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Effect Of Fertigation On Performance Of Papaya- A Review

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ABSTRACT
The literature on fertigation on papaya cultivation has been well documented. In this article efforts have been made to review the literature available on application of fertigation on different crops.
***Key words** : Fertigation, Growth character, Yield attributes, Yield, Nutrients uptake, Quality characters*

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I. INTRODUCTION

Papaya is one among the fruits which has attained a great popularity in recent years because of gynodioecious nature, its easy cultivation, quick returns, adoptