Patra (2016) reported a highest leaf area index of 3.21 in banana cv. Martaman, AAB receiving 80 per cent RDN through fertigation and lowest value for leaf area index (2.28) was recorded in plants receiving 50 per cent RDN through fertigation.

2.1.1.5 ***Height at first flowering (cm)***

Jeyakumar *et al.* (2010) documented that application of N and K_2O through drip resulted in flowering at the lowest height (96.32 cm) in 100 % RD of papaya cv. CO 7. In control plants flowering occurred at a height of 103.41 cm.

Significant differences with respect to height at first flowering due to different fertigation treatments was reported by Valji (2011) in papaya var. Madhu Bindu. The papaya plants which received 80 % RD of N and K through fertigation flowered at shortest height (60.45 cm) which was followed by fertigation at 100 % RD of N and K (62.65 cm), whereas, application of 100 % RD of nutrients through soil (control) registered a height of 74.71 cm at flowering. Fertigation with N and K_2O at 60 % RD flowered at a maximum height of 83.28 cm.

Parag *et al.* (2016) documented that adoption of fertigation level at 100 per cent RDN resulted in minimum first flowering height (76.57 cm) in papaya cv. Red Lady under Navsari (Gujarat) conditions, whereas papaya plants receiving 80 per cent and 60 per cent RDN flowered at a height of 78.74 cm and 84.16 cm respectively.

2.1.1.6 *Days to flowering*

Application of 100 % RD of N and K through fertigation reduced the days for flowering (282 days) in banana cv. Grand Naine (Bhalerao *et al.*, 2009), whereas plants received 100 % and 50 % RD of N and K through soil, took 291 days and 299 days respectively for flowering.

Singh *et al*. (2010) documented early flowering (104.42 days after transplanting) in papaya cv. Ranchi on foliar sprays with borax (0.50 %). Control took 124.83 days to flower.

The fertigation study conducted by Valji (2011) in papaya var. Madhu Bindu revealed that plants which received drip irrigation at 0.8 PEF along with N and K_2O at 100 % RD initiated first flower significantly in less number of days (69.10) after transplanting. The treatment which received drip irrigation at 0.4 PEF along with N and K_2O at 60 % RD recorded maximum number of days (91.27) after transplanting for the appearance of first flower.

Babaji (2013) reported significantly minimum days (109.46) to first flower initiation in papaya cv. Red Lady receiving N and K_2O at 100 % RD as fertigation. Plants receiving 60 % RD of N and K_2O recorded more days to first flower initiation (122.32 days).

Foliar application of borax (30 mg l^{-1}) was found to give earliness in initiation of flowering (93.40 days) in papaya cv. Taiwan Red Lady, whereas it took 128.40 days for flower initiation in water spray (control) (Bhalerao *et al*., 2014).

Days to first flowering in papaya cv. Red Lady was found lowest (108.58) in plants receiving 100 per cent RDN through fertigation under Navsari (Gujarat) conditions, whereas it took 122.56 days to appear first flower in plants receiving 60 per cent RDN through fertigation (Parag *et al*., 2016).

2.1.1.7 ***Sex expression of plant***

Highest number of hermaphrodite (63.05) flowers per plant was noticed upon application of 50 % RDN through fertigation in pomegranate cv. Mridula (Shanmugasundaram, 2013). It was followed by 75 % RDN through fertigation (57.70 hermaphrodite flowers per plant). However, control registered lowest number of hermaphrodite flowers per plant (39.30).

Thanari and Suma (2018) documented that pomegranate plants receiving 100 % RDN through fertigation resulted in higher number of hermaphrodite (107.0) and male flowers (92.0), while lesser numbers of hermaphrodite and male flowers (84.0 and 78.0) were observed in treatment receiving 100 per cent RDN through soil application (control).

2.1.1.8 ***Number of flowers cluster^{-1}***

Kazemi (2014) suggested that foliar application of zinc sulfate at 150 mg l^{-1} significantly increased the number of flowers (15.70), while plants with no spray (control) registered lowest number of flowers (7.20).

Rahman *et al*. (2016) documented increased number of flowers buds per plant (31.53) in strawberry on foliar sparys with zinc (1.5 kg ha^{-1}) and lowest number of flowers buds per plant (29.21) was reported in control.

2.1.1.9 ***Fruit set percentage***

Hada (2013) revealed maximum fruit set percentage (78.57) in guava cv. L-49 upon foliar spraying with 0.8% $ZnSO_4$ and 0.4% borax. Minimum fruit set percentage (70.92) was recorded in control.

A significantly higher fruit set percentage of 0.37 and 0.35 were observed in plants supplied with 125 per cent and 100 per cent RDN of NPK respectively in mango cultivar ‘Alphonso’ under ultra high density planting, whereas plants provided with 50 per cent RDN recorded a lowest fruit set percentage of 0.29 (Prakash *et al*., 2015).

Makhmale and Delvadia (2016) noted that application of 0.5% zinc sulphate and 0.3% borax as foliar spray increased the fruit set percentage (16.30) in custard apple (*Annona squamosa* L.) cv. Sindhan. Control (water spray) plants recorded lowest fruit set percentage of 13.10

Chander *et al*. (2017) opined that foliar application of borax (0.6 %) increased the fruit set per cent (59.92 %) in guava variety Lalit. The minimum fruit set per cent (54.16 %) was recorded in control. They also reported same results in guava variety Shweta. Foliar application of borax (0.6 %) increased the fruit set per cent (58.27 %). Control plants recorded a minimum fruit set per cent of 52.69.

2.1.1.10 *Time for first harvest (days)*

Bhalerao *et al*. (2009) reported that application of 100 % RD of N and K through fertigation reduced the days for harvest of fruits (388 days) in banana cv. Grand Naine whereas, plants received 100 % and 50 % RD of N and K through soil, took 398 days and 416 days respectively for harvest.

Valji (2011) opined that application of varying levels of fertigation in papaya var. Madhu Bindu had significant influence on days taken to maturity of first fruit. The minimum days (249 days) to maturity of first fruit after transplanting was noted in the treatment which received drip irrigation at 0.8 PEF along with N and K_2O at 100 % RD. The application of drip irrigation at 0.4 PEF along with N and K_2O at 60 % RD had taken maximum days (278 days) to maturity of first fruit after transplanting.

Shanmugasundaram, (2013) pointed that plants receiving 125 per cent RDN through fertigation recorded lowest number of days (141.85 days) from flowering to harvest in pomegranate cv. Mridula, whereas treatments receiving 100 per cent RDN through fertigation registered 142.73 days from flowering to harvest. Highest number of days (145.90 days) from flowering to harvest was recorded in control.

2.1.2 Yield parameters

2.1.2.1 ***Fruit weight (g)***

Dutta (2004) illustrated that spraying mango trees cv. Himsagar with 3000 ppm boric acid solution significantly increased fruit and pulp weight.

According to Trivedi *et al.* (2012), maximum fruit weight of 162.01 g was recorded in application of boric acid (0.5%) and zinc sulphate (0.6%), however control recorded minimum fruit weight (85.55 g) in guava.

Jadhav *et al*. (2016) evaluated the impact of varying levels of fertigation (100, 80 and 60 % of RDN (200:200:250)) on fruit weight in papaya cv. Red Lady. The results showed that highest average fruit weight of 1.12 kg was obtained from plants receiving 100 per cent RDN and least average fruit weight of 0.83 kg was obtained from plants receiving 60 per cent RDN.

Foliar sprays of zinc and boron significantly increased the fruit weight (301.74 g) in pomegranate cv. Ganesh (Dhurve *et al.*, 2018). Fruits from control registered a fruit weight of 222.98 g.

Mahida *et al*. (2018) suggested that foliar application of 0.50 % $FeSO_4$ along with 0.50 % $ZnSO_4$ was an effective method for increasing the fruit weight (289.77 g) of mango cv. Kesar and fruits from no foliar spray gave a significantly lower weight of 236.97g.

2.1.2.2 ***Fruit length (cm)***

Adoption of fertigation level at 100 % RD of fertilizer (200g N, 200 g P_2O_5 and 250 g K_2O) recorded significantly highest fruit length (22.93 cm) in papaya cv.

Red Lady, whereas plants receiving 60 per cent RDN through fertigation recorded lowest fruit length of 18.63 cm (Jadhav *et al*., 2016).

Mishra *et al*. (2017) documented that foliar spraying of borax (0.25%), $ZnSO_4$ (0.25%) along with $CuSO_4$ (0.4%) increased the fruit length (3.72 cm) in aonla (*Emblica officinalis*) cv. Na-7, while control (water spray) recorded a fruit length of 3.15 cm.

According to Tirkey *et al*. (2018) foliar spraying with zinc sulphate 0.8% increased the fruit length (6.21 cm) in guava cv. Allahabad Safeda, while fruits from control treatment recorded a lesser fruit length of 5.84 cm.

2. 1.2.3 *Fruit girth (cm)*

Khan *et al*. (2012) reported significantly highest fruit girth of 6.45 cm in mandarin cv. Feutrell’s Early upon foliar spray with 0.3% boric acid and 0.5% zinc sulphate at fruit set stage, whereas control treatment registered a lowest fruit girth of 5.82 cm.

Maximum fruit girth of 6.07 cm was obtained by foliar application of $ZnSO_4$ (0.4%) in guava (*Psidium guajava* L.), while control recorded minimum fruit girth (5.22 cm) (Arshad and Ali, 2016).

Kaur *et al*. (2019) revealed that highest fruit diameter of 13.04 cm was recorded with application of 100 per cent RDN through fertigation in cucumber (*Cucumis sativus* L.), while soil application of 100 per cent RDN gave lowest fruit diameter 9.78 cm.

2. 1.2.4 *Fruit volume (cc)*

According to Valji (2011) fertigation in papaya var. Madhu Bindu was found to be significant with respect to volume of fruits. The plants with drip and fertigation of N and K_2O at 100 % RD produced the fruits with higher fruit volume (1357.95 cc).

The minimum fruit volume (1027.44 cc) was noted in the treatment with N and K_2O at 60 per cent of RD.

Baranwal *et al*. (2017) documented that application of $ZnSO_4$ (1%) and Borax (0.6 %) significantly increased the fruit volume in guava (*Psidium guajava* L.) (141.83 cc and 144.66 cc respectively), whereas fruits from control recorded a fruit volume of 130.80 cc.

Application of $ZnSO_4$ (1.0 %) and borax (1.0 %) revealed significantly higher fruit volume (620.06 ml) in pineapple cv. Mauritius and lesser fruit volume (405.00 ml) was recorded in control (Kumari and Deb, 2018a).

2. 1.2.5 *Physical composition (%)*

Impact of fertigation on yield attributes of mango cv. Amrapali was studied by Thakur (2003). The result indicated that application of 100 per cent RDN through fertigation gave maximum pulp weight (147.75 g), minimum stone and peel weight (34.25 g and 30.25 g respectively), whereas minimum pulp weight of 108.65 g and maximum stone and peel weight of 40.75 g and 33.47 g respectively was observed in conventional method of fertilizer application and surface irrigation (control).

Influence of foliar spray of different nutrients on physical properties of guava cv. Pant Prabhat was studied by Kumar *et al*. (2015). Application of borax at 0.03% at fruit set stage significantly increased the pulp to seed ratio (87.59), while a lowest pulp to seed ratio of 53.41 was recorded in control.

Foliar sprays of $ZnSO_4$ (0.25%), borax (0.25%) along with $CuSO_4$ (0.4%) increased the pulp stone ratio (21.59) in aonla (*Emblica officinalis*) cv. Na-7, whereas lowest pulp stone ratio (15.75) was documented in control (water spray) (Mishra *et al*., 2017).

Application of 100 per cent RDN through fertigation recorded significantly higher aril weight (183.4 g), peel weight (98.30 g) and aril to peel ratio (1.87) in pomegranate (*Punica granatum* L.) while lowest aril weight, peel weight and aril to peel ratio of 110.25, 79.75 and 1.32 respectively was registered in 100 per cent soil application of RDN (Tanari *et al*., 2019).

2. 1.2.6 *Flesh thickness (cm)*

The reports of Singh *et al.* (2010) pointed that spraying with Borax (0.50%) along with $ZnSO_4$ (0.25%) increased the flesh thickness (3.12) in papaya cv. Ranchi whereas lowest flesh thickness was noticed in control (2.63).

Influence of fertigation on pulp thickness of papaya cv. Red Lady was studied by Jadhav *et al*. (2016). They reported that a greater pulp thickness of 3.33 cm was obtained in plants receiving 100 per cent RDN through fertigation and a lesser pulp thickness of 3.06 cm was obtained in plants receiving 60 per cent RDN.

Foliar sprays of 0.8% zinc sulphate and 0.8% borax alone to guava cv. Allahabad Safeda showed a pulp thickness of 1.84 cm and 1.87 cm respectively (Tirkey *et al*., 2018) whereas fruits from control treatment registered a pulp thickness of 1.42 cm.

2. 1.2.7 *Number of fruits per plant*

Sadarunnisa *et al*. (2010) documented that application of 75 % RD of N and K through fertigation recorded maximum number of fruits per plant (74.39) and lowest number of fruits per plant was observed in treatment receiving recommended dose of nutrients through soil (54.88).

Babaji, (2013) reported highest number of fruits per plant (27.38) upon receiving N and K_2O at 100 per cent RDN as fertigation in papaya cv. Red Lady, whereas plants receiving 60 % RD of N and K_2O as fertigation registered lowest number of fruits per plant (20.39).

Application of boron and zinc on pomegranate (cv. Ardestani) significantly increased (65.9) the number of fruits per tree compared to control (50.6) (Davarpanah *et al*., 2016).

Venkataramudu *et al*. (2017) revealed that application of RDN through fertigation improved the number of fruits per plant (67.11) in pomegranate cv. Ganesh and control (soil application of RD of NPK along with surface irrigation) recorded lowest number of fruits per plant (46.00).

2. 1.2.8 ***Number of seeds per fruit***

Foliar application of $ZnSO_4$ (0.5%) reduced the number of seeds (8.27) in acid lime (*Citrus aurantifolia*) cv. Kagzi. Whereas, fruits from control treatment recorded 9.87 seeds (Jagtap *et al*., 2013).

Singh *et al*. (2018) suggested that foliar spraying with boric acid (0.3%), zinc sulphate (0.5%) along with 0.7% copper sulphate reduced the number of seeds (8.10) in sweet orange (*Citrus sinensis* L.) cv. Mosambi, whereas lowest number of seeds (11.33) was registered in water spray (control).

Tirkey *et al*. (2018) reported a reduced seed number of 239.33 in guava cv. Allahabad Safeda upon foliar spraying with zinc sulphate (0.8%). They also registered a reduction in seed number (304.33) by foliar spraying with borax 0.8% and highest number of seeds (317.66) was noticed in fruits from control.

2. 1.2.9 ***Seed germination percentage***

Santhosh (2012) opined that foliar application of boron enhanced the seed germination percentage in tomato (*Solanum lycopersicum* L.).

2. 1.2.10 *Yield per plant (kg)*

Bahadur *et al*. (1998) noticed that foliar sprays of 0.25% zinc sulphate during flower bud differentiation increased fruit yield (23.7 kg tree^{-1}) in mango compared to control (16 kg tree^{-1}).

Usha and Singh (2002) documented that foliar spray of boron (Borax, 0.4%) in grape cv. Perlette at two growth stages *i.e*., at pre-bloom and at fruitset improved the yield per plant (7.5 kg plant^{-1}) compared to untreated control (3.7 kg plant^{-1}). Enhanced number of bunches per plant (20 in boron treated plant and 14 in control) and increased single berry weight (1.8g for boron treated plant and 1g for untreated control) contributed towards an improved bunch yield in response to Boron compared to untreated control.

Tariq *et al*. (2007) opined that foliar sprays of boron and zinc significantly increased the fruit yield (115.3 kg tree^{-1}) of sweet orange (*Citrus sinensis* L.) compared to control (63 kg tree^{-1}).

Bhalerao *et al.* (2009) evaluated the impact of fertigation and conventional method of fertilizer application on yield parameters of banana cv. Grand Naine. They noted that supply of 100 % RD of N and K through drip increased the yield in banana (91.4 t ha^{-1}), whereas application of 50 % RD of N and K through soil gave a lowest yield of 68.4 t ha^{-1}.

Yield per plant in papaya (31.03 kg plant^{-1}) cv. Red Lady was significantly highest in plants treated with N and K_2O at 100 per cent RDN through drip application, whereas N and K_2O at 60 per cent RDN recorded lowest yield per plant (16.60 kg plant^{-1}) (Babaji, 2013).

Influence of fertigation on yield parameters of papaya was studied by Prajapati *et al*. (2017). Highest fruit yield plant^{-1} (22.38 kg) was recorded in 100 per cent RDN and lowest yield of 14.94 kg was reported in conventional irrigation methods.

2. 1.2.11 *Yield ha^{-1}*

Singh *et al*. (2010) revealed that 0.50% borax with 0.25% $ZnSO_4$ increased the yield ha^{-1} (93.00 tonnes) in papaya cv. Ranchi and control treatment recorded a minimum yield ha^{-1} of 61.56 tonnes.

Baranwal *et al*. (2017) documented the impact of foliar sprays of borax (0.2, 0.4, 0.6% solution) and $ZnSO_4$ (0.50, 0.75, 1.00% solution) on yield ha^{-1} in guava (*Psidium guajava* L.). They concluded that foliar spray of 0.6% borax and 1.00% $ZnSO_4$ on guava (*Psidium guajava* L.) plants twice *i.e*. once before first flowering and again after fruit setting are beneficial to get higher yield (45.17 kg ha^{-1} and 44.10 kg ha^{-1}), whereas control plants gave a lower yield of 32.70 kg ha^{-1}.

Highest fruit yield of 69.07 MT ha^{-1} was reported in papaya upon application of 100 per cent RDN through fertigation whereas, conventional irrigation system gave a lowest fruit yield (46.11 MT ha^{-1}) (Prajapati *et al.*, 2017).

2. 1.2.12 *Days taken for maturity and ripening*

Early maturity of fruits for harvest (249.00 days) was obtained in plants receiving drip irrigation at 0.8 PEF along with N and K_2O at 100 per cent RDN in papaya cv. Madhu Bindu (Tank *et al.*, 2011). Delayed maturity (278.00 days) was noticed in treatments receiving drip irrigation at 0.4 PEF along with N and K_2O at 60 per cent RDN.

Gonge *et al*. (2015) noticed that supply of 80 per cent RDN by fertigation in banana cv. Grand Naine significantly reduced the number of days (336.52 days) required for achieving maturity and maximum days (360.50 days) for achieving maturity was observed in plants supplied with 40 per cent RDN by fertigation.

Parag *et al*. (2016) revealed minimum days (260.99 days) to attain fruit maturity in papaya cv. Red Lady upon receiving 100 per cent RDN through fertigation and plants receiving 60 per cent RDN recorded more number of days (276.90 days) to attain fruit maturity after transplanting.

2.1.3 Fruit quality parameters

In general, horticultural crops respond to the changes in water and nutrient management, and therefore to the fertigation techniques also. These improved water and nutrient supply management of to horticultural crops were found to have beneficial impact on product quality.

2.1.3.1 *Total soluble solids (°Brix)*

Trivedi *et al.* (2012) documented highest total soluble solids (15.40 °Brix) upon foliar sprays with zinc sulphate (0.6%) and boric acid (0.5%) in guava, whereas control registered minimum total soluble solids (9.62 °Brix).

Application of N and K_2O at 100 per cent RDN gave maximum total soluble solids (7.47 °Brix) in fruits of papaya cv. Red Lady, whereas a minimum total soluble solid content of 5.96 °Brix was registered in plants receiving 60 % RD of N and K_2O as fertigation (Babaji, 2013).

Pramanik and Patra (2016) reported that total soluble solid content was found to be significantly highest (23.51°Brix) in banana cv. Martaman, AAB receiving 80 per cent of RDN through fertigation and a lowest value of 21.21°Brix was recorded in plants receiving 50 per cent of RDN through fertigation.

Impact of drip irrigation and fertigation on biochemical parameters of sapota cv. Kalipatti was studied by Patel *et al.* (2017a). Highest TSS of 19.30 °Brix was recorded in plants receiving 100 per cent RDN and lowest TSS (18.30 °Brix) was obtained in plants receiving 50 per cent RDN.

2.1.3.2 ***Acidity (%)***

Singh *et al.* (2010) documented that foliar spray with borax at 0.25% reduced the titratable acidity (0.107 %) of fruits of papaya cv. Ranchi and highest titratable acidity (0.151 %) was registered in control fruits.

A study was performed by Venkataramudu *et al*. (2017) in pomegranate cv. Ganesh to elucidate the impact of fertigation on fruit qualities. The study pointed that supply of 125 % RD through fertigation reduced the acidity of fruits (0.36 %) and fruits obtained from control (soil application of RD of NPK along with surface irrigation) plants recorded highest acidity (0.40 %).

Kumari and Deb (2018b) investigated the impact of zinc and boron on quality attributes of pineapple cv. Mauritius. The study documented that application of $ZnSO_4$ (0.5%) in combination with borax (0.5%) resulted in lowest acidity of 0.67 %, whereas highest acidity was recorded in control plants (0.86).

2.1.3.3 ***Total carotenoids (mg100g^{-1})***

Singh *et al*. (2010) pointed that foliar spraying with borax 0.50 % in combination with $ZnSO_4$ 0.25 % significantly increased the carotenoid content (3327.14 µg 100 g^{-1}) in papaya cv. Ranchi, while control registered lowest carotenoid content of 2119.62 µg 100 g^{-1}.

Tank *et al*. (2011) recorded no significant differences in total carotenoid content of fruits of papaya cv. Madhu Bindu receiving different levels of fertigation. Plants receiving drip irrigation at 0.4 PEF along N and K_2O at 60 per cent RDN recorded a more total carotenoid content of 2.33 mg 100 g^{-1} pulp and lower carotenoid content (2.17 mg 100 g^{-1} pulp) was noticed in treatments receiving drip irrigation at 0.8 PEF along with N and K_2O at 100 per cent RDN.

Foliar spray with boric acid (0.02 %) significantly increased the carotenoid content (12.34 mg 100 g^{-1}) of mango cv. Alphonso, while control registered lowest carotenoid content (9.66 mg 100 g^{-1}) (Sankar *et al*., 2013).

Effect of different doses of fertigation on carotenoid content of *Citrus sinensis* cv. Mosambi was studied by Nirgude *et al*. (2016). They concluded that plants supplied with 60 per cent RDN recorded highest carotenoid content (0.578 mg 100 g^{-1}) and plants supplied with 120 per cent RDN registered lowest carotenoid content (0.362 mg 100 g^{-1}).

2.1.3.4 *Ascorbic acid (mg 100g^{-1})*

Supply of 100 % RD of N and K_2O through drip recorded highest ascorbic acid content (69.54 mg g^{-1}) in papaya cv. Co.7 and plants receiving 50 % RD of N and K_2O through drip registered lowest value (62.10 mg g^{-1}) (Jeyakumar *et al*., 2010).

The reports of Baranwal *et al*. (2017) on foliar sprays of $ZnSO_4$ and borax on guava (*Psidium guajava* L.) revealed that application of $ZnSO_4$ (1.00 %) and borax (0.6 %) significantly increased the ascorbic acid content (186.67 mg 100g^{-1} and 186.92 mg 100g^{-1} respectively) of fruits compared to control (171.0 mg 100g^{-1}).

The ascorbic acid content of pomegranate cv. Early Bhagwa was found to be highest (15.05 mg 100g^{-1}) in treatment receiving 100 per cent RDN and minimum (14.13 mg 100g^{-1}) was found in plants receiving 75 per cent RDN (Garg, 2018).

2.1.3.5 *Total sugar (%)*

Singh *et al.* (2010) reported highest total sugar content of 6.88 % in papaya cv. Ranchi upon foliar sprays with borax (0.50%) and $ZnSO_4$ (0.25%) and lowest value (4.44 %) was noticed in control.

Trivedi *et al.* (2012) documented that foliar sprays of zinc sulphate (0.6%) and boric acid (0.5%) increased the total sugar content (8.66 %) of guava. Minimum total sugar content of 5.81 % was found in control.

Patel *et al.* (2018) revealed that foliar sprays of $ZnSO_4$ (0.5%) and borax (0.2%) alone to aonla cv. NA-6 improved the total sugar content (5.70 and 5.94% respectively). Aonla plants provided with water spray (control) recorded lowest total sugar content of 4.46%.

Drip irrigation in combination with fertigation and foliar spray of micronutrient increased the total sugar content (21.53 %) in banana cv. Grand Naine, while soil application of region specific RDN along with flood irrigation (control) registered a lower total sugar content of 19.26 % (Das and Bhattacharyya, 2019).

2.1.3.6 *Reducing sugar (%)*

Impact of fertigation on reducing sugar content of fruits of papaya cv. Red Lady was studied by Babaji (2013). The study pointed that application of N and K_2O at 100 per cent RDN through fertigation gave a maximum reducing sugar content of 8.44 % and lowest reducing sugar content of 6.89 % was reported in plants receiving 60 % RD of N and K_2O as fertigation.

Foliar application of borax at 0.03% and 0.01% respectively on fruit set and two weeks after fruit set improved the reducing sugar content (4.10 and 4.91 % respectively) of guava cv. Pant Prabhat compared to control which registered a reducing sugar content of 3.24 % (Kumar *et al*., 2015).

Venkataramudu *et al*. (2017) pointed that 125 % RD of N and K through fertigation increased the reducing sugar content (11.36 %) of fruits of pomegranate cv. Ganesh and fruits from control (soil application of RD of NPK + surface irrigation) plants recorded lowest reducing sugar content (10.01 %).

2.1.3.7 ***Non reducing sugar (%)***

Foliar application of boric acid 0.02% on mango cv. Alphonso increased the non reducing sugar content (10.70 %) of fruits, while control (water spray) recorded a minimum nonreducing sugar content of 9.04 % (Sankar *et al*., 2013).

Application of nutrients as per POP (soil application) with basin irrigation resulted in a highest non reducing sugar content of 2.58 % in banana cv. Nendran. Fertigation using urea and MOP along with soil application of rock phosphate recorded lowest non reducing sugar content of 2.43 % (Shimi, 2014).

Effect of foliar spray of different nutrients on non reducing sugar content of guava cv. Pant Prabhat was studied by Kumar *et al*. (2015). Application of borax (0.01%) on fruit set increased non reducing sugar content (2.75 %) of guava fruits, while a lowest non reducing sugar content of 1.79 % was reported in control.

2.1.3.8 ***Shelf life (days)***

Effect of micronutrients, $ZnSO_4$ (0.25%) and borax (0.1%) on shelf life of papaya cv. Red Lady was studied by Manjunatha, (2012). Application of micronutrients significantly prolonged the storage life of papaya fruits (8.67 days), whereas untreated control recorded a shorter shelf life of six days.

Foliar application of borax at 30 mg l^{-1} was found to give longest shelf life of 6.71 days in papaya cv. Taiwan Red Lady, and fruits from control plants recorded shortest shelf life of 3.86 days (Bhalerao *et al*., 2014).

Thirupathaiah *et al*. (2017) reported a maximum shelf life of 12 days in fruits of sapota cv. Kalipatti upon foliar spraying with 0.5% $ZnSO_4$, 0.5% $FeSO_4$ along with 0.3% Borax, whereas minimum shelf life of 8.00 days was noticed in control.

Nayak *et al*. (2018) documented that fertigation with 100 per cent RDN in pointed gourd (*Trichosanthes dioica* Roxb.) recorded maximum shelf life of 11.40

days, while soil application of RDN along with irrigation in furrow had lowest shelf life of 7.80 days.

2.1.3.9 ***Organoleptic evaluation (nine point hedonic scale)***

Influence of foliar sprays of boron and zinc singly or in combination on flavour, colour, taste and texture of guava cv. Allahabad Safeda was studied by Pandita (2000). Foliar spraying with zinc sulphate (0.3 %) and boric acid (0.3 %) were distinctly superior in organoleptic rating (19.11) to other sprays and lowest rating of 11.60 was noticed in control.

Porro *et al.* (2013) investigated the effect of fertigation on sensory qualities of apple (*Malus* × *domestica*) fruits. They concluded that fertigation improved firmness, crunchiness, juiciness, aromatic compounds, sweet taste and reduced the bitterness and acidic taste.

Haneef *et al.* (2014) opined that fertigation with 125 per cent RDN in pomegranate cv. Bhagwa resulted in highest organoleptic rating of 7.52, which was followed by 100 per cent RDN (7.46) and lowest score was recorded with 50 per cent RDN (6.94).

A study on sapota cv. Kalipatti by Thirupathaiah *et al*. (2017) was done to elucidate the impact of micronutrients zinc, iron and boron on organoleptic characters. The study documented that application of $ZnSO_4$ (0.5%), $FeSO_4$ (0.5%) and borax (0.3%) as foliar sprays gave highest score for skin colour (6.00), appearance (6.01), texture (6.20), taste (6.00) and overall acceptance (5.94) compared to water spray which secured a score of 4.63, 5.25, 5.13, 5.63, 5.16 respectively for skin colour, appearance, texture, taste and overall acceptance.

2.1.4 Index leaf analysis for primary, secondary and micronutrients (B and Zn)

Jeyakumar *et al*. (2001) reported a higher zinc content of 63.44 ppm in treatments receiving foliar application of $ZnSO_4$ (0.5 %) and H_3BO_3 (0.1 %) in leaves of papaya cv. Co5. Control plants recorded a lowest zinc content of 44.42 ppm. They also reported a higher boron content of 39.89 ppm in foliar application of $ZnSO_4$ (0.5 %) and H_3BO_3 (0.1 %), whereas control recorded a lowest boron content of 33.35 ppm.

Differences in leaf nutrient status of papaya cv. Co.7 upon application of different doses of fertigation were studied by Jeyakumar *et al*. (2010). 100 % RD of N and K_2O through drip resulted in highest leaf N and leaf K (1.72 % and 2.91 % respectively). Control plants receiving RDN through soil application recorded a leaf N and leaf K content of 1.37 % and 2.46 % respectively. Lowest leaf N and K (1.28 % and 2.23 % respectively) was found in plants supplied with 50 % RD of N and K_2O through drip.

Valji (2011) concluded that nitrogen content in leaf of papaya (*Carica papaya* L.) var. Madhu Bindu was significantly influenced due to different treatments of fertigation. The plants receiving the treatment, drip irrigation at 0.8 PEF along with N and K_2O at 100 % RD registered maximum nitrogen content (1.82 %) in leaves of papaya. The minimum nitrogen content (1.15 %) in leaves was noted in papaya plant grown under the treatment drip irrigation at 0.4 PEF + N and K_2O at 60 % RD.

Higher phosphorus content in leaves (0.43 %) was registered in treatment receiving 100 % RD of N and K_2O through fertigation in papaya var. Madhu Bindu (Valji, 2011), whereas lowest phosphorus content in leaves (0.38 %) was recorded in in plants receiving N and K_2O at 60 % RD.

Valji (2011) noticed a significant difference in potash content of leaves upon application of different levels of fertigation in papaya (*Carica papaya* L.) var. Madhu

Bindu. Highest potash content of 2.91 % in leaves of papaya was recorded in plants which received higher level of fertigation (drip irrigation at 0.8 PEF along with N and K_2O at 100 % RD). The plants treated with lower level of fertigation (drip irrigation at 0.4 PEF along with N and K_2O at 60 % RD) resulted in minimum leaf potash content (2.25 %).

Tank and Patel (2013) conducted field investigation to study the influence of fertigation on nutrient status in leaf of papaya (*Carica papaya* L.) var. Madhu Bindu under South Gujarat conditions. The assessment on nutritional status in leaf of papaya revealed that the N and K content were significantly influenced by fertigation while, P did not show significant variation.

Foliar spray with 30 gm of zinc sulphate twice a year significantly increased the Zn concentration (28 µg g^{-1}) in persimmon (*Diospyros kaki* L.) leaves. Lowest Zn concentration of 10 µg g^{-1} in leaves was noticed in control (Ali *et al*., 2014).

2.1.5 Pest and diseases incidence (%)

High levels of nitrogen fertigation tend to increase occurrence of rotting in strawberry (Nestby, 1998).

Batal *et al*. (1994) reported increased susceptibility to pests and decreased marketing quality upon fertigation with excessive nitrogen. In addition, Patnaik *et al*. (1998) pointed a decreased damage to fruits upon use of balanced fertilizer dose.

Ndereyimana *et al*. (2013) reported lowest shoot borer (7.74 per cent) and fruit borer (8.91 per cent) incidence in eggplant (*Solanum* m*elongena* L.) grafts receiving lowest fertigation level (75 per cent RDN), whereas highest shoot borer (11.54 per cent) and fruit borer (13.28 per cent) incidence was documented under highest nutrition level (125 per cent RDN).

Effect of different levels of fertigation (50, 75, 100 and 125 per cent RDN) on response to fruit borer (*Virachola isocrates*) and bacterial blight (*Xanthomonas axonopodies* pv.punicae) incidence was studied by Shanmugasundaram, (2013). The fruit borer and bacterial blight incidence ranged from 8.6 to 12.0 % and 5.4 to 7.7 % respectively. The plants which received 50 per cent RDN through fertigation registered the lowest fruit borer (8.6 %) and bacterial blight incidence (5.4 %), whereas highest fruit borer incidence (12.0 %) was recorded in control and highest bacterial blight incidence of 7.7 % was documented in plants receiving 125 per cent RDN through fertigation.

Xu *et al.* (2013) opined that increasing nitrogen input via fertigation led to increased mildew development in strawberry (cv. Elsanta) leaves.

2.1.6 Nutrient (N, P, K) concentration studies of fruits at peak harvest stage

Chater (2015) reported that foliar spraying with $ZnSO_4$ (4000 mg l^{-1}) increased the fruit N, P, K concentrations (1260, 161, 1292 mg 100 g^{-1} respectively) in pomegranate var. Wonderful, while spraying with deionized water registered lowest fruit N, P, K concentrations (1139, 141, 1256 mg 100 g^{-1} respectively).

2.1.7 Soil analysis (available N,P,K) before and after the experiment

In pomegranate cv. Mridula, highest available soil nitrogen, phosphorus and potassium contents (226.80 kg ha^{-1}, 23.01 kg ha^{-1} and 317.45 kg ha^{-1} respectively) at harvesting stage was noticed in plants receiving 125 per cent RDN through fertigation (Shanmugasundaram, 2013), whereas lowest value of soil nitrogen, and potassium content (172.29 kg ha^{-1} and 272.15 kg ha^{-1} respectively) was recorded in control and lowest available soil phosphorus content (21.25 kg ha^{-1}) was registered in plants receiving 50 per cent RDN at harvesting stage.

In papaya var. Madhu Bindu, Tank and Patel (2013) studied the role of different levels of fertigation on soil nutrient status. The results revealed that the plots treated with higher level of fertilizers recorded higher available N and K_2O in soil and no significant difference was noticed in phosphorus status of soil which received different treatments.

2.1.8 Economic analysis

Valji (2011) indicated that fertigation enabled to achieve higher yield in papaya var. Madhu Bindu and it was economically viable also. Treatment receiving 80 % RD of N and K_2O registered higher benefit cost ratio of 3.58. Moreover, fertigation was found more beneficial and recorded higher benefit cost ratio than control (100 % of N, P_2O_5 and K_2O through soil) (1.91).

Improved net returns and B: C ratio was reported by Hada (2013) in guava (*Psidium guajava* L.) cv. L-49 upon foliar spraying with zinc and boron. Highest net return (Rs. 3,15,506.89 ha^{-1}) was recorded in spraying with 0.8% $ZnSO_4$ and 0.4% borax and the lowest (Rs 1,27,793.51 ha^{-1}) was recorded in control. Highest B: C ratio (8.43: 1) was also documented in foliar application of 0.8% $ZnSO_4$ and 0.4% borax whereas, lowest B: C ratio (3.70: 1) was observed in control.

Fertigation with urea and MOP along with soil application of rock phosphate recorded highest net income (Rs. 8,67,172 ha^{-1}) and B: C ratio (5.01) in banana cv. Nendran, whereas application of nutrients as per POP (soil application) with basin irrigation reported a net income of Rs. 8,43,292 ha^{-1} with B: C ratio of 4.25 (Shimi, 2014).

2.2 POSTHARVEST MANAGEMENT PRACTICES FOR EXTENSION OF SHELF LIFE IN PAPAYA

Papaya is a climacteric fruit that is highly perishable due to rapid ripening and softening and susceptibility to biotic or abiotic stresses, resulting in large losses during storage. Major contributing factor to this postharvest loss is anthracnose caused by fungus *Colletotrichum gloeosporioides*. Sunken stains that are round and watery on the surface of mature fruits are the symptoms of this disease. Traditionally, people resort to the application of synthetic chemical fungicides on the crop and to the fruits during storage to control the disease. But their repeated use has caused resistance in microorganisms and toxicity for humans.

Hence, nowadays there has been increasing interest in using postharvest practices like precooling, surface sanitization, hot water treatment and use of natural alternatives like waxing, etc. Postharvest changes in fresh fruits cannot be stopped but can be slowed down within certain limits by these practices. Aglar *et al*. (2017) opined that both pre and postharvest treatments have inevitable role in improving the quality and storage life of produce. Review of literature on merits of certain postharvest practices followed in this study are scribbled below.

Manganaris *et al*. (2007) reported reduced stem browning and surface shriveling in cherry (*Prunus avium* L. cv. Tragana Edessis) fruit, as a result of hydrocooling which delayed the deterioration, senescence and thereby maintaining a higher quality. A reduced pericarp temperature by 6.2 ± 0.3 °C in litchi (*Litchi chinensis* cv. Feizixiao) was reported by Liang *et al*. (2013) upon hydrocooling for 30 minutes. Further, delayed electrolyte leakage and reduced enzymatic activity of polyphenol oxidase and peroxidase in pericarp, prolonged the storage life of litchi fruit also.

Chlorinated compounds, particularly hypochlorites, are widely used in microbial control. According to Nishijima (1994) sodium hypochlorite was found to be safe to use in a five minute dip at 8,000 ppm for papaya fruits instead of mancozeb (which is still having concern for residues of ethylene bisdithiocarbamate and ethylene thiourea) for the prevention of major postharvest disease as well as blight caused by *Phytophthora palmivora.* Kazemi *et al*. (2013) reported a reduction in weight loss (29.74 per cent) for pomegranate fruits sanitized with 10 per cent sodium hypochlorite against fruits (35.80 per cent) washed with distilled water.

In Eksotika II papaya, Ali *et al*. (2011) reported that chitosan is effective in weight loss reduction, maintaining firmness, and delaying the peel colour changes during five weeks of storage. Barrera *et al*. (2015) reported that papaya fruits coated with chitosan were damage free until day eight, while it was two in control. Also chitosan treated fruits registered reduced deterioration index compared to the control without significantly affecting the physicochemical properties of fruits. Kaya *et al*. (2016) suggested three possible action mechanisms for extending the shelf life of chitosan coated fruit. Those are: chitosan coating decreases polyphenol oxidase activity and prevents enzymatic degradation of the fruit, reduces the respiration rate and weight loss and antimicrobial activity.

Discovery and commercialization of ethylene absorbents or inhibitors has emerged as a breathtaking new technique for regulating ethylene production. Ethylene can profoundly influence the quality of harvested products. Forsyth *et al*. (1967) demonstrated the ability of potassium permanganate to readily oxidize ethylene concentration in the atmosphere around apples. Wills and Warton (2004) reported delay in ripening of many climacteric fruits upon addition of potassium permanganate to the storage atmosphere. In papaya, elevated ethylene evolution and increased respiratory rate are the factors contributing to the rapid ripening of physiologically mature fruit after harvesting. To enhance the postharvest life of papaya, it is essential to utilize technologies that lessen or eliminate the ethylene of the storage atmosphere, and this can be attained by using products such as $KMnO_4$. Resende *et al*. (2001) reported that this product oxidizes the ethylene produced by the fruit during ripening, lengthening the pre-climacteric period and storage life. In 1980, Stead and Chithambo noticed a delay in ripening of mango by five days when stored in polythene bags containing potassium permanganate ($KMnO_4$) at ambient temperature of 20-30 °C. Correa *et al*. (2010) observed delay in ripening by nine days in papaya cv. Sunrise Solo on storage with ethylene absorber. Further it had kept the fruits firmer and with less intensity of colour changes, without affecting the fresh matter loss. Ethylene scrubber hindered the ripening of fruit upto 35.20 days in banana cv. Dwarf Cavendish whereas, control fruits ripened within 19.80 days (Saravanan *et al*., 2013).

Heat treatment (hot water, hot air, vapour heat) of fruits, done as a postharvest measure to prevent fungal infection and for insect eradication (Paull, 1994; Lurie, 1998) will gives a significant benefit as it will leaves no chemical residues on the fruits. It is useful in controlling diseases like anthracnose on mango and crown rot on banana and for insect control to satisfy quarantine requirements for some commodities, such as mango and papaya (Kader, 2013). In 1991, Golan and Phillips reported that most of the fruits can tolerate a temperature of 50 - 60 °C for up to 10 minutes. But if the temperatures for heat treated disinfestation are below 50 °C, it takes 60 minutes or more (Lurie, 1998). Arina *et al*. (2010) reported that hot water treatment at specific temperature can conserve postharvest quality of Eksotika papaya fruit and suggested it as a viable techniue for fruit fly disinfestation which is a quarantine statute for the papaya exportation businesses. The carrier rate of *Colletotrichum gloeosporioides* in fruit peel can be reduced by hot water treatment at 54°C for 4 minutes (Li *et al*., 2013). They further elaborated that this method can significantly inhibit the anthracnose and stem-end rot incidence and can efficiently delay the fruit softening. No negative impact on quality parameters of pulp and skin of papaya cv. Maradol at their colour brake stage of ripeness was diagnosed by Sanchez *et al*. (2013) upon anti-fungal hot water treatment of 55 °C for 3 minutes. So, this treatment can be used in order to postone decay advancement during the papaya trade at non-refrigerated temperatures (25 °C).

Waxing of fruits and vegetables reduces water loss from the commodity and thus reducing shriveling, weight loss, improve the appearance of fruit, protects from minor infections and increase the shelf life of the commodity (Sharma, 2010). Carnauba palm (*Copernicia prunifera*) which is a native of Brazil, is the source of Carnauba wax. The leaves of carnauba palm yields wax in profusion, which on heating in a limited water can yield upto 5-10 grams of wax from each leaf.

Review of literature on effects of various post harvest treatments on fruits are described below.

2.2.1 Physical quality (Sensory analysis)

After 30 days of storage at 2°C, Jiang and Li (2001) reported good eating quality in chitosan treated longan fruit.

In mango cv. Kesar, hot water treatment at 52^0C for 10 minutes registered a significantly higher overall organoleptic score of 7.20, while fruits without any treatment gave a lesser overall organoleptic score 6.40 (Waskar and Gaikwad, 2005).

Papaya fruits of variety Eksotika II treated with 1.5 per cent chitosan concentration after 5 weeks of cold storage showed significant superiority in sensory attributes with a firm, crisp pulp (Ali *et al*., 2011). However, untreated fruits and ripened after 3 weeks of storage, thereafter began to decompose.

Mango cv. Kesar fruits subjected to hot water dip treatment at 50ºC for 20 minutes reported maximum consumer preference and higher score for all organoleptic parameters (Mayani *et al*., 2017). However fruits without any dip obtained lowest organoleptic scores.

Paramesha *et al*. (2017) observed that with respect to appearance, taste and overall acceptability, fig fruits packed with 2 per cent $KMnO_4$ secured significantly higher score of 3.68, 3.43 and 3.43 respectively out of 4.00, whereas appearance taste and overall acceptability scores of control fruits was too low (2.06, 2.50 and 2.75 respectively out of 4.00).

2.2.2 Physiological quality

2.2.2.1 *Shelf life (days)*

Influence of potassium permanganate on shelf life of mango fruits was studied by Azad *et al*. (2008). Fruits treated with 20 g potassium permanganate recorded longest shelf life of 19.95 days, whereas shortest shelf life of 7.08 days was noticed in control.

In banana cv. Dwarf Cavendish, treatment with wax (6 %) along with hot water treatment and ethylene absorbent significantly improved the green life upto 54.60 days (Saravanan *et al*., 2013) whereas, control treatment recorded a green life of 21.8 days.

Jayasheela (2014) reported that fruits of papaya var. Coorg Honeydew treated with hot water 50°C for 20 minutes with waxing and ethylene absorbent ($KMnO_4$) recorded highest shelf life of 11 days and lowest shelf life (4 days) was noticed in control fruits.

Delayed ripening and prolonged storage life up to 7 days at ambient conditions (28-32°C and 32 - 41% RH) was noticed in guava var. Allahabad Safeda treated with 1 per cent chitosan (Krishna and Rao, 2014).

Hewajulige *et al*. (2015) noticed enhanced storage period upto 14 days at 13±1°C in papaya cv. Ratna coated with 1 per cent chitosan.

2.2.2.2 *Physiological loss in weight* (PLW) (%)

Least physiological loss in weight of 9.68 % even after five days of storage was noticed in pointed gourd (*Trichosanthes dioica*) fruits treated with 100 mg litre^{-1}

sodium hypochlorite in combination with 500 mg litre^{-1} potassium metabisulphite and carnauba wax, whereas highest physiological loss in weight (23.72%) was noticed in control (Koley *et al*., 2009).

Impact of waxing on storage behaviour of papaya was studied by Dikki *et al*. (2010). Fruits treated with 6 per cent wax recorded minimum physiological loss in weight (21.57 %) while the highest (26.81 %) was recorded in control.

Saravanan *et al*. (2013) documented that the fruits of banana cv. Dwarf Cavendish treated with 8 % wax along with ethylene absorbent recorded least physiological loss in weight (3.02 per cent) as against 7.27 per cent in control.

Jayasheela (2014) opined that fruits of papaya var. Coorg Honeydew treated with hot water 50°C for 20 minutes with waxing and ethylene absorbent ($KMnO_4$) recorded lowest physiological loss in weight of 2.98 per cent and highest physiological loss in weight (6.85 per cent) was noted in control.

Fruits of papaya cv. Rathna treated with 1 per cent chitosan had least physiological loss in weight (4.1%) whereas untreated control fruits recorded maximum physiological loss in weight (5.3%) (Hewajulige *et al*., 2015).

Reduction in weight loss from mango fruit was reported on treatment with $KMnO_4$ in combination with wax on storage by Elzubeir *et al*. (2018). Weight loss was reduced by 38.1 per cent and 46.0 per cent in fruits packed in carton boxes with 1.0 and 2.0 g potassium permanganate, respectively, compared with the control.

2.2.2.3 *Ion leakage* (%)

Percentage ion leakage is an indicator of loss of membrane integrity occurring from membrane injury. Membrane injury can occur because of water (Pimental and Walder, 2002) or by salt stress (Amor *et al*., 2006), ripening or senescence of detached plant organs due to cell destruction (Azevedo *et al*., 2008) which may lead to an increase in membrane permeability and further leakage of intracellular volume (electrolytic leakage).

Azevedo *et al*. (2008) documented that the increase in electrolyte leakage in papaya fruit may be an expression of the fruit ripening and senescence program and may represent a starting point for additional studies on a putative hormonally regulated programmed cell death process during fruit maturation.

2.2.3 Chemical quality

2.2.3.1 ***Total Carotenoid*** **(mg 100g^{-1})**

Anwar and Malik (2007) studied the impact of hot water treatment on physicochemical characters of mango cv. Sindhri. Fruits subjected to hot water treatment (48°C for 60 minutes) recorded lowest carotenoid content of 66.18 µg g^{-1}, while fruits with no treatment registered highest carotenoid content of 72.52 µg g^{-1}.

2.2.3.2 ***TSS*** **(°Brix)**

Dikki *et al*. (2010) noticed that papaya fruits coated with 6 per cent wax resulted in highest TSS (11.58 °Brix), however minimum TSS (9.30 °Brix) was found in control.

Effect of pre storage treatments on TSS of papaya (*Carica papaya* L.) fruits was studied by Jayasheela *et al*. (2016). Highest total soluble solids (12.66 °Brix) was documented in fruits subjected to hot water treatment (50° C for 20 minutes) followed by waxing and storage with ethylene absorbent. Lowest TSS (10.33° B) was found in the control sample.

Paramesha *et al*. (2017) observed that eight days after storage of fig fruits, maximum TSS of 15.40 °Brix was noticed in untreated fruits (control) whereas fruits packed along with 2% $KMnO_4$ recorded a TSS of 14.37 °Brix. Untreated fruits lost their keeping quality after eight days of storage, and fruits packed along with 2% $KMnO_4$ registered a TSS of 15.20 °Brix after 10 days of storage.

2.2.3.3 *Total sugar* (%)

Effect of wax coating on total sugar content of papaya (*Carica papaya* L.) fruits was elucidated by Dikki *et al*. (2010). They indicated that coating of fruits with 6 per cent wax resulted in highest total sugar content (7.69 %). However, minimum total sugar (6.71 %) was noticed in control.

Lowest total sugar of 10.99 % was registered in banana cv. Grand Naine fruits stored in unperforated polythene bags with $KMnO_4$ and maximum total sugar content of 16.78 % was observed in fruits without any treatment after eight days of storage (Kaur and Kaur, 2018). Removal of ethylene and ripening inhibition achieved by the inclusion of $KMnO_4$ in polythene bags contributed to the delay in the increase of the sugars.

2.2.3.4 *Reducing sugar* (%)

Ripening inhibiting effect of $KMnO_4$ in banana cv. Grand Naine was studied by Kaur and Kaur (2018). Untreated fruits recorded maximum reducing sugar content (10.30 %) whereas minimum reducing sugar content (7.89 %) were noticed in the fruits stored in unperforated polythene bags with $KMnO_4$ after eight days of storage, because fruits were unripe even after eight days of storage.

Mayani *et al*. (2017) reported minimum reducing sugar content of 3.54% on 25^{th} day of storage in mango cv. Kesar treated with hot water dip treatment at 50°C for 20 min, whereas control recorded maximum reducing sugar content (4.69%). Abrupt decomposition of starch into soluble sugars, sucrose and glucose during ripening leads to the maximum reducing sugar in untreated fruits than treated fruits.

2.2.3.5 *Acidity* (%)

The titrable acidity is an important physico-chemical parameter which affects the product quality and protects against the development of microorganism to a large extent.

Hot water treatment (55°C for 12 min) of litchi fruits recorded minimum acidity of 0.15 % after 18 days of storage, while fruits without any treatment registered an acidity of 0.18 % (Marboh *et al*., 2012).

Drop in titratable acidity during storage was significantly delayed in mango cvs. Kitchner and Abu-Samaka subjected to waxing followed by packaging with $KMnO_4$ (Elzubeir *et al*., 2018).

2.2.4 Percentage disease index

The most common pathogen in papaya is *Colletotrichum gloeosporioides* which causes anthracnose (Yon, 1994; Carrillo *et al*., 2002; Aires *et al*., 2004).

According to Abbasi *et al*. (2009) chitosan coating of mango cv. Summer Bahisht Chaunsa hintered the growth of a broad variety of bacteria and fungi. Study pointed that after 2 weeks of storage, fruit spoiling fungi (*Colletotrichum gleosporioides*) were observed in control, whereas it took 5 weeks to cause damage in chitosan coated fruits. The percentage infection was 13.30 in control fruits after 14 days of storage while, it was 6.90 in chitosan coated fruits.

Hai *et al*. (2014) noticed that longan (cv. Long) fruits treated with 200 ppm sodium hypochlorite in combination with 6% bees carnauba mixed wax did not showed decay throughout 25 days of storage, whereas fruits without any treatment began to decay (3.3%) after 10 days of storage, and thereafter decay accelerated to 50.4 % after 25 days storage.

The disease severity index was significantly low in chitosan treated fruits (0.74), whereas it was high (6.17) in untreated control fruits of papaya cv. Rathna (Hewajulige *et al*., 2015).

2.2.5 Microbial load (cfg g^{-1})

Effect of 200 ppm sodium hypochlorite in combination with 6% bees carnauba mixed wax on microbial population on longan fruit surface was studied by Hai *et al*. (2014). They concluded that after 25 days of storage, fruits treated with sodium hypochlorite and 6% bees carnauba mixed wax maintained relatively low total microorganism levels (2.2-5.9 x 10^6 CFU ml^{-1}) compared to untreated fruits (19.6 x 10^6 CFU ml^{-1}).

Jayasheela (2014) investigated efficacy of different sanitizing agents on surface decontamination of fruits of papaya cv. Coorg Honeydew. The results revealed that papaya fruits harvested at ¼ yellow for local market and fully mature green fruits for distant market, washed and subjected to hot water treatment at 50°C for 20 minutes and warm sodium hypochlorite at 150 ppm was found effective in reducing bacterial and fungal population.

Dotto *et al*. (2015) documented that coating of papaya fruits with 150 kDa chitosan solution preserved the fruits during storage at room temperature and the product was microbiologically safe.

According to Minh *et al*. (2019), prolonged shelf life of chitosan (0.75%) coated soursop (*Annona muricata*) is due to effective inhibition of growth of microorganisms.

Materials and Methods

3. MATERIALS AND METHODS

The present investigation on the 'Fertigation studies in papaya (*Carica papaya* L.)' was carried out at the Department of Fruit Science, College of Agriculture, Vellayani, Thiruvananthapuram during 2017-2020.

The whole programme was divided into two major experiments

3.1 Fertigation and foliar nutrition studies in papaya

3.2 Postharvest management practices for extension of shelf life in papaya

3.1 FERTIGATION AND FOLIAR NUTRITION STUDIES IN PAPAYA

3.1.1 Experimental site

3.1.1.1 *Location*

The experimental field was laid out in the Instructional Farm attached to the College of Agriculture, Vellayani. The field was located at 8° 25' 46'' N latitude and 76° 59' 24'' E longitude and at an altitude of 19 m above mean sea level.

3.1.1.2 *Soil*

The soil of the experimental site is sandy clay loam which belongs to the order oxisols, Vellayani series. Chemical properties of soil prior to experiment are summarized in Table 1.

Table 1. Chemical characteristics of soil prior to experiment

Particulars	Value	Method used
Organic C (%)	1.30	Walkley and Black rapid titration method (Jackson, 1973)
Available N (kg ha^{-1})	160.00	Alkaline $KMnO_4$ method (Subbiah and Asija, 1956)

Available P (kg ha^{-1})	18.50	Bray's colorimetric method (Jackson, 1973)
Available K (kg ha^{-1})	207.50	Ammonium acetate method (Jackson, 1973)
Soil reaction (pH)	4.50	pH meter with glass electrode (Jackson, 1973)
Electrical conductivity (d S m^{-1})	0.10	Digital conductivity meter (Jackson, 1973)

3.1.2 Season and weather conditions

The field experiment was conducted from August 2018 to February 2020. The data on weather parameters (monthly rainfall, maximum temperature, minimum temperature, relative humidity, evaporation and sunshine hours) during the cropping period are presented in Fig. 1 a and Fig. 1 b and in Appendix I.

3.1.3 Experimental material

Papaya variety Surya released from IIHR by crossing Sunrise Solo with Pink Flesh Sweet was used for conducting the experiment. The variety is gynodioecious in nature with no male plants. Healthy seeds of papaya variety Surya were procured from Indian Institute of Horticultural Research, Bangalore.

3.1.4 Experimental design and layout

The experiment was carried out to evaluate the effect of different levels of fertigation and different foliar nutrition in papaya.

Design : RBD
No. of treatments : 14
No. of replication : 3
No. of plants plot^{-1} : 6
Plot size : 24 m^2
Spacing : 2m x 2m

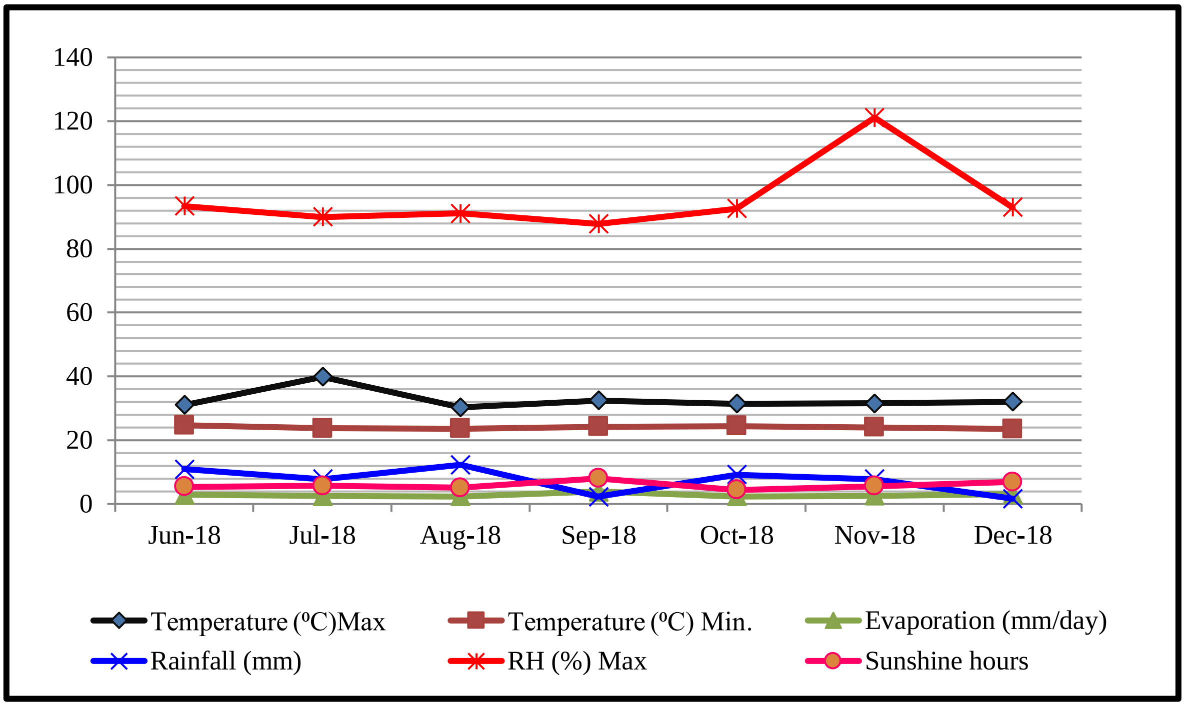


Fig. 1 a. Weather parameters during the cropping period (Jun. to Dec. 2018)

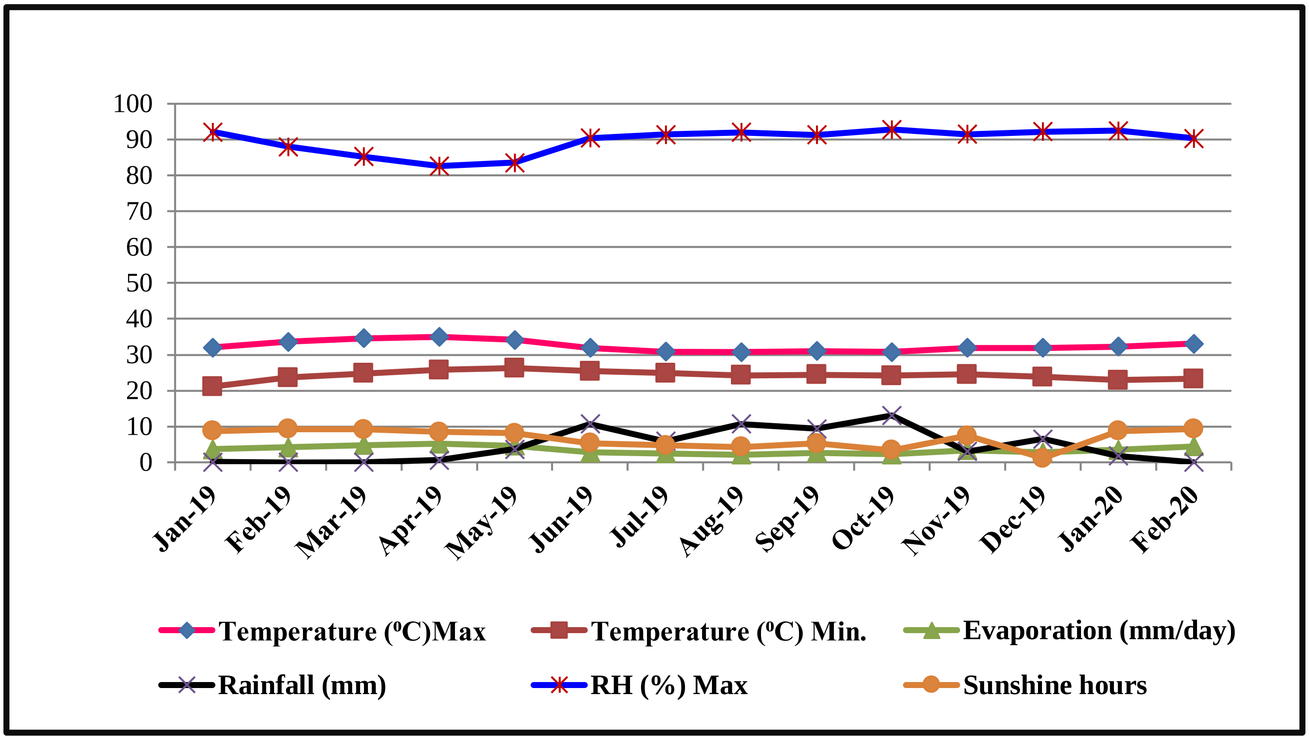


Fig. 1 b. Weather parameters during the cropping period (Jan. 2019 to Feb. 2020)

3.1.4.1 *Treatments*

A. Fertigation levels (N)

Fertigation treatments were fixed based on the N and K recommendation as per KAU POP (240: 480 g NK plant^{-1} year^{-1}, soil application of nutrients) for papaya (KAU, 2016) and fertilizers were applied based on soil test data.

N_1 – 75 % of recommended dose of N and K

N_2 – 100 % of recommended dose of N and K

N_3– 125 % of recommended dose of N and K

N_4 – 150 % of recommended dose of N and K

B. Foliar nutrition (F)

F_1 –19:19:19 (1.0 %) (at bimonthly interval starting from 4 month after planting to 16 month after planting)

F_2 – $ZnSO_4$ (0.5 %) + Borax (0.3 %) (4th, 8th, 12th and 16th month after planting)

F_3 – Water spray (at bimonthly interval starting from 4 month after planting to 16 month after planting)

Control

Control 1. KAU POP (187:170:341 g NPK plant^{-1} year^{-1} based on soil test data, soil application of nutrients with conventional land management)

Control 2. 100% of recommended dose of NPK as organic (soil application of nutrients based on soil test data with conventional land management). In these organic manures were applied on nitrogen equivalent basis in six splits at an interval of two months for 20 months. Combination of farm yard manure, poultry manure and vermicompost in the ratio 2:1:1 were added. Additional phosphorus and potassium requirement were fulfilled through the application of rock phosphate and potassium sulphate respectively.

3.1.4.2 ***Treatment combinations*** (4x3) + 2 = 14

T_1- N_1F_1 T_2- N_1F_2 T_3- N_1F_3

T_4- N_2F_1 T_5- N_2F_2 T_6- N_2F_3

T_7- N_3F_1 T_8- N_3F_2 T_9- N_3F_3

T_{10}- N_4F_1 T_{11}- N_4F_2 T_{12}- N_4F_3

T_{13}- Control 1 T_{14}- Control 2

Layout of the experiment was depicted in Fig 2.

The water for fertigation was diverted with pump from Vellayani lake. Disc filter and screen filter were used for removing the impurities in water. Injector was also provided for fertigation. Four submains were laid out in the field to dispense water and fertilizer to the respective plots. From each submain, lateral was linked to the respective plots. Pressure compensating drippers with a discharge rate of 8 litres hour^{-1} were connected on the laterals to supply water and fertilizer to individual plots. The submains and laterals were provided with flushing devices to discard water and fertilizer after each application.

3.1.5 Cultivation practices of papaya

3.1.5.1 ***Raising of seedlings***

Seeds were treated with 200 ppm GA_3 for 8 hours for uniform germination and were sown in portrays filled with a mixture of FYM, soil and sand in equal proportions. Seeds were germinated in two weeks (Plate 1). 15 days old seedlings were transplanted into polythene bags of 20 cm x 15 cm size filled with a mixture of FYM, soil and sand in equal proportions (Plate 2). 45 days old seedlings were transplanted into main field.

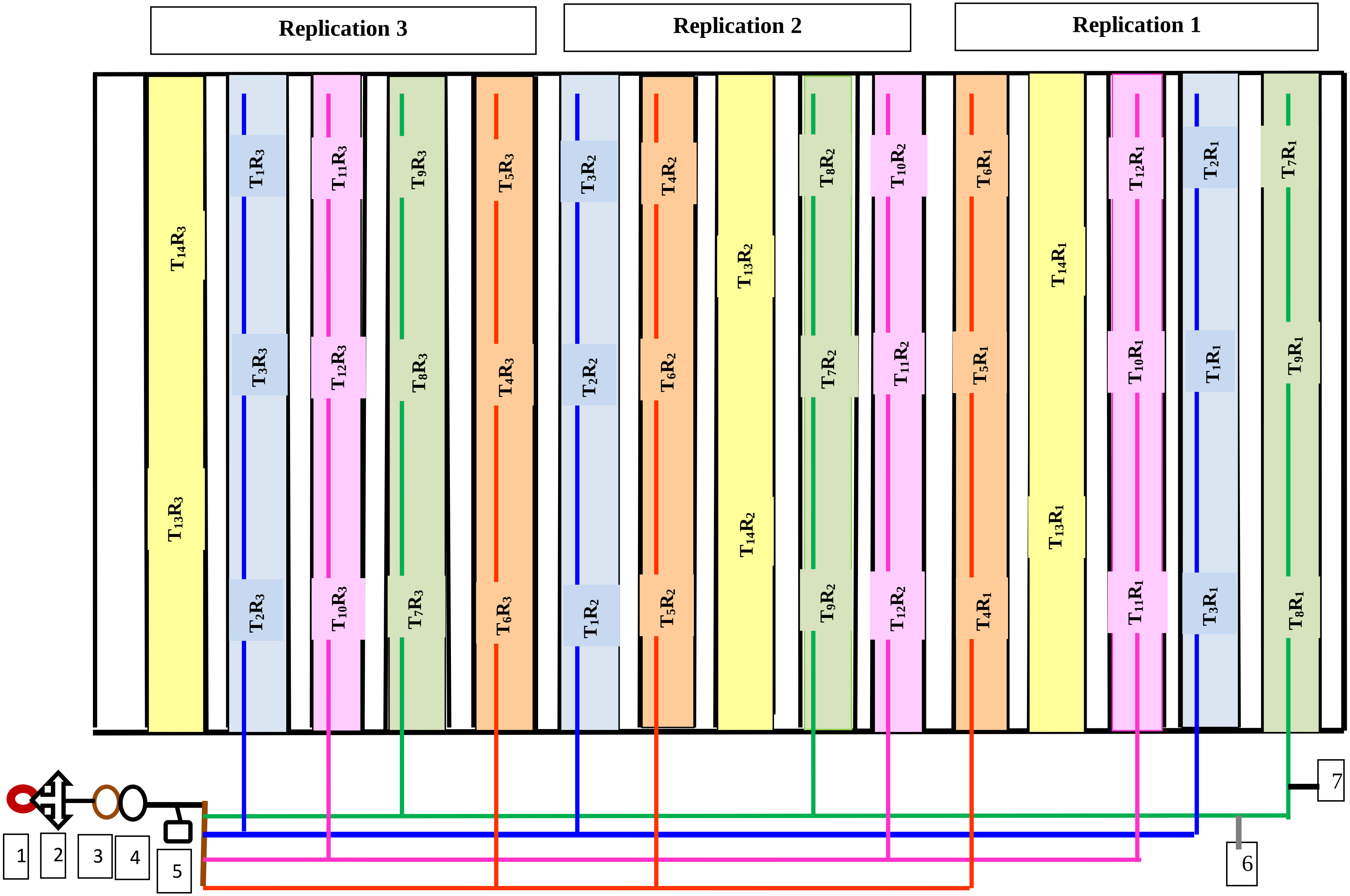
3.1.5.2 *Field preparation and planting*

Deep ploughing up to 50 cm depth was done and raised beds of 30 cm height and 1.5 m width were taken with channels of 1 m width in between beds for proper drainage and to prevent capillary movement of water to the adjacent plots (Plate 3). Seedlings were planted at a depth of 15-20cm at 2 m x 2 m spacing (Plate 4). The requirement of lime and phosphorus was calculated based on the initial soil status and the same (500g and 850g respectively based on soil test data) was applied uniformly to all treatments. Organic manure (15 kg FYM plant^{-1}) was given uniformly to all treatments as basal.

For control 1 (T_{13}) and control 2 (T_{14}) pits of 50 cm x 50 cm x 50 cm were taken at a spacing of 2 m x 2m. For organic treatment potassium sulphate was used as source of potassium.

3.1.5.3 *Fertigation scheduling*

Fertigation was done at weekly interval and a total of 76 fertigations were given from one month after planting to 20 month after planting. Urea and Muriate of Potash were used as fertilizer sources for fertigation. Quantity of different fertilizers (g plant^{-1} year^{-1}) used in fertigation are furnished in Table 2. Nutrient solution for fertigation was prepared by dissolving required quantity of fertilizers. The tube attached to the injector unit was immersed in the nutrient solution and the system was operated to supply the nutrients along with irrigation water. Flushing of mains and laterals were done before the start of fertigation. After every fertigation, drip irrigation was continued for five to ten minutes. Cleaning of disc filter and screen filter were also being carried out once in three days.



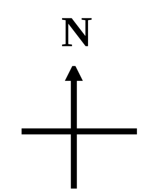


Fig. 2. Layout plan of Experiment 1

1. Source 2. Control valve 3. Screen filter 4. Disc filter 5. Injector 6. Submains 7. Laterals

Plate 1. Seedlings in protrays

Plate 2. Seedlings in polybag

Plate 3. Field preparation

Plate 4. Field at initial stage

Plate 4a. Field at 4 MAP

Plate 5. General view of experiental plot

Table 2. Quantity of fertilizers (g plant^{-1} year^{-1}) used in fertigation

Fertigation	**Urea (g plant^{-1} year^{-1})**	**MOP (g plant^{-1} year^{-1})**
75 per cent RDF	304.89	426.25
100 per cent RDF	406.52	568.33
125 per cent RDF	508.15	710.41
150 per cent RDF	609.78	852.50

The other cultural operations were carried out as per KAU POP.

3.1.6 Observations

3.1.6.1 *Biometric parameters*

3.1.6.1.1 *Planth height*

Height of plants were recorded in centimeters from soil level to the tip of growing point from all observation plants at bimonthly intervals up to peak harvesting stage and average were worked out.

3.1.6.1.2 *Plants girth*

Girth of the stem was assessed at 10 cm above the ground level with help of measuring tape at bimonthly intervals up to peak harvesting stage and average were worked out and expressed in centimeters.

3.1.6.1.3 *Number of leaves*

Total number of active leaves per plant was counted from all observation plants at bimonthly intervals up to peak harvesting stage and the average number of leaves was worked out. Fully developed and newly emerged leaves, excluding dead and dry leaves were considered as active leaves.

3.1.6.1.4 ***Leaf Area Index***

Leaf area was measured with the help of graph paper in square centimetre and average was worked out. The index leaf (sixth leaf) from all observation plants were collected at 6, 12, 18 months after planting and at final harvest for the measurement. Leaf area index was calculated using the formula

$$\text{LAI} = \frac{\text{Leaf area}}{\text{Spacing (m}^2\text{)}}$$

3.1.6.1.5 ***Height at first flowering***

Height at which first flower appeared was recorded in centimeters from the ground level in all observation plants and average was worked out.

3.1.6.1.6 ***Days to flowering***

Number of days from transplanting to the opening of first female or hermaphrodite flower was recorded in all observation plants and average was worked out.

3.1.6.1.7 ***Sex expression of plant***

Total number of hermaphrodite and female flowers in all observation plants were noted throughout the crop period and expressed in per cent and average was worked out.

3.1.6.1.8 ***Number of flowers cluster*** $^{-1}$

Number of flowers found in a cluster was counted and recorded in all observation plants and average was worked out.

3.1.6.1.9 ***Fruit set percentage***

Total number of hermaphrodite and female flowers and fruits produced were recorded in all observation plants and expressed in per cent and average was worked out.

$$\text{Fruit set percentage} = \frac{\text{Number of fruits set plant}^{-1} \times 100}{\text{Number of flowers plant}^{-1}}$$

3.1.6.1.10 ***Time for first harvest***

The number of days taken from transplanting to the harvest of first formed fruit in all observation plant was recorded and average was worked out.

3.1.6.2 ***Yield parameters***

3.1.6.2.1 ***Fruit weight***

Five fruits were randomly selected from each observation plant and average fruit weight was worked out and recorded in grams.

3.1.6.2.2 ***Fruit length***

Fruit length was measured from the stalk end to the floral end of five randomly selected fruits from each observation plant and average fruit length was worked out and expressed in centimeters.

3.1.6.2.3 ***Fruit girth***

The girth of five randomly selected fruits from each observation plant was assessed at the maximum width point with measuring tape and average girth was worked out and expressed in centimeters.

3.1.6.2.4 *Fruit volume*

Five randomly selected fruits from each observation plant were taken and fruit volume was calculated by water displacement method. It's average was worked out and expressed in cc.

3.1.6.2.5 *Physical composition*

Fruits were randomly selected from each observation plant. Weight of fruit was recorded and then separated into different components. Weight of peel, pulp and seed were recorded separately and relative proportion of each of the component to total weight was worked out.

Further pulp/ peel ratio was calculated using the formula:

$$\text{Pulp/ peel ratio} = \frac{\text{Percentage of pulp}}{\text{Percentage of peel}}$$

3.1.6.2.6 *Flesh thickness*

Flesh thickness of five randomly selected fruits from each observation plant was measured and average was worked out and expressed in centimeters.

3.1.6.2.7 *Number of fruits per plant*

Total number of fruits from each observation plant was counted and average worked out.

3.1.6.2.8 *Number of seeds per fruit*

Seeds were extracted from five randomly selected fruits from each observation plant, counted and average was worked out.

3.1.6.2.9 ***Seed germination percentage***

Seeds were extracted from the fruit when ¾th of the fruit skin turned yellow and mucilage was removed by rubbing with hands. 50 seeds were collected from fruits of each observation plants and allowed to germinate. The germinated seed count was taken after 10 days.

$$\text{Germination percentage} = \frac{\text{Number of seeds germinated}}{\text{Total number of seeds sown}} \times 100$$

3.1.6.2.10 ***Total yield plant^{-1}***

Total number of fruits from each plant was multiplied with average fruit weight for getting total yield per plant and expressed in kilogram plant^{-1}.

3.1.6.2.11 ***Yield ha^{-1}***

Yield per hectare was calculated by multiplying per plant yield with number of plants per hectare.

3.1.6.2.12 ***Days taken for maturity***

Flowers of each observation plant were tagged on the day of anthesis and number of days taken from fruit set to reach harvest maturity (full green mature stage) was counted.

3.1.6.2.13 ***Days taken for ripening***

Number of days taken by fruits to reach fully ripe stage while on tree from attaining harvest maturity was counted and reported as days taken for fruit ripening.

3.1.6.3 *Fruit quality parameters*

3.1.6.3.1 *Total soluble solids*

TSS of the fruit pulp was measured using a hand refractometer (Erma) (range 0-32°Brix) expressed in degree brix (A.O.A.C, 1980).

3.1.6.3.2 *Acidity*

The titrable acidity was estimated by titrating with 0.1 N sodium hydroxide (NaOH) solution using phenolphthalein as an indicator and expressed as per cent of citric acid. A known weight of fruit was ground using distilled water and made upto 100 ml in a standard flask. An aliquot of 10 ml from this was titrated against 0.1 N NaOH (Ranganna, 1997).

$$\text{Acidity} = \frac{\text{Normality} \times \text{Titre value} \times \text{Equivalent weight} \times \text{Volume made up} \times 100}{\text{Weight of sample} \times \text{Aliquot of sample} \times 1000}$$

3.1.6.3.3 *Total carotenoids*

Determination of total carotenoids was done by extraction with acetone and petroleum ether. The colour was measured at 452 nm using petroleum ether as blank in spectrophotometer. Total carotenoids were expressed as $\mu g\ 100g^{-1}$ of material (Ranganna, 1997).

$$\text{Total carotenoids } (\mu g\ 100g^{-1}) = \frac{3.857 \times \text{Optical density} \times \text{Volume made up} \times 100}{\text{Weight of the sample}}$$

3.1.6.3.4 ***Ascorbic acid***

Five grams of the fruit was taken and extracted with four per cent oxalic acid. Ascorbic acid was estimated by using standard indicator dye 2,6- dichlorophenol indophenol and expressed as mg $100g^{-1}$ of fruit (Sadasivam and Manickam, 1996).

3.1.6.3.5 ***Total sugar***

Total sugar was determined according to the procedure described by Ranganna (1997) using Fehling's solution and expressed as gram of glucose per 100 grams of pulp.

3.1.6.3.6 ***Reducing sugar***

Reducing sugar was determined according to the procedure described by Ranganna (1997) using Fehling's solution and expressed as gram of glucose per 100 grams of pulp.

3.1.6.3.7 ***Non reducing sugar***

The estimation of nonreducing sugar was done by subtracting the reducing sugar from the total sugar and expressed as grams of glucose per 100 grams of pulp.

3.1.6.3.8 ***Shelf life***

Shelf life was computed by counting the days required to fully ripe the papaya fruits as to possessing optimum marketing and eating qualities.

3.1.6.3.9 ***Sugar / acid ratio***

Sugar/ acid ratio was calculated using the following formula:

$$\text{Sugar/ acid ratio} = \frac{\text{Total sugar content (\%) in fruits}}{\text{Acidity (\%) in fruits}}$$

3.1.6.3.10 *Organoleptic evaluation*

The fruits obtained from each treatment were assessed using a nine point hedonic scale to evaluate the appearance, colour, flavour, texture, taste, after taste and overall acceptability of the products by a panel of 15 semi trained judges (Appendix II).

3.1.6.4 *Index leaf analysis for primary, secondary and micronutrients (B and Zn)*

Petiole of sixth leaf at six month after planting (index leaf) was taken for analysis. The plant samples were dried in a hot air oven at 70°C till constant weight was obtained and powdered. The required quantity of powdered samples were then weighed out accurately and analysed for primary, secondary and micronutrients viz., boron and zinc. The methods adopted for the chemical analysis are given in the Table 3.

Table 3. Methods adopted for plant nutrient status estimation

Particulars	Method	References
N (%)	Digestion with H_2SO_4 and Microkjeldahl distillation	Jackson (1973)
P (%)	Digestion with Nitric-perchloric (9:4) acid and spectrophotometry	Jackson (1973)
K (%)	Digestion with Nitric-perchloric (9:4) acid and flamephotometry	Jackson (1973)
Ca (%)	Digestion with Nitric-perchloric (9:4) acid and atomic absorption spectrophotometry	Piper (1967)
Mg (%)		

S (%)	Turbidimetric method	(Chesnin and Yien, 1950)
Zn (ppm)	Digestion with Nitric-perchloric (9:4) acid and atomic absorption spectrophotometry	Jackson (1973)
B (ppm)	Dry ashing, azomethane-H method	Gupta (1967)

3.1.6.5 ***Pest and disease incidence***

Foot rot caused by *Phytophthora* sp. was observed as the major disease in the field in the early stages. Scoring of foot rot in papaya was done using score chart devised by Tesoriero and Bertus (2004). (Appendix III). It was effectively controlled by drenching copper oxychloride @ 0.4 per cent. From one to six month after planting, systematic pesticides were applied as a prophylactic measure to control leaf sucking insects.

3.1.6.6 ***Nutrient (N, P, K) concentration studies of fruits at peak harvest stage***

Fruit samples were selected for analysis at 16 month after planting (peak harvest stage). The fruit samples were dried in a hot air oven at 70°C till constant weight was attained, powdered, required quantity of powdered samples were then weighed out accurately and analysed for primary nutrients. Analysis for fruit nitrogen, phosphorus and potassium was done using modified kjeldahl method (Jackson, 1973), single acid digestion & colorimetry method (Piper, 1967) and single acid digestion & flame photometry method (Piper, 1967) respectively.

3.1.6.7 ***Soil analysis (available N, P, K) after the experiment***

Soil samples were collected after the experiment from experimental plot. The composite samples drawn from the individual plots were air dried, powdered, sieved through 2 mm sieve and analysed for N, P and K as per the methods mentioned in Table 1.

3.1.6.8 ***Economic analysis***

3.1.6.8.1 ***Cost of cultivation***

The cost of inputs that were prevailing at the time of their purchase was considered for working out cost of cultivation. While calculating cost of cultivation, drip installation cost was distributed over 10 years by amortization (Appendix IV).

Cost of cultivation under different treatments are presented in Appendix V.

3.1.6.8.2 ***Gross income***

Gross income per hectare^{-1} was calculated by taking into consideration the market price of the papaya fruit that was prevailing during the investigation period and expressed as ha^{-1}. Market price of the produce is shown in Appendix VI.

3.1.6.8.3 ***Net income***

Net income was computed by subtracting cost of cultivation from gross income and expressed in ha^{-1}.

3.1.6.8.4 ***B: C ratio***

B : C ratio was figured out as the ratio of gross income to cost of cultivation.

$$\text{B : C ratio} = \frac{\text{Gross income (ha}^{-1}\text{)}}{\text{Cost of cultivation (ha}^{-1}\text{)}}$$

3.1.6.9 ***Statistical analysis***

The data was analysed statistically by applying the techniques of analysis of variance (Panse and Sukhatme, 1985).

For organoleptic test, Kruskal Wallis test was performed and the mean rank scores were taken to differentiate the best treatment.

Experiment II

3.2 POSTHARVEST MANAGEMENT PRACTICES FOR EXTENSION OF SHELF LIFE IN PAPAYA

Papaya variety Surya was raised according to KAU POP for studying the extension of shelf life. Fruits were collected at fully mature green stage, subjected to different postharvest management practices, packaged in CFB boxes and stored under ambient conditions till the end of shelf life (Plate 6). Observations on changes in physical quality, physiological quality, chemical quality, percentage disease index and microbial load were recorded at three days interval till the end of shelf life.

The postharvest management practices given were;

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$

S_8 – Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

3.2.1 Observations

Observations were noted at three days interval till the end of shelf life.

3.2.1.1 *Physical quality (Sensory analysis)*

Same as mentioned in 3.1.6.3.9

3.2.1.2 *Physiological quality*

3.2.1.2.1 *Shelf life*

Shelf life of papaya fruits as influenced by different postharvest treatments was calculated by counting the days required to ripe fully as to retaining optimum marketing and eating qualities.

3.2.1.2.2 *Physiological Loss in Weight (PLW)*

PLW was calculated on the initial weight basis as suggested by Srivastava and Tandon (1968) at three days interval and expressed as percentage.

$$PLW = \frac{\text{Initial weight - Final weight}}{\text{Initial weight}} \times 100$$

3.2.1.2.3 *Ion leakage* (%)

The uniform sized fruit pieces were made into thin slices, immersed in 100 ml distilled water for three hours and absorbance was read in UV spectrophotometer at 273 nm. The immersed slices were heated in water bath at 100° C for 20 minutes, filtered, filtrate was made upto 100 ml and the absorbance was read in UV spectrophotometer at 273 nm. The loss of membrane integrity was expressed in per

Plate 6. CFB boxes used for packaging of papaya fruits

Plate 6a. Papaya fruits packaged in CFB boxes

cent ion leakage. Percent leakage was calculated using the formula and expressed as percentage (Amith, 2012):

$$\text{Percent leakage: } \frac{\text{Initial absorbance of bathing medium}}{\text{Final absorbance of bathing medium}} \times \text{Dilution factor}$$

3.2.1.3 *Chemical quality*

3.2.1.3.1 *Total Carotenoid*

Same as mentioned in 3.1.6.3.3

3.2.1.3.2 *TSS*

Same as mentioned in 3.1.6.3.1

3.2.1.3.3 *Total sugar*

Same as mentioned in 3.1.6.3.5

3.2.1.3.4 *Reducing sugar*

Same as mentioned in 3.1.6.3.6

3.2.1.3.5 *Acidity*

Same as mentioned in 3.1.6.3.2

3.2.1.4 *Percentage disease index*

Papaya fruits subjected to different postharvest management practices were visually observed for fungal spoilage and fruit rots. The number of fruits infected or spoiled was recorded periodically to assess the effect of treatments on retarding fruit spoilage. It was reported as percentage disease index and was calculated by the following formula (Marpudi *et al*., 2011).

$$\text{Percentage disease index} = \frac{(0xa) + (1xb) + (2xc) + (3xd) + (4xe) + (5xf)}{a + b + c + d + e + f} \times \frac{100}{X}$$

Where 0,1,2,3,4,5 are infection categories

0 – no lesions (no disease symptoms)

1 – 5 to ≤ 15 per cent disease symptoms (spot first appearing)

2 - ≥ 16 to ≤ 25 per cent disease symptoms (spots increasing in size and number)

3 - ≥ 26 to ≤ 50 per cent disease symptoms (small to large brownish sunken spots with slight to moderate mycelium growth)

4 - ≥ 51 to ≤ 75 per cent disease symptoms (large spots with wide spread mycelium growth, fruit is partially or completely rotten)

5 - ≥ 75 per cent disease symptoms

a, b, c, d, e and f are number of fruits that fall into the infection categories

X = maximum number of infection categories

3.2.1.5 *Microbial load*

The enumeration of microbial load in pre and post treated sample was carried out by serial dilution technique. Nutrient agar and Martin's Rose Bengal agar medium were used for enumeration of bacterial and fungal population of the fruit surfaces respectively. The details of media composition are furnished in Appendix VII.

The fruit was washed with 100 ml sterile distilled water and shaken thoroughly for two minutes. One ml of supernatant was accurately pipetted out into eppendroff tube containing 900 µl of sterile distilled water to get 10^{-3} dilution. This procedure was repeated to get 10^{-5} dilution. 100 µl each of 10^{-3}, 10^{-4}, 10^{-5} and 10^{-6} were used for enumeration of total bacterial and fungal count. Bacterial count was enumerated for three days countinuouly from the next day of inoculation whereas fungal count was taken from three days after inoculation and the count just before the damage of the treatment was represented. Number of microorganisms (bacteria and fungi) per cm^2 of post treated sample was calculated as per the following formula (Amith, 2012).

$$\text{No. of colony forming units (cfu) / ml of the sample} = \frac{\text{Total number of colony formed X Dilution factor}}{\text{Aliquot plated}}$$

Results

4. RESULTS

The present experiment was conducted in the Instructional Farm attached to the College of Agriculture, Vellayani during June 2018 to February 2020 to standardize the nutrient level for yield improvement through fertigation and foliar nutrition in papaya and to investigate the postharvest management practices for extending the shelf life of fruits. The experimental data collected were assessed statistically and the findings are illustrated in this chapter under the following sections.

4.1 Fertigation and foliar nutrition studies in papaya

4.2 Postharvest management practices for extension of shelf life in papaya

4.1 FERTIGATION AND FOLIAR NUTRITION STUDIES IN PAPAYA

4.1.1 Biometric parameters

4.1.1.1 *Plant height (cm)*

Height of papaya plants were recorded at bimonthly interval from 2 MAP (Month After Planting) up to peak harvesting stage (16 MAP) and are presented in Table 4. Plant height differed significantly among the treatments at each month.

At 2 MAP, highest plant height of 85.70 cm was recorded for the treatment receiving 125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 (T_7). It was on par with treatments receiving 125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (T_8) and 125 % RD of N and K through fertigation with water spray (T_9) (85.36 cm and 84.98 cm respectively). However this effect was solely due to fertigation, as foliar sprays with 1.0% 19:19:19, 0.5% $ZnSO_4$ and 0.3% borax and water spray was done from 4 MAP. Control 1 (T_{13}) which received KAU POP (soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data, with conventional land management) and control

2 (T_{14}) which received 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures registered a plant height of 73.86 cm and 73.17 cm respectively. Lowest plant height (60.16 cm) was witnessed in treatment receiving 75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 (T_1). It was on par with treatment receiving 75 % RD of N and K through fertigation with water spray (T_3) and 75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (T_2) which registered a plant height of 61.21 cm and 63.15 cm respectively.

Observations recorded at 4 MAP revealed that T_7 registered a highest plant height of 112.53 cm. It was found to be on par with T_9 and T_8 (111.03 cm and 110.62 cm. Control 1 (T_{13}) which received KAU POP recorded a plant height of 103.87 cm and control 2 (T_{14}) registered a plant height of 102.04 cm. However T_3 recorded lowest plant height of 88.18 cm, which was found to be on par with treatments T_2 and T_1 with 90.72 cm and 91.53 cm respectively.

Results of data on plant height at 6 MAP recorded highest height of 149.19 cm in plants receiving 100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 (T_4), which was found to be on par with T_5 (147.11 cm) which received 100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax and differed significantly from other treatments. Control 2 (T_{14}) recorded a plant height of 135.22 cm and control 1 (T_{13}) which received KAU POP registered a plant height of 132.05 cm. Lowest plant height of 108.46 cm was noticed in T_3 and differed significantly from other treatments.

Plant height recorded at 8 MAP indicated that T_4 registered highest plant height of 190.23 cm, which differed significantly from other treatments. This was followed by T_5 (184.50 cm) which also had significant difference over other treatments. Control 2 (T_{14}) recorded a plant height of 167.88 cm and control 1 (T_{13})

which received KAU POP registered a plant height of 153.53 cm. T_3 recorded least plant height of 144.09 cm, which had significant difference over other treatments.

Statistical analysis at 10 MAP revealed a highest plant height of 214.80 cm for T_4, which was on par (211.88 cm) with T_5 and differed significantly from other treatments. Control 2 (T_{14}) recorded a plant height of 188.50 cm, whereas plants received KAU POP (control 1 - T_{13}) registered a plant height of 173.29 cm. Lowest plant height of 164.10 cm was noticed in T_3, which had significant difference over other treatments.

Results recorded at 12 MAP registered highest plant height (236.40 cm) for T_4, which differed significantly from other treatments. It was followed by T_5 with a plant height of 230.15 cm, which also had significant difference over other treatments. Control 2 (T_{14}) recorded a plant height of 209.19 cm and control 1 (T_{13}) which received KAU POP registered a plant height of 185.69 cm. T_3 recorded least plant height of 176.52 cm, which had significant difference over other treatments.

Plant height recorded at 14 MAP showed that T_4 had highest score of 249.25 cm. It was found to be on par with T_5 (245.39 cm) and differed significantly from other treatments. Control 2 (T_{14}) recorded a plant height of 223.02 cm, whereas plants received KAU POP (control 1 - T_{13}) registered a plant height of 202.09 cm. Lowest plant height of 192.47 cm was noticed in T_3, and differed significantly from other treatments.

At 16 MAP, highest plant height of 262.56 cm was recorded for the treatment receiving T_4 which differed significantly from other treatments. It was followed by T_5 (258.28 cm), which also had significant difference over other treatments. Control 2 (T_{14}) recorded a plant height of 238.30 cm, whereas plants received KAU POP (control 1 - T_{13}) registered a plant height of 213.50 cm. Lowest plant height (201.73 cm) was recorded T_3, which had significant difference over other treatments.

Table 4. Effect of fertigation and foliar sprays on height (cm) of papaya plants

Treatments	Plant height (cm)							
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP	14 MAP	16 MAP
T_1	60.16	91.53	124.19	165.14	187.49	208.55	219.19	235.36
T_2	63.15	90.72	123.25	162.81	185.96	205.27	218.87	233.49
T_3	61.21	88.18	108.46	144.09	164.10	176.52	192.47	201.73
T_4	82.37	106.56	149.19	190.23	214.80	236.40	249.25	262.56
T_5	81.36	106.55	147.11	184.50	211.88	230.15	245.39	258.28
T_6	82.17	104.72	139.08	158.76	179.32	199.98	210.80	224.41
T_7	85.70	112.53	145.57	171.46	205.08	221.62	234.22	250.96
T_8	85.36	110.62	145.09	175.71	208.56	226.05	238.50	254.72
T_9	84.98	111.03	142.60	161.01	181.50	201.64	215.51	229.38
T_{10}	68.83	92.59	122.74	155.38	174.98	194.23	207.58	217.76
T_{11}	72.31	95.97	127.67	170.76	197.17	219.33	232.36	244.30
T_{12}	70.09	93.12	118.32	151.02	170.16	183.54	199.99	210.12
T_{13}	73.86	103.87	132.05	153.53	173.29	185.69	202.09	213.50
T_{14}	73.17	102.04	135.22	167.88	188.50	209.19	223.02	238.30
SEm (±)	1.13	1.49	0.78	0.74	1.06	1.38	1.80	1.19
CD(5%)	3.30	4.35	2.26	2.14	3.10	4.02	5.22	3.45

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

4.1.1.2 *Plant girth (cm)*

Data of plant girth influenced by application of different levels of fertigation and different foliar sprays are presented in Table 5. Observations on girth of plant recorded at bimonthly intervals from 2 MAP to 16 MAP (peak harvest stage) showed significant variation among treatments.

Plant girth recorded at 2 MAP showed that T_7 which received 125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 had highest score (11.29 cm). It was found to be on par with treatments T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax), T_5 (100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax), T_6 (100 % RD of N and K through fertigation with water spray), T_4 (100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19) and T_9 (125 % RD of N and K through fertigation with water spray) with a plant girth of 11.25 cm, 10.89 cm, 10.85 cm, 10.85 cm and 10.77 cm respectively and differed significantly from other treatments. Control 1 (T_{13}) and control 2 (T_{14}) registered a plant girth of 8.31 cm and 7.52 cm respectively. Lowest plant girth of 6.79 cm was recorded in T_3 which received 75 % RD of N and K through fertigation with water spray. It was found to be on par with treatments T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with a plant girth of 7.04 cm and 7.08 cm respectively and differed significantly from other treatments. However this effect on plant girth recorded at 2 MAP was solely due to fertigation, as foliar sprays with 1.0% 19:19:19, 0.5% $ZnSO_4$ and 0.3% borax and water spray was done from 4 MAP.

At 4 MAP, highest stem girth (21.99 cm) was observed in treatment T_7, which was on par with T_8 with a plant girth of 21.94 cm, but differed significantly from all other treatments. Control 2 (T_{14}) recorded 17.99 cm plant girth, which was found to be on par with control 1 (T_{13}) with a plant girth of 17.79 cm. Lowest plant girth observed at 4 MAP (12.23 cm) was for T_3, which was on par with T_2 with a plant girth of 12.80 cm and differed significantly from other treatments.

Results of data on plant girth at 6 MAP showed that the highest girth of 25.92 cm was registered in T_4. It was on par with T_5 and T_7 with a plant girth of 25.36 cm and 24.94 cm respectively, and differed significantly from all other treatments. Control 2 (T_{14}) recorded a plant girth of 20.99 cm. However, control 1 (T_{13}) registered 19.82 cm plant girth. T_3 had lowest plant girth (18.32 cm) at 6 MAP, which was on par with T_{12} (150 % RD of N and K through fertigation with water spray) with a plant girth of 18.39 cm and differed significantly from other treatments.

Observations recorded at 8 MAP revealed that T_4 registered highest plant girth of 39.33 cm, which differed significantly from other treatments. It was followed by T_5 with a plant girth of 37.46 cm which differed significantly from other treatments. T_{14} (control 2) recorded 30.70 cm plant girth at 8 MAP. However, control 1 (T_{13} which received KAU POP) registered a plant girth of 26.19 cm. Lowest plant girth of 21.86 cm was recorded in T_3. It was followed by T_{12} with a plant girth of 23.94 cm.

Statistical analysis at 10 MAP revealed a highest plant girth of 45.80 cm for T_4, which was on par with T_5 with 45.75 cm plant girth and differed significantly from other treatments. It was followed by T_8, T_7, T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) and T_1 with a plant girth of 43.31 cm, 40.24 cm, 37.92 cm and 36.23 cm respectively at 10 MAP, which differed significantly among treatments and other treatments. T_{14} (control 2), which recorded 36.08 cm plant girth was found to be on par with T_1. Control 1 (T_{13}) registered a plant girth of 30.11 cm. Lowest plant girth of 25.09 cm at 10 MAP was observed in T_3. It was found to be on par with T_{12} with 25.31 cm plant girth and differed significantly from other treatments.

Table 5. Effect of fertigation and foliar sprays on girth (cm) of papaya plants

Treatments	Plant girth (cm)							
	2 MAP	4 MAP	6 MAP	8 MAP	10 MAP	12 MAP	14 MAP	16 MAP
T_1	7.04	13.68	21.16	30.04	36.23	40.00	43.12	46.09
T_2	7.08	12.80	20.47	28.57	34.35	37.94	41.04	44.20
T_3	6.79	12.23	18.32	21.86	25.09	30.92	33.92	36.48
T_4	10.85	20.08	25.92	39.33	45.80	51.65	54.78	56.92
T_5	10.89	20.15	25.36	37.46	45.75	49.99	53.03	55.17
T_6	10.85	19.50	20.78	28.00	32.29	37.01	40.69	43.41
T_7	11.29	21.99	24.94	32.94	40.24	45.27	47.28	50.16
T_8	11.25	21.94	23.08	34.30	43.31	48.90	51.06	52.97
T_9	10.77	20.72	21.17	30.03	34.09	39.99	43.26	45.69
T_{10}	8.50	13.68	19.87	24.01	28.49	32.01	34.78	37.58
T_{11}	8.36	14.29	21.31	32.88	37.92	43.91	47.74	49.79
T_{12}	8.21	14.28	18.39	23.94	25.31	31.00	34.61	37.53
T_{13}	8.31	17.79	19.82	26.19	30.11	35.17	36.86	38.92
T_{14}	7.52	17.99	20.99	30.70	36.08	39.73	41.40	44.00
SE (±)	0.31	0.31	0.34	0.39	0.47	0.42	0.60	0.42
CD(5%)	0.89	0.92	0.99	1.15	1.38	1.21	1.75	1.23

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

At 12 MAP, highest plant girth (51.65 cm) was recorded in T_4 which differed significantly from all other treatments. It was followed by T_5 with a plant girth of 49.99 cm, which was on par with T_8 with 48.90 cm plant girth and differed significantly from other treatments. T_{14} (Control 2) registered 39.73 cm plant girth whereas, plants receiving KAU POP - control 1 (T_{13}) recorded 35.17 cm. Lowest plant girth of 30.92 cm was noticed in T_3, which was on par with T_{12} and T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with a plant girth of 31.00 cm and 32.01 cm respectively, which differed significantly from other treatments.

Plant girth recorded at 14 MAP showed that T_4 had highest score (54.78 cm), which was on par with T_5 with a plant girth of 53.03 cm, which differed significantly from other treatments. It was followed by T_8 and T_{11} with 51.06 cm and 47.74 cm plant girth respectively. T_7 with 47.28 cm plant girth was found to be on par with T_{11}. Control 2 (T_{14}) recorded a plant girth of 41.40 cm. However, control 1 (T_{13}) registered 36.86 cm plant girth. T_3 had lowest plant girth (33.92 cm) at 14 MAP, which was on par with T_{12} and T_{10} with a plant girth of 34.61 cm and 34.78 cm respectively which differed significantly from other treatments.

Results recorded at 16 MAP registered highest plant girth (56.92 cm) for T_4, which differed significantly from other treatments. It was followed by T_5 with a plant girth of 55.17 cm, which also differed significantly from other treatments. Control 2 (T_{14}) and control 1 (T_{13}) which received KAU POP recorded a plant girth of 44.00 cm and 38.92 cm respectively. Lowest plant girth of 36.48 cm was noticed in T_3, which was on par with T_{12} and T_{10} with a plant girth of 37.53 cm and 37.58 cm respectively which differed significantly from other treatments.

4.1.1.3 ***Number of leaves***

Number of leaves influenced by application of different levels of fertigation and different foliar sprays are presented in Table 6. Observations on number of leaves recorded at bimonthly intervals from 2 MAP to 16 MAP (peak harvest stage) showed significant variation among treatments.

At 2 MAP, maximum number of leaves (13.67) was noted in T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax), which was on par with T_9 (125 % RD of N and K through fertigation with water spray) with 13.00 leaves and differed significantly from other treatments. It was followed by T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19), T_4 (100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19) and T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with a leaf count of 12.22, 11.89 and 11.89 respectively, which were on par. Control 1 (T_{13}) which received KAU POP and control 2 (T_{14}) recorded 11.78 and 11.66 number of leaves respectively. Least number of leaves (8.89 each) was recorded in T_3 (75 % RD of N and K through fertigation with water spray) and T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax), which was on par with T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with a leaf count of 9.44 and differed significantly from other treatments. However this effect on number of leaves recorded at 2 MAP was solely due to fertigation as foliar sprays with 1.0% 19:19:19, 0.5% $ZnSO_4$ and 0.3% borax and water spray was done from 4 MAP.

Results recorded at 4 MAP registered a maximum leaf number of 16.56 in T_7, which was on par with T_8, T_9 and T_4 with a leaf count of 16.22, 15.89 and 15.78 respectively, and differed significantly from other treatments. Control 1 (T_{13}) registered 13.66 number of leaves and control 2 (T_{14}) recorded a leaf number of 13.56. The minimum number of leaves (10.67) was noted in T_3, which was on par with T_1 (11.33) and T_2 (12.00) and differed significantly from other treatments.

Number of leaves recorded at 6 MAP indicated maximum leaves (18.11) in T_4, which was on par with T_5, T_8 and T_7 with a leaf score of 17.78, 17.44 and 17.22

respectively, and differed significantly from other treatments. Control 2 (T_{14}) recorded 14.78 number of leaves. Minimum number of leaves (11.00) was noted in T_3 which differed significantly from other treatments. This was followed by T_{12} (150 % RD of N and K through fertigation with water spray) with 13.56 number of leaves, which was on par with T_{13} (control 1), T_2, T_1 and T_{10} with 14.00, 14.00, 14.11 and 14.11 leaves respectively and differed significantly from other treatments.

Statistical analysis at 8 MAP revealed that T_4 recorded highest number of leaves (22.34), which was on par with T_5 and T_8 with 21.78 and 21.56 leaves respectively and differed significantly from other treatments. Control 2 (T_{14}) recorded 19.89 leaves and control 1 (T_{13}) registered 17.22 leaves. Lowest value of 14.89 was reported in T_3 which was on par with T_{12} with 16.00 leaves and differed significantly from other treatments.

Results recorded at 10 MAP indicated a highest number of leaves (29.11) in T_4 and differed significantly from other treatments. It was followed by T_5, which was on par with T_8 with 27.89 and 27.78 leaves respectively and differed significantly from other treatments. T_{14} (control 2) recorded 25.22 leaves. Least number of leaves (15.11) was documented in T_3, and differed significantly from other treatments. It was followed by T_{12} which was on par with T_{13} (control 1) with 17.11 and 18.00 leaves respectively and differed significantly from other treatments.

Data on number of leaves recorded at 12 MAP, revealed a highest number of leaves (31.22) in T_4 which differed significantly from other treatments. It was followed by T_5 which was found on par with T_8 with 29.33 and 29.22 leaves respectively, and differed significantly from other treatments. Control 2 (T_{14}) recorded 26.67 leaves. Among the treatments receiving 150 % RD of N and K as fertigation (T_{10}, T_{11} and T_{12}), T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) recorded a maximum number of leaves (26.66) at 12 MAP. However, among the treatments receiving 75 % RD of N and K

Table 6. Effect of fertigation and foliar sprays on number of leaves of papaya plants

Treatments	Number of leaves							
	2 MAP	**4 MAP**	**6 MAP**	**8 MAP**	**10 MAP**	**12 MAP**	**14 MAP**	**16 MAP**
T_1	9.44	11.33	14.11	19.67	24.33	26.22	24.34	19.78
T_2	8.89	12.00	14.00	19.22	22.22	23.89	22.89	19.00
T_3	8.89	10.67	11.00	14.89	15.11	16.56	15.00	11.67
T_4	11.89	15.78	18.11	22.34	29.11	31.22	28.67	25.11
T_5	11.33	14.44	17.78	21.78	27.89	29.33	27.78	23.00
T_6	11.55	14.33	15.56	17.89	19.00	21.00	19.78	17.22
T_7	12.22	16.56	17.22	20.78	26.44	27.66	26.11	21.22
T_8	13.67	16.22	17.44	21.56	27.78	29.22	27.00	21.78
T_9	13.00	15.89	16.33	18.44	20.67	23.11	22.67	17.78
T_{10}	11.89	13.22	14.11	17.67	18.22	19.45	17.11	14.33
T_{11}	11.22	13.33	15.78	20.11	25.78	26.66	25.22	21.22
T_{12}	11.33	12.67	13.56	16.00	17.11	19.11	15.22	12.67
T_{13}	11.78	13.66	14.00	17.22	18.00	19.78	17.67	14.00
T_{14}	11.66	13.56	14.78	19.89	25.22	26.67	25.00	20.00
SE (±)	0.41	0.49	0.32	0.48	0.35	0.36	0.36	0.34
CD (5%)	1.20	1.41	0.92	1.38	1.01	1.07	1.07	0.97

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

as fertigation (T_1, T_2 and T_3), T_1 witnessed a maximum leaf number of 26.22. Minimum number of leaves (16.56) was noticed in T_3 and it differed significantly from other treatments.

Observations recorded at 14 MAP indicated that in all the treatments number of leaves reduced in papaya as month progress from 12 MAP. Maximum number of leaves (28.67) was noted in T_4 at 14 MAP. It was on par with T_5 with 27.78 leaves and differed significantly from other treatments. It was followed by T_8 and T_7 with 27.00 and 26.11 leaves and were on par. Among the treatments receiving 75 % RD of N and K as fertigation (T_1, T_2 and T_3), T_1 recorded maximum number of leaves (24.34) at 14 MAP and was found to be on par with T_{14} (control 2). Minimum number of leaves (15.00) was reported in T_3, which was on par with T_{12} with 15.22 leaves and differed significantly from other treatments.

At 16 MAP, maximum number of leaves (25.11) was observed in T_4 which differed significantly from other treatments. It was followed by T_5 with 23 leaves and had significant difference over other treatments. Control 2 (T_{14}) registered 20.00 leaves. Among the treatments receiving 75 % RD of N and K as fertigation (T_1, T_2 and T_3), T_1 recorded maximum number of leaves (19.78) at 16 MAP. Control 1 (T_{13}) which received KAU POP registered 14.00 leaves. T_3 recorded minimum number of leaves (11.67) at 16 MAP and differed significantly from other treatments.

4.1.1.4 *Leaf area index*

Data on leaf area index recorded at 6, 12, 18 MAP and at last harvest (20 MAP) showed significant variation among treatments (Table 7).

At 6 MAP, highest leaf area index of 1.71 was recorded in T_4 (100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19), which differed significantly from other treatments. It was followed by T_5 (100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax) with a leaf area index of 1.62. Among treatments receiving 125 % RD of N and K through fertigation (T_7, T_8 and T_9), T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) recorded highest leaf area index of 1.58 each at 6 MAP, which was found to be on par with T_{11} (150 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with a leaf area index of 1.57. Leaf area index of 1.50 was recorded in control 2 (T_{14}). Among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3), T_1 (75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19) registered highest leaf area index of 1.45. Lowest value for leaf area index (1.18) was recorded in T_3 (75 % RD of N and K through fertigation with water spray), which was found to be on par with T_{12} (150 per cent of RD of N and K through fertigation with water spray) and T_{13} (KAU POP - control 1) with a leaf area index of 1.19 and 1.22 respectively.

Observations on leaf area index recorded at 12 MAP registered highest value (4.20) for T_4, which was on par with T_5 with a leaf area index of 4.11 and differed significantly from other treatments. Among treatments receiving 125 % RD of N and K through fertigation (T_7, T_8 and T_9), T_8 recorded highest leaf area index of 4.00, which was on par with T_7 with 3.95. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} recorded highest leaf area index of 3.85. However, T_{14} - control 2 registered a leaf area index of 3.79. T_1 recorded highest leaf area index (3.60) among T_1, T_2 and T_3 which received 75 % RD of N and K through fertigation. Control 1 (T_{13}) which received KAU POP, registered a leaf area index of 3.05. Lowest leaf area index of 2.71 was recorded in T_3, which was found to be on par with T_{12} with a leaf area index of 2.83.

Results on leaf area index recorded at 18 MAP indicated a highest value (2.43) in T_4. It was followed by T_5, T_8, T_7 and T_{11} with a leaf area index of 2.34, 2.25, 2.11 and 2.03 respectively which differed significantly among each other and among other treatments. Leaf area index of 1.98 was registered in T_{14} (control 2), which was found to be on par with T_1 with a leaf area index of 1.97. Application of KAU POP (T_{13} - control 1) registered a leaf area index of 1.71, which was on par with T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) (1.70). Lowest value for leaf area index (1.55) was recorded in T_3, which was found to be on par with T_{12} (1.56).

Leaf area index recorded at final harvest (20 MAP) revealed significant difference among treatments. Highest leaf area index of 2.28 was witnessed in T_4, which was on par with T_5 (2.23) and differed significantly from other treatments. Among treatments receiving 125 % RD of N and K through fertigation (T_7, T_8 and T_9), T_8 recorded highest leaf area index of 2.13, which was followed by T_7 with 2.05. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} recorded highest leaf area index of 1.97, whereas, T_{14} (control 2) witnessed a leaf area index of 1.94 which was on par. T_1 recorded highest leaf area index (1.91) among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3). Application of KAU POP (T_{13} - control 1) registered a leaf area index of 1.69. Lowest leaf area index of 1.52 was recorded in T_3, which was found to be on par with T_{12} with a leaf area index of 1.53 which differed significantly from other treatments.

4.1.1.5 ***Height at first flowering (cm)***

Data on height at first flowering showed significant variation among treatments (Table 8).

It is apparent from the data that application of 100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 (T_4) flowered at shortest height of 74.38 cm and differed significantly from other treatments. It was followed by T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) which flowered at 81.43 cm also differed significantly from other treatments. Control 2 (T_{14}) flowered at a height of 104.94 cm. Flowering started at maximum height (113.53 cm) in the treatment T_3 (75 % RD of N and K through fertigation with water spray) which was on par with the treatments T_{12} (150 % RD of N and K through fertigation with water spray) (110.88 cm) and T_{13} (control 1 - KAU POP) (110.85 cm).

4.1.1.6 ***Days to flowering***

The data obtained on days taken to first flowering in papaya after application of different levels of fertigation and different foliar sprays are illustrated in Table 8.

Statistical analysis of the results indicated that the number of days taken for flowering in papaya provided with different levels of fertigation and different foliar sprays differed significantly. T_5 (100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax) registered significantly minimum days (142.67 days) to first flowering. It was found to be on par with T_4 (100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19) which flowered at 145.78 days. T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) and T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) also recorded minimum days to flowering (150.00 days and 150.44 days respectively) after T_4. Control 2 (T_{14}) took 156.55 days for appearance of first flower, whereas plants received KAU POP (control 1 - T_{13}) took 174.11 days. However, significantly maximum days (186.00 days) for flowering was registered in T_3 (75 % RD of N and K through fertigation with water spray), which was found to be on par with treatment receiving 150 % RD of N and K through fertigation with water spray (T_{12}) which took 181.78 days for appearance of first flower.

4.1.1.7 ***Sex expression of plant***

The sex expression of papaya plant influenced by different levels of fertigation and different foliar sprays are presented in Table 9.

Table 7. Effect of fertigation and foliar sprays on leaf area index of papaya plants

Treatments	Leaf area index			
	6 MAP	**12 MAP**	**18 MAP**	**At last harvest**
T_1	1.45	3.60	1.97	1.91
T_2	1.39	3.44	1.93	1.87
T_3	1.18	2.71	1.55	1.52
T_4	1.71	4.20	2.43	2.28
T_5	1.62	4.11	2.34	2.23
T_6	1.50	3.27	1.79	1.76
T_7	1.58	3.95	2.11	2.05
T_8	1.58	4.00	2.25	2.13
T_9	1.54	3.31	1.82	1.78
T_{10}	1.33	3.14	1.70	1.64
T_{11}	1.57	3.85	2.03	1.97
T_{12}	1.19	2.83	1.56	1.53
T_{13}	1.22	3.05	1.71	1.69
T_{14}	1.50	3.79	1.98	1.94
SE (±)	0.02	0.07	0.02	0.02
CD(5%)	0.06	0.20	0.07	0.06

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

Table 8. Effect of fertigation and foliar sprays on height at first flowering and days to flowering of papaya plants

Treatments	Height at first flowering (cm)	Days to flowering
T_1	108.10	164.00
T_2	109.71	162.89
T_3	113.53	186.00
T_4	74.38	145.78
T_5	81.43	142.67
T_6	89.35	161.22
T_7	100.50	153.33
T_8	92.32	150.00
T_9	102.04	159.22
T_{10}	110.07	170.00
T_{11}	104.51	150.44
T_{12}	110.88	181.78
T_{13}	110.85	174.11
T_{14}	104.94	156.55
SE (±)	1.93	1.88
CD (5%)	5.60	5.46

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

The data implies that application of different levels of fertigation and different foliar sprays on sex expression of papaya differed significantly among treatments. The number of female plants was found to be highest (83.33 %) in T_4 which received 100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19. It was found to be on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) and T_8 (125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax) with 77.78 % female plants for both. Control 2 (T_{14}) and control 1 (T_{13}) registered 66.67 % and 61.11 % female plants respectively. Whereas, lowest number of female plants (38.89 %) were found in treatments T_3 (75 % RD of N and K through fertigation and water spray) and T_{12} (150 % RD of N and K through fertigation and water spray), which was found to be on par with T_1 (44.44 %) which received 75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19.

Lowest hermaphrodite plants (16.67 %) was recorded in T_4. It was found to be on par with treatments T_5 and T_8 with 22.22 % hermaphrodite plants for both. However, highest number of hermaphrodite plants (61.11 %) was observed in treatments T_3 and T_{12}. It was found to be on par with T_1 (55.56 %).

4.1.1.8 *Number of flowers cluster^{-1}*

Data on number of flowers per cluster showed significant variation among treatments (Table 10).

Among different treatments T_5 (100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax) registered highest number of flowers per cluster (2.78), which was on par with treatments T_4 (100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19) and T_8 (125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax), both recorded 2.67 flowers per cluster. Control 2 (T_{14}) produced two flowers per cluster,

Table 9. Effect of fertigation and foliar sprays on sex expression of papaya plants

Treatments	Sex expression	
	Female plants (%)	Hermaphrodite plants (%)
T_1	44.44	55.56
T_2	55.56	44.44
T_3	38.89	61.11
T_4	83.33	16.67
T_5	77.78	22.22
T_6	66.67	33.33
T_7	72.22	27.78
T_8	77.78	22.22
T_9	66.67	33.33
T_{10}	55.56	44.44
T_{11}	66.67	33.33
T_{12}	38.89	61.11
T_{13}	61.11	38.89
T_{14}	66.67	33.33
SE (±)	5.87	5.87
CD (5%)	17.06	17.06

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data
T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

whereas plants receiving KAU POP - control 1 (T_{13}) recorded 1.78 flowers per cluster. T_3 (75 % RD of N and K through fertigation with water spray) registered lowest number of flowers per cluster (1.44) which was on par with T_{12} (150 % RD of N and K through fertigation and water spray) with 1.67 flowers per cluster.

4.1.1.9 *Fruit set (%)*

Significant difference in fruit set was observed among the treatments in the present study (Table 10). The fruit set was highest (86.27 %) in the treatment T_4 (100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19), which was on par with T_5 (100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax) with a fruit set of 85.43 per cent, which differed significantly from all other treatments. It was followed by treatments T_8 (125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax), T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19), T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) and T_{14} (control 2) which recorded a fruit set of 83.18 %, 82.12 %, 81.47 % and 80.80 % respectively. T_3 (75 % RD of N and K through fertigation with water spray) registered lowest fruit set of 64.50 %.

4.1.1.10 *Time for first harvest (days)*

The data on time taken for first harvest in different treatments are presented in table 10 and that exhibited significant differences. It revealed that application 100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (T_5) had reduced the days (275.00 days) taken for harvest of first papaya fruit and differed significantly from other treatments. This was followed by T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) which was on par with T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) took 278.89 days and 280.78 days respectively for the first harvest. Fruits were harvested after 304.00 days from control 2 (T_{14}). It was found to be on par with treatments T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax which took 305.11 days and 306.89 days respectively for harvest of first fruit. Application of KAU POP - control 1 (T_{13}) commenced first harvest at 313.67 days. Among the treatments, T_3 (75 % RD of N and K through fertigation with water spray) took more number of days (327.56 days) for first harvest and it differed significantly from other treatments.

4.1.2 Yield parameters

Influence of different levels of fertigation and different foliar sprays on yield parameters were recorded and analysed data is furnished below.

4.1.2.1 *Fruit weight (g)*

Fruit weight of 14 treatments influenced by different levels of fertigation and different foliar sprays are presented in table 11, which showed significant difference among the treatments (Plate 7). Highest fruit weight of 797.51 g was noticed in plants receiving 100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 (T_4), which was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with a fruit weight of 792.42 g which differed significantly from other treatments. It was followed by T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) (754.60 g), which was found to be on par with T_7 (125% RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 747.95 g. Among the treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) registered significantly higher fruit weight of 741.49 g. It was followed by T_{14} (control 2) with 711.31 g and the treatments T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) was on par with a fruit

Table 10. Effect of fertigation and foliar sprays on number of flowers per cluster, fruit set (%) and time for first harvest of papaya plants

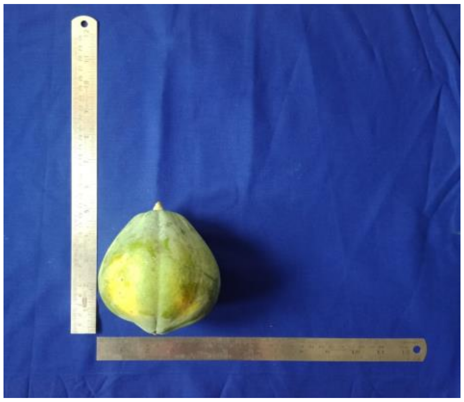
Treatments	Number of flowers per cluster	Fruit set (%)	Time for first harvest
T_1	2.00	80.57	305.11
T_2	2.11	79.34	306.89
T_3	1.44	64.50	327.56
T_4	2.67	86.27	278.89
T_5	2.78	85.43	275.00
T_6	1.89	75.13	299.56
T_7	2.44	82.12	285.67
T_8	2.67	83.18	280.78
T_9	2.00	77.25	292.67
T_{10}	1.89	70.87	311.78
T_{11}	2.11	81.47	288.67
T_{12}	1.67	66.70	322.89
T_{13}	1.78	70.20	313.67
T_{14}	2.00	80.80	304.00
SE (±)	0.15	0.57	1.29
CD (5%)	0.42	1.67	3.75

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

weight of 708.93 g and 703.47 g respectively. Application of KAU POP - control 1 (T_{13}) exhibited a fruit weight of 608.71 g. Lowest fruit weight of 569.84 g was noticed in plants receiving 75 % RD of N and K through fertigation with water spray (T_3) which differed significantly from other treatments.

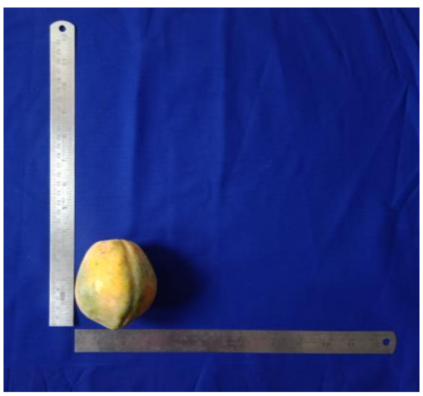
4.1.2.2 ***Fruit length (cm)***

Fruit length influenced by different treatments are illustrated in table 11. Highest fruit length (16.90 cm) was noticed in T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19), which was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with 16.79 cm fruit length which differed significantly from other treatments. Among the treatments receiving 125 % RD of N and K through fertigation (T_7, T_8 and T_9), T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) registered highest fruit length of 16.31 cm, which was on par with T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 16.09 cm. Among the treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), treatment T_{11} which received foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax in addition to 150 % RD of N and K through fertigation registered highest fruit length of 15.62 cm. Fruit length of 15.01 cm was noticed in control 2 (T_{14}). T_1 which received 75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 recorded highest fruit length of 14.60 cm among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3). It was on par with T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with a fruit length of 14.45 cm. Application of KAU POP - control 1 (T_{13}) exhibited a fruit length of 10.43 cm. Lowest fruit length of 9.15 cm was noticed in T_3 (75 % RD of N and K through fertigation with water spray) which differed significantly from other treatments.

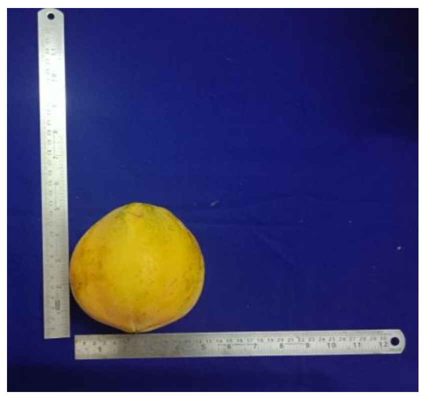


T$_1$

T$_2$



T$_3$

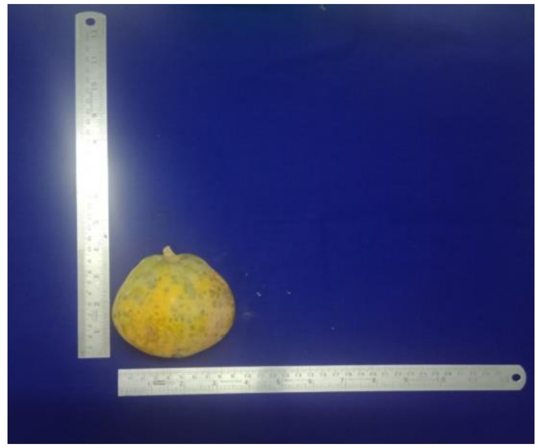


T$_4$

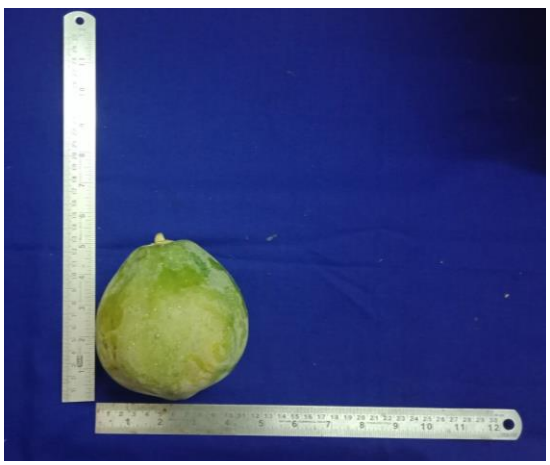
Plate 7. Fruits of papaya receiving different treatments

T$_1$ - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T$_2$ - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T$_3$ - 75 % RD of N and K through fertigation and water spray
T$_4$ - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19

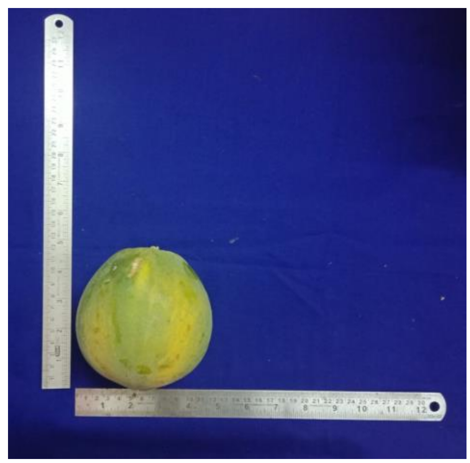
T5



T6



T7

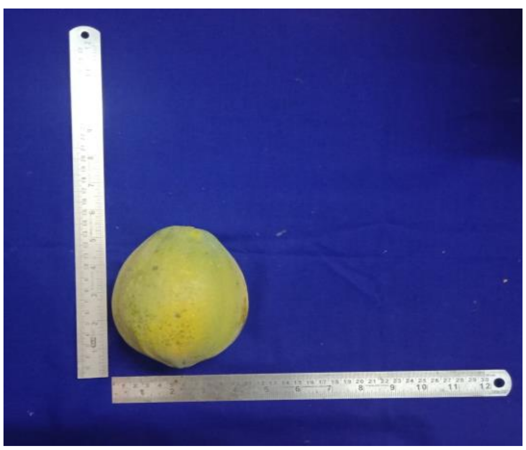


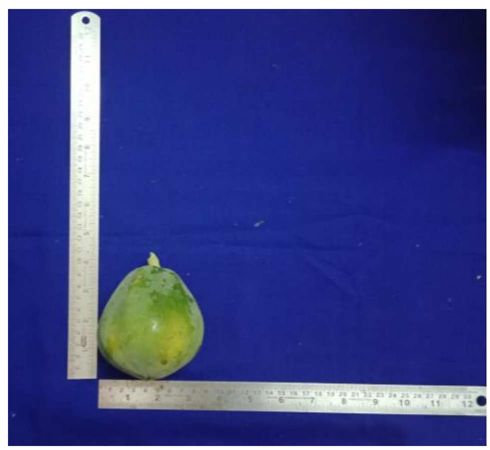
T8

Plate 7a. Fruits of papaya receiving different treatments

T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax

T_9 T_{10}

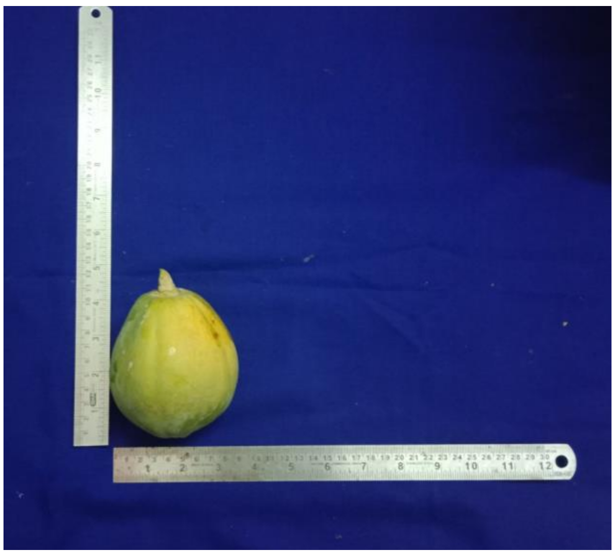


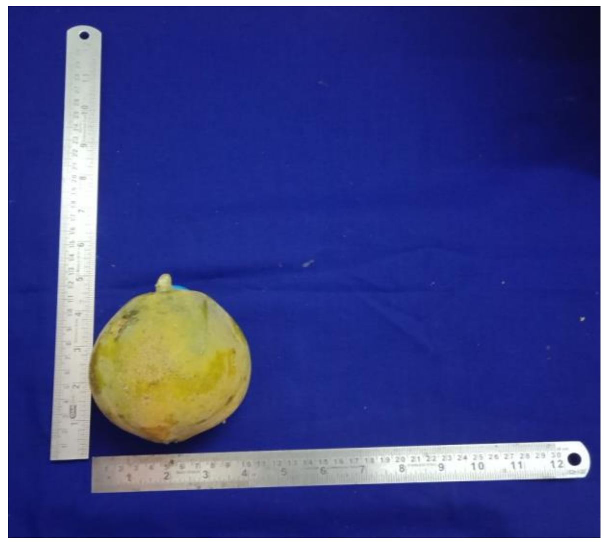


T_{11} T_{12}

Plate 7b. Fruits of papaya receiving different treatments

T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray





T_{13} T_{14}

Plate 7c. Fruits of papaya receiving different treatments

T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data

T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

4.1.2.3 *Fruit girth (cm)*

Effect of different levels of fertigation and different foliar sprays on fruit girth of 14 treatments are presented in table 11 and it exhibited significant variation among treatments. T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) reported highest fruit girth of 13.90 cm, which was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with a fruit girth of 13.74 cm which differed significantly from other treatments. It was followed by T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with 12.98 cm fruit girth which was on par with T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with fruit girth of 12.74 cm and 12.68 cm respectively. Control 2 (T_{14}) recorded 11.90 cm fruit girth. It was found to be on par with T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 11.83 cm. Application of KAU POP - control 1 (T_{13}) exhibited a fruit girth of 8.51 cm. Lowest fruit girth of 7.86 cm was noticed in T_3 (75 % RD of N and K through fertigation with water spray) which differed significantly from other treatments.

4.1.2.4 *Fruit volume (cc)*

From table 11 it is evident that application of different levels of fertigation and different foliar sprays had significant effect on fruit volume. Highest fruit volume (751.76 cc) was reported in T_4. It was on par with T_5 with a fruit volume of 744.58 cc which differed significantly from other treatments. Among the treatments receiving 125 % RD of N and K through fertigation (T_7, T_8 and T_9), T_8 registered highest fruit volume of 709.02 cc. T_{11} recorded highest fruit volume of 693.91 cc among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}). Fruit volume of 664.22 cc was noticed in control 2 (T_{14}). It was on par with T_1 which registered a fruit volume of 661.11 cc. Application of KAU POP - control 1 (T_{13})

exhibited a fruit volume of 551.71 cc. Plants receiving 75 % RD of N and K through fertigation with water spray (T_3) recorded lowest fruit volume of 501.91 cc which differed significantly from other treatments.

4.1.2.5 ***Physical composition (%)***

The percentage of each component of the fruit namely skin, flesh and seed is the physical composition of fruit and in the current study significant difference was observed in the physical composition among the treatments (Table 12). The pulp percentage ranged from 64.02 to 83.53 %. Plants receiving 100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 (T_4) showed maximum pulp percentage (83.53 %). It was found to be on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) and T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with 82.85 % and 81.59 % pulp respectively which differed significantly from other treatments. Pulp percentage of 79.04 was noticed in control 2 (T_{14}). It was on par with T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with 78.58 % and 77.89 % pulp respectively. Application of KAU POP - control 1 (T_{13}) registered a pulp percentage of 68.33 %. While the minimum pulp percentage (64.02 %) was observed in T_3 (75 % RD of N and K through fertigation with water spray), which was on par with T_{12} (150 % RD of N and K through fertigation with water spray) with 64.65 % of pulp and differed significantly from other treatments.

Seed percentage ranged from 9.10 to 24.79 % exhibited significant difference among treatments. Lowest seed percentage of 9.10 was registered in T_5. It was on par with T_4 and T_8 with 9.24 and 9.38 % seed respectively which differed significantly from other treatments. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} (150 RD of N and K through fertigation and foliar

Table 11. Effect of fertigation and foliar sprays on fruit weight, fruit length, fruit girth and fruit volume of papaya

Treatments	Fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Fruit volume (cc)
T_1	708.93	14.60	11.83	661.11
T_2	703.47	14.45	11.13	652.56
T_3	569.84	9.15	7.86	501.91
T_4	797.51	16.90	13.90	751.76
T_5	792.42	16.79	13.74	744.58
T_6	634.60	13.03	9.98	586.49
T_7	747.95	16.09	12.74	702.40
T_8	754.60	16.31	12.98	709.02
T_9	644.11	13.37	10.20	594.00
T_{10}	631.38	10.98	8.96	582.05
T_{11}	741.49	15.62	12.68	693.91
T_{12}	592.45	9.89	8.45	528.82
T_{13}	608.71	10.43	8.51	551.71
T_{14}	711.31	15.01	11.90	664.22
SE (±)	2.80	0.14	0.16	3.18
CD (5%)	8.13	0.41	0.46	9.24

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data
T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

sprays of 0.5% $ZnSO_4$ and 0.3% borax) recorded least seed percentage of 10.60. Control 2 (T_{14}) registered 11.83 % seed. T_1 registered lowest seed percentage (11.92 %) among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3). Seed percentage of 19.77 was observed in treatment receiving KAU POP - control 1 (T_{13}). Among all the 14 treatments, T_3 recorded highest seed percentage (24.79 %) and differed significantly from other treatments.

Peel percentage of different treatments influenced by different levels of fertigation and different foliar sprays ranged from 7.23 to 11.98 %. T_4 registered lowest peel percentage (7.23 %). It was on par with T_5 with 8.05 % peel which differed significantly from other treatments. Among treatments receiving 125 % RD of N and K through fertigation (T_7, T_8 and T_9), T_8 recorded lowest peel percentage of 9.03. It was on par with T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_{14} (control 2) with 9.05 % and 9.13 % peel respectively. T_1 registered lowest peel percentage (9.49 %) among T_1, T_2 and T_3 (which received 75 % RD of N and K through fertigation). It was on par with T_2 and T_6 (100 % RD of N and K through fertigation with water spray) with 9.56 % and 9.63 % peel respectively. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} recorded lowest peel percentage of 9.83. Highest peel percentage of 11.98 was registered in T_{12}, which was on par with T_{13} (KAU POP - control 1), T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 and T_3 with 11.89 %, 11.46 % and 11.19 % respectively which differed significantly from other treatments.

Pulp/ peel ratio of papaya fruits ranged from 5.40 to 11.55 showed significant difference among treatments (Table 12). T_4 recorded highest pulp/ peel ratio of 11.55 which was on par with T_5 (10.29). T_{14} registered a pulp/ peel ratio of 8.66 whereas, in T_{13} it was 5.75. Least pulp/ peel ratio of 5.40 was noticed in T_{12}.

4.1.2.6 *Flesh thickness (cm)*

The observation on flesh thickness of papaya fruit showed significant difference among treatments (Table 13). T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) recorded highest flesh thickness of 3.42 cm, which was on par with T_5 receiving 100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (3.39 cm) and differed significantly from other treatments. Plants receiving 125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (T_8) recorded highest flesh thickness (3.18 cm) among treatments receiving 125 % RD of N and K through fertigation (T_7, T_8 and T_9), whereas among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) registered highest flesh thickness (2.90 cm). Application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures (control 2 – T_{14}) gave fruits with flesh thickness of 2.69 cm. Among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3), T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) had highest flesh thickness of 2.48 cm which was found to be on par with T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with a flesh thickness of 2.41 cm. Plants receiving KAU POP - control 1 (T_{13}) recorded 1.80 cm flesh thickness in fruits. Fruits with lowest flesh thickness of 1.55 cm were observed in treatment receiving 75 % RD of N and K through fertigation with water spray (T_3) which differed significantly from other treatments.

4.1.2.7 *Number of fruits per plant*

Influence of different levels of fertigation and foliar sprays on number of fruits per plant are presented in table 13, which depicted significant difference among the treatments. Application of 100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 (T_4) registered highest number of fruits per plant (48.11). It

Table 12. Effect of fertigation and foliar sprays on physical composition and pulp/ peel ratio of papaya fruits

Treatments	Physical composition (%)			Pulp/ peel ratio
	Pulp	Seed	Peel	
T_1	78.58	11.92	9.49	8.28
T_2	77.89	12.55	9.56	8.15
T_3	64.02	24.79	11.19	5.72
T_4	83.53	9.24	7.23	11.55
T_5	82.85	9.10	8.05	10.29
T_6	72.35	18.02	9.63	7.51
T_7	80.02	10.92	9.05	8.84
T_8	81.59	9.38	9.03	9.04
T_9	71.91	17.20	10.89	6.60
T_{10}	68.50	20.04	11.46	5.98
T_{11}	79.57	10.60	9.83	8.09
T_{12}	64.65	23.37	11.98	5.40
T_{13}	68.33	19.77	11.89	5.75
T_{14}	79.04	11.83	9.13	8.66
SE (±)	0.82	0.47	0.48	0.51
CD (5%)	2.39	1.37	1.40	1.48

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with 47.45 fruits which differed significantly from other treatments. Among treatments receiving 125 % RD of N and K through fertigation (T_7, T_8 and T_9), T_8 receiving 125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax recorded highest number of fruits per plant (45.00). It was found to be on par with T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 44.33 fruits per plant. Control 2 (T_{14}) recorded 42.56 fruits per plant. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) registered highest number of fruits per plant (42.00), whereas T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) recorded highest fruit per plant (41.00) among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3). 34.55 fruits per plant was observed in KAU POP (control 1 - T_{13}). T_3 registered lowest number of fruits per plant (28.45) and it differed significantly from other treatments.

4.1.2.8 *Number of seeds per fruit*

Table 13 indicates the observation on number of seeds per fruit among different treatments under study. T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) reported lowest number of seeds (383.00) and it differed significantly from other treatments. It was followed by T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with 407.13 seeds and it also differed significantly from other treatments. Among treatments receiving 125 % RD of N and K through fertigation (T_7, T_8 and T_9), T_8 receiving 125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax recorded lowest number of seeds per fruit (439.09). However, among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3%

borax) registered lowest number of seeds per fruit (475.80). Control 2 (T_{14}) recorded 532.53 seeds. T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) registered lowest seed count of 591.40 among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3). 780.93 seeds per fruit was observed in control 1 (T_{13}). Highest number of seeds per fruit (829.69) was registered in T_3 (75 % RD of N and K through fertigation with water spray) and it also differed significantly from other treatments.

4.1.2.9 *Seed germination (%)*

The data with regard to germination percentage of papaya seeds are shown in table 13, which exhibited significant differences among treatments. T_5 registered highest seed germination (87.78 %) which differed significantly from other treatments. It was followed by T_8 and T_4 with 84.67 per cent and 82.89 per cent seed germination respectively which were on par. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) registered highest germination percentage of 80.22. Control 2 (T_{14}) recorded 78.44 per cent seed germination, whereas in treatments receiving KAU POP (control 1 - T_{13}) seed germination was 75.33 per cent. Among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3), T_2 which received foliar spray of 0.5% $ZnSO_4$ and 0.3% borax in addition to 75 % RD of N and K through fertigation registered highest germination percentage of 74.22. Lowest seed germination percentage of 67.78 was reported in T_3 (75 % RD of N and K through fertigation with water spray). Treatments T_{12} (150 % RD of N and K through fertigation with water spray) and T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 68.89 per cent and 69.56 per cent seed germination repectively was on par.

4.1.2.10 *Yield per plant (kg)*

Table 14 depicts the data on fruit yield per plant of different treatments influenced by different levels of fertigation and different foliar sprays. There was significant difference among the treatments under study. Application of 100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 (T_4) registered highest fruit yield of 38.30 kg plant^{-1}, which was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with 37.60 kg plant^{-1}. It was followed by T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) and T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with a fruit yield of 33.96 kg plant^{-1} and 33.16 kg plant^{-1} respectively which varied significantly from other treatments. T_{11} which received 150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax recorded highest fruit yield per plant (31.14 kg plant^{-1}) among treatments provided with 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}) and it was found to be on par with T_{14} (control 2) which yielded 30.27 kg plant^{-1}. Among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3), T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) recorded highest fruit yield of 29.06 kg plant^{-1}, which was on par with T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax with 28.21 kg plant^{-1} fruit yield. Lowest fruit yield of 16.21 kg plant^{-1} was noticed in T_3 (75 % RD of N and K through fertigation with water spray) which differed significantly from other treatments. It was followed by T_{12} (150 % RD of N and K through fertigation with water spray) and T_{13} (KAU POP - control 1) with 17.78 kg plant^{-1} and 21.03 kg plant^{-1} fruit yield respectively.

Table 13. Effect of fertigation and foliar sprays on flesh thickness, number of fruits per plant, number of seeds per fruit and seed germination percentage of papaya

Treatments	Flesh thickness (cm)	Number of fruits per plant	Number of seeds per fruit	Seed germination percentage
T_1	2.48	41.00	591.40	69.56
T_2	2.41	40.11	612.95	74.22
T_3	1.55	28.45	829.69	67.78
T_4	3.42	48.11	383.00	82.89
T_5	3.39	47.45	407.13	87.78
T_6	2.14	37.22	697.49	79.56
T_7	3.04	44.33	461.65	81.33
T_8	3.18	45.00	439.09	84.67
T_9	2.16	38.44	686.75	79.78
T_{10}	1.90	33.78	704.84	72.22
T_{11}	2.90	42.00	475.80	80.22
T_{12}	1.72	30.00	799.91	68.89
T_{13}	1.80	34.55	780.93	75.33
T_{14}	2.69	42.56	532.53	78.44
SE (±)	0.05	0.40	2.67	0.71
CD (5%)	0.15	1.15	7.78	2.07

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

4.1.2.11 *Yield ha^{-1}*

Data on fruit yield ha^{-1} showed significant difference among treatments under study (Table 14). T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) registered highest fruit yield per hectare (95.76 t ha^{-1}). It was on par with treatments receiving 100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (T_5) with a fruit yield of 93.99 t ha^{-1} and differed significantly from other treatments. It was followed by T_8 receiving 125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (84.89 t ha^{-1}), which was on par with T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 82.89 t ha^{-1} fruit yield. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}) T_{11} recorded highest fruit yield of 77.84 t ha^{-1}, which was on par with control 2 - T_{14} (75.67 t ha^{-1}). Among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3), T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) recorded highest fruit yield of 72.66 t ha^{-1}. Application of KAU POP (control 1 - T_{13}) registered 52.58 t ha^{-1} fruit yield. Lowest fruit yield per hectare (40.52 t ha^{-1}) was noticed in T_3 receiving 75 % RD of N and K through fertigation with water spray which differed significantly from other treatments.

4.1.2.12 *Days taken for maturity*

The days taken for attaining maturity of papaya fruits in different treatments are presented in table 14, which differed significantly among the treatments. Least number of days for fruit maturity (119.44 days) was noticed in T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19). Treatments T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax), T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) and T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) which reported 120.22 days, 120.33 days and 122.33 days respectively for fruit maturity were on par. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) registered least days for fruit maturity (123.00 days). It was followed by T_9 (125 % RD of N and K through fertigation with water spray) (123.89 days), which was on par with T_{14} (control 2), T_1 and T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax which took 124.67 days, 124.89 days and 125.22 days respectively for attaining fruit maturity. Application of KAU POP (control 1 - T_{13}) resulted in 129.11 days for fruit maturity. T_3 recorded maximum days (132.33 days) for attaining fruit maturity. T_{12} receiving 150 % RD of N and K through fertigation with water spray (131.00 days) was on par.

4.1.2.13 ***Days taken for ripening***

Days taken for ripening of papaya fruits as influenced by different levels of fertigation and foliar sprays are presented in table 14, which exhibited significant differences among treatments. Number of days taken by fruits to reach fully ripe stage while on tree from attaining harvest maturity is counted as days taken for ripening. T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) reported maximum days for fruits ripening (10.44 days) which differed significantly from other treatments. It was followed by treatments T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax), T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with 9.89 days, 9.67 days and 9.55 days respectively which was on par. Among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3), T_2 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) recorded maximum days to ripening of fruits (7.89 days), which was same in T_{14} (control 2). Application of KAU POP (control 1 - T_{13}) registered 7.55 days for fruit ripening. Minimum days for ripening (6.11 days) was recorded in T_3 (75 % RD of N and K through fertigation with water spray) which differed significantly from other treatments.

4.1.3 Fruit quality parameters

Effect of different levels of fertigation and foliar sprays on quality parameters of papaya fruits were recorded and statistically analysed data is furnished below.

4.1.3.1 *Total soluble solids (°Brix)*

Table 15 depicts the data on Total Soluble Solids (TSS) of fruits influenced by different levels of fertigation and different foliar sprays. There was significant difference in TSS among the treatments under study. Highest TSS of 15.10°Brix was noticed in fruits from T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax), which was on par with T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with a TSS of 14.90°Brix for fruits which differed significantly from other treatments. It was followed by T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with a TSS of 14.73°Brix and 14.43°Brix respectively for fruits. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) produced fruits with highest TSS of 14.32°Brix. Control 2 (T_{14}) registered 13.61°Brix for fruits, was found to be on par with plants receiving KAU POP (control 1 - T_{13}) which produced fruits with 13.40°Brix. T_2 which received 75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax recorded highest TSS of 13.36°Brix in fruits, among T_1, T_2 and T_3 which received 75 % RD of N and K through fertigation in common. T_3 (75 % RD of N and K through fertigation with water spray) registered lowest TSS (12.50°Brix), which differed significantly from other treatments.

Table 14. Effect of fertigation and foliar sprays on yield per plant, yield ha^{-1} and days taken for maturity and ripening of papaya

Treatments	Yield per plant (kg)	Yield (t ha^{-1})	Days taken for maturity	Days taken for ripening
T_1	29.06	72.66	124.89	7.33
T_2	28.21	70.53	125.22	7.89
T_3	16.21	40.52	132.33	6.11
T_4	38.30	95.76	119.44	9.67
T_5	37.60	93.99	120.22	10.44
T_6	23.62	59.05	125.89	8.00
T_7	33.16	82.89	122.33	8.67
T_8	33.96	84.89	120.33	9.89
T_9	24.76	61.90	123.89	8.55
T_{10}	21.33	53.32	127.11	7.11
T_{11}	31.14	77.84	123.00	9.55
T_{12}	17.78	44.45	131.00	6.89
T_{13}	21.03	52.58	129.11	7.55
T_{14}	30.27	75.67	124.67	7.89
SE (±)	0.32	0.80	1.11	0.18
CD (5%)	0.93	2.32	3.24	0.54

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data
T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

4.1.3.2 ***Acidity (%)***

Titrable acidity of papaya fruits was influenced significantly by the application of different levels of fertigation and different foliar sprays (Table 15). T_5 registered lowest titratable acidity (0.13 %), which differed significantly from other treatments. It was followed by T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with a titratable acidity of 0.15% for fruits, which was on par with T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 0.16 % titratable acidity each. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) produced fruits with lowest titratable acidity (0.17 %). It was on par with treatments T_6 (100 % RD of N and K through fertigation with water spray), T_9 (125 % RD of N and K through fertigation with water spray) and T_{14} (control 2) with titratable acidity of 0.17 %, 0.17 % and 0.18 % respectively for fruits. Application of KAU POP (control 1 - T_{13}) to plants produced fruits with a titratable acidity of 0.22 %, was on par with T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax with 0.23 % titratable acidity. T_3 (75 % RD of N and K through fertigation with water spray) registered highest titratable acidity (0.28 %) which was on par with T_{12} (150 % RD of N and K through fertigation with water spray) with 0.27 % titratable acidity for fruits and it differed significantly from other treatments.

4.1.3.3 ***Total carotenoids (mg100g^{-1})***

Data on total carotenoid content of papaya fruits differed significantly among the treatments under study (Table 15). Application of 100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (T_5) resulted in highest total carotenoids (2.21 mg 100g^{-1}) in fruits which differed significantly among other treatments. It was followed by T_8 which was found to be on par with T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 2.09 mg $100g^{-1}$ and 2.08 mg $100g^{-1}$ carotenoids respectively. T_{11} which received 150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax produced highest carotenoid content of 1.98 mg $100g^{-1}$, among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}). It was on par with T_9 (125 % RD of N and K through fertigation with water spray) with 1.96 mg $100g^{-1}$ carotenoids in fruits. Carotenoid content of 1.91 mg $100g^{-1}$ in fruits was reported in T_{14} (control 2), whereas application of KAU POP (control 1 - T_{13}) resulted in fruits with 1.86 mg $100g^{-1}$ carotenoid content. Among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3), T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) recorded highest carotenoid content of 1.81 mg $100g^{-1}$. It was followed by T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 1.64 mg $100g^{-1}$ carotenoid content. T_3 (75 % RD of N and K through fertigation with water spray) recorded lowest carotenoid content of 1.46 mg $100g^{-1}$. It was on par with T_{12} (150 % RD of N and K through fertigation with water spray) with 1.49 mg $100g^{-1}$ carotenoid content for fruits and differed significantly from other treatments.

4.1.3.4 *Ascorbic acid (mg $100g^{-1}$)*

It was clear from the table 15 that ascorbic acid content of papaya fruits differed significantly among treatments under study. T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) registered highest ascorbic acid content of 68.38 mg $100g^{-1}$. It was on par with T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with 67.69 mg $100g^{-1}$ ascorbic acid in fruits which differed significantly from other treatments. T_{11} recorded highest ascorbic acid content of 63.93 mg $100g^{-1}$ among treatments receiving 150 % RD of N and K through fertigation. Control 2 (T_{14}) registered 62.22 mg $100g^{-1}$ ascorbic acid, whereas plants receiving KAU POP (control 1 - T_{13}) recorded an ascorbic acid content of 58.12 mg $100g^{-1}$. It was on par with T_2 receiving 75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax with an ascorbic acid content of 57.78 mg $100g^{-1}$. T_3 (75 % RD of N and K through fertigation with water spray) recorded lowest ascorbic acid content (43.42 mg $100g^{-1}$) in fruits which differed significantly from other treatments.

4.1.3.5 *Total sugar (%)*

Table 16 showed total sugar content of papaya fruit as influenced by application of different levels of fertigation and different foliar sprays. T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) recorded highest total sugar content of 9.66 % which differed significantly from other treatments. It was followed by treatments T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax), T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 9.45 %, 9.30 % and 9.15 % total sugar respectively which differed significantly among each other and among other treatments. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} which received 150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax recorded highest total sugar content of 9.00 % in fruits. It was on par with T_9 (125 % RD of N and K through fertigation with water spray) which recorded 8.92 % total sugar content. Control 2 (T_{14}) registered 8.36 % total sugar, whereas plants receiving KAU POP (control 1 - T_{13}) recorded a total sugar content of 8.15 %. T_2 recorded highest total sugar content of 7.80 % in fruits, among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3). Lowest total sugar content of 7.15 % was registered in T_3 receiving 75 % RD of N and K through fertigation with water spray which differed significantly from other treatments.

4.1.3.6 *Reducing sugar (%)*

Table 16 shows data on reducing sugar content of papaya fruits and they differed significantly among the treatments under study. Highest reducing sugar content of 8.05 % was recorded in plants receiving 100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (T_5). It was on par with T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) having 7.98 % reducing sugar content in fruits which differed significantly from other treatments. It was followed by treatments T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with reducing sugar content of 7.84 % each. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} which received 150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax recorded highest reducing sugar content of 7.79 % in fruits. Reducing sugar content of 6.80 % in fruits was reported in T_{14} (control 2), whereas application of KAU POP (control 1 - T_{13}) resulted in fruits with 6.72 % reducing sugar content. Among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3), T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) recorded highest reducing sugar content of 6.22 %. T_3 (75 % RD of N and K through fertigation with water spray) registered lowest reducing sugar content of 5.97 % in fruits which differed significantly from other treatments.

4.1.3.7 *Non reducing sugar (%)*

Non reducing sugar content of papaya fruits was significantly influenced by the application of different levels of fertigation and different foliar sprays (Table 16). Plants receiving 100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (T_5) registered highest non reducing sugar content (1.61 %). It was on par with treatments T_2 (75 % RD of N and K through fertigation and foliar

Table 15. Effect of fertigation and foliar sprays on total soluble solids, acidity, total carotenoids and ascorbic acid content of papaya fruits

Treatments	Total soluble solids (°Brix)	Acidity (%)	Total carotenoids ($mg 100g^{-1}$)	Ascorbic acid ($mg\ 100g^{-1}$)
T_1	13.15	0.26	1.64	54.36
T_2	13.36	0.23	1.81	57.78
T_3	12.50	0.28	1.46	43.42
T_4	14.73	0.16	2.08	65.30
T_5	15.10	0.13	2.21	68.38
T_6	14.01	0.17	1.92	62.91
T_7	14.43	0.16	2.02	64.96
T_8	14.90	0.15	2.09	67.69
T_9	14.11	0.17	1.96	63.59
T_{10}	13.10	0.26	1.56	51.28
T_{11}	14.32	0.17	1.98	63.93
T_{12}	12.89	0.27	1.49	49.23
T_{13}	13.40	0.22	1.86	58.12
T_{14}	13.61	0.18	1.91	62.22
SE (±)	0.07	--	8.50	1.64
CD (5%)	0.22	0.01	24.71	4.77

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

sprays of 0.5% $ZnSO_4$ and 0.3% borax) and T_{14} (control 2) which recorded non reducing sugar content of 1.58 % and 1.56 % respectively which differed significantly from other treatments. It was followed by treatments T_6 (100 % RD of N and K through fertigation with water spray), T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax), T_9 (125 % RD of N and K through fertigation with water spray) and T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 1.51 %, 1.47 %, 1.47 % and 1.46 % non reducing sugar respectively which was on par with each other. Application of KAU POP (control 1 - T_{13}) recorded 1.43 % non reducing sugar content in fruits. Lowest non reducing sugar content of 1.12 % was noticed in fruits obtained from plants receiving 150 % RD of N and K through fertigation with water spray (T_{12}), which was on par with T_3 (75 % RD of N and K through fertigation with water spray) with 1.18 % non reducing sugar content which differed significantly from other treatments.

4.1.3.8 *Shelf life (days)*

Application of different levels of fertigation and different foliar sprays have significant effect on shelf life of papaya fruits (Table 16). T_5 registered longest shelf life of 5.78 days, which was on par with T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) (5.22 days) which differed significantly from other treatments. It was followed by T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) with 5.11 days shelf life. Among treatments receiving 150 % RD of N and K through fertigation (T_{10}, T_{11} and T_{12}), T_{11} which received 150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax recorded highest shelf life of 5.00 days. Control 2 (T_{14}) registered 4.45 days shelf life, whereas plants receiving KAU POP, (control 1 - T_{13}) and T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) recorded a shelf life of 4.44 days each. T_3 (75 % RD of

N and K through fertigation with water spray) registered shortest shelf life of 3.78 days which differed significantly from other treatments.

4.1.3.9 *Sugar/ acid ratio*

Sugar/ acid ratio of papaya fruits ranged from 25.54 to 74.31 and exhibited significant difference among treatments (Table 16). Highest sugar/ acid ratio was reported in T_5, which was followed by T_8 (63.00). T_{14} registered a sugar/ acid ratio of 46.44 whereas, it was 37.05 in T_{13}. Least sugar/ acid ratio of 25.54 was noticed in T_3.

4.1.3.10 *Organoleptic evaluation (nine point hedonic scale)*

Papaya fruits obtained from plants of 14 treatments after application of different levels of fertigation and different foliar sprays were organoleptically evaluated by a panel of 15 semi trained judges. The mean rank scores of appearance, colour, flavour, texture, taste, after taste and overall acceptability of fruits are given in the table 17. The mean rank scores for appearance (8.20), colour (8.07), flavour (7.87), texture (8.00), odour (8.07), taste (8.27), after taste (8.07) and overall acceptability (8.00) were highest for fruits obtained from T_5 receiving 100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax. Highest total score (64.55) was also noticed in fruits from T_5 which differed significantly from other treatments. Fruits obtained from T_4, T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) and T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) recorded next highest total scores of 62.92, 62.86 and 61.46 respectively. Least total score of 53.93 was recorded in fruits obtained fromT_3 (75 % RD of N and K through fertigation with water spray) which differed significantly from other treatments.

4.1.4 Index leaf analysis for primary, secondary and Micronutrients (B and Zn)

The statistical report on plant analysis done at 6 MAP indicated highest percentage of nitrogen (2.29 %) in treatment T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) which differed significantly from other treatments (Table 18). It was followed by T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) and T_{12} (150 % RD of N and K through fertigation with water spray) with nitrogen content of 2.20 % and 1.99 % respectively, which differed significantly among each other and among other treatments. Among treatments receiving 125 % RD of N and K through fertigation and different foliar sprays (T_7, T_8 and T_9), highest nitrogen content (1.87 %) was observed in T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19), which was found to be on par with T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with 1.84 % nitrogen content. Among treatments receiving 100 % RD of N and K through fertigation and different foliar sprays (T_4, T_5 and T_6), T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) registered highest nitrogen content (1.75 %), which was found to be on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) (1.71 %). Control 2 (T_{14}) recorded 1.51 % nitrogen content. Among treatments receiving 75 % RD of N and K through fertigation and different foliar sprays (T_1, T_2 and T_3), highest nitrogen content (1.41 %) was observed in T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19). Nitrogen content of 1.28 % was reported in leaf petiole of plants receiving KAU POP (control 1 - T_{13}). Lowest nitrogen content of 1.18 % was noticed in T_3 (75 % RD of N and K through fertigation with water spray) which differed significantly from other treatments.

Application of different levels of fertigation and different foliar sprays did not register any significant difference in phosphorus content of leaf petiole (Table 18).

Plant petiole analysis revealed highest potassium content (2.99 %) in T_{10} which differed significantly from other treatments (Table 18). It was followed by T_{12} and T_{11} with potassium content of 2.94 % and 2.89 % respectively, which differed significantly among each other and among other treatments. Among treatments

Table 16. Effect of fertigation and foliar sprays on total sugar, reducing sugar, non reducing sugar, shelf life and sugar/ acid ratio of papaya fruits

Treatments	Total sugar (%)	Reducing sugar (%)	Non reducing sugar (%)	Shelf life (days)	Sugar/ acid ratio
T_1	7.46	6.13	1.32	4.22	28.69
T_2	7.80	6.22	1.58	4.44	33.91
T_3	7.15	5.97	1.18	3.78	25.54
T_4	9.30	7.84	1.46	5.11	58.12
T_5	9.66	8.05	1.61	5.78	74.31
T_6	8.73	7.21	1.51	4.56	51.35
T_7	9.15	7.84	1.30	4.78	57.19
T_8	9.45	7.98	1.47	5.22	63.00
T_9	8.92	7.45	1.47	4.56	52.47
T_{10}	7.45	6.05	1.40	4.22	28.65
T_{11}	9.00	7.79	1.21	5.00	52.94
T_{12}	7.16	6.03	1.12	4.00	26.52
T_{13}	8.15	6.72	1.43	4.44	37.05
T_{14}	8.36	6.80	1.56	4.45	46.44
SE (±)	0.03	0.07	0.08	0.20	1.35
CD (5%)	0.10	0.19	0.23	0.60	3.93

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

Table 17. Effect of fertigation and foliar sprays on organoleptic qualities of papaya fruits

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
T_1	6.87 (69.60)	6.87 (66.90)	6.87 (75.40)	7.00 (82.07)	6.87 (85.50)	6.80 (61.34)	6.33 (68.73)	6.93 (75.97)	54.54
T_2	7.20 (89.83)	7.33 (89.57)	6.93 (83.20)	6.93 (82.63)	6.73 (84.47)	6.80 (71.40)	6.80 (76.50)	7.00 (80.27)	55.72
T_3	7.00 (75.13)	6.93 (62.47)	6.67 (72.90)	6.73 (77.80)	6.80 (84.83)	6.53 (69.57)	6.47 (58.33)	6.80 (65.93)	53.93
T_4	8.13 (139.50)	7.93 (136.33)	7.80 (132.60)	7.73 (122.20)	7.53 (127.73)	8.00 (135.73)	7.93 (145.30)	7.87 (138.07)	62.92
T_5	8.20 (152.33)	8.07 (143.27)	7.87 (141.80)	8.00 (142.60)	8.07 (161.43)	8.27 (152.23)	8.07 (153.97)	8.00 (144.97)	64.55
T_6	7.4 (109.13)	7.53 (108.43)	7.27 (101.10)	7.47 (106.80)	6.93 (101.20)	7.67 (115.37)	7.47 (115.40)	7.40 (103.10)	59.14
T_7	7.67 (116.10)	7.60 (110.13)	7.60 (121.90)	7.93 (135.70)	7.13 (104.77)	8.00 (135.40)	7.73 (131.80)	7.80 (135.47)	61.46
T_8	7.73 (122.30)	7.80 (126.63)	7.80 (136.80)	7.87 (134.00)	7.53 (130.07)	8.20 (146.90)	8.00 (149.13)	7.93 (143.37)	62.86

T_9	7.8 (125.93)	7.73 (123.37)	7.67 (130.00)	7.27 (94.90)	7.27 (114.20)	7.73 (118.90)	7.40 (107.41)	7.67 (126.43)	60.54
T_{10}	7.13 (93.90)	7.47 (100.83)	6.87 (83.70)	7.33 (97.80)	6.87 (90.20)	7.20 (89.70)	7.07 (94.33)	7.13 (87.73)	57.07
T_{11}	7.33 (97.40)	7.47 (102.80)	7.13 (94.30)	7.53 (112.10)	7.13 (104.47)	7.20 (91.83)	7.20 (99.03)	6.93 (88.70)	57.92
T_{12}	7.07 (85.97)	7.33 (91.53)	7.00 (90.30)	7.20 (91.60)	6.73 (84.47)	6.87 (75.50)	6.73 (77.20)	7.07 (88.27)	56.00
T_{13}	7.47 (104.17)	7.40 (100.93)	7.27 (101.10)	7.27 (93.30)	7.07 (98.67)	7.47 (102.07)	7.20 (98.07)	7.27 (94.07)	58.42
T_{14}	7.60 (107.44)	7.67 (113.80)	7.47 (111.90)	7.40 (103.50)	7.07 (105.00)	7.73 (121.03)	7.33 (108.70)	7.40 (104.67)	59.67
K W value	32.31	33.20	32.87	26.12	27.99	52.47	53.43	43.46	
χ^2 – 22.36 (13, 0.05)									

receiving 125 % RD of N and K through fertigation and different foliar sprays (T_7, T_8 and T_9), highest potassium content (2.83 %) was observed in treatments T_7 and T_8. Among treatments receiving 100 % RD of N and K through fertigation and different foliar sprays (T_4, T_5 and T_6), T_4 registered highest potassium content (2.66 %), which was followed by T_5 (2.62 %). Control 2 (T_{14}) recorded 2.50 % potassium content. Among treatments receiving 75 % RD of N and K through fertigation and different foliar sprays (T_1, T_2 and T_3), highest potassium content (2.40 %) was observed in T_1. Plants receiving KAU POP, (control 1 - T_{13}) registered potassium content of 2.09 % in leaf petiole. Lowest potassium content of 1.98 % was noticed in T_3 which differed significantly from other treatments.

Data on calcium content of papaya petiole influenced by different levels of fertigation and foliar nutrition are recorded in table 19. There was significant difference among the treatments under study. Highest calcium content of 0.57 % was registered in T_5 which differed significantly from other treatments. It was followed by T_8, T_4, T_7 and T_{11} with a calcium content of 0.55 %, 0.50 %, 0.48 % and 0.45 % respectively which differed among each other and among other treatments. Control 2 (T_{14}) recorded 0.42 % calcium content. Among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3), T_2 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) registered highest calcium content of 0.38 %, which was on par with T_1 with 0.37 % calcium content. Among treatments T_3, T_6 (100 % RD of N and K through fertigation with water spray), T_9 (125 % RD of N and K through fertigation with water spray) and T_{12} which received different levels of fertigation with water spray, T_9 recorded highest calcium content (0.33 %) in leaf petiole, which was followed by T_6 (100 % RD of N and K through fertigation with water spray) (0.30 %). Application of KAU POP (control 1 - T_{13}) recorded calcium content of 0.26 % in leaf petiole. Lowest calcium content of 0.16 % was noticed in T_3 which differed significantly from other treatments.

Data pertaining to magnesium content of leaf petiole influenced by different levels of fertigation and different foliar sprays are presented in table 19. Significant difference was noticed among the treatments under study. Highest magnesium content (0.29 %) was noticed in T_5 which differed significantly from other treatments. It was followed by T_8, T_4, T_7 and T_{11} with a magnesium content of 0.24 %, 0.22 %, 0.20 % and 0.18 % respectively which differed among each other and among other treatments. Among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3), T_2 recorded highest magnesium content of 0.17 %, which was same in T_{14} (control 2). It was found to be on par with T_1 with 0.16 % magnesium content. Among treatments receiving different levels of fertigation with water spray (T_3, T_6, T_9 and T_{12}), T_9 registered highest magnesium content (0.14 %). Application of KAU POP (control 1 - T_{13}) recorded magnesium content of 0.11 % in leaf petiole. T_3 recorded lowest magnesium content of 0.08 % which differed significantly from other treatments.

Table 19 depicts the influence of different levels of fertigation and foliar sprays on sulphur content of papaya petiole. T_5 registered highest sulphur content of 0.33 % which differed significantly from other treatments. It was followed by T_8, T_4, T_7 and T_{11} with a sulphur content of 0.29 %, 0.28 %, 0.25 % and 0.23 % respectively which differed among each other and among other treatments. Among treatments receiving 75 % RD of N and K through fertigation (T_1, T_2 and T_3), T_2 recorded highest sulphur content of 0.21 % which was same in T_{14} (control 2) also. It was found to be on par with T_1. Among treatments receiving different levels of fertigation with water spray (T_3, T_6, T_9 and T_{12}), T_9 registered highest sulphur content of 0.18 %. Application of KAU POP (control 1 - T_{13}) recorded 0.14 % sulphur content in leaf petiole, which was the same in T_{12} also. Lowest sulphur content of 0.12 % was noticed in T_3 which differed significantly from other treatments.

Data on micronutrient, zinc content of papaya petiole influenced by different levels of fertigation and foliar nutrition are recorded in table 20. There was significant

Table 18. Effect of fertigation and foliar sprays on primary nutrients (NPK) content of index leaf

Treatments	Nitrogen (%)	Phosphorus (%)	Potassium (%)
T_1	1.41	0.41	2.40
T_2	1.29	0.41	2.13
T_3	1.18	0.40	1.98
T_4	1.75	0.41	2.66
T_5	1.71	0.40	2.62
T_6	1.42	0.40	2.45
T_7	1.87	0.41	2.83
T_8	1.84	0.41	2.83
T_9	1.76	0.41	2.69
T_{10}	2.29	0.41	2.99
T_{11}	2.20	0.41	2.89
T_{12}	1.99	0.40	2.94
T_{13}	1.28	0.41	2.09
T_{14}	1.51	0.41	2.50
SE (±)	0.02	0.00	0.01
CD (5%)	0.06	NS	0.03

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

difference among the treatments under study. Highest zinc content of 32.00 ppm was noticed in treatment T_8 which differed significantly from other treatments. It was followed by T_5, T_{11} and T_2 with zinc content of 31.01 ppm, 27.88 ppm and 27.36 ppm respectively in leaf petiole, which differed significantly among each other and among other treatments. Among treatments receiving different dose of fertigation and foliar sprays of 1.0% 19:19:19 (T_1, T_4, T_7 and T_{10}), T_7 recorded highest zinc content of 25.75 ppm. It was followed by T_4 with zinc content of 23.01 ppm in leaf petiole. T_{14} (control 2) registered 22.39 ppm zinc content. It was found to be on par with T_1 with 22.14 ppm zinc content. Among treatments receiving different dose of fertigation with water spray (T_3, T_6, T_9 and T_{12}), T_9 registered highest zinc content of 20.08 ppm, which was followed by T_6 (18.27 ppm). Application of KAU POP (control 1 - T_{13}) recorded 17.40 ppm zinc content in leaf petiole. T_3 recorded lowest zinc content of 14.97 ppm in leaf petiole which differed significantly from other treatments.

Table 20 depicts the influence of different levels of fertigation and different foliar sprays on boron content of papaya leaf petiole. T_8 recorded highest boron content of 38.93 ppm which differed significantly from other treatments. It was followed by T_5, T_{11} and T_2 with boron content of 37.93 ppm, 34.80 ppm and 33.28 ppm respectively in leaf petiole, which differed significantly among each other and among other treatments. Among treatments receiving foliar sprays of 1.0% 19:19:19 with different dose of fertigation (T_1, T_4, T_7 and T_{10}), T_7 registered highest boron content of 28.01 ppm, which was followed by T_4 with boron content of 27.10 ppm in leaf petiole. T_{14} (control 2) recorded 26.15 ppm boron content. Among treatments receiving different dose of fertigation with water spray (T_3, T_6, T_9 and T_{12}), T_9 registered highest boron content of 25.10 ppm. Application of KAU POP (control 1 - T_{13}) recorded 19.87 ppm boron content in leaf petiole. T_3 recorded lowest boron content of 17.92 ppm in leaf petiole which differed significantly from other treatments.

Table 19. Effect of fertigation and foliar sprays on secondary nutrient (Ca, Mg, S) content of index leaf

Treatments	Calcium (%)	Magnesium (%)	Sulphur (%)
T_1	0.37	0.16	0.20
T_2	0.38	0.17	0.21
T_3	0.16	0.08	0.12
T_4	0.50	0.22	0.28
T_5	0.57	0.29	0.33
T_6	0.30	0.12	0.17
T_7	0.48	0.20	0.25
T_8	0.55	0.24	0.29
T_9	0.33	0.14	0.18
T_{10}	0.28	0.12	0.17
T_{11}	0.45	0.18	0.23
T_{12}	0.21	0.10	0.14
T_{13}	0.26	0.11	0.14
T_{14}	0.42	0.17	0.21
SE (±)	0.00	0.00	0.00
CD (5%)	0.02	0.01	0.01

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

4.1.5 Pest and diseases incidence (%)

Though the incidence of foot rot disease was noticed in the initial stage of seedling establishment, there was no significant variation among treatments. Hence a uniform score of one was given as depicted in the score chart presented in Appendix III.

4.1.6 Nutrient (N, P, K) concentration studies of fruits at peak harvest stage

Fruit nitrogen content estimated at peak harvest stage (16 MAP) revealed significant difference among treatments due to application of different levels of fertigation and different foliar sprays (Table 21). Highest fruit nitrogen content (1.89 %) was noticed in T_{12} (150 % RD of N and K through fertigation with water spray) which differed significantly from other treatments. It was followed by T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19) and T_9 (125 % RD of N and K through fertigation with water spray) with 1.81 % and 1.76 % fruit nitrogen content respectively which differed significantly among each other and among other treatments. Application of KAU POP (control 1 - T_{13}) registered fruit nitrogen content of 1.58 % whereas, T_{14} (control 2) recorded 1.54 % nitrogen content in fruits. Among treatments receiving 100 % RD of N and K through fertigation (T_4, T_5 and T_6), T_6 (100 % RD of N and K through fertigation with water spray) registered highest fruit nitrogen content of 1.44 %. It was on par with T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) with fruit nitrogen content of 1.42 %. Lowest fruit nitrogen content of 1.19 % was reported in T_3 receiving 75 % RD of N and K through fertigation with water spray which differed significantly from other treatments.

Phosphorus content of fruits estimated at peak harvest stage (16 MAP) revealed no significant variation among treatments (Table 21).

Table 20. Effect of fertigation and foliar sprays on zinc and boron content of index leaf

Treatments	Zinc (ppm)	Boron (ppm)
T_1	22.14	25.28
T_2	27.36	33.28
T_3	14.97	17.92
T_4	23.01	27.10
T_5	31.01	37.93
T_6	18.27	22.11
T_7	25.75	28.01
T_8	32.00	38.93
T_9	20.08	25.10
T_{10}	17.60	20.92
T_{11}	27.88	34.80
T_{12}	16.77	19.10
T_{13}	17.40	19.87
T_{14}	22.39	26.15
SE (±)	0.17	0.21
CD (5%)	0.49	0.61

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data
T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

Potassium content of fruits estimated at peak harvest stage (16 MAP) showed significant difference among treatments on application of different levels of fertigation and different foliar sprays (Table 21). T_{12} registered highest fruit potassium content (2.45 %) which differed significantly from other treatments. It was followed by T_{10} and T_9 with 2.33 % and 2.10 % fruit potassium respectively which differed significantly among each other and among other treatments. Application of KAU POP (control 1 - T_{13}) registered fruit potassium content of 2.01 % whereas, T_{14} (control 2) recorded 1.95 % potassium content in fruits. Among treatments receiving 100 % RD of N and K through fertigation (T_4, T_5 and T_6), T_6 registered highest fruit potassium content of 1.74 %. T_3 recorded minimum potassium content in fruits (1.33 %) which differed significantly from other treatments.

4.1.7 Soil analysis (available N, P, K) after the experiment

The statistical analysis of soil nitrogen content estimated after the experiment revealed significant variation among treatments (Table 22). Highest soil nitrogen content of 243.13 kg ha^{-1} was observed in field receiving 150 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (T_{11}), which was found to be on par with T_{12} (150 % RD of N and K through fertigation with water spray) with a soil nitrogen content of 242.90 kg ha^{-1} which differed significantly from other treatments. It was followed by T_{10} (241.30 kg ha^{-1}). Among treatments receiving 125 % RD of N and K through fertigation and different foliar sprays (T_7, T_8 and T_9), highest soil nitrogen content (222.61 kg ha^{-1}) was observed in treatments T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19). It was followed by treatments T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) and T_9 with 219.91 kg ha^{-1} and 219.82 kg ha^{-1} soil nitrogen respectively which were on par. Among treatments receiving 100 % RD of N and K through fertigation and different foliar sprays (T_4, T_5 and T_6), highest soil nitrogen content (206.80 kg ha^{-1}) was observed in treatment T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19), which was found to be on par with T_6 (100 % RD of N and K through fertigation with water spray) with soil nitrogen content of 206.64 kg ha^{-1}. Among treatments receiving 75 % RD of N and K through fertigation and different foliar sprays (T_1, T_2 and T_3), highest soil nitrogen content (192.75 kg ha^{-1}) was observed in treatment T_1 (75 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19). T_{14} (control 2) recorded 191.31 kg ha^{-1} soil nitrogen content, which was on par with T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) (190.65 kg ha^{-1}). Lowest soil nitrogen content of 179.32 kg ha^{-1} was observed in T_{13} (KAU POP - control 1) which differed significantly from other treatments.

Application of different levels of fertigation and different foliar sprays did not register any significant difference in soil phosphorus content and ranged from 42.40 to 43.04 kg ha^{-1} (Table 22).

Application of different levels of fertigation and different foliar sprays had significant effect on soil potassium content (Table 22). Highest soil potassium content (326.89 kg ha^{-1}) was noticed in T_{10}, which was on par with T_{12} (326.66 kg ha^{-1}) which differed significantly from other treatments. It was followed by T_{11} (325.71 kg ha^{-1}). Among treatments receiving 125 % RD of N and K through fertigation and different foliar sprays (T_7, T_8 and T_9), highest soil potassium content (315.11 kg ha^{-1}) was observed in treatments T_8. It was followed by T_7 and T_9 (125 % RD of N and K through fertigation with water spray) with 313.68 kg ha^{-1} and 312.72 kg ha^{-1} soil potassium content respectively, which differed significantly among each other and among other treatments. Among treatments receiving 100 % RD of N and K through fertigation and different foliar sprays (T_4, T_5 and T_6), highest soil potassium content (288.54 kg ha^{-1}) was observed in treatment T_6, which was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax (288.28 kg ha^{-1}). T_{14} (control 2) registered soil potassium content of 274.12 kg ha^{-1}. Among treatments receiving 75 % RD of N and K through fertigation and different foliar sprays (T_1, T_2 and T_3), highest soil potassium content (271.34 kg ha^{-1}) was

Table 21. Effect of fertigation and foliar sprays on nutrient (N, P, K) content of fruits at peak harvest stage

Treatments	Fruit N (%)	Fruit P (%)	Fruit K (%)
T_1	1.22	0.25	1.37
T_2	1.28	0.25	1.39
T_3	1.19	0.25	1.33
T_4	1.36	0.25	1.65
T_5	1.30	0.26	1.45
T_6	1.44	0.25	1.74
T_7	1.49	0.25	1.87
T_8	1.33	0.25	1.50
T_9	1.76	0.26	2.10
T_{10}	1.81	0.25	2.33
T_{11}	1.42	0.25	1.70
T_{12}	1.89	0.25	2.45
T_{13}	1.58	0.25	2.01
T_{14}	1.54	0.25	1.95
SE (±)	0.00	0.00	0.00
CD (5%)	0.01	NS	0.01

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data
T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

observed in treatment T_2, which was on par with T_3 (75 % RD of N and K through fertigation with water spray (270.65 kg ha^{-1}). Application of KAU POP (control 1 - T_{13}) registered lowest soil potassium content of 263.51 kg ha^{-1} which differed significantly from other treatments.

4.1.8 Economic analysis

Data on economic analysis presented in Table 23 revealed significant difference in gross income, net income and B : C ratio among treatments receiving different levels of fertigation and different foliar sprays.

Application of 100 % RD of N and K through fertigation and foliar sprays of 1.0% 19:19:19 (T_4) recorded significantly higher net income of 11,73,356.83 ha^{-1}. It was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5% $ZnSO_4$ and 0.3% borax) (11,40,623.49 ha^{-1}) which differed significantly from other treatments. Plants receiving 75 % RD of N and K through fertigation with water spray (T_3) recorded significantly lowest net income of 81,118.54 ha^{-1} which differed significantly from other treatments.

Significantly higher B : C ratio of 2.58 was registered by T_4, which was on par with T_5 with a B : C ratio of 2.54 which differed significantly from other treatments. However, T_3 recorded lowest B : C ratio of 1.11 which differed significantly from other treatments.

4.2 POSTHARVEST MANAGEMENT PRACTICES FOR EXTENSION OF SHELF LIFE IN PAPAYA

Papaya, as a living entity is a highly perishable commodity that is affected by number of factors leading to postharvest losses which is a major concern. This underlines the necessity to develop new and effective methods of controlling postharvest losses that are perceived as safe by the public and pose negligible risk to

Table 22. Effect of fertigation and foliar sprays on available N, P, K content of soil after the experiment

Treatments	Soil nitrogen ($Kg\ ha^{-1}$)	Soil phosphorus ($Kg\ ha^{-1}$)	Soil potassium ($Kg\ ha^{-1}$)
T_1	192.75	42.49	268.84
T_2	190.65	42.98	271.34
T_3	189.83	42.94	270.65
T_4	206.80	43.00	287.07
T_5	204.23	42.62	288.28
T_6	206.64	42.65	288.54
T_7	222.61	42.59	313.68
T_8	219.91	42.55	315.11
T_9	219.82	42.81	312.72
T_{10}	241.30	42.68	326.89
T_{11}	243.13	43.04	325.71
T_{12}	242.90	42.51	326.66
T_{13}	179.32	42.40	263.51
T_{14}	191.31	42.71	274.12
SE (±)	0.28	0.00	0.26
CD (5%)	0.80	NS	0.77

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

human health and environment. Hence, postharvest management practices for extension of shelf life in papaya were resorted in this study.

Papaya variety Surya was raised according to KAU POP and fruits were collected at fully mature green stage, different postharvest management practices were given and packaged in CFB boxes and stored under ambient conditions till the end of shelf life.

4.2.1 Physical quality (Sensory analysis)

Effect of different postharvest treatments on sensory parameters of papaya variety Surya is shown in table 24, 25 and 26. Papaya fruits harvested at fully mature green stage, subjected to different postharvest treatments and packaged in CFB boxes and stored under ambient conditions showed significant difference in sensory parameters at 3 DAS (Table 24). The mean scores of appearance (8.47), colour (7.60), flavour (7.47), texture (7.93), odour (8.07), taste (8.20), after taste (7.93) and overall acceptability (7.93) were highest for control (S_9) with a total score of 63.60. Fruits subjected to surface sanitization with sodium hypochlorite (150 ppm) (S_2) registered a total score of 56.34 at 3 DAS, whereas for precooling (Hydro cooling) (S_1) of fruits a total score of 52.99 was noticed. Minimum total score of 45.47 was observed for postharvest treatments S_3 (external coating with chitosan (1%)), S_4 (precooling followed by external coating with 1% chitosan), S_5 (packaging with ethylene scrubber $KMnO_4$), S_6 (precooling followed by packaging with ethylene scrubber $KMnO_4$), S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) and S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) at 3 DAS.

After six days of storage, significant difference was noticed in sensory qualities of papaya fruits subjected to different postharvest treatments. Highest mean score for appearance (8.67), colour (8.40), flavour (8.33), texture (8.53), odour (8.33),

Table 23. Effect of fertigation and foliar sprays on economics of papaya cultivation

Treatments	**Gross income (ha^{-1})**	**Net income (ha^{-1})**	**B : C ratio**
T_1	1453166.67	716085.21	1.97
T_2	1410666.67	676185.21	1.92
T_3	810500.00	81118.54	1.11
T_4	1915166.67	1173356.83	2.58
T_5	1879833.33	1140623.49	2.54
T_6	1181000.00	446890.16	1.61
T_7	1657833.33	886904.03	2.27
T_8	1697833.33	929504.03	2.21
T_9	1238000.00	474770.70	1.62
T_{10}	1066500.00	278646.91	1.35
T_{11}	1556833.33	771580.24	1.98
T_{12}	889166.67	109013.58	1.14
T_{13}	1051666.67	383126.17	1.58
T_{14}	1513500.00	694128.85	1.85
SE (±)	15989.37	15989.37	0.41
CD (5%)	46491.07	46491.07	0.11

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

taste (8.53), after taste (8.47) and overall acceptability (8.87) was observed in fruits externally coated with chitosan (1%) (S_3), with a total score of 68.13 after six days of storage. It was followed by S_5 (packaging with ethylene scrubber $KMnO_4$) with a total score of 68.00, whereas fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) and hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber, $KMnO_4$ (S_8) recorded lowest total score of 57.59 after six days of storage.

Fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) and hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$ (S_8) recorded highest total score of 69.19 after nine days of storage. Their mean score for appearance, colour, flavour, texture, odour, taste, after taste and overall acceptability were 8.53, 9.00, 8.60, 8.33, 8.60, 8.73, 8.73 and 8.67 respectively.

4.2.2 Physiological quality

4.2.2.1 *Shelf life (days)*

The effect of different postharvest treatments on shelf life of papaya variety Surya fruits packaged in CFB boxes and stored under ambient conditions is shown in table 27. Significantly higher shelf life of 9.67 days was observed in fruits treated with precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7), which was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) with a shelf life of 9.00 days (Plate 8). It was followed by S_4 (precooling followed by external coating with 1% chitosan) with 7.67 days shelf life. Application of precooling followed by packaging with ethylene scrubber $KMnO_4$ (S_6) was on par (7.33 days). External coating with chitosan (1%) (S_3) and packaging with ethylene

Table 24. Effect of postharvest management practices on sensory qualities of papaya fruit (3 DAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
S_1	6.93 (90.13)	7.00 (96.50)	6.73 (87.47)	6.73 (95.87)	6.60 (90.53)	6.27 (81.63)	6.13 (76.80)	6.60 (90.60)	52.99
S_2	7.67 (110.33)	7.00 (94.90)	7.07 (97.40)	7.00 (100.00)	6.93 (102.17)	6.93 (100.83)	6.67 (97.73)	7.07 (100.73)	56.34
S_3	5.73 (47.83)	5.80 (50.80)	5.87 (52.17)	5.60 (48.83)	5.60 (49.17)	5.60 (50.70)	5.60 (52.07)	5.67 (49.73)	45.47
S_4	5.73 (47.83)	5.80 (50.80)	5.87 (52.17)	5.60 (48.83)	5.60 (49.17)	5.60 (50.70)	5.60 (52.07)	5.67 (49.73)	45.47
S_5	5.73 (47.83)	5.80 (50.80)	5.87 (52.17)	5.60 (48.83)	5.60 (49.17)	5.60 (50.70)	5.60 (52.07)	5.67 (49.73)	45.47
S_6	5.73 (47.83)	5.80 (50.80)	5.87 (52.17)	5.60 (48.83)	5.60 (49.17)	5.60 (50.70)	5.60 (52.07)	5.67 (49.73)	45.47
S_7	5.73 (47.83)	5.80 (50.80)	5.87 (52.17)	5.60 (48.83)	5.60 (49.17)	5.60 (50.70)	5.60 (52.07)	5.67 (49.73)	45.47
S_8	5.73 (47.83)	5.80 (50.80)	5.87 (52.17)	5.60 (48.83)	5.60 (49.17)	5.60 (50.70)	5.60 (52.07)	5.67 (49.73)	45.47
S_9	8.47 (124.53)	7.60 (115.80)	7.47 (114.13)	7.93 (123.13)	8.07 (124.30)	8.20 (125.33)	7.93 (125.07)	7.93 (122.27)	63.60
K W value	83.36	59.42	52.72	76.03	75.53	70.11	63.56	71.80	
χ^2 – 15.51 (8, 0.05)									

Table 25. Effect of postharvest management practices on sensory qualities of papaya fruit (6 DAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
S_1	-	-	-	-	-	-	-	-	-
S_2	-	-	-	-	-	-	-	-	-
S_3	8.67 (71.33)	8.40 (62.70)	8.33 (59.17)	8.53 (67.57)	8.33 (59.17)	8.53 (62.70)	8.47 (63.37)	8.87 (68.70)	68.13
S_4	7.80 (48.10)	8.13 (53.90)	8.07 (49.83)	7.93 (47.97)	8.07 (49.83)	8.07 (46.17)	8.00 (47.23)	8.27 (47.10)	64.34
S_5	8.67 (71.33)	8.40 (62.70)	8.33 (59.17)	8.40 (63.30)	8.33 (59.17)	8.53 (62.70)	8.47 (63.37)	8.87 (68.70)	68.00
S_6	7.67 (43.93)	8.13 (53.90)	8.07 (49.83)	7.93 (47.97)	8.07 (49.83)	8.07 (46.17)	8.00 (47.23)	8.27 (47.10)	64.21
S_7	6.67 (19.07)	6.80 (19.90)	7.33 (27.50)	7.13 (23.10)	7.33 (27.50)	7.53 (27.63)	7.40 (25.90)	7.40 (20.70)	57.59
S_8	6.67 (19.07)	6.80 (19.90)	7.33 (27.50)	7.13 (23.10)	7.33 (27.50)	7.53 (27.63)	7.40 (25.90)	7.40 (20.70)	57.59
S_9	-	-	-	-	-	-	-	-	-
K W value	65.60	54.89	30.12	48.29	30.12	33.56	38.52	58.88	
χ^2 – 11.07 (5, 0.05)									

Table 26. Effect of postharvest management practices on sensory qualities of papaya fruit (9 DAS)

Treatments	Appearance	Colour	Flavour	Texture	Odour	Taste	After taste	Overall acceptability	Total score
S_1	-	-	-	-	-	-	-	-	-
S_2	-	-	-	-	-	-	-	-	-
S_3	-	-	-	-	-	-	-	-	-
S_4	-	-	-	-	-	-	-	-	-
S_5	-	-	-	-	-	-	-	-	-
S_6	-	-	-	-	-	-	-	-	-
S_7	8.53	9.00	8.60	8.33	8.60	8.73	8.73	8.67	69.19
S_8	8.53	9.00	8.60	8.33	8.60	8.73	8.73	8.67	69.19
S_9	-	-	-	-	-	-	-	-	-
K W value	-	-	-	-	-	-	-	-	

scrubber $KMnO_4$ (S_5) registered a shelf life of 6.33 days. Precooling (hydro cooling) (S_1) and surface sanitization with sodium hypochlorite (150 ppm) (S_2) gave a shelf life of 5.67 days and 5.00 days respectively. Significantly lowest shelf life of 4.33 days was observed in control (S_9).

4.2.2.2 ***Physiological Loss in Weight (%)***

The weight of fruit reduced after harvest due to the water loss and the loss in weight of fruits affects the quality of produce. Physiological loss in weight of papaya variety Surya fruits increased in all the treatments during storage under ambient conditions (Table 28). Papaya fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) had significantly lowest physiological loss in weight (1.49 %) after three days of storage. It was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) with 1.59 per cent physiological loss in weight. Application of precooling followed by packaging with ethylene scrubber $KMnO_4$ (S_6) to papaya fruits recorded a physiological loss in weight of 2.47 per cent, which was on par with S_4 (precooling followed by external coating with 1% chitosan) (2.77 %). In control fruits (S_9) the weight loss reached 7.54 per cent after three days of storage and was significantly higher.

After six days of storage, significant difference was noticed in physiological loss in weight of papaya fruits subjected to different postharvest treatments. S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) and S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) registered lowest physiological loss in weight of 3.63 per cent and 3.96 per cent respectively after six days of storage which was on par with each other. However, highest physiological loss in weight of 6.80 per cent and 6.47 per cent was recorded for S_3 (external coating with chitosan (1%)) and S_5 (packaging with ethylene scrubber $KMnO_4$) respectively after six days of storage.

Lowest physiological loss in weight of 5.64 per cent was noticed in S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) after nine days of storage, whereas highest physiological loss in weight (6.50 %) was witnessed in S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$).

4.2.2.3 *Ion leakage (%)*

Initial analysis (0 DAS) of papaya fruits revealed no significant difference in ion leakage (%) of fruits among treatments (Table 29). However, after three days of storage, fruits treated with various postharvest treatments, packaged in CFB box and stored under ambient condition witnessed significant differences in ion leakage of papaya fruits. Fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) had least ion leakage (34.63 %) after three days of storage, which was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) (37.02 %). Control sample (S_9) had highest ion leakage (90.25 %), which was followed by surface sanitization with sodium hypochlorite (150 ppm) (S_2) (81.07 %) after three days of storage.

After six days of storage, significant differences in ion leakge (%) of papaya fruits subjected to different postharvest management practices was noticed. Least ion leakage of 63.14 % was observed in fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7), which was on par with fruits subjected to hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$ (S_8)

Table 27. Effect of postharvest management practices on shelf life of papaya fruit

Treatments	Shelf life (days)
S_1	5.67
S_2	5.00
S_3	6.33
S_4	7.67
S_5	6.33
S_6	7.33
S_7	9.67
S_8	9.00
S_9	4.33
SEm (±)	0.29
CD (0.05)	0.87

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

Table 28. Effect of postharvest management practices on physiological loss in weight (%) of papaya fruit

Treatments	Physiological loss in weight (%)			
	Initial (0 DAS)	**3 DAS**	**6 DAS**	**9 DAS**
S_1	0.00	4.48(2.12)	-	-
S_2		5.75 (2.40)	-	-
S_3		3.51 (1.87)	6.80 (2.61)	-
S_4		2.77 (1.66)	5.83 (2.41)	-
S_5		3.16 (1.78)	6.47 (2.54)	-
S_6		2.47 (1.57)	5.64 (2.37)	-
S_7		1.49 (1.21)	3.63 (1.90)	5.64
S_8		1.59 (1.26)	3.96 (1.99)	6.50
S_9		7.54 (2.74)	-	-
SEm (±)	-	0.18 (0.05)	0.18 (0.04)	0.17
CD (0.05)	-	0.52 (0.15)	0.56 (0.12)	4.64*

DAS: Days after storage

Values in bracket are square root transformed values

*T statistic value

T- Table (0.05) : 2.048

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with 1% chitosan

S_4 – Precooling + external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$

S_6 – Precooling + packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling + external coating + packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment + waxing with 6% carnauba wax + packaging with ethylene scrubber $KMnO_4$

S_9 - Control

Plate 8. Papaya fruits after three days of storage in each treatments

(64.23 %). S_3 (external coating with chitosan (1%)) recorded highest ion leakage of 92.24 per cent after six days of storage.

After nine days of storage, least ion leakage of 93.41 per cent was noticed in fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7), whereas S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) registered highest ion leakage (95.78 %).

4.2.3 Chemical quality

4.2.3.1 *Total Carotenoids (mg 100g^{-1})*

Initial analysis (0 DAS) of papaya fruits revealed no significant difference in total carotenoid content among treatments whereas, it varied significantly among treatments after three days of storage (Table 30). Highest total carotenoid content (2.70 mg 100g^{-1}) was recorded in control (S_9) after three days of storage. It was followed by surface sanitization with sodium hypochlorite (150 ppm) (S_2) and precooling (hydro cooling) (S_1) with total carotenoid content of 2.55 mg 100g^{-1} and 2.50 mg 100g^{-1} respectively which was on par. Lowest total carotenoid content of 1.40 mg 100g^{-1} was found in fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) after three days of storage. It was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) with 1.45 mg 100g^{-1} total carotenoid content.

After six days of storage, significant difference in total carotenoid content was noticed among different treatments. Highest total carotenoid content (2.77 mg 100g^{-1}) was recorded in S_3 (external coating with chitosan (1%)), whereas S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) recorded lowest total carotenoid content (1.89 mg 100g^{-1}).

Table 29. Effect of postharvest management practices on ion leakage (%) of papaya fruit

Treatments	Ion leakage (%)			
	Initial (0 DAS)	**3 DAS**	**6 DAS**	**9 DAS**
S_1	11.37	64.39	-	-
S_2	11.04	81.07	-	-
S_3	11.21	60.47	92.24	-
S_4	10.64	51.43	84.33	-
S_5	10.63	57.80	91.85	-
S_6	10.60	46.50	80.07	-
S_7	10.70	34.63	63.14	93.41
S_8	10.74	37.02	64.23	95.78
S_9	11.37	90.25	-	-
SEm (±)	0.29	0.98	0.97	-
CD (0.05)	NS	2.91	3.01	6.09*

DAS: Days after storage
*T statistic value
T-Table (0.05) : 2.048

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

Treatment S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) recorded highest total carotenoid content (2.64 mg $100g^{-1}$) after nine days of storage, whereas fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) registered lowest total carotenoid content (2.50 mg $100g^{-1}$).

4.2.3.2 ***TSS (°Brix)***

Impact of different postharvest management practices on TSS of papaya variety Surya showed significant variation (Table 31) after three days of storage. Highest TSS of 13.23°Brix was observed in S_9 (control). Fruits subjected to surface sanitization with sodium hypochlorite (150 ppm) (S_2) recorded 12.70°Brix, which were on par. Lowest TSS (10.20°Brix) was found in fruits treated with precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) after three days of storage. It was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) and S_4 (precooling followed by external coating with 1% chitosan) with 10.33°Brix and 10.73°Brix respectively.

Present study also found significant variation in TSS of papaya fruits subjected to different post harvest treatments after six days of storage. S_3 (external coating with chitosan (1%)) recorded highest TSS (14.33°Brix) after six days of storage, which was on par with S_5 (packaging with ethylene scrubber $KMnO_4$) and S_4 (precooling followed by external coating with 1% chitosan) with TSS of 14.03°Brix and 13.67°Brix respectively. However, S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) recorded lowest TSS (11.20°Brix) and S_8 (hot water treatment followed by waxing with 6% carnauba

Table 30. Effect of postharvest management practices on total carotenoid (mg $100g^{-1}$) content of papaya fruit

Treatments	Total carotenoid (mg $100g^{-1}$)			
	Initial (0 DAS)	3 DAS	6 DAS	9 DAS
S_1	0.98	2.50	-	-
S_2	1.15	2.55	-	-
S_3	1.29	2.34	2.77	-
S_4	1.05	1.83	2.61	-
S_5	1.01	2.20	2.69	-
S_6	1.11	2.11	2.67	-
S_7	1.02	1.40	1.89	2.50
S_8	1.01	1.45	2.11	2.64
S_9	1.12	2.70	-	-
SEm (±)	0.07	0.04	0.07	-
CD (0.05)	NS	0.13	0.22	8.25*

DAS: Days after storage

*T statistic value

T- Table (0.05) : 2.048

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

wax and packaging with ethylene scrubber $KMnO_4$) with 11.70°Brix was on par after six days of storage.

Fruits subjected to hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$ (S_8) had highest TSS (13.97°Brix) after nine days of storage, whereas S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) registered lowest TSS (13.50°Brix).

4.2.3.3 ***Total sugar (%)***

Significant difference was noticed in total sugar content of papaya variety Surya fruits subjected to different postharvest treatments after three days of storage (Table 32). Highest total sugar content of 9.40 per cent was noticed in S_9 (control) after three days of storage. Fruits subjected to surface sanitization with sodium hypochlorite (150 ppm) (S_2) recorded total sugar content of 8.94 per cent, which were on par. Lowest total sugar content (5.73 %) was recorded in fruits treated with precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) after three days of storage. It was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) and S_6 (precooling followed by packaging with ethylene scrubber $KMnO_4$) with 5.90 per cent and 6.35 per cent total sugar content respectively.

After six days of storage, significant difference was noticed in total sugar content of fruits subjected to different postharvest treatments. Highest total sugar content (9.87 %) was noticed in S_3 (external coating with chitosan (1%)), which was on par with S_5 (packaging with ethylene scrubber $KMnO_4$), S_4 (precooling followed by external coating with 1% chitosan) and S_6 (precooling followed by packaging with ethylene scrubber $KMnO_4$) with a total sugar content of 9.70 %, 9.49 % and 9.20 %

Table 31. Effect of postharvest management practices on TSS (°Brix) of papaya fruit

Treatments	TSS (°Brix)			
	Initial (0 DAS)	**3 DAS**	**6 DAS**	**9 DAS**
S_1	8.07	11.80	-	-
S_2	8.37	12.70	-	-
S_3	7.83	12.13	14.33	-
S_4	8.17	10.73	13.67	-
S_5	7.97	12.03	14.03	-
S_6	8.13	10.93	13.40	-
S_7	8.17	10.20	11.20	13.50
S_8	8.03	10.33	11.70	13.97
S_9	8.03	13.23	-	-
SEm (±)	0.14	0.22	0.30	-
CD (0.05)	NS	0.65	0.91	3.45*

DAS: Days after storage

*T statistic value

T- Table (0.05) : 2.048

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 – Control

respectively. However fruits treated with precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) recorded lowest total sugar content (7.75 %).

Fruits subjected to hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$ (S_8) had highest total sugar content (9.17 %) after nine days of storage, whereas S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) registered lowest total sugar content (8.58 %).

4.2.3.4 *Reducing sugar (%)*

A significant difference in reducing sugar was noticed between fruits subjected to different postharvest treatments after three days of storage (Table 33). Highest reducing sugar content (8.16 %) was noticed in S_9 (control) after three days of storage. S_2 (surface sanitization with sodium hypochlorite (150 ppm)) which recorded 7.59 per cent and S_1 (precooling (hydro cooling)) which recorded 7.52 per cent reducing sugar content were on par. Lowest reducing sugar content (5.36 %) was noticed in S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$). S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)), S_4 (precooling followed by external coating with 1% chitosan) and S_6 (precooling followed by packaging with ethylene scrubber $KMnO_4$) which recorded 5.52 %, 5.71 % and 5.77 % reducing sugar content were on par.

Fruits subjected to different postharvest treatments witnessed significant difference in reducing sugar content after six days of storage. S_3 (external coating with chitosan (1%)) recorded highest reducing sugar content (8.63 %) after six days of storage, which was on par with S_5 (packaging with ethylene scrubber $KMnO_4$), S_6 (precooling followed by packaging with ethylene scrubber $KMnO_4$) and S_4

(precooling followed by external coating with 1% chitosan) (8.43 %, 8.35 % and 8.07 % respectively). However, S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) registered lowest reducing sugar content (6.59 %). S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) with 6.89 % reducing sugar was on par.

Fruits subjected to hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$ (S_8) had highest reducing sugar content (8.43 %) after nine days of storage, whereas S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) registered lowest reducing sugar content (8.00 %).

4.2.3.5 *Acidity (%)*

Acidity showed significant difference between treatments after three days of storage (Table 34). Lowest acidity (0.16 %) was noticed in S_9 (control) after three days of storage. It was followed by fruits subjected to precooling (hydro cooling) (S_1) and surface sanitization with sodium hypochlorite (150 ppm) (S_2) which recorded 0.19 per cent acidity each. Highest acidity of 0.27 per cent was noticed in papaya fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7). It was followed by S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) with 0.25 per cent acidity, which differed significantly among other treatments.

Significant differences in acidity were noticed in fruits subjected to different postharvest practices after six days of storage. Lowest acidity (0.14 % each) was noticed in S_3 (external coating with chitosan (1%)) and S_5 (packaging with ethylene scrubber $KMnO_4$). Highest acidity (0.22 %) was observed in S_7 (precooling followed

Table 32. Effect of postharvest management practices on total sugar (%) content of papaya fruit

Treatments	Total sugar (%)			
	Initial (0 DAS)	3 DAS	6 DAS	9 DAS
S_1	5.03	8.58	-	-
S_2	5.08	8.94	-	-
S_3	4.75	7.26	9.87	-
S_4	4.99	6.54	9.49	-
S_5	5.10	7.53	9.70	-
S_6	5.01	6.35	9.20	-
S_7	5.00	5.73	7.75	8.58
S_8	4.92	5.90	8.14	9.17
S_9	4.99	9.40	-	-
SEm (±)	0.07	0.24	0.30	-
CD (0.05)	NS	0.72	0.94	4.82*

DAS: Days after storage
*T statistic value
T- Table (0.05) : 2.048

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$). S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber) with 0.21 % acidity was on par.

Fruits subjected to hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$ (S_8) registered lowest acidity (0.15 %) after nine days of storage, whereas treatment S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) recorded highest acidity (0.16 %).

4.2.4 Percentage disease index

Percentage disease index can be used as a criterion to demonstrate the impact of different postharvest treatments on the microbial quality of fruits registered significant differences among treatments after three days of storage (Table 35). Fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) and S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) recorded no fungal spoilage and fruit rots after three days of storage, with zero per cent disease index. It was on par with S_6 (precooling followed by packaging with ethylene scrubber $KMnO_4$) with 5.56 per cent disease index. It was followed by S_4 (precooling followed by external coating with 1% chitosan) with 11.11 % disease index. Highest disease index of 38.89 per cent was observed in control (S_9) after three days of storage. It was on par with fruits subjected to precooling (hydro cooling) (S_1) (33.33 %).

Table 33. Effect of postharvest management practices on reducing sugar (%) content of papaya fruit

Treatments	Reducing sugar (%)			
	Initial (0 DAS)	3 DAS	6 DAS	9 DAS
S_1	4.14	7.52	-	-
S_2	4.53	7.59	-	-
S_3	4.16	6.34	8.63	-
S_4	4.45	5.71	8.07	-
S_5	4.26	6.43	8.43	-
S_6	4.28	5.77	8.35	-
S_7	4.41	5.36	6.59	8.00
S_8	4.41	5.52	6.89	8.43
S_9	4.48	8.16	-	-
SEm (±)	0.06	0.23	0.31	-
CD (0.05)	NS	0.68	0.95	3.11*

DAS: Days after storage
*T statistic value
T- Table (0.05) : 2.048

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

Fruits subjected to different postharvest treatments witnessed significant difference in disease index percenatge after six days of storage. Packaging with ethylene scrubber $KMnO_4$ (S_5) recorded highest disease index (33.33 %) after six days of storage. S_3 (external coating with chitosan (1%)) and S_4 (precooling followed by external coating with 1% chitosan) which recorded 30.55 % and 27.78 % disease index respectively after six days of storage, was on par.

However after six and nine days of storage, lowest disease index (16.67 % and 27.78 % each respectively) was noticed in S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) and S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$).

4.2.5 Microbial load (cfg g^{-1})

The impact of different postharvest treatments on microbial load of papaya variety Surya is shown in Table 36 and 37. Significant difference in bacterial and fungal count was noticed among fruits receiving different postharvest treatments after three six and nine days of storage.

Lowest bacterial count was witnessed in fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) and hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) (S_8) (4.67 cfu ml^{-1} x 10^6 and 5.67 cfu ml^{-1} x 10^6 respectively) after three days of storage (Table 37) (Plate 9). It was followed by S_6 (precooling followed by packaging with ethylene scrubber $KMnO_4$) and S_4 (precooling followed by external coating with 1% chitosan) with a bacterial population of 14.00 cfu ml^{-1} x 10^6 and 14.33 cfu ml^{-1} x 10^6 respectively, which was on par with each other. Highest bacterial count of 89.33 cfu ml^{-1} x 10^6 was witnessed in control (S_9) after three days of storage. It was followed by S_2 (surface

Table 34. Effect of postharvest management practices on acidity (%) of papaya fruit

Treatments	Acidity (%)			
	Initial (0 DAS)	**3 DAS**	**6 DAS**	**9 DAS**
S_1	0.29	0.19	-	-
S_2	0.30	0.19	-	-
S_3	0.29	0.22	0.14	-
S_4	0.30	0.23	0.16	-
S_5	0.29	0.21	0.14	-
S_6	0.29	0.23	0.15	-
S_7	0.30	0.27	0.22	0.16
S_8	0.29	0.25	0.21	0.15
S_9	0.30	0.16	-	-
SEm (±)	0.00	0.00	0.00	-
CD (0.05)	NS	0.02	0.03	1.47* (NS)

DAS: Days after storage

*T statistic value

T- Table (0.05) : 2.048

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

sanitization with sodium hypochlorite (150 ppm)) and S_1 (precooling (hydro cooling)) with a bacterial population of 54.00 cfu ml^{-1} x 10^6 and 43.33 cfu ml^{-1} x 10^6 respectively, which differed significantly among each other and among other treatments.

Fruits subjected to different postharvest treatments witnessed significant difference in bacterial count after six days of storage. Lowest bacterial count (16.00 cfu ml^{-1} x 10^6) after six days of storage was noticed in fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7). It was found to be on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) with a bacterial count of 16.33 cfu ml^{-1} x 10^6. Whereas S_5 (packaging with ethylene scrubber $KMnO_4$) registered highest bacterial count (51.67 cfu ml^{-1} x 10^6) after six days of storage.

Fruits treated with precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) had lowest bacterial count (24.33 cfu ml^{-1} x 10^6) after nine days of storage. However S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) witnessed highest bacterial count (25.67 cfu ml^{-1} x 10^6).

Papaya fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) had a lowest fungal count of 1.67 cfu ml^{-1} x 10^3 after three days of storage (Table 37) (Plate 10). Fruits treated with hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) (S_8) (2.00 cfu ml^{-1} x 10^3) was on par. Control sample (S_9) registered highest fungal count (22.33 cfu ml^{-1} x 10^3). It was followed by S_2 (surface sanitization with sodium hypochlorite (150 ppm)) and S_1

Table 35. Effect of postharvest management practices on disease index (%) of papaya fruit

Treatments	Disease index (%)			
	Initial (0 DAS)	3 DAS	6 DAS	9 DAS
S_1	0.00	33.33 (35.26)	-	-
S_2		27.78 (31.75)	-	-
S_3		16.67 (24.10)	30.55 (33.51)	-
S_4		11.11 (16.45)	27.78 (31.75)	-
S_5		16.67 (24.10)	33.33 (35.16)	-
S_6		5.56 (8.81)	22.22 (28.03)	-
S_7		0.00 (1.17)	16.67 (24.10)	27.78
S_8		0.00 (1.17)	16.67 (24.10)	27.78
S_9		38.89 (38.56)	-	-
SEm (±)	-	3.05 (3.69)	2.78 (1.76)	-
CD (0.05)	-	9.16 (10.97)	8.56 (5.44)	0.00* (NS)

Values in bracket are angular transformed values

DAS: Days after storage

*T statistic value

T- Table (0.05) : 2.048

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

(precooling (hydro cooling)) with a fungal population of 14.67 cfu ml^{-1} x 10^3 and 13.67 cfu ml^{-1} x 10^3 respectively, which was on par with each other.

Significant difference in fungal count was noticed in fruits subjected to different postharvest practices after six days of storage. Lowest fungal count was noticed in fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) (4.67 cfu ml^{-1} x 10^3), after six days of storage. It was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) with a fungal count of 5.33 cfu ml^{-1} x 10^3. Whereas, S_3 (external coating with chitosan (1%)) and S_5 (packaging with ethylene scrubber $KMnO_4$) registered highest fungal count (9.33 cfu ml^{-1} x 10^3 each) after six days of storage.

Fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) recorded lowest fungal count (13.33 cfu ml^{-1} x 10^3) after nine days of storage, whereas fruits treated with hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) (S_8) registered highest fungal count (14.00 cfu ml^{-1} x 10^3).

Table 36. Effect of postharvest management practices on bacterial count of papaya fruit

Treatments	Bacterial count (cfu / ml x 10^6)			
	Initial (0 DAS)	3 DAS	6 DAS	9 DAS
S_1	2.67	43.33	-	-
S_2	3.33	54.00	-	-
S_3	2.67	22.33	46.33	-
S_4	3.33	14.33	36.00	-
S_5	2.67	19.33	51.67	-
S_6	2.67	14.00	31.67	-
S_7	2.67	4.67	16.00	24.33
S_8	2.67	5.67	16.33	25.67
S_9	3.67	89.33	-	-
SEm (±)	0.38	0.91	0.64	-
CD (0.05)	NS	2.74	1.97	2.83*

DAS: Days after storage
*T statistic value
T- Table (0.05) : 2.048

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

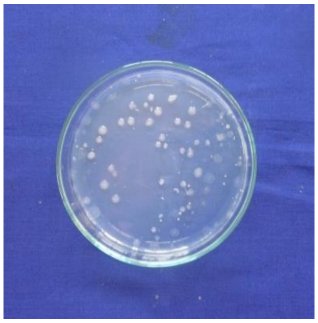
S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

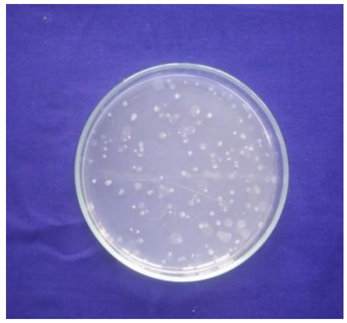
S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

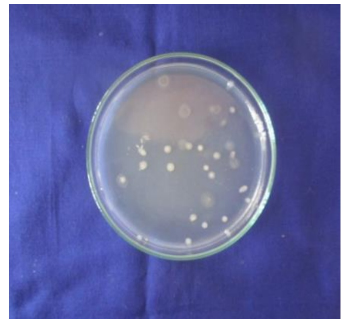
S_9 - Control



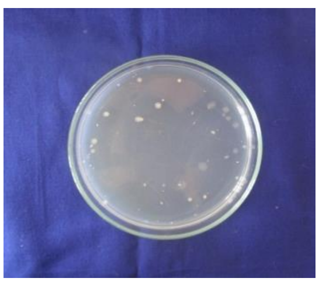
S_1 – Precooling (Hydro cooling)



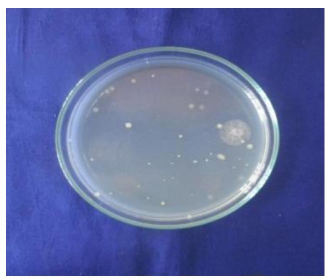
S_2 – Surface sanitization with sodium hypochlorite (150 ppm)



S_3 – External coating with 1% chitosan

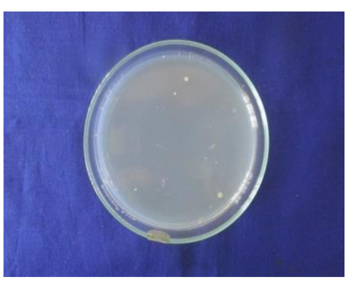


S_4 – Precooling + external coating with 1% chitosan

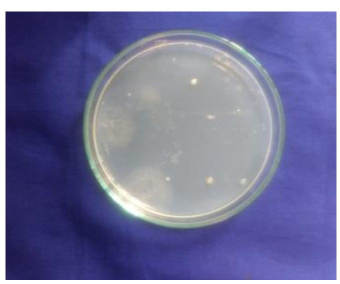


S_5 – Packaging with ethylene scrubber $KMnO_4$

S_6 – Precooling + packaging with ethylene scrubber $KMnO_4$



S_7 - Precooling + external coating + packaging with ethylene scrubber $KMnO_4$



S_8 - Hot water treatment + waxing with 6% carnauba wax + packaging with ethylene scrubber $KMnO_4$

S_9 - Control

Plate 9. Effect of postharvest treatments on bacterial population (3 DAS) of papaya fruits

Table 37. Effect of postharvest management practices on fungal count of papaya fruit

Treatments	Fungal count (cfu / ml x 10^3)			
	Initial (0 DAS)	3 DAS	6 DAS	9 DAS
S_1	0.67	13.67	-	-
S_2	0.33	14.67	-	-
S_3	0.67	7.33	9.33	-
S_4	0.67	6.00	8.67	-
S_5	1.00	6.67	9.33	-
S_6	0.67	5.00	8.33	-
S_7	0.33	1.67	4.67	13.33
S_8	0.33	2.00	5.33	14.00
S_9	1.33	22.33	-	-
SEm (±)	0.31	0.40	0.41	-
CD (0.05)	NS	1.20	1.26	2.65*

DAS: Days after storage
*T statistic value
T- Table (0.05) : 2.048

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

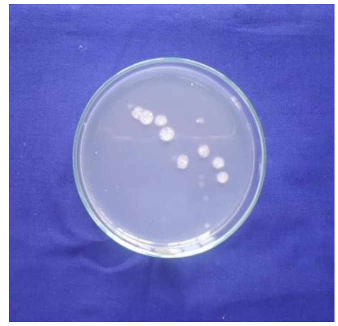
S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

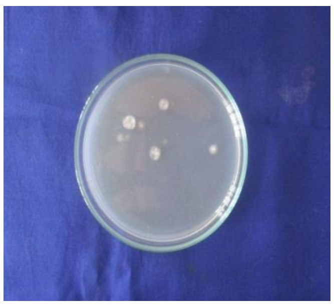
S_9 - Control

S_1 – Precooling (Hydro cooling)

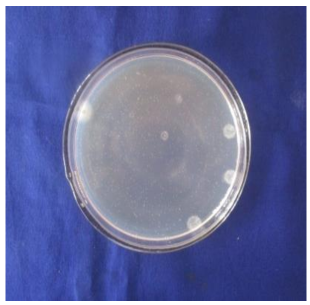
S_2 – Surface sanitization with sodium hypochlorite (150 ppm)



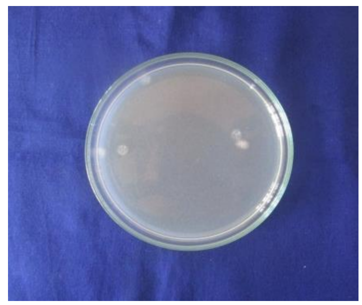
S_3 – External coating with 1% chitosan



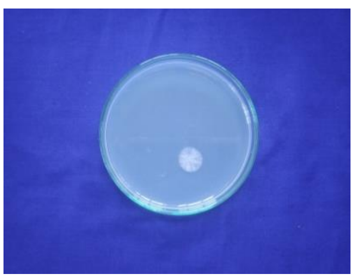
S_4 – Precooling + external coating with 1% chitosan



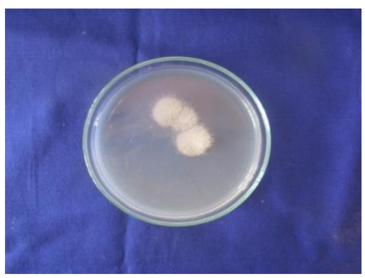
S_5 – Packaging with ethylene scrubber $KMnO_4$



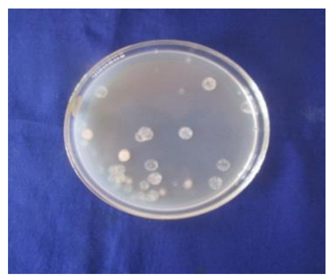
S_6 – Precooling + packaging with ethylene scrubber $KMnO_4$



S_7 - Precooling + external coating + packaging with ethylene scrubber $KMnO_4$



S_8 - Hot water treatment + waxing with 6% carnauba wax + packaging with ethylene scrubber $KMnO_4$



S_9 - Control

Plate 10. Effect of postharvest treatments on fungal population (3 DAS) of papaya fruits

Discussion

5. DISCUSSION

Papaya is one of the most widely cultivated tropical fruit crops, which amassed popularity due to its nutraceutical properties. It is gradually arising from the level of a homestead crop to that of commercial crop in Kerala. The existing scenario requires immediate attention of researchers to improve the yield and quality of papaya. Veerannah and Selvaraj (1984) and Sathya *et al*. (2008) opined that nutritional requirement of papaya differs from other fruit crops because of its enormous yield capability, precocious bearing and indeterminate growth pattern which coincides with vegetative growth, flowering and fruiting. Smith *et al*. (1979) and Syvertsen and Smith, (1996) documented that fertigation which supplies accurate quantity of fertilizers along with water to the active root zone helps maintain optimum soil fertility level according to the precise requirement of each crop and ensuing in elevated yields and satisfactory quality of fruits. Plant growth in fruit crops can be controlled by the integrated supply of micronutrients with macronutrients in adequate amount and suitable proportions. Apart from promoting plant growth, micronutrients also helps imparts disease resistance in cultivated crop species. Foliar application of micronutrients and fertilizers has been one of the approaches to achieve an improvement in yield and quality of different fruit crops and to optimise use of chemical fertilisers (Moustafa *et al.*, 1986; Bacha *et al.*, 1997).

Hence, the study on "Fertigation studies in papaya (*Carica papaya* L.)" was carried out in the Department of Fruit Science, College of Agriculture, Vellayani, during 2018-2020.

The results obtained from the study are critically discussed in this chapter under the following heads.

5.1 Fertigation and foliar nutrition studies in papaya

5.2 Postharvest management practices for extension of shelf life in papaya

5.1 FERTIGATION AND FOLIAR NUTRITION STUDIES IN PAPAYA

5.1.1 Biometric parameters

Impact of fertigation in combination with foliar nutrition can be easily diagnosed by observing biometric parameters.

5.1.1.1 *Plant height (cm)*

The study revealed a significant difference in plant height between treatments from 2 MAP to 16 MAP.

At 2 MAP and 4 MAP, supply of 125 % RD of N and K through fertigation (T_{7}, T_8 and T_9) registered highest plant height irrespective of the foliar spray (85.70 cm, 85.36 cm and 84.98 cm respectively at 2 MAP and 112.53 cm, 110.62 cm and 111.03 cm respectively at 4 MAP). Nevertheless, plants supplied with 75 % RD of N and K through fertigation (T_{1}, T_2 and T_3) recorded lowest plant height irrespective of the foliar spray (60.16 cm, 63.15 cm and 61.21 cm respectively at 2 MAP and 91.53 cm, 90.72 cm and 88.18 cm respectively at 4 MAP). The higher availability of major nutrient at initial stages, owing to their high amount of application and uptake by plant might have increased the plant height in these treatments at 2 and 4 MAP.

From 6 MAP to 16 MAP, application of 100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19 (T_4) registered highest plant height (149.19 cm, 190.23 cm, 214.80 cm, 236.40 cm, 249.25 cm and 262.56 cm respectively) which was on par with treatments receiving 100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax (T_5) at 6 MAP, 10 MAP and 14 MAP (147.11 cm, 211.88 cm and 245.39 cm respectively). However, T_3 which received 75 % RD of N and K through fertigation with water spray registered lowest plant height from 6 MAP to 16 MAP (108.46 cm, 144.09 cm, 164.10 cm, 176.52 cm, 192.47 cm and 201.73 cm respectively). Split application of adequate quantity of fertilizers during growth and development of papaya through fertigation that enhanced fertilizer use efficiency inaddition to the foliar application of 19:19:19 (1.0%) might have contributed to the maximum plant height in T_4. Similar results of enhanced plant height under 100 % fertigation was reported by Agrawal *et al*. (2010) in papaya cv. Red Lady. According to Krishnamoorthy (2011), fertigation which provides optimum dose of water and nutrients significantly increased the plant height in cocoa. Shimi (2014) reported that foliar application of 19:19:19 at 4 MAP was beneficial in improving the plant height in banana cv. Nendran.

Increase in plant height in the T_5 plants can be discussed in the light of fact that foliar spray with zinc helps in tryptophan synthesis which is a precursor of indole acetic acid synthesis, which thereby results in increased tissue growth and development. Dawood *et al.* (2001) reported similar results in Washington Navel orange due to foliar application of zinc sulphate. Reed (1946) opined that zinc plays a significant function in basic processes in the cellular mechanism and respiration. Wood and Sibley (1950) reported the presence of zinc in chloroplast cell was deemed the possible causes of increased growth of plants.

In control 1 (T_{13} which received KAU POP), the similar amount of nutrients were supplied to the soil and the performance could not be contested with any of that fertigation treatment. Lower nutrient use efficiency as a result of loss of nutrients and/or nutrient fixation in the soil might have contributed to this.

The minimum plant height obtained in T_3 can be due to the insufficient supply of fertilizers through fertigation (75 % RDF). Shirgure *et al.* (2001) reported less plant height with lower fertilizer dose in Nagpur mandarin. The findings of Deshmukh and Hardaha (2014) in papaya cv. Taiwan 786 was also in accordance with the study.

5.1.1.2 *Plant girth (cm)*

The findings obtained from the present research revealed that girth of plants varied significantly among treatments from 2 MAP to 16 MAP.

At 2 MAP and 4 MAP, highest plant girth (11.29 cm and 21.99 cm respectively) was noticed in T_7 which received 125 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19 and T_3 (75 % RD of N and K through fertigation with water spray) registered least plant girth (6.79 cm and 12.23 cm respectively). The higher availability of major nutrient at initial stages, owing to their high amount of application and uptake by plant might have increased the plant girth in these treatments at 2 and 4 MAP.

Application of 100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19 (T_4) registered highest plant girth at 6 MAP, 8 MAP, 10 MAP, 12 MAP, 14 MAP and 16 MAP (25.92 cm, 39.33 cm, 45.80 cm, 51.65 cm, 54.78 cm and 56.92 cm). It was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) at 6 MAP, 10 MAP and at 14 MAP with 25.36 cm, 45.75 cm and 53.03 cm plant girth respectively. However, T_3 registered lowest plant girth (18.32 cm, 21.86 cm, 25.09 cm, 30.92 cm, 33.92 cm and 36.48 cm respectively) from 6 MAP to 16 MAP. Increased uptake of nutrients, nitrogen and potassium under optimum dose of fertigation and foliar application of 19:19:19 (1.0 %) and $ZnSO_4$ (0.5 %) + borax (0.3 %) might have contributed to expansion of stem girth. Jeyakumar *et al*. (2010) reported significantly higher stem girth upon fertigation with 100 % RD of N and K in papaya. Protein and amino acids formed by utilizing the absorbed nitrogen and potash might have contributed to the formation of new tissues (Childers, 1966). Also the nutrient doses supplied at reasonable quantity contributed to the increased synthesis of IAA, further facilitating the cell elongation and improved stem girth. Enhanced photosynthetic efficiency achieved due to elevated uptake and deposition of nutrients in leaf tissues contributed to the greater synthesis, translocation and accumulation of carbohydrates which in turn improved the trunk girth (Ghanta *et al*., 1995).

Shimi (2014) documented that foliar application of 19:19:19 at 6 MAP was beneficial in improving the pseudostem girth in banana cv. Nendran.

Enzyme carbonic anhydrase which is involved in photosynthesis has zinc as a constituent. Activation of this enzyme by zinc sulphate foliar spray might have contributed to the enhanced photosynthesis and increase in plant girth in T_5. Bahadur *et al*. (1998) reported greatest increase in stem girth upon foliar application of 1.0 % zinc sulphate in mango. Alloway (2008) demonstrated a 50–70 % reduction in net photosynthesis in different plant species without the activity of this enzyme. The study also revealed a reduction in food reserve and adverse tree growth based on the severity of enzyme deficiency.

5.1.1.3 ***Number of leaves***

Observations on number of leaves recorded at bimonthly intervals from 2 MAP to 16 MAP (peak harvest stage) showed significant variation among treatments.

At 2 MAP, maximum number of leaves (13.67) was noted in T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax), which was on par with T_9 (125 % RD of N and K through fertigation with water spray) with 13.00 leaves and least number of leaves (8.89 each) was recorded in T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) and T_3 (75 % RD of N and K through fertigation with water spray). At 4 MAP, T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) registered a maximum leaf number (16.56), which was on par with T_8 and T_9 with a leaf count of 16.22 and 15.89 respectively and minimum number of leaves (10.67) was noted in T_3. The higher availability of major nutrient at initial stages, owing to their high amount of application and uptake by plant might have increased the number of leaves in these treatments at 2 and 4 MAP.

From 6 MAP to 16 MAP, application of 100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19 (T_4) registered maximum number of leaves (18.11, 22.34, 29.11, 31.22, 28.67 and 25.11 respectively), which was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) at 6 MAP, 8 MAP and 14 MAP (17.78, 21.78 and 27.78 leaves respectively). T_3 registered minimum number of leaves from 6 MAP to 16 MAP (11.00, 14.89, 15.11, 16.56, 15.00, 11.67 leaves respectively).

Improved number of leaves in T_4 and T_5 could be attributed to improved nutrient uptake because of optimum quantity of fertigation and foliar spray with 19:19:19 and $ZnSO_4$ + borax. Consistent moisture level and nutrient reserve developed in the soil as a result of drip fertigation at frequent intervals makes the roots remain active for a longer period (Wuertz *et al*., 2000). Mishra *et al*. (2005) noticed increase in accessibility of nutrients and enhanced movement of food materials to the plant, grown in soil equipped with adequate and continuous moisture in the soil, which further accelerated the vegetative growth of plant parts. The findings was in accordance with the records of Martinsson *et al*. (2006) in 'Elsanta' strawberries. Kachwaya and Chandel (2015) also registered more number of leaves in strawberry plants fertigated with full nutrient package compared to soil fertilization. Shimi (2014) reported that foliar spray with 19:19:19 at 4 and 6 MAP significantly enhanced the number of functional leaves per plant in banana cv. Nendran.

Amino acid, tryptophan which is the precursor of auxin has zinc in its structure. Thus foliar spray with zinc sulphate increased the production of auxin and thereby enhanced the vegetative growth in papaya. Singh *et al.* (2010) reported increased metabolic activities upon foliar spray with zinc and boron which lead to increased plant metabolites are accountable for cell division, cell elongation and ultimate plant growth. Sajid *et al*. (2010) noticed reduced leaf drop in plants provided with micronutrient foliar spray, which is achieved by increased production of photosynthetic compounds inside the plant tissue which ultimately give strength for their persistency. Singh *et al.* (2002) documenetd that foliar application of zinc and boron reduced the leaf drop and enhanced the leaf number in papaya.

Less frequent application of nutrients and nutrients loss or fixation in the soil because of leaching or volatilization might have contributed to the low performance in control 1 (T_{13}) when compared with fertigation method.

5.1.1.4 *Leaf Area Index*

Leaf area index, a measure of intercepted radiation and hence a crucial determinant of crop growth and productivity, observed at 6, 12, 18 MAP and at last harvest (20 MAP) exhibited significant differences among treatments.

At 6, 12, 18 and 20 MAP, highest leaf area index (1.71, 4.20, 2.43 and 2.28 respectively) was recorded in T_4 supplied with 100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19. It was found to be on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) at 12 and 20 MAP (4.11 and 2.23). Lowest value for leaf area index (1.18, 2.71, 1.55 and 1.52) was recorded in T_3 (75 % RD of N and K through fertigation with water spray) at all the stages of observation.

Higher leaf area index in T_4 might be due to optimum receival of major nutrients round the crop growth period by increased split supply through fertigation in relatively smaller quantity in addition to the foliar application of 19:19:19. Greater uptake and aggregation of nutrients in leaf tissues, contributes to the higher synthesis, transport and accumulation of carbohydrates further resulting in higher photosynthetic efficiency (Ghanta *et al*., 1995). Similar observations were documented by Srinivas (2000). Shimi (2014) reported that foliar supply with

19:19:19 at 4 and 6 MAP significantly increased the leaf area index in banana cv. Nendran.

According to Supriya *et al*. (1993), amino acid tryptophan which requires zinc as a prerequisite for its production, is the raw material for auxin generation and auxin plays a significant part in improving leaf area and tree canopy, which might have contributed to the increased leaf area index in T_5 upon foliar spray with $ZnSO_4$. Singh and Rajput (1976) and Rajput *et al*. (1976) documented increase in leaf area per shoot in mango on foliar spray with zinc sulphate.

5.1.1.5 *Height at first flowering (cm)*

Height at first flowering in papaya plants registered significant differences among treatments. T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) flowered at shortest height of 74.38 cm (Fig. 3). Flowering at maximum height (113.53 cm) was registered in treatment T_3 (75 % RD of N and K through fertigation with water spray). Fertigation gives an advantage of providing optimum dose of nutrients to the root zone on weekly basis which can be utilized efficiently. Foliar application of 1% 19:19:19 in addition to fertigation might have contributed to the flowering at shortest height in T_4. Jeyakumar *et al*. (2010), Sadarunnisa *et al*. (2010) and Jadhav *et al*. (2016) elaborated the association between optimum fertigation dosage and low flowering height in papaya.

5.1.1.6 *Days to flowering*

Significantly minimum number of days (142.67 days) for flowering was found in T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) which was found to be on par with T_4 (145.78 days) (Fig. 4). However, T_3 took significantly higher number of days (186.00 days) for flowering.

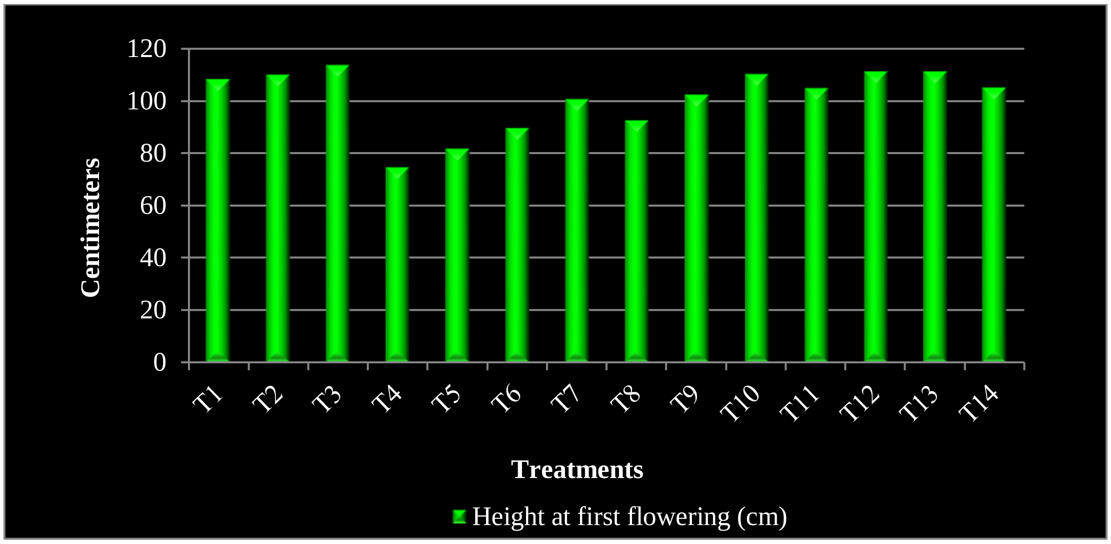


Fig. 3. Effect of fertigation and foliar sprays on height at first flowering in papaya variety Surya

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data
T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

The explanation for least days to first flowering can be ellaborated in the light of evidence that fertigation plays a significant role in plant metabolism by virtue of being a vital constituent of distinct type of metabolically active compounds like amino acids, proteins, nucleic acids, prophytins, nucleotide and co- enzymes and promote early flowering (Agrawal *et al*., 2010). Improved vegetative growth and delayed flower initiation are the aftermath of higher N and K dose, whereas, balanced nutrition attained as a result of application of 100 % RDF ensured satisfactory growth, development and facilitated early flowering. These outcomes are in harmony with the findings of Shree *et al*. (2018) and Gonge *et al*. (2015).

Also early flowering in fertigated plants could be interpreted by immediate production of leaves with enormous leaf area which would have resulted in reasonable photosynthetic activity, thus the mandatory net assimilation probably would have reached quickly in plants obtaining both N and K through fertigation (Mahalakshmi, 2000). This might have accelerated the process of flowering in papaya in the current study.

Also it can be inferred from the results that treatments T_5, T_4, T_8, T_{11} and T_7 which received nutrients through fertigation and different foliar sprays, significantly lessened the number of days for flowering (142.67 days, 145.78 days, 150.00 days, 150.44 days and 153.33 days respectively) in comparison with control 2 (T_{14}) (156.55 days). Madhumathi *et al*. (2004) reported vigorous growth and early flowering in banana cv. Robusta upon effective utilization of accurately placed fertilizers to the active root zone in soluble form. Breakage of apical dominance achieved as a result of transport of growth promoting substances like cytokinin to the auxiliary buds resulted in the early flowering in drip fertigated plants (Gonge *et al*., 2015). According to Katyal and Dutta (1971) high C/N ratio achieved as result of frequent irrigation and fertigation with optimum dose might have promoted early flowering in mango. Nitrogen which is a component of protoplasm, available at optimum level had

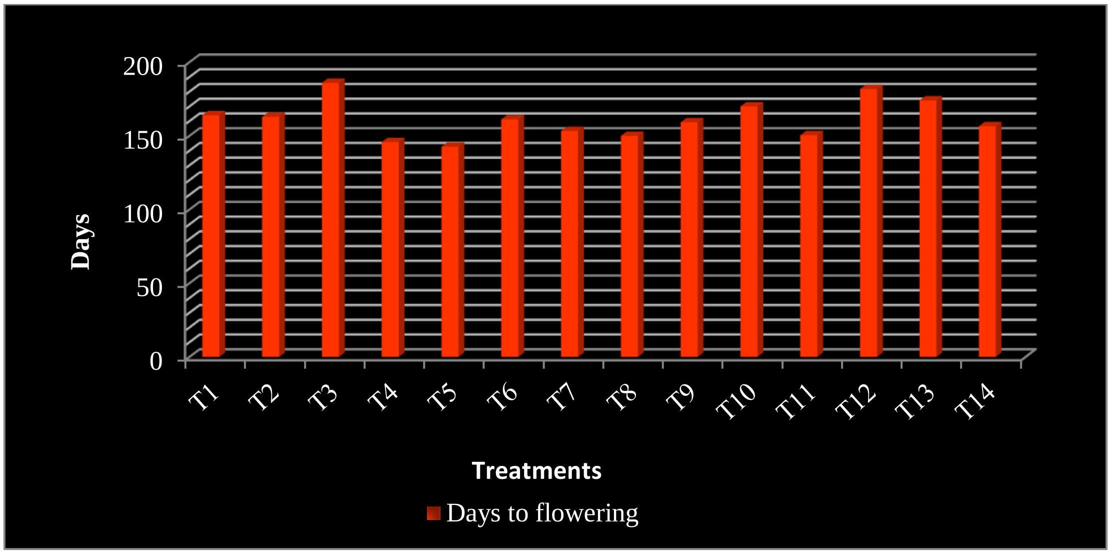


Fig. 4. Effect of fertigation and foliar sprays on days to flowering in papaya variety Surya

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

contributed to the earliness in flowering and assisted in chlorophyll production which increases the photosynthetic rate leading to more production of carbohydrates, flower initiation and profuse flowering (Chermahini *et al*. 2010).

It is clear from the study that treatments T_2, T_5, T_8 and T_{11} (receiving foliar spray of 0.5% $ZnSO_4$ and 0.3% borax) took minimum number of days for flowering at all the levels of fertigation (75 %, 100 %, 125 % and 150 % RD of N and K) than their respective treatments provided with foliar spray of 1.0% 19:19:19 and water spray. Muhammad *et al*. (2010) reported early flowering in sweet orange cv. Blood Red upon foliar spray with borax and zinc. Rahman *et al*. (2016) opined that foliar application of zinc reduced the days required to flowering (38.6 days) in strawberry compared to control (44.9 days). Singh *et al*. (2010) reported an early flowering (104.42 days) in papaya cv. Ranchi treated with borax at 0.50 per cent, whereas, control plants took 124.83 days to flower. In papaya cv. Taiwan Red Lady, Bhalerao *et al*. (2014) observed earliness in flower initiation (days) upon foliar application with borax. The earliness in flowering acheived in treatments receiving borax spray may be due to the role of boron in early flower initiation, formation of flower bud and production of indigenous and florigenic substances, besides incitation of pollen germination, pollen tube growth and fertilization process. Also, the role of boron in regulating the metabolism involved in transortation of carbohydrates, cell-wall development and RNA synthesis might contributed to the early flowering (Ram and Bose, 2000).

5.1.1.7 *Sex expression of plant*

T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) recorded highest number of female plants (83.33 %) in the study. Foliar spray with 1 per cent 19:19:19 in addition to the application of optimum quantity of nutrients through fertigation might have contributed to the production of more female plants. The findings are in harmony with the observation of Oliveira *et al*. (2004) where optimum availability of nitrogen to papaya plants increased the femaleness.

In all the fertigation levels (75 %, 125 % and 150 % RD of N and K) except treatments receiving 100 per cent RD of N and K, foliar application of $ZnSO_4$ (0.5 %) and borax (0.3 %) resulted in more number of female plants. Brahmachari *et al*. (1997) opined that foliar application of zinc sulphate 1.0 % significantly improved the number of pistilate flowers in litchi. Jena *et al.* (2018) opined that supply of $ZnSO_4$ at 0.5 % in cashew cv. BPP- 8 gave highest number of perfect flowers (66.33), whereas, control registered lowest number of perfect flowers (49.17). Transoprtation of reserve food material from vegetative part to reproductive part due to application of $ZnSO_4$ might have contributed to this. Physiological changes in the tissues influencing the flowering characters are stimulated by zinc and role of zinc in auxin biosynthesis also stimulated the flowering.

Lowest hermaphrodite plants (16.67 %) was found in treatments receiving T_4. Treatments T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) and T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) with 22.22 % hermaphrodite plants for both was on par. Highest number of hermaphrodite plants (61.11 %) was found in treatments T_3 (75 % RD of N and K through fertigation with water spray) and T_{12} (150 per cent of RD of N and K through fertigation with water spray).

5.1.1.8 *Number of flowers cluster $^{-1}$*

The data on number of flowers per cluster in papaya showed significant difference among treatments. Highest number of flowers per cluster (2.78) was reported in T_5. Treatments T_4, T_8 and T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) which recorded 2.67, 2.67 and 2.44 flowers per cluster respectively was found to be on par. Optimum availability of nutrient through fertigation and foliar spray leading to better flower bud differentiation and primordial development might have contributed to the increased flower production in treatments T_5, T_4, T_8 and T_7. Jeyakumar *et al*. (2010) supported the findings of the present study.

Plants which received foliar spray of $ZnSO_4$ (0.5 %) and borax (0.3 %) (T_5, T_8, T_{11} and T_2) registered higher number of flowers per cluster (2.78, 2.67, 2.11 and 2.11 respectively), among treatments with different levels of fertigation (75 %, 100 %, 125 % and 150 % RD of N and K). Increase in number of flowers per shoot upon foliar sray with zinc and boron was reported by Dhurve *et al*. (2018) in pomegranate cv. Ganesh. It can also be due to role of zinc in promoting the reproductive growth of plants and thereby causing increment in the number of flower buds. Foliar spray with zinc in strawberry resulted in increased number of flower buds (Rahman *et al*. 2016).

However, treatments T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) and T_{12} (150 % RD of N and K through fertigation with water spray) recorded lowest number of flowers per cluster than control 2 (T_{14}). Receival of higher dose of nitrogen to papaya plants might have contributed to this. Substantial nitrogen supply with considerable chance for carbohydrate synthesis is known to stimulate vegetative growth and lower flowering (Corbesier *et al*., 2002). *ie*, elevated nitrogen availability will result in low C: N ratio, which facilitates vegetative growth (Bernier *et al*., 1981 and Rideout *et al*., 1992).

5.1.1.9 ***Fruit set (%)***

Treatment T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) recorded highest fruit set (86.27 %) among different treatments, which was found to be on par with plants receiving 100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax (T_5) (85.43 %) (Fig. 5). However, T_3 (75 % RD of N and K through fertigation with water spray) recorded lowest fruit set (64.50 %). Enhanced synthesis of the hormones auxin and gibberellin achieved in plants due to increased uptake of nutrients in treatment T_4 contributed to the highest fruit set. Several studies pointed out minimal fruit drop in crops receiving water through drip irrigation. This is because water is supplied nearer to the root zone in this technique and soil moisture is always maintained in the field capacity range and no moisture stress is experienced during the flowering and fruit development stage, which might have contributed to the higher fruit set per cent. Singh *et al*. (2006) and Krishnamoorthy (2011) reported similar findings in mango and cocoa respectively.

Zinc influences flowering and fruit set through its role in auxin biosynthesis as auxin play a major role in flowering and fruit set. This might have resulted in the increased fruit set in plants receiving T_5 and T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax). Also, such an enhanced fruit set could have been due to blended effect of zinc and boron which have aided in improving pollen germination, growth of pollen tube that facilitate timely fertilization before the stigma loses its receptivity or the style become nonfunctional and higher metabolites synthesis (Peres-Lopez and Reyes, 1983). Reduced nutrient competition among fruitlets and enhanced hormonal balance achieved as a result of sprays with zinc and boron aided in preventing fruit drop and increased their survival. Yadav *et al*. (2011) opined that transportation of hormones, food substances and other factors stimulating fruit formation to the tissue of ovary in higher amount was achieved as a result of micronutrients application which thereby contributes to higher fruit set. Jeyakumar *et al*. (2001) documented that in papaya cv. Co 5, foliar spray of boron enhanced the fruit set. Motesharezade *et al*. (2001) reported increased fruit set upon foliar spray of zinc and boron in sweet cherry. Foliar spraying with 1.0 per cent $ZnSO_4$ increased the fruit set per cent in guava cv. L 49 (Yadav *et al*., 2017).

Increased foliar zinc content as a result of application of zinc at higher level, encourages the endogenous production of auxin thereby reducing fruit drop (Meena *et al*., 2014).

5.1.1.10 *Time for first harvest (days)*

The findings of the present study revealed a significant impact on time taken for first harvest in papaya upon application of different levels of fertigation and foliar sprays. Treatment T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) recorded least number of days for first harvest of fruits (275.00 days), whereas T_3 (75 % RD of N and K through fertigation with water spray) took more number of days (327.56 days) for first harvest (Fig. 6). Fertigation with nitrogen and potassium were done at weekly intervals in present study. Thus, papaya plants efficiently utilized the optimum application of fertilizers in solution form at the active root zone area leading to synthesis and deposition of photoassimilates. This further promoted higher growth, fruit bud differentiation and incited precocious flowering and early harvest (Babaji, 2013). Pandey *et al*. (2001) and Bhalerao *et al*. (2009) reported similar findings in banana. Balanced nutrition received as a result of application with 100% RDF in bitter gourd contributed to better growth, development and promoted early harvest (Shree *et al*., 2018). Foliar spraying with zinc sulphate and boric acid gave minimum days to first harvesting in pomegranate cv. Sindhuri (Yadav *et al*., 2018).

5.1.2 Yield parameters

The findings obtained from the present study regarding the yield parameters of papaya are discussed below.

5.1.2.1 *Fruit weight (g)*

Treatment T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) recorded significantly highest fruit weight (797.51 g), which was on par with treatment receiving 100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax (T_5) (792.42 g) (Fig. 7). Treatments receiving optimum doses of nutrients through fertigation and different foliar sprays

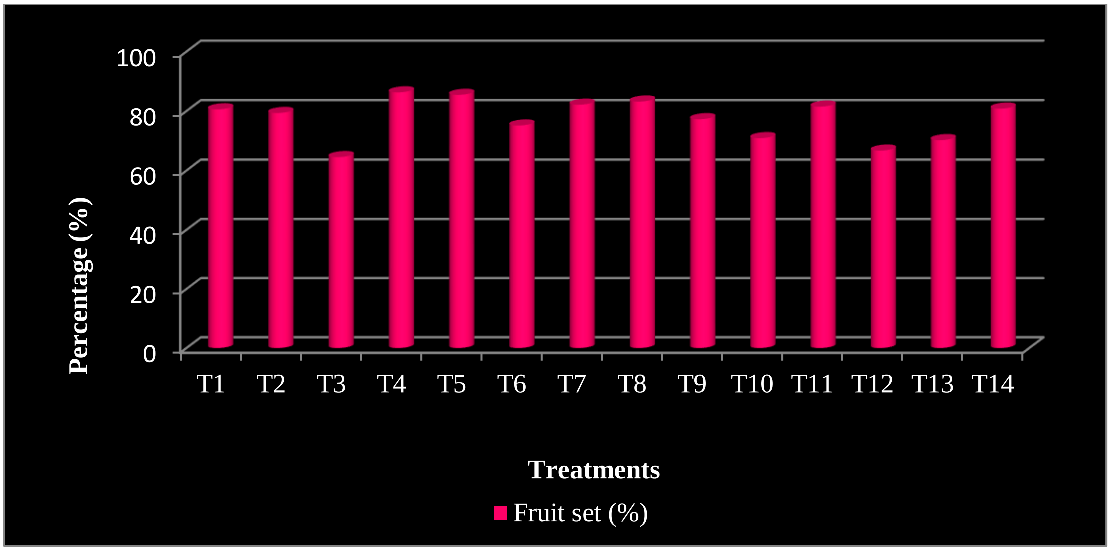


Fig. 5. Effect of fertigation and foliar sprays on fruit set (%) in papaya variety Surya

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19

T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax

T_3 - 75 % RD of N and K through fertigation and water spray

T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19

T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax

T_6 - 100 % RD of N and K through fertigation and water spray

T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19

T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax

T_9 - 125 % RD of N and K through fertigation and water spray

T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19

T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax

T_{12} - 150 % RD of N and K through fertigation and water spray

T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data

T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

were found to have highest fruit weight. According to Sharma *et al*. (2013) internal nutritive condition of plant have improved as a result of fertigation with 100 % RD of N and K, resulting in enhanced photosynthesis contributing to increased growth and vigour. Apart from this, the fertigation accelerated transportation of photosynthates from source to sink and further to fruits as influenced by the growth hormones thereby increasing the fruit weight. Fertigation with 100 % RD of N and K improved the fruit weight in papaya cv. Red Lady (Jadhav *et al*., 2016). Similar findings were put forth by Jeyakumar *et al*. (2010) and Tank *et al*. (2011) in papaya cv. Co.7 and cv. Madhu Bindu respectively.

Increase in fruit weight with foliar sprays of borax may be due to involvement of boron in hormonal metabolism, and thereby improvement in cell division and cell expansion.

Zinc plays a crucial role in facilitating formation of starch and transportation of carbohydrates in plants. Bhatt *et al*. (2012) reported a significantly highest fruit weight in mango cv. Dashehari treated with Borax 0.5%. Suganiya *et al*. (2015) reported an increased fruit weight in brinjal by foliar application of borax at 150 ppm.

Treatment T_3 (75 % RD of N and K through fertigation with water spray) registered lowest fruit weight (569.84 g) in present study, which was in agreement with the conclusions of Deshmukh and Hardaha (2014). They documented lowest fruit weight in plants receiving lower dose through fertigation in papaya cv. Taiwan 786.

5.1.2.2 ***Fruit length (cm)***

Application of 100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19 (T_4) resulted in highest fruit length (16.90 cm), which was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) (16.79 cm). The increase in fruit length upon receiving optimum doses

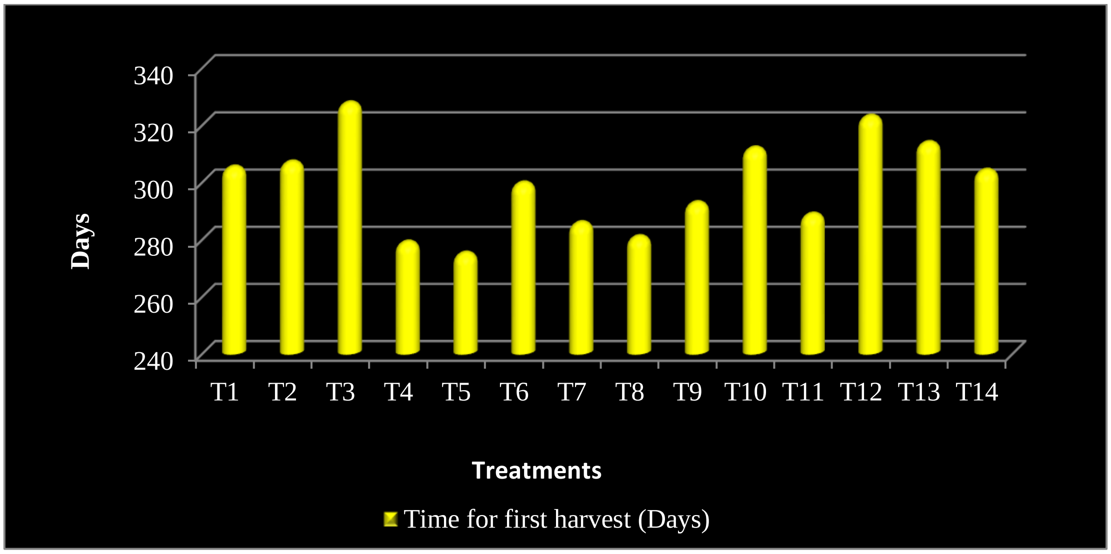


Fig. 6. Effect of fertigation and foliar sprays on time for first harvest in papaya variety Surya

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

of nutrients through fertigation inaddition to foliar spraying of 19:19:19 and $ZnSO_4$ (0.5 %) + borax (0.3 %) may be due to the incitation in the growth of flesh. Also it seems that under fertigation, uniform distribution of N and K, and its confinement to root zone might have increased its uptake and enhanced synthesis of metabolites resulting increase in fruit size. Jadhav *et al.* (2016) inferred that application of 100 % RD of N and K through fertigation was favourable for higher fruit length in papaya cv. Red Lady. A same findings was also put forth by Kaur *et al*. (2019) in cucumber.

Increase in fruit length in T_5 might be due to the function of zinc in governing the semi-permeability of cell walls, thus mobilizing more water into fruits resulted in increased fruit size. Similar findings were observed in papaya by Pant and Lavania (1989).

In the current study, lowest fruit length of 9.15 cm was observed in plants provided with 75 % RD of N and K through fertigation with water spray (T_3). The findings are in confirmity with Sharma *et al*. (2005), Singh and Singh (2006) in papaya and Thakur (2003) in mango cv. Amrapali.

5.1.2.3 *Fruit girth (cm)*

Plants receiving 100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19 (T_4) registered highest fruit girth of 13.90 cm in the present study. It was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) (13.74 cm). In papaya cv. Red Lady, application of 100 % RD of N and K through fertigation registered highest fruit girth (Jadhav *et al*., 2016). A related finding was also put forth in cucumber by Kaur *et al*. (2019). Similar result of increment in fruit girth due to combined application of zinc and boron was reported by Trivedi *et al.* (2012) in guava.

Lowest fruit girth of 7.86 cm was noticed in T_3 (75 % RD of N and K through fertigation with water spray) in present investigation. Deshmukh and Hardaha (2014)

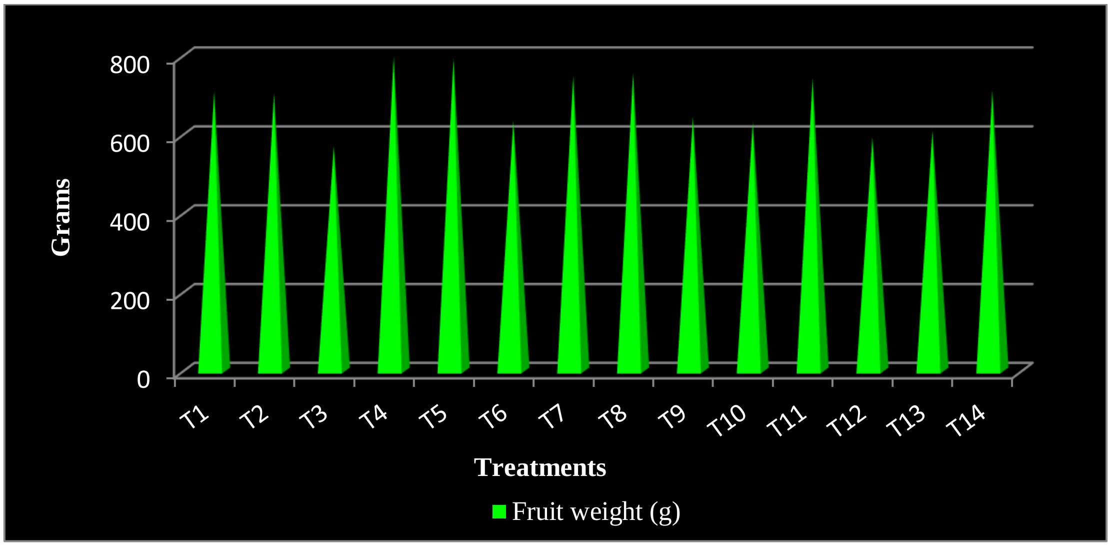


Fig. 7. Effect of fertigation and foliar sprays on fruit weight in papaya variety Surya

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data
T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

reported less fruit girth in plants receiving lower fertilizer dose in papaya cv. Taiwan 786. Goud *et al*. (2017) also registered similar conclusions in Nagpur mandarin.

5.1.2.4 *Fruit volume (cc)*

Significant variation in fruit volume was observed among different treatments. Among the 14 treatments, highest fruit volume of 751.76 cc was registered in T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19), which was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) (744.58 cc). The increase in fruit volume in T_4 and T_5 could be ascribed to bigger size of fruits on application of optimum dose of fertilizer through fertigation and foliar sprays of 19:19:19 (1.0 %) and $ZnSO_4$ (0.5 %) + borax (0.3 %).

Increased fruit volume in guava cv. Bhavnagar Red due to application of zinc (0.6%) as foliar spray was reported by Parmar *et al*. (2014). Related conclusions were also documented by Haque *et al*. (2000) in Mandarin orange. Also, this may be due to role of boron in cell division, cell expansion and heightened volume of intercellular space in mesocarpic cells which might have increased the fruit volume. Shreekant *et al*. (2017) reported the role of boron in increasing the fruit volume in guava cv. L-49.

In the present study, plants receiving 75 % RD of N and K through fertigation with water spray (T_3) registered lowest fruit volume of 501.91 cc. The lowest fruit volume in T_3 could be ascribed to smaller size of fruits obtained from treatment receiving lower fertilizer dose through fertigation. Valji (2011) supported the findings of present study in papaya var. Madhu Bindu.

5.1.2.5 *Physical composition (%)*

Physical composition of papaya fruits differed significantly (Fig. 8) among treatments. Highest pulp percentage (83.53 %) was observed in 100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19 (T_4). It was on par with T_5

(100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) with 82.85 % pulp. Minimum pulp percentage (64.02 %) was observed in T_3 (75 % RD of N and K through fertigation with water spray). Thakur (2003) also reported maximum pulp weight upon application of 100 % RDF through fertigation in mango cv. Amrapali.

The weight of fruit pulp in T_5 increased with the foliar sprays of zinc and boron in addition to application of 100 % RD of N and K through fertigation. The findings are in accordance with reports of Pandita (2000), who opined that foliar sprays of zinc (0.3 %) and boron (0.3 %) resulted in highest pulp weight (116.06 g) over control (70.22 g) in guava cv. Allahabad Safeda. Das and Bhattacharyya (2019) opined that pulp weight was influenced by the application of micronutrients in banana cv. Grand Naine. It indicates that both the micronutrients are very effective in producing more pulp either by more translocation of photosynthates (Sistler *et al*., 1956), or by increasing the photosynthesis and uptake of nutrients by roots (Humble *et al*., 1970) or by synthesis of more auxin through tryptophan (Nason and Mcelroy, 1963). Ningavva *et al.* (2014) studied foliar nutrition of micronutrients boron and zinc in banana cv. Grand Nain and reported improved quality of fruits with regard to higher pulp content which was attributed mainly to the role of micronutrients in rapid synthesis of carbohydrates and their translocation to fruits.

Seed percentage in this study ranged from 9.10 to 24.79 per cent and it exhibited significant difference among treatments. Lowest seed percentage was registered in T_5. It was on par with T_4 and T_8 (125 % RD of N and K through fertigation in combination with foliar spraying of $ZnSO_4$ (0.5 %) + borax (0.3 %)) with 9.24 and 9.38 % seed respectively. T_3 recorded highest seed percentage. This was in accordance with the findings of Yadaw (2017) who revealed a significantly minimum seed weight upon foliar spray with micronutrients zinc sulphate and borax in papaya cv. Red Lady. Hada (2013) also observed similar results in guava cv. L-49.

Minimum stone weight in mango cv. Amrapali was reported by Thakur (2003) upon receiving 100 % RDF.

Application of different levels of fertigation and different foliar sprays exhibited significant differences in peel percentage. T_4 registered least peel percentage (7.23 %), which was on par with T_5 with 8.05 % peel. Highest peel percentage of 11.98 was registered in T_{12} (150 % RD of N and K through fertigation with water spray). The results are in good agreement with the findings of Pathak *et al*. (2011) in banana upon foliar application of micronutrients.

Application of optimum dose of nutrients contributed to the highest pulp/ peel ratio (11.55) in T_4, which was followed by T_5 (10.29), whereas it was lowest in T_{12} (5.40). Raskar (2003) documented highest pulp/ peel ratio in banana fertigated with 100% RDN. Das and and Bhattacharyya (2019) reported that fruit qualities like pulp/ peel ratio is significantly influenced by application of micronutrients along with fertigation in banana cv. Grand Naine.

5.1.2.6 *Flesh thickness (cm)*

Present study revealed significant variation on flesh thickness of papaya fruit upon application of different levels of fertigation and different foliar sprays. Highest flesh thickness (3.42 cm) was observed in T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19), which was on par with T_5 receiving 100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax (3.39 cm). Treatment receiving 75 % RD of N and K through fertigation with water spray (T_3) registered lowest flesh thickness (1.55 cm).

Highest flesh thickness observed in T_4 and T_5 may be due to the efficient and timely usage of optimum dose of nutrients through fertigation and foliar sprays of 19:19:19 (1.0 %) and $ZnSO_4$ (0.5 %) + borax (0.3 %). According to Jadhav *et al*. (2016) fertigation with 100 % RD of N and K registered highest flesh thickness in fruits of papaya cv. Red Lady. Rapid synthesis of carbohydrates and their translocation to the Banana cv. Grand Naine as a result of foliar application of zinc and boron was reported by Ningavva *et al*. (2014), which might have caused relatively higher flesh thickness in T_5. Hada (2013) reported highest flesh thickness in guava cv. L-49 fruit on spraying with $ZnSO_4$ (0.8%) and borax (0.4%).

5.1.2.7 *Number of fruits per plant*

T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) registered highest number of fruits (48.11) in papaya (Fig. 9). It was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) with 47.45 fruits. Efficient and timely use of optimum quantity of nutrients through fertigation and foliar sprays might have contributed to the highest number of fruits registered in T_4 and T_5. Similar results of increment in number of fruits on supply of 100 % RD of N and K was reported by Tank and Patel (2013) and Jadhav *et al*. (2016) in papaya cv. Madhu Bindu and Red Lady respectively.

This was in confirmity with reports of Khan *et al*. (2012) which registered highest number of fruits per tree in mandarin cv. Feutrell's Early on foliar sprays with boron and zinc. Gurjar *et al*. (2015) also reported similar results in mango cv. Alphonso treated with borax (0.5%) and $ZnSO_4$ (1%) compared to plants which received water spray. Decrease in the fruit drop achieved as a result of micronutrient spray with borax and $ZnSO_4$ might have increased the fruit number. Nijjar (1985) elucidated the role of zinc in preventing the formation of abscission layer and reducing the pre-harvest fruit drop. According to Whiley *et al*. (1996) foliar application of micronutrients in avocado during flowering increased the number of fruits.

Edward (2009) opined that zinc stabilizes membrane permeability and boron increases photosynthesis and provides carbohydrates for calcium uptake which ultimately increase the number of fruits.

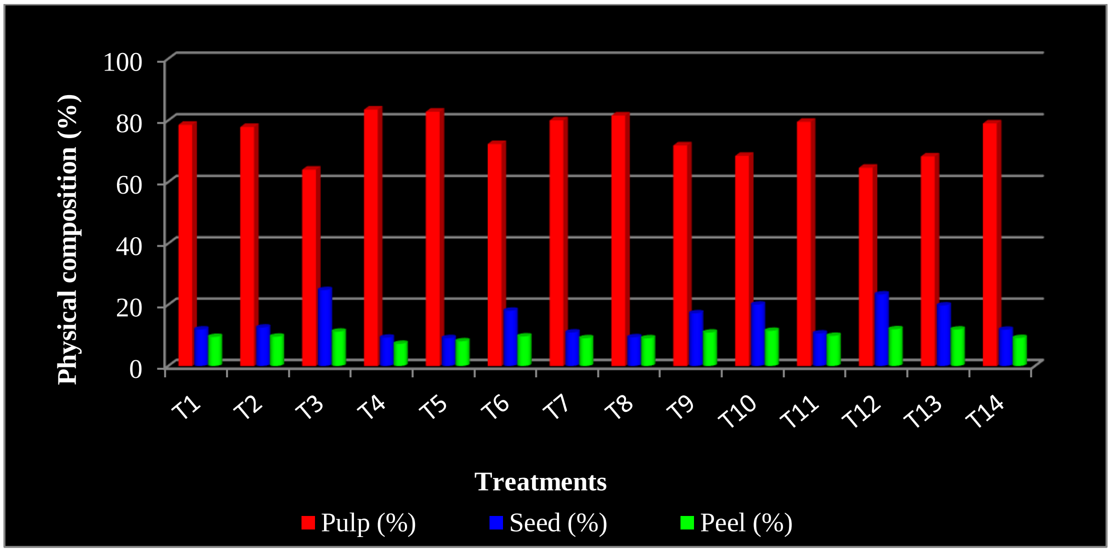


Fig. 8. Effect of fertigation and foliar sprays on physical composition (%) of papaya variety Surya

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

T_3 (75 % RD of N and K through fertigation with water spray) registered lowest number of fruits per plant (28.45) in the present investigation. Deshmukh and Hardaha (2014) reported less number of fruits in plants receiving lower fertilizer dose in papaya cv. Taiwan 786.

5.1.2.8 ***Number of seeds per fruit***

Number of seeds per fruit was found to be significantly different among treatments. T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) registered least number of seeds (383.00). It was followed by T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) with 407.13 seeds. Highest number of seeds per fruit (829.69) was registered in T_3 (75 % RD of N and K through fertigation with water spray). Singh *et al*. (2018) reported that foliar application of 0.5% zinc and 0.3% boron significantly reduced the number of seeds in sweet orange cv. Mosambi. The reduction of seed content of papaya fruits as the result of supply of boron was also documented by Shanmugavelu *et al*. (1973). According to Khan *et al*. (2012) spraying of mandarin cv. Feutrell's Early with 0.5% zinc sulphate reduced the number of seeds. Hada (2013) also observed reduced number of seeds in guava sprayed with $ZnSO_4$ and borax.

5.1.2.9 ***Seed germination percentage***

Significant variation in seed germination percentage was observed among different treatments. T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) registered highest seed germination percentage (87.78 %), which was followed by T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) and T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) with 84.67 % and 82.89 % respectively. Lowest seed germination percentage of 67.78 was reported in T_3 (75 % RD of N and K through fertigation with water spray). In tomato, highest germination percentage upon foliar spray with boron was reported by Santhosh, (2012).

5.1.2.10 *Yield per plant (kg)*

Significant difference in yield per plant was reported among treatments in the present investigation. T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) recorded highest yield (38.30 kg plant^{-1}). It was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) with 37.60 kg plant^{-1} (Fig. 10).

Higher yield per plant obtained in treatments T_4 and T_5 might be due to supply of optimum dose of fertilizers through fertigation (100 % RD of N and K) in addition to foliar spray with 19:19:19 and $ZnSO_4$ + borax, leading to more preferential inflow of photosynthates to the sink leading to increased fruit weight. Precise and timely supply of fertilizers through fertigation reduces nutrient loss and increases the nutrient use efficiency which contributes to high yied (Kumar *et al*., 2007).

According to Gutal *et al*. (2005), fertigation significantly improved the yield of strawberry compared to soil application of fertilizers. Raina *et al*. (2005) also noticed appreciably improved apricot fruit yield under fertigation trial over conventional soil fertilization. Higher yield obtained upon application of fertilizers through an irrigation system by the use of drippers, as a result of increased fertilizer use efficiency, reduced fertilizer application dosages and enhanced return on the fertilizer invested was reported by Hagin *et al*. (2002). Bravdo and Proebsting (1993) pointed that application of optimum quantity of fertilizing solutions and higher root density in the wetted soil volume as the potential factors on which effectiveness of fertigation depends upon.

Shimi (2014) reported that foliar sprays of 19:19:19 at 2, 4 and 6 MAP significantly enhanced the number of hands in banana cv. Nendran.

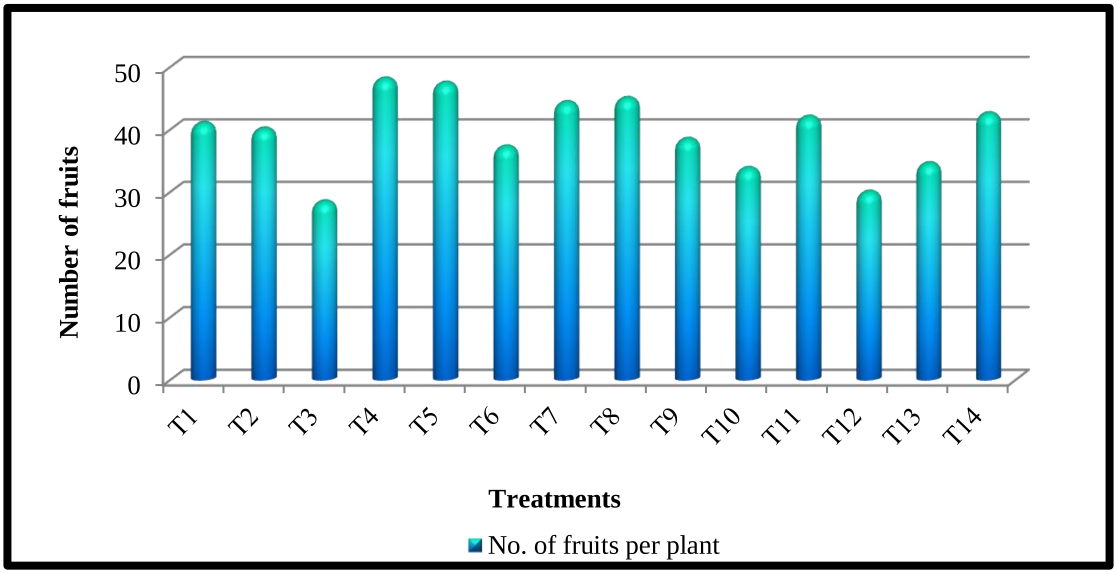


Fig. 9. Effect of fertigation and foliar sprays on number of fruits per plant of papaya variety Surya

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

These observations are in concordance with the work of Kavitha *et al*. (2000). They documented that in papaya cv. CO.5, foliar application of 0.1% boric acid and 0.5% zinc sulphate at 4th and 8th month after planting increased the yield. Role of zinc in regulating the semi-permeability of cell walls helps mobilize more water into fruits resulting in increased fruit size, thereby enhancing fruit yield. According to Sahota and Arora (1981), foliar application of zinc in sweet orange increased the fruit yield by enhancing the fruit weight.

Mansour *et al*. (1985) reported increased fruit set, reduced pre-harvest fruit drop and increased yield in guava trees upon foliar spray with 1.0 % zinc sulphate applied at full bloom stage. Garcia *et al*. (1984) documented that enhanced flowering and minimal fruit drop in sweet orange as a result of increased leaf zinc concentration contributed to higher fruit yield. Also boron application might have uplifted the movement of metabolites from source (leaf) to sink (fruit) and promoted the accumulation of dry matter within the fruits, resulting into higher yield. Usenik and Stampar (2002) reported higher yield in zinc + boron treated trees of sweet cherry.

The present study noticed lowest yield (16.21 kg plant^{-1}) in T_3 (75 % RD of N and K through fertigation with water spray) which obtained lowest nutrient dose. Deshmukh and Hardaha (2014) also reported lowest yield in plants receiving lower fertilizer dose in papaya cv. Taiwan 786. In banana cv. Grand Naine, Mane *et al.* (2016) reported similar findings.

5.1.2.11 *Yield ha^{-1}*

Highest yield per hectare (95.76 t ha^{-1}) was recorded in T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19), which was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) with an yield of 93.99 t ha^{-1}. Lowest yield per hectare (40.52 t ha^{-1})

was noticed in T_3 receiving 75 % RD of N and K through fertigation with water spray.

Optimum nutrient concentration in the root zone maintained throughout the crop growth period by supply of optimum dose of nutrients through fertigation enhanced the fruit yield in T_4 and T_5 by way of increasing weight, diameter and length of fruit. Also, these increase in yield can be justified by the fact that timely application of judicious amounts of nutrients directly to the crop root zone by fertigation improved the nutrient use efficiency of crops and reduced the N and K losses through leaching and percolation (Rolston *et al*., 1986; Mahalakshmi *et al*., 2001; Kavino *et al*., 2002). Growth attributes of plants witnessed an increasing trend with fertigation due to enhanced uptake of moisture and nutrients which increases the photosynthetic rate and absorption of photosynthetically active radiation. It will further leads to translocation of photosynthates towards reproductive organ (sink) which results in increased yield of plant (Kaur *et al*., 2019). Also, the cumulative effect of fertigation with optimum dose and foliar sprays of 19:19:19 and zinc sulphate with borax might have helped to increase the fruit size and fruit weight and thereby increase in fruit yield. Lesser availability of nutrients might have contributed to the low yield in T_3.

5.1.2.12 *Days taken for maturity*

The results of present study revealed significant difference in days taken for maturity among treatments. Least number of days for fruit maturity (119.44 days) was noticed in T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) (Fig. 11). Treatments T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax), T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) and T_7 (125 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) which reported

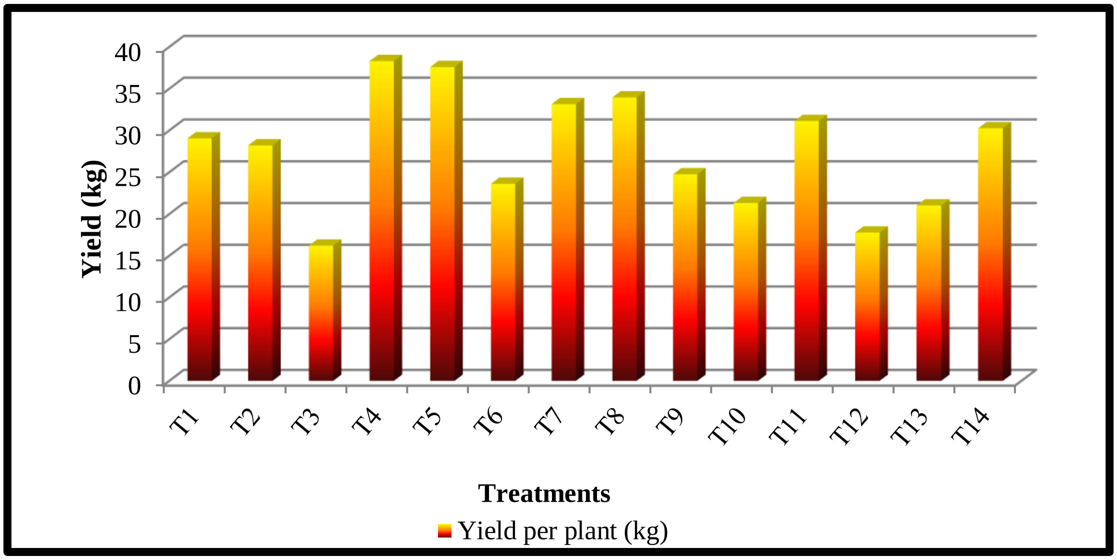


Fig. 10. Effect of fertigation and foliar sprays on yield per plant (kg) of papaya variety Surya

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data
T_{14} - Soil application of 187:170:341 g NPK $plant^{-1}$ $year^{-1}$ based on soil test data as organic manures

120.22 days, 120.33 days and 122.33 days respectively for fruit maturity were on par. Plants receiving 75 % RD of N and K through fertigation with water spray (T_3) recorded maximum days (132.33 days) for attaining fruit maturity.

Tank *et al*. (2011) reported minimum days for attaining fruit maturity after flowering in papaya cv. Madhu Bindu receiving 100 per cent RDF through fertigation. The findings of current study are in concordance with those of Sharma *et al*. (2005) and Sadarunnisa *et al*. (2010) in papaya. Kolesnik and Cerevitinov (1966) reported that spray of zinc sulphate during flowering and again in August not only increased the enzymatic activity but promotes early maturity in apple. Mane *et al.* (2016) noticed maximum days for attaining fruit maturity after flowering in plants receiving lower fertilizer dose in banana cv. Grand Naine.

5.1.2.13 *Days taken for ripening*

Significant difference in days taken for fruit ripening was noticed among treatments in the present study. Significantly highest days to ripening of fruits (10.44 days) was reported in T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax). It was followed by treatments T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax), T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) and T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax), which was on par. Minimum days for fruit ripening (6.11 days) was observed in treatment T_3 which received 75% RD of N and K through fertigation with water spray. Optimum nutrients available throughout the plant growth and fruiting period in T_5 might have increased the membrane resistance to bio-chemical changes (Bhatt *et al.*, 2012) and leads to maximum days for fruit ripening, but the insufficient availability of nutrients might have caused rapid ripening of fruits in T_3. Thirupathaiah *et al*. (2017) reported maximum number of days to ripening in sapota cv. Kalipatti sprayed with $ZnSO_4$ and borax.

5.1.3 Fruit quality parameters

Fertilizer application through fertigation improves water and nutrient availability in soil and therefore, it is readily available to trees and facilitates positive effects on several aspects of fruit quality (Nirgude *et al*., 2018).

5.1.3.1 ***Total soluble solids (°Brix)***

Significant difference in TSS of fruits was observed among the treatments in the present study. T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) recorded highest TSS (15.10°Brix). It was on par with T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) with a TSS of 14.90°Brix. Treatment T_3 (75 % RD of N and K through fertigation with water spray) registered lowest TSS (12.50°Brix).

Maximum TSS in Kinnow mandarin upon treatment with 100 % NPK as fertigation was reported by Grace (2011). Trivedi *et al*. (2012) reported highest TSS in guava (*Psidium guajava* L.) applied with 0.5 % boric acid and 0.6 % zinc sulphate. Similar findings of higher TSS content due to foliar application of boron and zinc have also been reported by Kavitha *et al.* (2000), Singh *et al*. (2010) in papaya and Singh and Kaur (2016) in litchi cv. Dehradun.

Efficient translocation of photosynthates from source to the fruit by regulation of boron might have contributed to the higher total soluble solids in T_5 and T_8. Marschner (1995) documented that boron facilitates sugar transport within the plant. Sugar-borate complex can more easily transverse the membrane (Singh *et al*., 2009). Since boron helps in the trans-membrane sugar transport, this may be the cause of TSS improvement (Gauch and Dugger, 1953). Also increase in TSS content with the micronutrient spray may be associated with the quick metabolic transformation of starch and pectin into soluble compounds and rapid translocation of sugars from leaves to developing fruits (Brahmachari and Rani, 2001).

5.1.3.2 ***Acidity (%)***

The present study revealed significant difference in acidity of fruits upon application of different levels of fertigation and foliar sprays. Fruits from treatment T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) recorded lowest titratable acidity (0.13 %), whereas T_3 (75 % RD of N and K through fertigation with water spray) registered highest titratable acidity (0.28 %).

Abedy (2001) reported that zinc has an important role in photosynthesis and enzyme activation, resulting in increasing sugar and decreasing acidity. Earliness in ripening achieved due to borax treatment leads to degradation of acid and aided in preventing polymerization of sugar and accumulation of more sugar in the cells of fruits (Hada, 2013). Similar findings of reduced acidity in papaya upon foliar sprays of boron and zinc with other nutrients was reported by Singh *et al*. (2010). Similar observations were also documented by Patel *et al*. (2010) in banana cv. Basrai and Yadav *et al*. (2018) in pomegranate cv. Sindhuri. Rashmi and Singh (2007) found that foliar spray of boron on mango trees cv. Langra reduced the titratable acidity of fruit.

5.1.3.3 ***Total carotenoids (mg100g^{-1})***

Significant difference in total carotenoid content of fruits was observed among treatments in the present study. Treatments receiving balanced nutrition inclusive of major and micro nutrients (T_5 - (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) recorded highest total carotenoid content (2.21 mg 100g^{-1}), whereas plants receiving lower dose of nutrients ie., 75 % RD of N and K through fertigation with water spray (T_3) registered lowest total carotenoid content (1.46 mg 100g^{-1}). Foliar spray with boric acid 0.02 per cent significantly increased the carotenoids content in mango when compared to control (Sankar *et al*., 2013). Nirgude *et al*. (2016) documented that carotenoid contents were

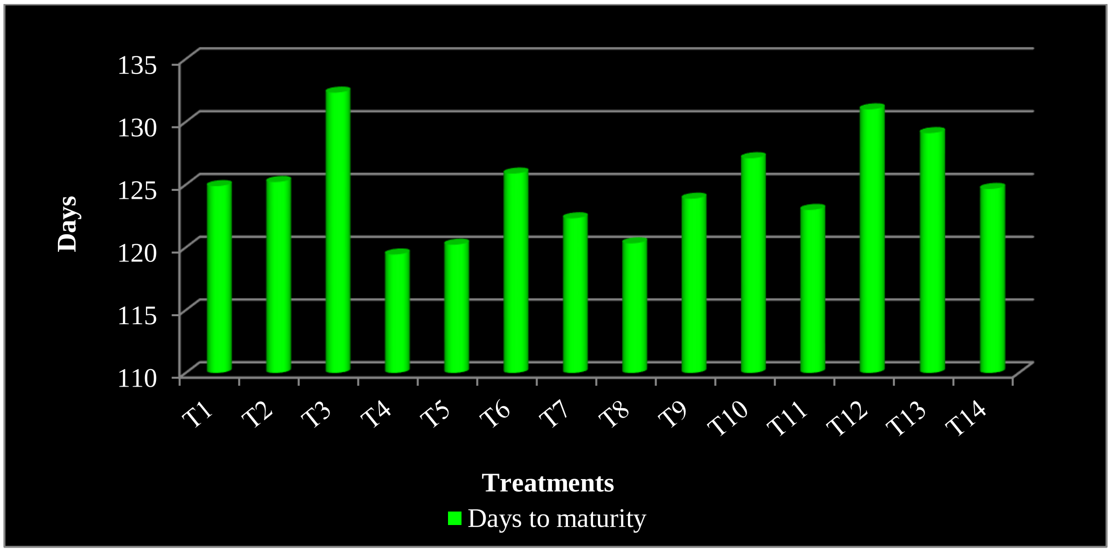


Fig. 11. Effect of fertigation and foliar sprays on days for fruit maturity in papaya variety Surya

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data
T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

found to be decreased in the treatments with higher doses of fertigation in *Citrus sinensis* cv. Mosambi; this might be because of the fact that higher potassium levels results in fruits with poor carotenoids.

5.1.3.4 *Ascorbic acid (mg 100g^{-1})*

Ascorbic acid content of papaya fruits showed significant difference among treatments. T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) recorded highest ascorbic acid content of 68.38 mg 100g^{-1}. It was found to be on par with T_8 which received 125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax (67.69 mg 100g^{-1}). T_3 (75 % RD of N and K through fertigation with water spray) recorded lowest ascorbic acid content (43.42 mg 100g^{-1}).

Application of optimum levels of nitrogen might have enhanced the synthesis and catalytic activity of several enzymes and co-enzymes which are required for ascorbic acid synthesis (Boora and Devi, 2000), which have contributed to the higher ascorbic acid content in T_5. Fertigation with 100 % RD of N and K significantly enhanced the ascorbic acid content in papaya (Jeyakumar *et al*., 2010).

The positive influence of zinc and boron sprays on ascorbic acid content may be due to efficient synthesis and translocation of vitamin C content to the developing fruits. Apart from this zinc plays a crucial role in the production of auxin in plant species (Alloway, 2008), and according to Nakhlla (1998) in Navel orange and Nawaz *et al*. (2008) in Kinnow mandarin the ascorbic acid content increases with production of auxin.

Higher synthesis of nucleic acid by virtue of plant metabolism on application of 0.6 per cent $ZnSO_4$ with 0.5 per cent boric acid contributed to the augmented synthesis of ascorbic acid in guava fruit (Trivedi *et al*., 2012). The role of $ZnSO_4$ and borax in improving the ascorbic acid content have also been elucidated by Singh and Chhonkar (1983), Wahid *et al*. (1991) in guava, and Rai *et al*. (1988) in orange.

5.1.3.5 *Total sugar (%)*

Plants receiving 100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax (T_5) recorded highest total sugar content (9.66 %) which may be due to receival of well balanced nutrition inclusive of major and micro nutrients. However, T_3 (75 % RD of N and K through fertigation with water spray) which received lower dose of nutrients performed inferiorly with lowest total sugar content of 7.15 %. Nutrition has a significant positive role on plant physiological mechanisms related to quality especially activation of many important enzymes aiding in accumulation and translocation of sugars (Malvi, 2011). Absorption of optimum quantity of nitrogen from 100 % RD of N and K through drip might have exerted a regulatory role in affecting the fruit quality, contributing to higher sugar content of fruits. 100 % RD of N and K through drip irrigation registered higher total sugar content in papaya (Jeyakumar *et al*., 2010).

The increase in sugar content in T_5 and T_8 could be due to enhanced sugar movement from leaves to developing fruits by boron. Dugger (1983) and Singh *et al*. (2009) explained the mechanism of such rapid translocation of sugar under boron application. Sugar-borate complex formed by the reaction of borate with sugar can more easily transported within the plant (able to transverse membrane). Findings are in agreement with the documents of Babu and Yadav (2005) who reported that application of zinc and boron increased the total sugar percentage in Khasi mandarin. Bauri *et al*. (2014) also documented maximum total sugar in banana cv. Martaman on application with borax (0.1 %).

5.1.3.6 *Reducing sugar (%)*

Reducing sugar content of papaya fruits registered significant difference among the treatments under study. Highest reducing sugar content (8.05 %) was noticed in T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax), which was on par with T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) (7.98 %). However, T_3 (75 % RD of N and K through fertigation with water spray) registered lowest reducing sugar content (5.97 %) in fruits.

Highest reducing sugar content in T_5 may be due to role of zinc in improving the auxin content and it also acts as a catalyst in oxidation reduction processes in plants. Zinc also aids in other enzymatic reaction like transformation of carbohydrates, activity of hexokinase and formation of cellulose and change in sugar. Also the highest reducing sugar content in T_5 and T_8 might be due to the role of micronutrient in photosynthetic processes, translocation of photosynthates and other metabolic and physiological processes in the plant (Das and Bhattacharyya, 2019). Kumari and Deb (2018b) documented that foliar sprays of borax (0.5 %) and $ZnSO_4$ (0.5 %) significantly influenced the reducing sugar content of pineapple cv. Mauritius. Sankar *et al*. (2013) also reported maximum reducing sugar in mango cv. Alphonso on application with borax (0.02 %). Thakur and Singh (2004) registered highest reducing sugar in mango, supplied with 100 % RD of N and K applied through drip irrigation.

5.1.3.7 *Non reducing sugar (%)*

Present study revealed significant variation on non reducing sugar content of papaya fruit upon application of different levels of fertigation and foliar sprays. Highest non reducing sugar content (1.61 %) was observed in T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax). However, plants receiving 150 % RD of N and K through fertigation with water spray (T_{12}) registered lowest non reducing sugar content (1.12 %).

In guava cv. Apple Colour foliar spray with zinc sulphate significantly influenced the non reducing sugar (Rajesh *et al*., 2016). Sankar *et al*. (2013) also reported maximum non reducing sugar in mango cv. Alphonso on application with borax (0.02 %).

5.1.3.8 *Shelf life (days)*

Longest shelf life of 5.78 days was recorded in fruits from T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) (Fig. 12), which was on par with T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) (5.22 days). In addition to foliar sprays with zinc and boron, application of nutrients and water through fertigation in a sustainable manner and their optimum utilisation by the papaya plants contributed to the increased shelf life of fruits. The findings are in confirmity with Raja (2010) and Shekhar *et al*. (2010) in papaya. Improvement in post harvest shelf life of pointed gourd upon application with 100 % RDF through fertigation was documented by Nayak *et al*. (2018).

Chaturvedi *et al.* (2005) opined that foliar spraying with 0.6% zinc sulphate bestowed the maximum shelf life in strawberry cv. Chandler. Raja (2010) reported that boron nutrition had significant influence on post harvest life of papaya, because of its role in calcium mobility and cell wall formation. Also, the probable reason for increase in shelf life might be due to increase in concentration of boron in middle lamella of cell wall which provides physical strength to cell wall (Singh *et al*. 2017). Shear (1980) opined that the reduction in total nitrogen in fruit due to boron nutrition is also another reason for better shelf life since nitrogen is known to increase respiration and reduce post harvest life.

In the present study shortest shelf life of 3.78 days was observed in fruits from T_3 (75 % RD of N and K through fertigation with water spray).

5.1.3.9 *Sugar/ acid ratio*

Highest sugar/ acid ratio (74.31) reported in T_5 may be due to an increase in sugar content at ripening stage with lower acidity of papaya fruits. Haneef *et al*. (2014) noticed a higher sugar/ acid ratio on fertigation with 100 % RD in pomegranate cv. Bhagwa. Trivedi *et al*. (2012) documented increased sugar/ acid ratio in guava fruits on foliar spraying with micronutrients zinc and boron. Similar findings were also reported by Singh *et al*. (2010) in papaya cv. Ranchi.

In present study, least sugar/ acid ratio of 25.54 was noticed in T_3. Nirgude *et al*. (2016) reported least sugar/ acid ratio in treatments receiving lowest dose of fertigation in *Citrus sinensis* cv. Mosambi.

5.1.3.10 *Organoleptic evaluation (nine point hedonic scale)*

Apart from the supply of major nutrients in optimum quantities, foliar spray of micronutrients have positive impact on organoleptic qualities of papaya fruits. The mean rank scores for appearance, colour , flavour, texture, odour, taste, after taste and overall acceptability were highest for fruits obtained from T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) with highest total score of 64.55. Sugar/ acid ratio in T_5 was found to be highest among different treatments which might have contributed to this better organoleptic score. Haneef *et al*. (2014) observed highest organoleptic rating in pomegranate cv. Bhagwa supplemented with 100 per cent fertilizer through drip. Paul and Nair (2015) reported the efficiency of foliar spray with micronutrients on improving the sweetness and overall acceptability of banana cv. Nendran. Bhoyar and Ramdevputra (2016) also reported that foliar sparys of micronutrients zinc, iron and boron on guava cv. Sardar

L-49 enhanced the sensory parameters of fruits. Thirupathaiah *et al*. (2017) also witnessed similar findings in sapota cv. Kalipatti.

In the present study least total score of 53.93 was recorded in fruits obtained from T_3 (75 % RD of N and K through fertigation with water spray).

5.1.4 Index leaf analysis for primary, secondary and Micronutrients (B and Zn)

Plant analysis for leaf nitrogen content done at 6 MAP indicated significant difference between treatments which ranged from 1.18 per cent to 2.29 per cent. Highest percentage of leaf nitrogen was observed in T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19), which was followed by T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) and T_{12} (150 % RD of N and K through fertigation with water spray). Lowest leaf nitrogen content was noticed in T_3 (75 % RD of N and K through fertigation with water spray), which was followed by T_{13} (KAU POP - control 1). According to Smith, (2001) nitrogen losses in the soil tree system by way of ammonia volatilization and nitrate leaching can be reduced by delivering nitrogen through fertigation, which has contributed to highest leaf nitrogen content in treatments T_{10}, T_{11} and T_{12}. Also application of higher dose (150 % RD) of N through fertigation may have contributed to this. Similar results were put forth by Wold and Opstad (2007) in strawberry wherein, higher leaf nitrogen was recorded in treatment receiving higher dose of nitrogen fertilizer through fertigation. The application of nitrogen in one time or in bulk is likely to convert into nitrate which being highly mobile, has tendency to move to the periphery of the water front and remain unavailable to the tree (Haynes, 1985), which might have contributed to the reduced leaf nitrogen content in T_{13} (KAU POP - control 1). Jeyakumar *et al*. (2010) also observed similar findings in papaya cv. Co.7.

Considering the nature of precipitation and clogging in drippers, phosphorus was applied directly into soil as basal dose and statistical analysis of phosphorus content of leaf petiole did not register any significant difference between treatments. Similar reports were observed by Jeyakumar *et al*. (2010) in papaya cv. Co.7 and Babaji (2013) in papaya cv. Red Lady.

Plant petiole analysis done at 6 MAP revealed significant variation in leaf potassium content. Highest leaf potassium content (2.99 %) was noticed in T_{10}, which was followed by T_{12} and T_{11} (Table 18). Whereas, lowest leaf potassium content (1.98 %) was noticed in T_3, which was followed by T_{13} (KAU POP - control 1). Better diffusion of potassium achieved under optimum moisture conditions leads to higher K concentration in leaf petioles (Balasubramanian and Rao, 1984). Also, application of higher dose (150 % RD) of K through fertigation may have contributed to the increased potassium content in leaves. In strawberry plants, higher leaf potassium was recorded in treatments supplied with higher dose of potassium fertilizer through fertigation (Wold and Opstad, 2007). In papaya cv. Red Lady, Babaji (2013) documented similar findings.

Increased availability of N and K in soil, in addition to regular and optimum supply of water near root zone area through drip might be resulted in better absorption of these nutrients by papaya plants which might be reflected as increased content of N and K in leaves. Intermitent application of nutrients through drip system in fertigation improved the nutrients uptake in plants (Sathya *et al*., 2008). It is achieved because of the continuous replenishment of nutrients in the depletion zone at the vicinity of root interface and by enhanced transport of dissolved nutrients by mass flow, due to the higher water content in the medium. Leaching loss and fixation in the soil might have reduced availability of nutrients to plants in treatments receiving full dose of N, P and K through conventional method, resulting in low N, P and K content in the leaves of papaya.

Calcium content of papaya petiole observed at 6 MAP revealed significant difference among treatments. Highest calcium content (0.57 %) was registered in T_5,

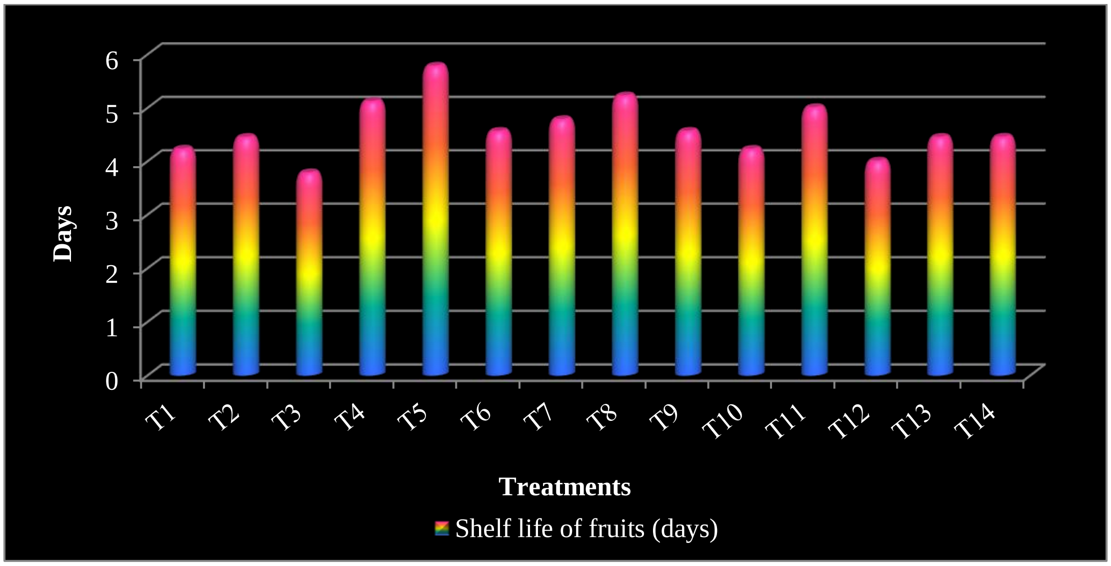


Fig. 12. Effect of fertigation and foliar sprays on shelf life (days) of papaya fruits variety Surya

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data
T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

which was followed by T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) and T_4. Lowest calcium content of 0.16 % was noticed in T_3. Synergetic relationship between calcium and zinc might have contributed to the increased leaf calcium content in treatment receiving foliar spray with zinc. Razzaq *et al*. (2013) reported that foliar sprays with zinc sulphate increased leaf calcium content in Kinnow mandarin. Similar findings were put forth by Samra (1985) in Balady mandarin.

Present study revealed significant variation on magnesium content of leaf petiole between treatments at 6 MAP. Highest magnesium content (0.29 %) was noticed in T_5, which was followed by T_8 and T_4. T_3 recorded lowest magnesium content (0.08 %). Kachwaya and Chandel (2015) observed highest leaf magnesium content in drip fertigated strawberry (cv. Chandler) plants with RD of N and K.

Sulphur content of leaf petiole estimated at 6 MAP revealed significant variation among treatments. T_5 registered highest sulphur content (0.33 %), which was followed by T_8 and T_4. However, lowest sulphur content (0.12 %) was noticed in T_3.

In the present study, zinc content of papaya petiole registered significant variation among treatments. Leaf zinc content ranged from 14.97 ppm to 32.00 ppm at 6 MAP. Highest zinc content was noticed in treatment T_8, which was followed by T_5, T_{11} and T_2 (75 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax). However, T_3 recorded lowest zinc content. According to Davarpanah *et al*. (2016) tree nutrient status in pomegranate was improved due to application of zinc and boron which resulted in increased leaf concentrations of both microelements. Nijjar *et al.* (1976) registered a higher zinc concentration in leaves of mango supplied with 0.2% zinc sulphate as foliar spray. Bahadur *et al*. (1998) also reported significantly higher concentration of zinc in leaf tissue of mango, foliar sprayed with zinc sulphate.

Plant petiole analysis for boron done at 6 MAP revealed significant variation among treatments. Boron content ranged from 17.92 ppm to 38.93 ppm. T_8 registered highest boron content. It was followed by T_5, T_{11} and T_2. T_3 registered lowest boron content in leaf petiole. In 1999, Maurer and Taylor reported that boron sprays increased the leaf boron concentration in navel orange. A similar result was also put forth by Raja (2010) in papaya cv. Surya and Khan *et al*. (2012) in mandarin cv. Feutrell's Early.

5.1.5 Pest and diseases incidence (%)

Pest and disease incidence did not show any variation due to different treatments.

5.1.6 Nutrient (N, P, K) concentration studies of fruits at peak harvest stage

Nitrogen content of fruit estimated at peak harvest stage (16 MAP) revealed significant difference among treatments. Fruit nitrogen content ranges from 1.19 per cent to 1.89 per cent. Highest fruit nitrogen content was noticed in T_{12} (150 % RD of N and K through fertigation with water spray). It was followed by T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) and T_9 (125 % RD of N and K through fertigation with water spray). Lowest fruit nitrogen content was reported in T_3 receiving 75 % RD of N and K through fertigation with water spray. Nikzad *et al*. (2020) reported that total uptake of nitrogen by cabbage curds increased with increasing fertilizer doses through fertigation.

Phosphorus content of fruits estimated at peak harvest stage (16 MAP) revealed no significant variation among treatments.

Statistical analysis of fruit potassium content estimated at peak harvest stage (16 MAP) revealed significant variation among treatments. T_{12} registered highest fruit potassium content (2.45 %). It was followed by T_{10}. Lowest fruit potassium content (1.33 %) was recorded in fruits obtained from T_3.

5.1.7 Soil analysis (available N, P, K) after the experiment

The statistical analysis of soil nitrogen content estimated after the experiment revealed significant variation among treatments. Soil nitrogen content ranged from 179.32 kg ha^{-1} to 243.13 kg ha^{-1}. Highest soil nitrogen content was observed in field receiving 150 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax (T_{11}), which was found to be on par with T_{12} (150 % RD of N and K through fertigation with water spray). Lowest soil nitrogen content was observed in T_{13} (KAU POP - control 1). Available nitrogen and potassium content of soil showed increasing trend with increasing fertilizer doses. The increased available nitrogen in soil with higher level of fertilizer application might be due to direct contribution towards the available nitrogen pools in the soil (Nikzad *et al*., 2020). Tank and Patel (2013) opined that the plots treated with higher level of fertilizers recorded higher available N in soil, which might be due to higher availability on higher the dose of application.

The phosphorus status in soil was not influenced significantly due to different treatment under study. This may be due to immobile nature of phosphorus in soil.

Highest soil potassium content (326.89 kg ha^{-1}) was observed in T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19), which was on par with T_{12} (326.66 kg ha^{-1}). Application of KAU POP (control 1 - T_{13}) registered lowest soil potassium content of 263.51 kg ha^{-1}. Available potassium content of soil showed increasing trend with increasing fertilizer doses. The increased available potassium in soil with higher level of fertilizer application might be due to direct contribution towards the available potassium pools in the soil (Nikzad *et al.*, 2020). Tank and Patel (2013) opined that the plots treated with higher level of fertilizers recorded higher available K_2O in soil, which might be due to higher availability on higher dose of application.

5.1.8 Economic analysis

In the present study, application of different levels of fertigation and foliar sprays caused significant variation in gross income, net income and B : C ratio. Treatment receiving 100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19 (T_4) registered significantly higher gross income and net income, which was on par with T_5 receiving 100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax. High yield obtained in these treatments have contributed to increased gross income. Drip fertigation with considerable saving in labour resulted in high net income. Moreover, the cost of drip installation for fertigation treatments was equally distributed over 10 years by following amortization. All these factors favourably enhanced the B : C ratio in T_4 (2.58) (Fig. 13), which was found to be on par with T_5 (2.54). Significantly minimum gross income, net income and B : C ratio was recorded in plants receiving 75 % RD of N and K through fertigation with water spray (T_3). Higher gross returns, net returns and return per rupee investment make fertigation economically viable when compared to conventional method of fertilizer application. The high initial investment cost for the system is one of the major constraints, but considering the benefits in terms of water saving, increased crop productivity and higher returns, the study can suggest its wider dissemination.

5.2 POSTHARVEST MANAGEMENT PRACTICES FOR EXTENSION OF SHELF LIFE IN PAPAYA

Worldwide popularity and widespread consumption of papaya fruits is due to its peculiar flavour and nutritional characteristics. However, rapid deterioration and high incidence of rots during handling and storage limits its shelf life. Diseases caused by fungi limits the postharvest storage life of this commodity. Couey *et al*. (1984) and Sulsusi *et al*. (1993) opined that diseases of fruit crops can be effectively controlled by pre and postharvest fungicide treatments. However, fungicides may leave residues on the fruit surfaces posing a health hazard to consumers. Use of edible films, coatings, ethylene absorbers, precooling of fruits etc. are other alternatives to these. Therefore to enhance the shelf life and to improve the market value of papaya an attempt was done by adopting different postharvest practices. Liu (2002) opined that proper postharvest handling ensures preservation of quality until the produce reaches the consumers.

In the present study papaya variety Surya was raised according to KAU POP and fruits were collected at fully mature green stage. Later fruits were subjected to different postharvest management practices and packaged in CFB boxes and stored under ambient conditions till the end of shelf life.

5.2.1 Physical quality (Sensory analysis)

Papaya fruits harvested at fully mature green stage, subjected to different postharvest treatments and stored in CFB boxes showed significant difference in sensory parameters at 3 DAS. The mean scores of all parameters were highest for control (S_9) with a total score of 63.60 after three days of storage (Fig. 14). Minimum total score of 45.47 was observed for postharvest treatments S_3 (External coating with chitosan (1%)), S_4 (Precooling followed by external coating with 1% chitosan), S_5 (Packaging with ethylene scrubber $KMnO_4$), S_6 (Precooling followed by packaging with ethylene scrubber $KMnO_4$), S_7 (Precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) and S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) at 3 DAS. This indicates that ripening of fruits was hastened in control, which was depicted by the highest sensory scores for all the parameters. Whereas, in all other treatments ripening was delayed due to postharvest management measures adopted. Reduction in field heat in shortest possible time, lower moisture loss, restricted metabolic and respiratory activities and reduction in ethylene production by the fruits might have contributed to the delayed ripening (Hardenburg *et al*., 1990).

After six days of storage, highest total score (68.13) was observed for fruits externally coated with chitosan (1%) (S_3). Whereas, fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) and hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$ (S_8) had lowest total score of 57.59.

Fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) and hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$ (S_8) retained the maximum sensory quality with highest total score of 69.19 after nine days of storage.

Reduced field heat with restricted respiratory activities achieved in the fruits as a result of pre-cooling done immediately after the harvest, delayed the fruit ripening and contributed to the sensory qualities of fruits up to nine days under treatment S_7. Jawandha *et al*. (2016) reported that sensory quality rating of peach cv. Shan-i-Punjab fruits subjected to precooling (hydrcooling) increased up to 21 days of storage. In mango, a similar conclusion was recorded by Ram *et al*. (2003). Kittur *et al*. (2001) chitosan coated mangoes had significantly higher sensory scores than the control, after 21 days of storage. Freitas *et al.* (2015) opined that chitosan coating preserved brightness and visual quality of grapes. Bhanushree *et al*. (2018) reported higher score of overall acceptability in papaya fruits coated with chitosan after seven days of storage.

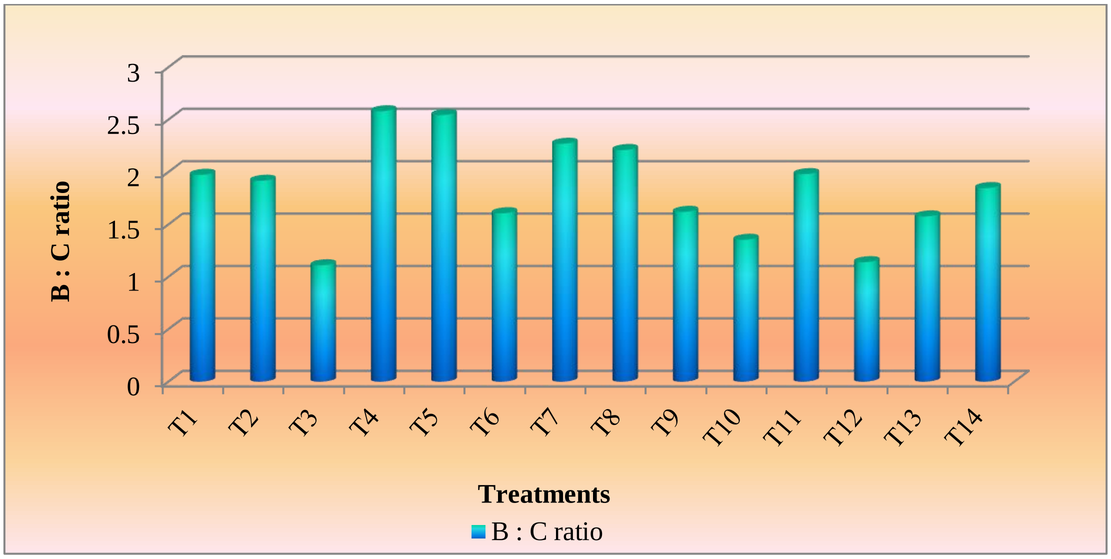


Fig. 13. Effect of fertigation and foliar sprays on B: C ratio of papaya cultivation

T_1 - 75 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_2 - 75 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_3 - 75 % RD of N and K through fertigation and water spray
T_4 - 100 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_5 - 100 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_6 - 100 % RD of N and K through fertigation and water spray
T_7 - 125 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_8 - 125 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_9 - 125 % RD of N and K through fertigation and water spray
T_{10} - 150 % RD of N and K through fertigation and foliar spraying of 1.0% 19:19:19
T_{11} - 150 % RD of N and K through fertigation and foliar spraying of 0.5% $ZnSO_4$ and 0.3% borax
T_{12} - 150 % RD of N and K through fertigation and water spray
T_{13} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data
T_{14} - Soil application of 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures

5.2.2 Physiological quality

5.2.2.1 *Shelf life (days)*

The present study found significant difference in shelf life of papaya cv. Surya fruits subjected to different postharvest treatments and stored in CFB boxes. Higher shelf life (9.67 days) was registered in fruits treated with precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7), which was on par with S_8 (Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) (9.00 days). Control (S_9) fruits registered lowest shelf life of 4.33 days) (Fig. 15).

Rapid removal of field heat from the freshly harvested papaya by precooling and ability of potassium permanganate to absorb ethylene produced by the fruit during ripening process aids in retarding respiration, ripening, senescence, water loss and decay in treatment S_7. In addition to this, external coating with chitosan (1%) helped in forming an excellent film over the produce which retards the respiration rate and also helped in maintaining the optimum quality and prolonged shelf life of fruits in S_7. Brosnan and Sun (2001) depicted precooling as the first and most crucial line of defense in reducing the field heat of horticultural produce thereby reducing its metabolic activity and enter a low energy consumption state and prolongs its shelf life. The findings are in concordance with the observations of Ravikumar *et al*. (2018) who revealed that precooling extended the shelf life in banana, whereas lowest shelf life was observed in control. Ali *et al*. (2011) elaborated the commercial application of chitosan as a promising edible coating for extending the storage life of the papaya cv. Eksotika. Dotto *et al*. (2015) reported that coating of papaya fruits with chitosan was microbiologically safe during storage. Potassium permanganate ($KMnO_4$) is a potent oxidizing agent which has long been used to remove ethylene from the storage atmosphere. It aids in reducing ethylene levels by oxidizing it to carbon dioxide and water (Salunkhe and Desai, 1984). Ethylene absorbents or ethylene scrubers works by absorbing the ethylene or blocking the ethylene binding to its receptor, thus hamper the build up of ethylene around produce. Use of ethylene absorbents to delay ripening was recorded by Hopfman *et al*. (2001) in avocado, custard apple, mango and papaya; Manenoi *et al*. (2007) in papaya; Zewter *et al*. (2012) in banana; Ahmed *et al*. (2013) and Razali *et al*. (2013) in papaya.

Jayasheela (2014) reported that hot water treatment followed by waxing with carnauba wax and ethylene scrubber significantly improved the shelf life of papaya cv. Coorg Honeydew. Doshi and Sutar (2010) and Kechinski *et al*., (2012) opined that wax treatment exerted a significant influence on shelf life and it retards the fruit ripening.

Also, the elevated carbondioxide level which develops in the CFB boxes, with the progress of storage have been shown to retard fruit ripening due to the inhibition of ethylene activity (Kader *et al*., 1989), thereby improving the shelf life. This will protect the fruit from physiological, pathological and physical deterioration in the marketing channel and retains its freshness. Al-Ati and Hotchkiss (2003) also reported that the modified atmospheric storage enhance the shelf life of produce by reducing the respiration rate, delaying senescence, and inhibiting the growth of many spoilage organisms.

The barrier properties of edible films and coatings to gases and moisture can create a modified atmosphere inside the fruit that can extend the shelf life and improve the quality of fruits and vegetables (Coma *et al*., 2001). Wax treated fruits of banana cv. Robusta stored in polythene bags containing $KMnO_4$ improved shelf life (Rao and Rao, 1979).

5.2.2.2 ***Physiological Loss in Weight (%)***

In the present study significant difference in physiological loss in weight was found among fruits provided with different postharvest treatments during storage

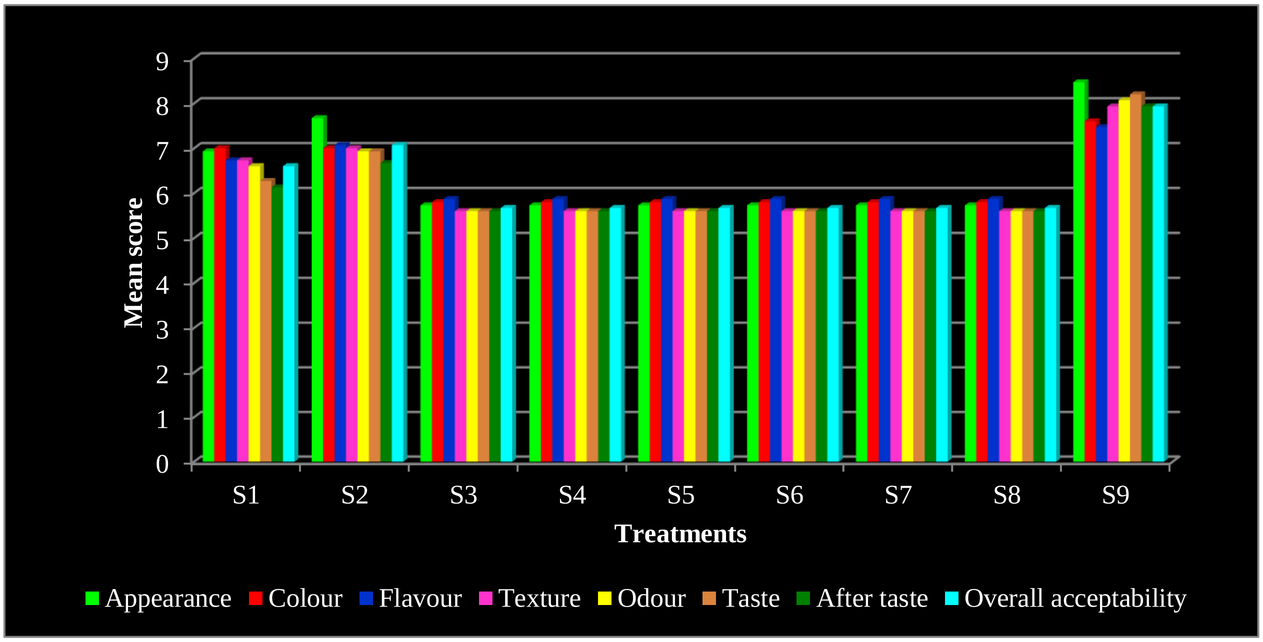


Fig. 14. Effect of postharvest management practices on organoleptic qualities of papaya fruit

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

compared to control. Papaya fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) had lowest physiological loss in weight (1.49 %, 3.63 % and 5.64 % respectively) after three, six and nine days of storage. It was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) (1.59 % and 3.96 %) at three and six days after storage. Highest physiological loss in weight (7.54 %) was noticed in control (S_9) after three days of storage (Fig 16).

Physiological loss in weight depicts the total moisture lost during storage and ripening, ultimately resulting in desiccation and shriveled appearance of fruit (Davies and Hobson, 1981). This physiological loss in weight is essentially due to transpiration and respiration (Krishnamurthy and Subramanyam, 1970). Retardation of transpiration and respiration in treated fruits might have contributed to the reduction in weight loss as substantiated by results of Bhullar and Farmahan (1980) in guava; Manenoi and Paull (2007) and Dikki *et al.* (2010) in papaya.

The combined effect of precooling, external coating with chitosan (1%) and packaging with ethylene scrubber might have contributed to the reduced physiological loss in weight of S_7 treatment after three, six and nine days after storage. Also, hot water treatment combined with waxing (carnauba wax 6%) and packaging with ethylene scrubber might have contributed to the reduced physiological loss in weight of S_8 treatment after three and six days after storage. Jawandha *et al*. (2016) reported that pre-cooled fruits of peach cv. Shan-i-Punjab exhibited relatively slower loss in weight on all the storage intervals as compared to the non pre-cooled (control) fruits. Delayed egress of moisture from the fruit into the environment as a result of the chitosan film formed on the surface of the papaya reduced the weight loss during storage (Ali *et al*., 2011). Garcia *et al*. (1996) also reported similar findings in strawberry. Paull and Chen (1989) observed that chitosan

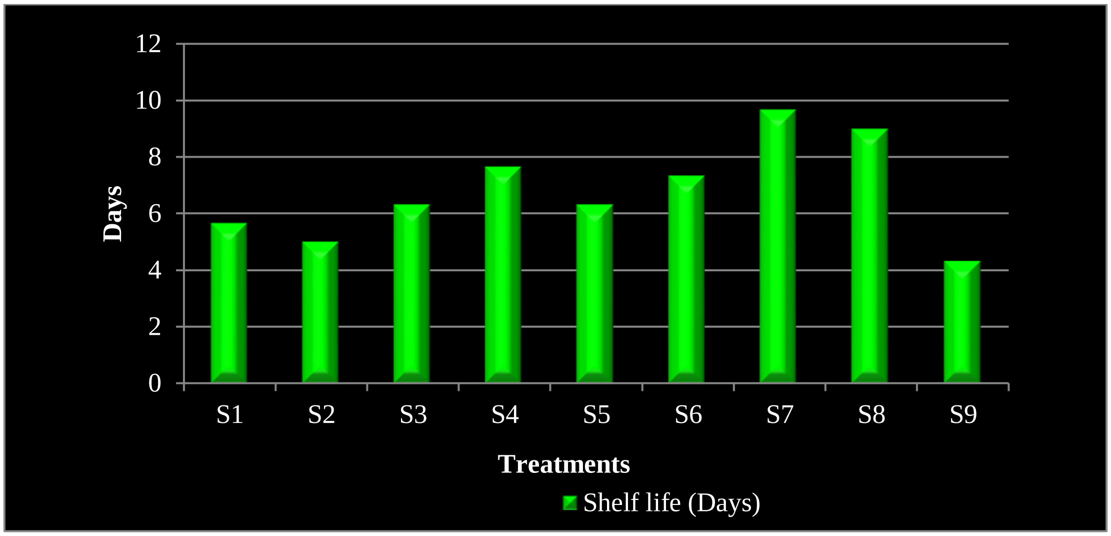


Fig. 15. Effect of postharvest management practices on shelf life of papaya fruit

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

coating has the capability to develop a film on fruit surface and thereby provide a barrier against diffusion of moisture through stomata, contributing towards reduced weight loss. This might have also contributed to the reduced weight loss in S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$).

Jayasheela (2014) also reported least physiological loss in weight in papaya cv. Coorg Honeydew subjected to hot water treatment followed by waxing with carnauba wax and ethylene scrubber compared to control. Waskar and Gaikwad (2005) reported that physiological loss in weight of hot water treated mango (cv. Kesar) fruits increased at slower rate. Water and fat binding properties of carnauba wax augmented with lower activities of enzymes might have contributed to the lower moisture loss in wax treated fruits (Koley *et al*., 2009). According to McGuire and Hallman (1995) and Baldwin *et al*. (1999) carnauba wax coating reduced the weight loss in guava and mango cv. Tommy Atkins respectively. Elzubeir *et al*. (2018) supported the findings of the present study. They reported that reduction in weight loss from the mango fruits on storage was due to the use of $KMnO_4$ along with waxing. Delayed ripening achieved due to presence of $KMnO_4$ further reduced the tissue permeability and weight loss from fruits.

Higher physiological loss in weight in the untreated fruits (control) may be due the normal accelerated metabolic activities of the fruits and breakdown of reserved carbohydrates during respiration. Whereas, reduction in the respiratory activities slowed down various vital processes and helped to prolong the maintenance of postharvest quality such as reduction in weight loss and retention of textural quality in all the treatments except control.

5.2.2.3 ***Ion leakage (%)***

The present study revealed significant differences in ion leakage of papaya fruits treated with various postharvest treatments after three days of storage. Fruits

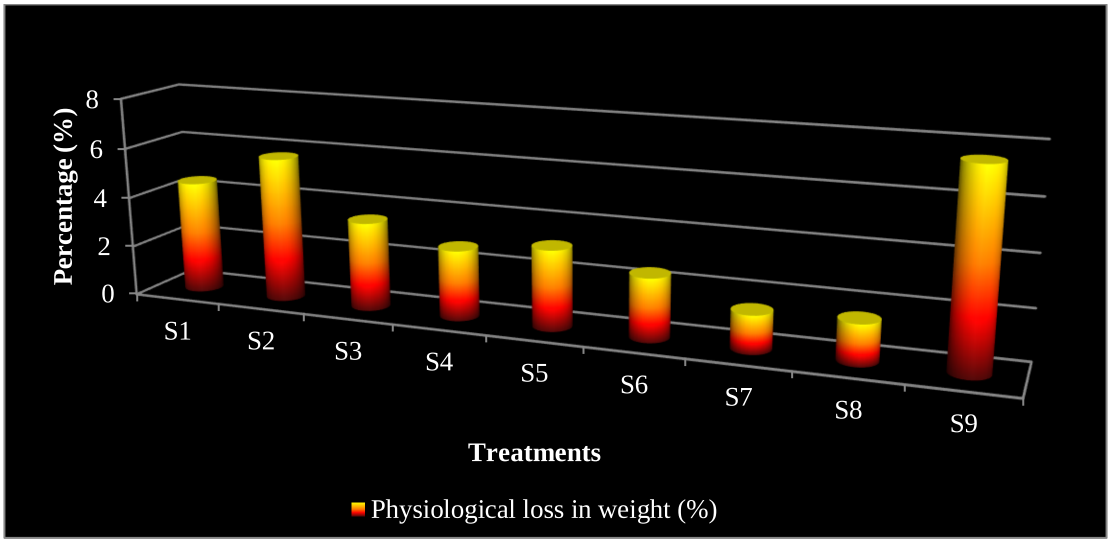


Fig. 16. Effect of postharvest management practices on physiological loss in weight of papaya fruit (3 DAS)

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) had least percent leakage (34.63 %, 63.14 % and 93.41 % respectively) after three, six and nine days of storage, which was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) (37.02 %) after three days of storage. Control sample (S_9) had highest percent leakage (90.25 %), which was followed by fruits subjected to surface sanitization with sodium hypochlorite (150 ppm) (S_2) (81.07 %) after three days of storage (Fig. 17).

The lower ion leakage of treatments S_7 and S_8 might be due to the intact membrane which resulted from the better treatments like precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber in S_7 and hot water treatment coupled with waxing and ethylene absorbent application in S_8. Jayasheela *et al*. (2016) supported the findings of the present study. They concluded that fruits of papaya cv. Coorg Honeydew subjected to HWT at 50° C for 20 minutes with waxing and with ethylene absorbent had least percent leakage.

According to Parker and Maalekuu (2013) there is a very high and positive correlation with membrane ion leakage and high water loss rate. A similar proportional relationship between water loss and membrane ion leakage was depicted by Walter *et al*. (1990). The higher percent ion leakage in control might be due to the loss of physical integrity of cellular membrane leading to the loss of ion and unrestricted travel of fluids within cellular compartments, a condition deleterious to fruits (Maalekuu *et al*., 2004).

5.2.3 Chemical quality

5.2.3.1 *Total Carotenoids (mg 100g^{-1})*

Significant variation in total carotenoid content was noticed in papaya cv. Surya fruits subjected to different postharvest treatments after three days of storage.

Highest total carotenoid content (2.70 mg $100g^{-1}$) was recorded in control (S_9) after three days of storage. It was followed by surface sanitization with sodium hypochlorite (150 ppm) (S_2) with total carotenoid content of 2.55 mg $100g^{-1}$. Lowest total carotenoid content of 1.40 mg $100g^{-1}$, 1.89 mg $100g^{-1}$ and 2.50 mg $100g^{-1}$ respectively was found in fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) after three, six and nine days of storage. It was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) with 1.45 mg $100g^{-1}$ total carotenoid content at three days after storage. Petriccione *et al*. (2015) noticed that chitosan treatment delayed the senescence rate and consequently there was a delay in increase in carotenoid content throughout the storage in loquat (*Eriobotrya japonica* Lindl.) fruits compared to control. Kumar *et al*. (2009) documented that total carotenoids content increased in stored pointed gourd (*Trichosanthes dioica* Roxb.) fruits and in untreated fruits the increment in total carotenoids content was faster when compared to treated fruits. They observed that even after 10 days of storage, the total carotenoid formation was effectively slowed down in carnauba wax and sodium hypochlorite treated fruits. This may be achieved due to meagre activity of pectin methyl esterase enzyme and delayed chlorophyll degradation in conjunction with enzymatic action. Khaleghi *et al*. (2014) noted that hot water treatment at 45°C delayed degradation of chlorophyll and the development of carotenoids compared to control in tomato cv. Chef.

5.2.3.2 *TSS (°Brix)*

TSS content of papaya fruits increased in all the treatments during storage, and varied significantly among each treatment after three, six and nine days of storage in the present study. Untreated fruits sample (control - S_9) stored in CFB box had highest TSS (13.23°Brix) after three days of storage. Whereas, lowest TSS was found in fruits treated with precooling followed by external coating with 1% chitosan

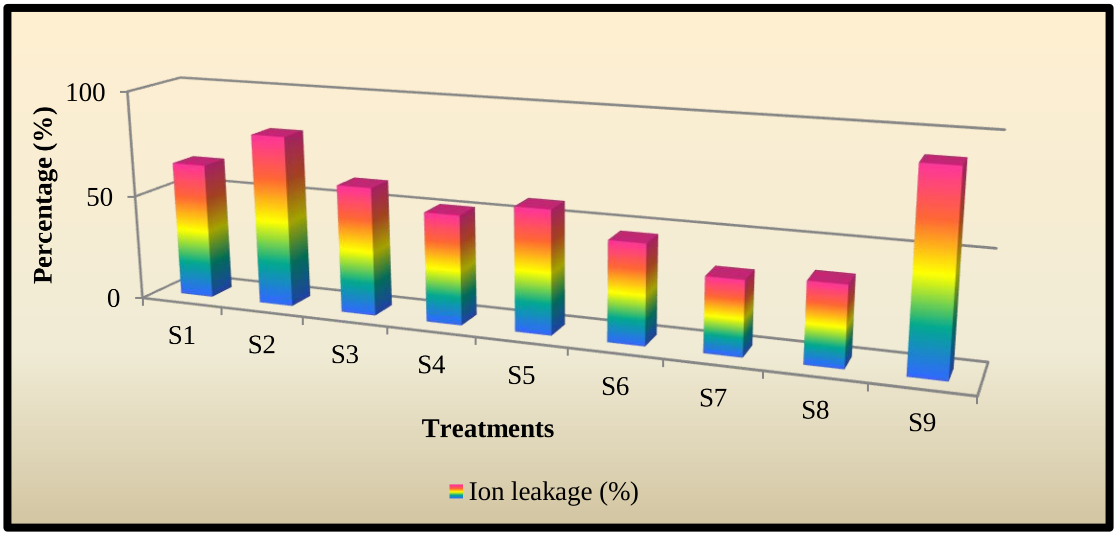


Fig. 17. Effect of postharvest management practices on ion leakage (%) of papaya fruit (3 DAS)

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

and packaging with ethylene scrubber $KMnO_4$ (S_7) after three, six and nine days of storage (10.20°Brix, 11.20°Brix and 13.50°Brix respectively). Fruits subjected to hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$ (S_8) also registered lowest TSS after three and six days of storage (10.33°Brix and 11.70°Brix respectively).

Breakdown of starch and polysaccharides into simple sugars during ripening contributes to the increment in the TSS during storage. Therefore the higher TSS observed in S_9 after three days of storage indicates that ripening was hastened in untreated fruits, whereas cumulative effect of precooling, external coating with chitosan (1%) and packaging with ethylene scrubber $KMnO_4$ delayed the ripening in S_7, which is proved by the lowest TSS after three, six and nine days of storage. Similarly the collective effect of hot water treatment, waxing (carnauba wax 6%) and packaging with ethylene scrubber $KMnO_4$ contributed to the delayed ripening in $S_{8,}$ indicated by the lowest TSS after three and six days after storage. Jawandha *et al*. (2016) opined that slower increment in TSS under pre-cooling treatments might be due to immediate removal of field heat after the harvest from the fruit, which limits the respiratory activities and reduced the moisture loss and hydrolysis of starch into simple sugars. Similar findings were also pointed by Makwana *et al*. (2014) in mango cv. Kesar. Waskar and Gaikwad (2005) reported a significantly lower rate of increase in TSS of hot water treated mango (cv. Kesar) fruits.

5.2.3.3 ***Total sugar (%)***

Papaya fruits registered an increasing trend in total sugar during storage. Untreated fruits (control – S_9) recorded significantly higher percent of total sugar (9.40 %) at 3 DAS. Fruits subjected to surface sanitization with sodium hypochlorite (150 ppm) (S_2) recorded total sugar content of 8.94 per cent, which was on par. Lowest total sugar content (5.73 %) was recorded in treatment with precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber

$KMnO_4$ (S_7) after three days of storage. It was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) and S_6 (precooling followed by packaging with ethylene scrubber $KMnO_4$) with 5.90 per cent and 6.35 per cent total sugar content respectively.

Higher percent of total sugar in untreated fruits (control – S_9) is due to rapid increase in respiration rate. The rate of increase of total sugar was at normal in all other treatments due to slow degradation of polysaccharides to sugars and gradual buildup of sugars concomitant with reduced utilization of sugars as substrates during respiration. The slow buildup of sugars in S_7 and S_8 treated fruits after three days of storage is attributed to more shelf life. In papaya cv. Coorg Honeydew, similar findings have been documented by Jayasheela (2014).

5.2.3.4 *Reducing sugar (%)*

The amount of reducing sugar showed an upward trend with the advancement of storage period. Highest reducing sugar content (8.16 %) was noticed in S_9 (control) after three days of storage. Lowest reducing sugar content (5.36 %, 6.59 % and 8.00 % respectively) was noticed in S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) after three, six and nine days of storage. S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) which recorded 5.52 % and 6.89 % reducing sugar content respectively after three and six days of storage was on par.

Low respiration rate coupled with lower enzymatic activity contribed to low reducing sugar content in S_7 and S_8. This slow buildup of reducing sugar was achieved by the reduced utilization of sugars in respiration.

Kaur and Kaur (2018) reported that banana cv. Grand Naine fruits stored in unperforated polythene bags with $KMnO_4$ witnessed minimum reducing sugar after eight days of storage compared to control and opined that it is due to ripening inhibiting effect of $KMnO_4$. They further registered increment in reducing sugar as ripening progresses.

5.2.3.5 ***Acidity (%)***

In the present study it was found that titratable acidity of papaya fruits decreases with increasing storage time in all the treatments. The decrease in acidity during storage is attributed to the utilisation of acids in respiration process and conversion to sugars which demonstrates the fruit ripening. Lowest acidity (0.16 %) was noticed in S_9 (control) after three days of storage, whereas papaya fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) recorded highest acidity after three, six and nine days of storage (0.27 %, 0.22 % and 0.16 % respectively). The result indicates that, fruits subjected to combination of different postharvest treatments delayed the ripening in papaya whereas in fruits with no postharvest treatments (control) ripening was hastened. Slow ripening of papaya fruits in all treatments except that of control (S_9) resulted in the delayed breakdown of organic acid and higher titratable acidity after three days of storage. According to Jawandha *et al.* (2016), precooling (hydrocooling) retained maximum acid content than control in peach cv. Shan-i-Punjab fruits after 35 days of storage. Slower conversion of acids into sugars after pre-cooling and utilization of acids during respiration might have contributed to this. Ali *et al*. (2011) opined that in chitosan coated fruits of papaya cv. Eksotika, the titratable acidity declined throughout the storage period though at a slower rate, as compared to the control.

Sanches *et al*. (2019) reported higher titratable acidity in pinha (*Anonna squamosa* L.) fruits packed with $KMnO_4$ sachets in relation to the control, indicating a less advancement of ripening in $KMnO_4$ supplied packs due to the slower consumption of organic acids. Delayed drop in titratable acidity during storage in mango cv. Kitchner was reported by Elzubeir *et al*. (2018) upon waxing and $KMnO_4$ treatment.

5.2.4 Percentage disease index

Anthracnose and stem end rot are the major postharvest fungal diseases affecting papaya during storage.

Number of fruits infected with anthracnose showed significant difference among treatments in the present study. Lowest disease incidence of zero per cent was witnessed in S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) and S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$)) after three days of storage. However, higher sign of lesions (38.89 %) was observed in control after three days of storage (Fig. 18).

Packaging with ethylene scrubber $KMnO_4$ (S_5) recorded highest disease index (33.33 %) after six days of storage. However after six days and nine days of storage, lowest disease index was noticed in S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) and S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) (16.67 % and 27.78 % respectively for each at six and nine days of storage). Combined application of three postharvest management measures in S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) and S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) might have contributed to the reduced disease incidence. Jawandha *et al*. (2016) opined that precooling (hydrocooling) effectively reduced the spoilage of peach cv. Shan-i-Punjab fruits. Pre-cooling reduced fruit spoilage by reducing metabolic, respiration and ripening rate and prolonging keeping quality. These observations are in concordance with the

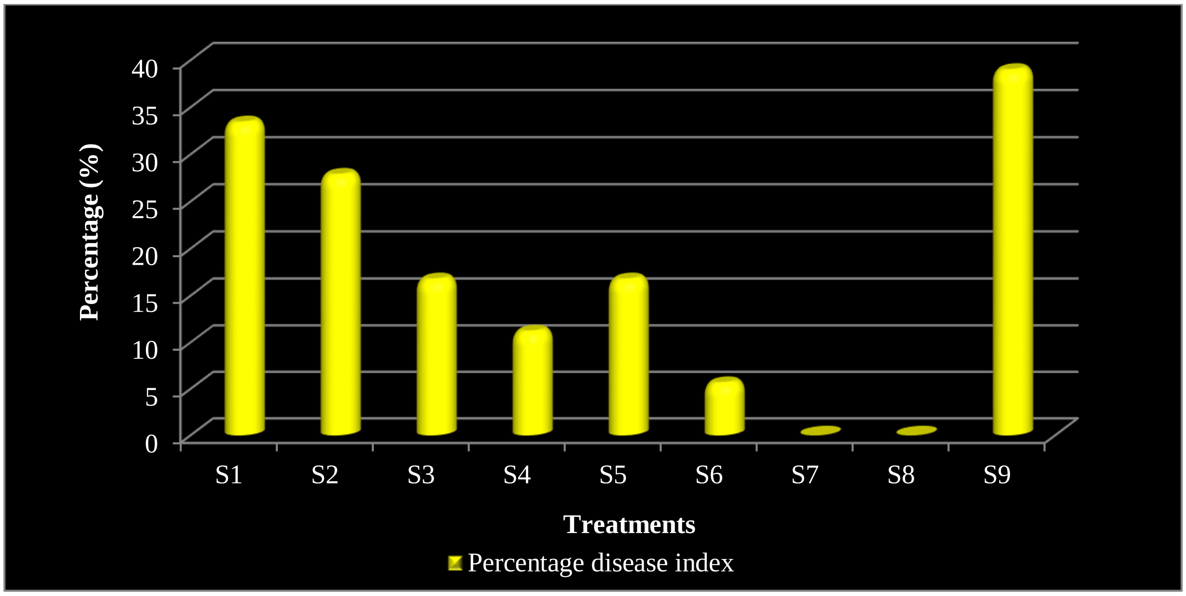


Fig. 18. Effect of postharvest management practices on percentage disease index of papaya fruit (3 DAS)

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

findings of Dhemre (2001) and Sondkar (2002) in mango. Eryani-Raqeeb *et al*. (2009) reported that chitosan controlled the disease incidence in papaya cv. Eksotika. According to Abbasi *et al.* (2009) chitosan treatment can inhibit the growth of bacteria and fungi as observed in mango cv. Summer Bahisht Chaunsa. Shiekh *et al*. (2013) attributed natural antimicrobial activity of chitosan responsible for delayed fruit deterioration in commodities by inhibiting the growth of microorganisms.

Li *et al*. (2013) and Zhao *et al*. (2013) opined hot water treatment of papaya fruit as an effective technique in reducing the carrier rate of *Colletotrichum gloeosporioides* in fruit peel. Mango fruits coated with carnauba wax exhibited reduced fruit decay during storage (Baldwin *et al.*, 1999). According to Issar *et al.* (2010) the reduced spoilage in waxed fruits was probably due to the covering of bruised points with wax and restricting the entry of microorganisms into the fruit.

5.2.5 Microbial load (cfu g^{-1})

Lowest bacterial count was witnessed in fruits treated with precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) after three, six and nine days of storage (4.67 cfu/ml x 10^6, 16.00 cfu/ml x 10^6 and 24.33 cfu/ml x 10^6 respectively). Fruits subjected to hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) (S_8) was on par with S_7 at three and six days of storage (5.67 cfu/ml x 10^6 and 16.33 cfu/ml x 10^6 respectively) (Fig. 19). The present study also revealed significant reduction in bacterial count in all the treatments except control after three days of storage. Highest bacterial count of 89.33 cfu/ml x 10^6 was witnessed in control (S_9) after three days of storage.

Papaya fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) had a lowest fungal count of 1.67 cfu/ml x 10^3, 4.67 cfu/ml x 10^3 and 13.33 cfu/ml x 10^3 respectively after three days, six days and nine days of storage (Fig. 20). Fruits treated with hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) (S_8) was on par at three days and at six days after storage (2.00 cfu/ml x 10^3 and 5.33 cfu/ml x 10^3 respectively). Control sample (S_9) registered highest fungal count (22.33 cfu/ml x 10^3) after three days of storage.

Fruits subjected to different postharvest treatments recorded significantly lower bacterial and fungal count after three days of storage compared to untreated fruits (control). Minh *et al*. (2019) documented that chitosan coating effectively inhibited the growth of microorganisms on soursop. Youwei and Yinzhe (2013) opined that chitosan coating had preventive effect against microbes and can reduce decay. Hewajulige *et al*. (2015) pointed that chitosan have antifungal properties against anthracnose causing fungi isolated from papaya. Martins *et al.* (2010) was of the opinion that papaya fruit treated with hot water at 48-50°C for 20 minutes controlled the anthracnose disease in papaya. Jayasheela (2014) reported that papaya fruits sanitized with hot water treatment at 50°C for 20 minutes with waxing and with ethylene absorbent had lowest number of bacterial and fungal populations. Edible films and coatings can acts as a barrier against microbial invasion (Kester and Fennema 1986). Bhowmik and Pan (1992) observed a significant reduction in microbial count of tomato fruit sanitized with sodium hypochlorite before packaging.

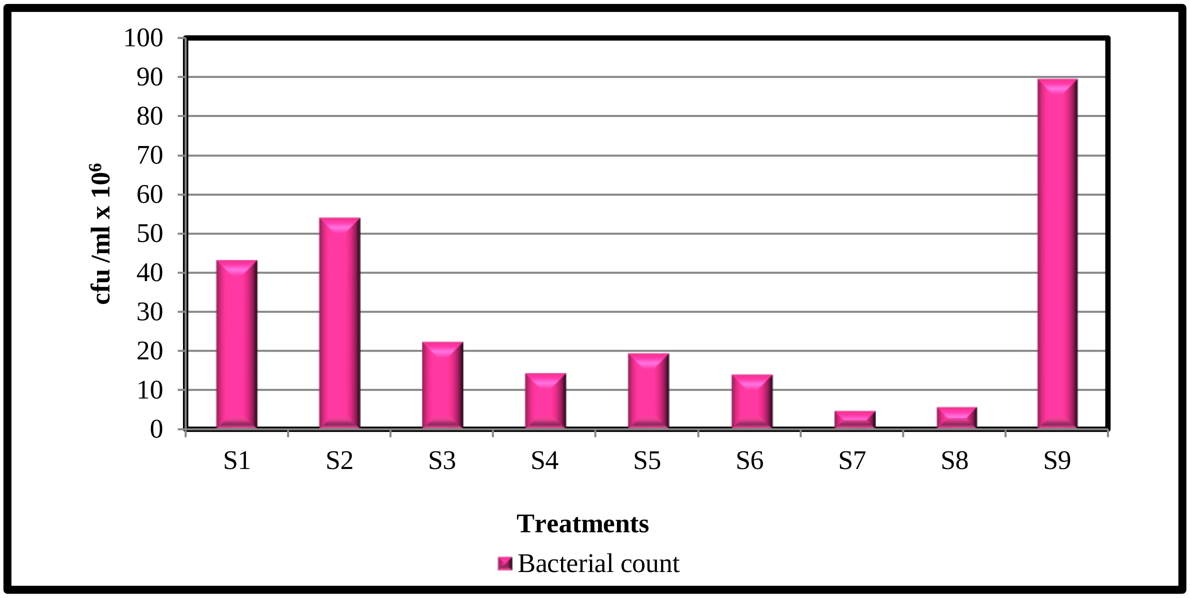


Fig. 19. Effect of postharvest management practices on bacterial count of papaya fruit (3 DAS)

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

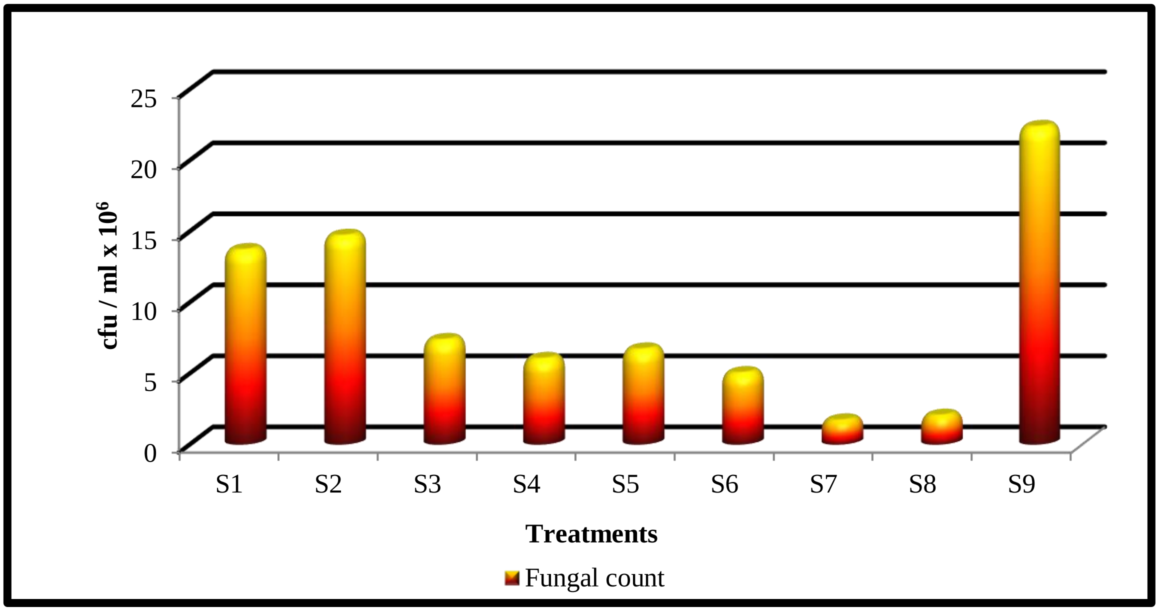


Fig. 20. Effect of postharvest management practices on fungal count of papaya fruit (3 DAS)

S_1 – Precooling (Hydro cooling)

S_2 – Surface sanitization with sodium hypochlorite (150 ppm)

S_3 – External coating with chitosan (1%)

S_4 – Precooling followed by external coating with 1% chitosan

S_5 – Packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight)

S_6 – Precooling followed by packaging with ethylene scrubber $KMnO_4$

S_7 - Precooling followed by external coating and packaging with ethylene scrubber $KMnO_4$

S_8 - Hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$

S_9 - Control

Summary

6. SUMMARY

An investigation on "Fertigation studies in papaya (*Carica papaya* L.)" was carried out at Department of Fruit Science, College of Agriculture, Vellayani, during 2018-2020 to standardize the nutrient level for yield improvement through fertigation and foliar nutrition in papaya variety Surya and to study the postharvest management practices for extending the shelf life of papaya fruits. The experiment was undertaken in two parts. In part I, standardization of nutrient level for fertigation and foliar nutrition was carried out in RBD with 14 treatments replicated thrice. A combination of four fertigation doses of 75 %, 100 %, 125 % and 150 % RDF of N (304.89, 406.52, 508.15 and 609.78 g urea plant^{-1} year^{-1} respectively based on soil test data in 76 fertigation) and K (426.25, 568.33, 710.42 and 852.50 g MOP plant^{-1} year^{-1} respectively based on soil test data in 76 fertigation) and three foliar sprays (1.0 % 19:19:19 at bimonthly interval starting from 4 MAP to 16 MAP, 0.5% $ZnSO_4$ + 0.3% borax at 4th, 8th, 12th and 16th MAP and water spray at bimonthly interval starting from 4 MAP to 16 MAP) were compared with soil application of RD of NPK (187:170:341 g NPK plant^{-1} year^{-1} based on soil test data) (control 1) and 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures as combination of FYM, poultry manure and vermicompost in the ratio of 2:1:1 (control 2). In control 2, additional requirement of P and K were met through the application of rock phosphate and potassium sulphate respectively. The general practices such as deep ploughing (50 cm) and taking raised beds (30 cm height, 1.5 m width) were uniformly followed except in two controls. Organic manure (15 kg FYM plant^{-1}) was given uniformly to all treatments as basal. Lime and rock phosphate (500g and 850g respectively based on soil test data) was applied uniformly for all treatments as basal except controls. Urea and Muriate of Potash (MOP) were used as fertilizer sources for fertigation and applied weekly from 1 MAP to 20 MAP. Separate submains were laid out in the field, to deliver water and fertilizer to the respective plots and fertigation was done using injector.

The salient results of part I are summarized below:

Application of different levels of fertigation and different foliar sprays had significant effect on growth of papaya. Growth parameters *viz*., plant height, stem girth and number of leaves were significantly higher in plants receiving 100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19 (T_4) at bimonthly interval starting from 6 MAP to 16 MAP. T_4 also recorded highest leaf area index at 6, 12, 18 MAP and at final harvest, flowering at the shortest height (74.38 cm), highest number of female plants (83.33 %) and highest fruit set (86.27 %). However, application of 100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax at 4^{th}, 8^{th}, 12^{th} and 16^{th} MAP (T_5) initiated earliness in flowering (142.67 days) and harvest (275.00 days).

Yield contributing characters like fruit length (16.90 cm), fruit girth (13.90 cm), fruit volume (751.76 cc), pulp percentage (83.53 %), flesh thickness (3.42 cm), fruit weight (797.51 g) and number of fruits per plant (48.11) was found highest in T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19). T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) was found on par with T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) in all these yield contributing characters with 16.79 cm fruit length, 13.74 cm fruit girth, 744.58 cc fruit volume, 82.85 % pulp, 3.39 cm flesh thickness, 792.42 g fruit weight, and 47.45 number of fruits per plant. Highest yield per plant of 38.30 kg was noticed in T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) which was on par with T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) with 37.60 kg. Lowest number of seeds (383.00) and least number of days for fruit maturity (119.44 days) was noticed in T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19). T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) registered highest seed germination (87.78 %) and maximum days to ripening of fruits (10.44 days). Fruit quality parameters *viz*., TSS (15.10°Brix), carotenoids (2.21 $mg100g^{-1}$), ascorbic acid (68.38 $mg100g^{-1}$), total sugar (9.66 %), reducing sugar (8.05 %) and non reducing sugar (1.61 %) were found highest in T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax). Fruits from T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) also registered longest shelf life (5.78 days) and highest mean sensory score for appearance (8.20), colour (8.07), flavour (7.87), texture (8.00), odour (8.07), taste (8.27), after taste (8.07) and overall acceptability (8.00) with a highest total score of 64.55. Index leaf analysis at 6 MAP revealed highest nitrogen (2.29 %) and potassium (2.99 %) content of leaf in T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19). Highest calcium (0.57 %), magnesium (0.29 %) and sulphur content (0.33 %) in leaf were found in T_5 (100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax), whereas highest zinc (32.00 ppm) and boron content (38.93 ppm) were witnessed in T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax). Highest nitrogen (1.89 %) and potassium (2.45 %) content of fruit were observed in T_{12} (150 % RD of N and K through fertigation with water spray). However highest nitrogen (243.13 kg ha^{-1}) content of soil was noticed in T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) and T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) witnessed highest potassium (326.89 kg ha^{-1}) content in soil. Pest and disease incidence did not show any variation due to different treatments.

T_4 (100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19) was most economically viable in terms of net income and B: C ratio (2.58). T_5 was equally effective in enhancing the B: C ratio (2.54).

In part II, papaya variety Surya was raised according to KAU POP recommendations for studying the extension of shelf life. Fruits harvested at fully mature green stage were subjected to different postharvest management practices, packaged in CFB boxes and stored under ambient conditions till the end of shelf life. Postharvest treatments were precooling (hydro cooling) (S_1), surface sanitization with 150 ppm sodium hypochlorite (S_2), external coating with 1% chitosan (S_3), precooling followed by external coating with 1% chitosan (S_4), packaging with ethylene scrubber $KMnO_4$ (8g per Kg of fruit weight) (S_5), precooling followed by packaging with ethylene scrubber $KMnO_4$ (S_6), precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7), hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$ (S_8) and control (S_9).

Papaya fruits harvested at fully mature green stage and subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) recorded the longest shelf life of 9.67 days, which was on par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) (9.00 days). These treatments also retained maximum sensory quality with highest total score of 69.19 after nine days of storage. Lowest physiological loss in weight of 5.64 per cent and least ion leakage of 93.41 per cent were noticed in S_7 after nine days of storage. S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) and S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$) recorded maximum total carotenoids, total soluble solids, total sugar, reducing sugar and minimum acidity after nine days of storage which indicated extended shelf life. No fungal spoilage and fruit rot were recorded in S_7 and S_8 after three days of storage, with zero per cent disease index. After six and nine days of storage also lowest disease index (16.67 % and 27.78 % each respectively) was noticed in S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$) and S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$). Lowest bacterial count of 24.33 cfu/ml x 10^6 and lowest fungal count of 13.33 cfu/ml x 10^3 after nine days of storage were noticed in S_7 (precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$).

Application of 100 % RD of N and K (406.52 g urea $plant^{-1}$ $year^{-1}$ and 568.33 g $plant^{-1}$ $year^{-1}$ respectively) through weekly fertigation from one to 20 MAP and foliar sprays of 0.5 % $ZnSO_4$ + 0.3 % borax at 4^{th}, 8^{th}, 12^{th} and 16^{th} MAP, along with basal application of 850g rock phosphate and 15 kg FYM was standardised as the fertigation dose for papaya. This schedule is effective when followed along with better land management practices of deep ploughing (50 cm deep) and raised beds (30 cm height).

Further studies are required on fertigation scheduling in papaya for enhancing the fruit yield.

By comparing the economics of postharvest treatments (Appendix VIII) it was found that S_7 had more shelf life (9.67 days) with a benefit cost ratio of 1.14. Hence, fruits harvested at fully mature green stage and subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ was identified as the suitable practice for enhancing the shelf life in papaya variety Surya.

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Appendices

APPENDIX – I

Weather parameters during the cropping period (Aug. 2018 to Feb. 2020)

Month and year	Temperature (^oC)		RH (%) Max.	Bright sunshine hours	Rainfall (mm)	Evaporation (mm day^{-1})
	Max.	Min.				
Jun -18	31.06	24.66	93.37	5.37	10.88	2.91
Jul -18	39.83	23.75	90.03	5.71	7.74	2.45
Aug -18	30.29	23.59	91.10	5.06	12.28	2.41
Sept -18	32.40	24.25	87.80	8.00	2.23	3.90
Oct -18	31.42	24.43	92.55	4.36	9.19	2.32
Nov -18	31.56	23.99	121.13	5.58	7.79	2.54
Dec -18	32.01	23.52	92.97	6.86	1.66	3.03
Jan -19	31.98	21.13	92.10	8.73	0.08	3.68
Feb -19	33.65	23.61	88.00	9.27	0.02	4.18
Mar -19	34.56	24.79	85.26	9.20	0.00	4.82
Apr -19	34.99	25.80	82.62	8.48	0.59	5.20
May -19	34.11	26.29	83.55	8.13	3.61	4.66
Jun -19	31.91	25.37	90.40	5.33	10.67	2.72
Jul -19	30.89	24.91	91.42	4.73	5.89	2.46
Aug -19	30.76	24.24	92.03	4.27	10.70	2.10
Sept -19	31.00	24.43	91.30	5.27	9.32	2.66
Oct -19	30.76	24.14	92.84	3.41	13.06	2.27
Nov -19	31.90	24.55	91.50	7.37	3.04	3.36
Dec -19	31.91	23.84	92.22	1.17	6.48	2.79
Jan -20	32.32	22.93	92.48	8.71	1.77	3.51
Feb -20	33.04	23.26	90.31	9.28	0.00	4.44

APPENDIX - II

Score card for organoleptic evaluation of papaya variety Surya fruits

Name of the judge:
Date:

Characteristics	Score													
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}
Appearance														
Colour														
Flavour														
Texture														
Odour														
Taste														
After taste														
Overall acceptability														

9 point Hedonic scale

Like extremely	9
Like very much	8
Like moderately	7
Like slightly	6
Neither like nor dislike	5
Dislike slightly	4
Dislike moderately	3
Dislike very much	2
Dislike extremely	1

Signature:

APPENDIX – III

Score chart for foot rot disease

Grade	Description
0	No visible symptoms
1	Pale coloured hypocotyls or stem base, no wilting; or leaves angled down
2	Yellow/ brown hypocotyls or stem base, slight wilt and / or yellowing
3	Fungal mycelium visible or brown hypocotyl lesion or stem base, moderate wilt (leaves angled down, dehydration in 20 – 40 % of leaves) and leaf yellowing
4	Brown, necrotic lesion or stem base, severe wilt (leaves angled down, dehydration in 40 – 100 % of leaves) and leaf yellowing
5	Dead (Permanently wilted)

APPENDIX – IV

Cost of drip installation

A) Fixed cost of drip installation per annum

Life span of drip system (n) = 10 years

Interest rate (i) = 9 % per annum

Cost of installation of drip system (S) = 100000

Fixed cost of drip system

$$= \frac{i\,(i + 1)^{n} \quad x\ S}{(i + 1)^{n} - 1}$$

$$= \frac{0.09\,(0.09 + 1)^{10}\ x\ 100000}{(0.09 + 1)^{10} - 1}$$

= 15569.34

B) Variable cost per annum

Maintenance cost of drip system = 10 % of cost of installation of drip system

= 10000

Cost of drip installation = A + B

= 25569.34

APPENDIX –V

Cost of cultivation of papaya with different levels of fertigation and different foliar sprays

Treatments	Cost of cultivation (ha^{-1})
T_1	737081.46
T_2	734481.46
T_3	729381.46
T_4	741809.84
T_5	739209.84
T_6	734109.84
T_7	770929.30
T_8	768329.30
T_9	763229.30
T_{10}	787853.09
T_{11}	785253.09
T_{12}	780153.09
T_{13}	668540.50
T_{14}	819371.15

APPENDIX – VI

Market price of produce

Produce	Market price
Fruit	20 / kg

APPENDIX – VII

Media composition for microbial study

1. Nutrient agar medium

Sl.No.	Reagents	Quantity
1.	Peptone	5.00 g
2.	Sodium chloride	5.00 g
3.	Beef extract	3.00 g
4.	Agar	20.00 g
5.	Distilled water	1000.00 ml
6.	pH	7.00

2. Martin's Rose Bengal agar medium

Sl.No.	Reagents	Quantity
1.	Glucose	10.00 g
2.	Peptone	5.00 g
3.	KH2PO4	1.00 g
4.	MgSO4. 7 H2O	0.50 g
5.	Streptomycin	30.00 mg
6.	Agar	15.00 g
7.	Rose Bengal	35.00 mg
8.	Distilled water	1000.00 ml

APPENDIX – VIII

Economics of postharvest treatments

Particulars	Rate	Quantity	S_1	S_2	S_3	S_4	S_5	S_6	S_7	S_8	S_9
Cost of production of fruits	Rs. 8/ kg	18 kg	144	144	144	144	144	144	144	144	144
CFB boxes	Rs. 25/ box	3	75	75	75	75	75	75	75	75	75
Precooling	Rs. 0.1/ kg	-	1.80	-	-	1.80	-	1.80	1.80	-	-
Sodium hypochlorite	Rs. 100/ litre	500 ml	-	50	-	-	-	-	-	-	-
Chitosan	Rs. 80/ litre	500 ml	-	-	40.00	40.00		-	40.00	-	-
Potassium permanganate	Rs. 720/ kg	144 g	-	-	-	-	103.68	103.68	103.68	103.68	-
Hot water treatment	0.50/ kg	-	-	-	-	-	-	-	-	9.00	-
Waxing	Rs. 1000/ litre	70 ml	-	-	-	-	-	-	-	70.00	-
Labour	-	-	10	10	10	20	10	20	20	20	10
Miscellaneous	-	-	10	10	10	10	10	10	10	10	10
Cost of production (Rs.)	-	18 kg	240.80	289.00	279.00	290.80	342.68	354.48	394.48	431.68	239
Cost of production per kilo (Rs.)	-		13.38	16.05	15.50	16.15	19.04	19.69	21.91	23.98	13.28
Selling price per kilo	Rs. 24/kg		25	25	25	25	25	25	25	25	25
B : C ratio (Rs.)			1.87	1.56	1.61	1.55	1.31	1.27	1.14	1.04	1.88
Profit (Rs.)			11.62	8.95	9.50	8.85	5.96	5.31	3.09	1.02	11.72

FERTIGATION STUDIES IN PAPAYA (*Carica papaya* L.)

by

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(2017-22-006)

ABSTRACT OF THE THESIS

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ABSTRACT

The investigation entitled "Fertigation studies in papaya (*Carica papaya* L.)" was carried out in Instructional Farm, College of Agriculture, Vellayani during the period 2018 – 2020 with the objectives to standardize the nutrient level for yield improvement through fertigation and foliar nutrition in papaya variety Surya and to study the postharvest management practices for extending the shelf life of papaya fruits.

The experiment was undertaken in two parts. In part I, standardization of nutrient level for fertigation and foliar nutrition was carried out in RBD with 14 treatments replicated thrice. A combination of four fertigation doses of 75 %, 100 %, 125 % and 150 % RDF of N (304.89, 406.52, 508.15 and 609.78 g urea plant^{-1} year^{-1} respectively based on soil test data in 76 fertigation) and K (426.25, 568.33, 710.42 and 852.50 g MOP plant^{-1} year^{-1} respectively based on soil test data in 76 fertigation) and three foliar sprays (1.0 % 19:19:19 at bimonthly interval starting from 4 MAP to 16 MAP, 0.5% $ZnSO_4$ + 0.3% borax at 4th, 8th, 12th and 16th MAP and water spray at bimonthly interval starting from 4 MAP to 16 MAP) were compared with soil application of recommended dose of NPK (187:170:341 g NPK plant^{-1} year^{-1} based on soil test data) (control 1) and 187:170:341 g NPK plant^{-1} year^{-1} based on soil test data as organic manures as combination of FYM, poultry manure and vermicompost in the ratio of 2:1:1 (control 2). In control 2, additional requirement of P and K were met through the application of rock phosphate and potassium sulphate respectively. Organic manure (15 kg FYM plant^{-1}) was given uniformly to all treatments as basal. Lime and rock phosphate (500g and 850g respectively based on soil test data) was applied uniformly for all treatments as basal except controls. Urea and Muriate of Potash (MOP) were used as fertilizer sources for fertigation and applied weekly from 1 MAP to 20 MAP.

Application of different levels of fertigation and different foliar sprays had significant effect on growth, yield and quality of papaya. Growth parameters *viz*., plant height, stem girth and number of leaves were significantly higher in plants receiving 100 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19 (T_4) at bimonthly interval starting from 6 MAP to 16 MAP. T_4 also recorded highest leaf area index at 6, 12, 18 MAP and at final harvest, flowering at the shortest height, highest number of female plants and highest fruit set (86.27 %). However, application of 100 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax at 4^{th}, 8^{th}, 12^{th} and 16^{th} MAP (T_5) initiated earliness in flowering (142.67 days) and harvest (275.00 days).

Treatments T_4 and T_5 were on par in fruit length, fruit girth, fruit volume, pulp percentage, flesh thickness and yield contributing characters like fruit weight, number of fruits per plant and yield per plant (38.30 kg $plant^{-1}$ and 37.60 kg $plant^{-1}$ respectively). Fruit quality parameters *viz*., TSS, carotenoids, ascorbic acid, total sugar, reducing sugar and non reducing sugar were found highest in T_5. Fruits from T_5 also registered longest shelf life (5.78 days) and highest mean sensory score for all parameters. Index leaf analysis at 6 MAP revealed highest nitrogen and potassium content of leaf in T_{10} (150 % RD of N and K through fertigation and foliar sprays of 1.0 % 19:19:19). Calcium, magnesium and sulphur content of leaves were highest in T_5, whereas boron and zinc content were highest in T_8 (125 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax). Highest nitrogen and potassium of fruits were observed in T_{12} (150 % RD of N and K through fertigation with water spray). Highest nitrogen content in soil was noticed in T_{11} (150 % RD of N and K through fertigation and foliar sprays of 0.5 % $ZnSO_4$ and 0.3 % borax) and T_{10} witnessed highest potassium content. T_4 and T_5 were at par regarding B : C ratio (2.58 and 2.54 respectively).

In part II of the investigation, postharvest management for extending shelf life of papaya was carried out with nine treatments replicated thrice. Different postharvest treatments given were precooling - hydro cooling (S_1), surface sanitization with 150 ppm sodium hypochlorite (S_2), external coating with 1% chitosan (S_3), precooling followed by external coating with 1% chitosan (S_4), packaging with ethylene scrubber 8% $KMnO_4$ (S_5), precooling followed by packaging with ethylene scrubber 8% $KMnO_4$ (S_6), precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber 8% $KMnO_4$ (S_7), hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber 8% $KMnO_4$ (S_8) and control (S_9). Papaya variety Surya was raised at Instructional Farm, Vellayani and fruits at fully mature green stage were harvested, subjected to different postharvest treatments and packaging was done in CFB boxes and stored under ambient conditions till the end of shelf life.

Papaya fruits subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber $KMnO_4$ (S_7) recorded the longest shelf life of 9.67 days, which was at par with S_8 (hot water treatment followed by waxing with 6% carnauba wax and packaging with ethylene scrubber $KMnO_4$). Physiological loss in weight, ion leakage, percentage disease index, bacterial and fungal count were significantly lowest in S_7 and S_8 after three days of storage. These treatments also recorded maximum total carotenoids, total soluble solids, total sugar, reducing sugar and minimum acidity after nine days of storage which indicated extended shelf life. Highest mean rank score for sensory attributes were also recorded in treatments S_7 and S_8 after nine days of storage.

In conclusion, application of 100 % recommended dose of N and K (406.52 g urea plant^{-1} year^{-1} and 568.33 g plant^{-1} year^{-1} respectively) through weekly fertigation from one to 20 months after planting and foliar sprays of 0.5 % $ZnSO_4$ + 0.3 % Borax at 4th, 8th, 12th and 16th MAP, along with basal application of 850g rock phosphate and 15 kg FYM resulted in increased growth, yield and quality characters of papaya variety Surya with highest B: C ratio. Fruits at fully mature green stage when subjected to precooling followed by external coating with 1% chitosan and packaging with ethylene scrubber 8% $KMnO_4$ in CFB boxes exhibited a shelf life of 9.67 days in storage under ambient condition in papaya variety Surya.

സംഗ്രഹം

വെള്ളായണി അഗ്രികൾച്ചർ കോളേജിലെ ഇൻസ്ട്രക്ഷണൽ ഫാമിൽ വച്ച് 2018 – 2020 കാലയളവിൽ പപ്പായയിലെ വളസേചനത്തെക്കുറിച്ച് പഠനം നടക്കുകയുണ്ടായി. പപ്പായയുടെ വളർച്ചയും വിളവും വർധിപ്പിക്കുന്നതിന് അനുയോജ്യമായ വളസേചനത്തിൻെറ അളവും, പത്രപോഷണവും കണ്ടെത്തുകയും, വിവിധ വിളവെടുപ്പാനന്തര മാർഗങ്ങൾ അവലംബിക്കുന്നതിലൂടെ പഴങ്ങളുടെ സൂക്ഷിപ്പുകാലം കൂട്ടുകയും ആയിരുന്നു പഠനത്തിൻറെ ലക്ഷ്യം.

റാൻഡമൈസ്ഡ് ബ്ലോക്ക് ഡിസൈനിൽ (ആർ ബി ഡി), ട്രീറ്റ്മെൻറുകൾ മൂന്ന് തവണ ആവർത്തിച്ചുകൊണ്ടുള്ള ഫീൽഡ് പരീക്ഷണം, ഇന്ത്യൻ ഇൻസ്റ്റിറ്റ്യൂട്ട് ഓഫ് ഹോർട്ടികൾച്ചറൽ റിസർച്ച് ഇനമായ സൂര്യയിലാണ് നടത്തിയത്. 75%, 100%, 125%, 150% നൈട്രജൻ (മണ്ണ് പരിശോധന പ്രകാരം 304.89, 406.52, 508.15, 609.78 ഗ്രാം യൂറിയ), പൊട്ടാഷ്യം (മണ്ണ് പരിശോധന പ്രകാരം 426.25, 568.33, 710.42, 852.50 ഗ്രാം മ്യൂറിയേറ്റ് ഓഫ് പൊട്ടാഷ്) എന്നി നാല് വളസേചന അളവുകളും, മൂന്ന് പത്രപോഷണവും (നട്ട് 4 മാസങ്ങൾക്ക് ശേഷം മുതൽ 16 മാസം വരെ രണ്ടുമാസത്തെ ഇടവേളയിൽ 1% 19:19:19, നട്ട് 4, 8, 12, 16 മാസങ്ങൾക്ക് ശേഷം 0.5% സിങ്ക് സൾഫൈററ് + 0.3% ബോറാക്സ്, നട്ട് 4 മാസങ്ങൾക്ക് ശേഷം മുതൽ 16 മാസം വരെ രണ്ടുമാസത്തെ ഇടവേളയിൽ വെള്ളം സ്പ്രെ) കേരള കാർഷിക സർവ്വകലാശാലയുടെ ശുപാർശ പ്രകാരമുള്ള നൈട്രജൻ: ഫോസ്ഫറസ്: പൊട്ടാഷ്യം (മണ്ണ് പരിശോധന പ്രകാരം 187:170:341 ഗ്രാം) എന്ന ട്രീറ്റ്മെൻറുമായും, നൈട്രജൻ: ഫോസ്ഫറസ്: പൊട്ടാഷ്യം എന്നിവ പരിപൂർണമായും ജൈവവളമായി നൽകുന്ന ട്രീറ്റ്മെൻറുമായുമാണ് താരതമ്യ പഠനം നടത്തിയത്. എല്ലാ ട്രീറ്റ്മെൻറുകൾക്കും അടിവളമായി 15 കിലോ കാലിവളം നൽകി.

വളസേചനവും പത്രപോഷണവും ലഭിക്കുന്ന ട്രീറ്റ്മെൻറുകൾക്ക് മണ്ണ് പരിശോധന പ്രകാരം 500 ഗ്രാം കുമ്മായവും 850 ഗ്രാം റോക്ക് ഫോസ്ഫേറ്റും ചെടി നട്ടതിനു ശേഷം നൽകി. നട്ട് ഒരു മാസത്തിനുശേഷം മുതൽ 20 മാസം വരെ നൽകിയ വളസേചനത്തിന് യൂറിയയും മ്യൂറിയേറ്റ് ഓഫ് പോട്ടാഷുമാണ് ഉപയോഗിച്ചത്.

പല അളവിലുള്ള വളസേചനവും പത്രപോഷണവും പപ്പായയുടെ വളർച്ചയിലും, വിളവിലും, പഴങ്ങളുടെ

ഗുണനിലവാരത്തിലും ശ്രദ്ധേയമായ മാറ്റമുണ്ടാക്കുന്നതായി കണ്ടെത്തി. 100% നൈട്രജൻ, പൊട്ടാഷ്യം വളസേചനവും, 1% 19:19:19 പത്രപോഷണവും (T_4) നൽകുക വഴി സസ്യങ്ങളുടെ ഉയരവും വണ്ണവും, ഇലകളുടെ എണ്ണവും വർദ്ധിച്ചു. ഇത് വഴി പപ്പായ ചെടി പൂവിടുന്നതിൻെറ ഉയരം കുറയുന്നതായും കൂടുതൽ പെണ്സസ്യങ്ങളുണ്ടാകുന്നതായും, പഴങ്ങളുണ്ടാകുന്ന ശതമാനം ഏറുന്നതായും കണ്ടെത്തി. എന്നാൽ, 100% നൈട്രജൻ, പൊട്ടാഷ്യം വളസേചനവും, 0.5% സിങ്ക് സൾഫൈററ് + 0.3% ബോറാക്സ് പത്രപോഷണവും (T_5) നൽകുക വഴി പൂവിടാനെടുക്കുന്ന ദിവസങ്ങളും, വിളവെടുക്കാനെടുക്കുന്ന ദിവസങ്ങളും കുറഞ്ഞതായും കണ്ടെത്തി.

T_4 T_5 ട്രീറ്റ്മെൻറുകൾ നൽകുക വഴി ഫലങ്ങളുടെ ഭാരം, പഴത്തിൻെറ നീളം, പഴത്തിൻെറ ദൈർഘ്യം, പഴത്തിൻെറ അളവ്, പൾപ്പ് ശതമാനം, പഴത്തിൻെറ മാംസകനം, ഒരു ചെടിയിലെ പഴങ്ങളുടെ എണ്ണം, ഒരു ചെടിയിലെ ആകെ വിളവ് എന്നിവ അഭിവൃദ്ധിപ്പെട്ടതായി കണ്ടെത്തി. T_5 ട്രീറ്റ്മെൻറ് സ്വീകരിച്ച ചെടികളിലെ ഫലങ്ങളിൽ ഏറ്റവും കൂടുതൽ ടോട്ടൽ സോലുബിൾ സോളിഡ്സ്, ടോട്ടൽ കരോട്ടിനോയിഡ്സ്, അസ്കോർബിക് ആസിഡ്, ടോട്ടൽ ഷുഗേഴ്സ് എന്നിവയും, കുറഞ്ഞ അസിഡിറ്റിയും കണ്ടെത്തി. T_4 T_5 ട്രീറ്റ്മെൻറുകളിൽ മറ്റ് ട്രീറ്റ്മെൻറുകളെ അപേക്ഷിച്ച് വരുമാനം കൂടുതൽ ലഭിച്ചു.

പപ്പായ പഴങ്ങളുടെ സൂക്ഷിപ്പുകാലം കൂട്ടുന്നതിനുള്ള പഠനത്തിന് വേണ്ടി ഫലങ്ങൾ ഉത്പാദിപ്പിച്ചത് കേരള കാർഷിക സർവ്വകലാശാലയുടെ ശുപാർശ പ്രകാരമുള്ള 240: 240: 480 ഗ്രാം നൈട്രജൻ: ഫോസ്ഫറസ്: പൊട്ടാഷ്യം നൽകിയുള്ള ഫീൽഡ് പരീക്ഷണം വഴിയായിരുന്നു. മൂന്ന് തവണ ആവർത്തിച്ച 9 ട്രീറ്റ്മെൻറുകൾ ഉണ്ടായിരുന്ന പഠനത്തിൽ, പൂർണ്ണമായും മൂത്ത, പച്ച നിറത്തിലുള്ള പപ്പായ പഴങ്ങൾ ആണ് ഉപയോഗിച്ചത്. തണുപ്പിക്കൽ (S_1), സോഡിയം ഹൈപ്പോക്ലോറൈറ്റ് ഉപയോഗിച്ച് അണുവിമുക്തമാക്കൽ (S_2), 1% കൈറ്റോസാൻ ഉപയോഗിച്ച് ഒരു നേരിയ ആവരണം ഉണ്ടാക്കിയെടുക്കൽ (S_3), തണുപ്പിക്കൽ കൂടാതെ 1% കൈറ്റോസാൻ ഉപയോഗിച്ച് ഒരു നേരിയ ആവരണം ഉണ്ടാക്കിയെടുക്കൽ (S_4), എത്തിലീൻ നീക്കം ചെയ്യാൻ കഴിവുള്ള പൊട്ടാസ്യം മെറ്റാബൈസൾഫൈറ്റ് ഉപയോഗിക്കൽ (S_5), തണുപ്പിക്കൽ കൂടാതെ

എത്തിലീൻ നീക്കം ചെയ്യാൻ കഴിവുള്ള പൊട്ടാസ്യം മെറ്റാബൈസൾഫൈറ്റ് ഉപയോഗിക്കൽ (S_6), തണുപ്പിക്കൽ കൂടാതെ 1% കൈറ്റോസാൻ ഉപയോഗിച്ച് ഒരു നേരിയ ആവരണം ഉണ്ടാക്കിയെടുക്കലും, എത്തിലീൻ നീക്കം ചെയ്യാൻ കഴിവുള്ള പൊട്ടാസ്യം മെറ്റാബൈസൾഫൈറ്റ് ഉപയോഗിക്കലും (S_7), ചൂടു വെള്ളം ഉപയോഗിച്ചുള്ള പരിചരണം കൂടാതെ 6% കാർണൗബാ മെഴുക് കൊണ്ട് നേരിയ ആവരണം ഉണ്ടാക്കിയെടുക്കലും, എത്തിലീൻ നീക്കം ചെയ്യാൻ കഴിവുള്ള പൊട്ടാസ്യം മെറ്റാബൈസൾഫൈറ്റ് ഉപയോഗിക്കലും (S_8), നിയന്ത്രണം - വിളവെടുപ്പാനന്തര മാർഗങ്ങൾ അവലംബിക്കാത്തത് (S_9) എന്നിവയായിരുന്നു ട്രീറ്റ്മെൻറുകൾ. വിളവെടുപ്പിനു ശേഷം വിവിധ സാങ്കേതിക വിദ്യകൾ അവലംബിച്ച്, പഴങ്ങൾ കോർഗേറ്റഡ് ഫൈബർ ബോർഡ് ബോക്സിനുള്ളിൽ സൂക്ഷിപ്പുകാലാവധി കഴിയുന്നത് വരെ അന്തരീക്ഷ ഊഷ്മാവിൽ സൂക്ഷിച്ചു.

തണുപ്പിക്കൽ കൂടാതെ 1% കൈറ്റോസാൻ ഉപയോഗിച്ച് ഒരു നേരിയ ആവരണം ഉണ്ടാക്കിയെടുക്കലും, എത്തിലീൻ നീക്കം ചെയ്യാൻ കഴിവുള്ള പൊട്ടാസ്യം മെറ്റാബൈസൾഫൈറ്റ് ഉപയോഗിച്ചുള്ള പാക്കേജിംങ്ങും (S_7) ചേർന്ന ട്രീറ്റ്മെൻറ് ആണ് സൂക്ഷിപ്പുകാലം 9.67 ദിവസമായി കൂട്ടാൻ സഹായിച്ചത്. ഈ ട്രീറ്റ്മെൻറ് സ്വീകരിച്ച ഫലങ്ങളിൽ, ജലാംശം നഷ്ടപ്പെടുന്ന തും, ചർമപാളിക്ക് പുറത്തേക്കുള്ള അയോണുകളുടെ നഷ്ടവും, അണുജീവികളുടെ എണ്ണവും, മൂന്നു ദിവസത്തിനു ശേഷം മറ്റ് ട്രീറ്റ്മെൻറുകളെ അപേക്ഷിച്ച് കുറവുള്ളതായും പഠനം സൂചിപ്പിക്കുന്നു. അതുപോലെ ഈ ട്രീറ്റ്മെൻറ് സ്വീകരിച്ച പപ്പായ പഴത്തിൻ്റെ രൂപം, നിറം, ഘടന, രുചി, രസം, സ്വീകാര്യത തുടങ്ങിയ ഗുണങ്ങൾ ഒൻപതാം ദിവസവും മികച്ചതായി കണ്ടെത്തി.

ചുരുക്കത്തിൽ, പപ്പായ ഇനം സൂര്യ ചെടികൾ നട്ട് ഒരു മാസത്തിനു ശേഷം മുതൽ 20 മാസം വരെ വളസേചനമായി 100% നൈട്രജൻ (406.52 ഗ്രാം യൂറിയ ഒരു ചെടിക്ക്, ഒരു വർഷം), പൊട്ടാഷ്യം (568.33 ഗ്രാം മ്യൂറിയേറ്റ് ഓഫ് പൊട്ടാഷ് ഒരു ചെടിക്ക്, ഒരു വർഷം) എന്നിവയും, 0.5% സിങ്ക് സൾഫൈററ് + 0.3% ബോറാക്സ് പത്രപോഷണവും, അടിവളമായി 15 കിലോ കാലിവളവും, മണ്ണ് പരിശോധനയ്ക്ക് ശേഷം 850 ഗ്രാം റോക്ക് ഫോസ്ഫേറ്റും നൽകിയപ്പോൾ ചെടികളുടെ വളർച്ചയും, വിളവും, പഴങ്ങളുടെ

ഗുണനിലവാരവും മെച്ചപ്പെട്ടതായി കണ്ടെത്തി. പൂർണ്ണമായും മൂത്ത, പച്ച നിറത്തിലുള്ള പപ്പായ പഴങ്ങൾ, തണുപ്പിക്കൽ കൂടാതെ 1% കൈറ്റോസാൻ ഉപയോഗിച്ച് ഒരു നേരിയ ആവരണം ഉണ്ടാക്കിയെടുക്കലും, എത്തിലീൻ നീക്കം ചെയ്യാൻ കഴിവുള്ള പൊട്ടാസ്യം മെറ്റാബൈസൾഫൈറ്റ് ഉപയോഗിച്ചുള്ള പാക്കേജിംങ്ങും ചേർന്ന ട്രീറ്റ്മെൻറ് നൽകി കോർഗേറ്റഡ് ഫൈബർ ബോർഡ് ബോക്സിനുള്ളിൽ സൂക്ഷിച്ചപ്പോൾ, സംരക്ഷണ കാലാവധി 9.67 ദിവസമായി വർദ്ധിച്ചതായി കണ്ടെത്തി.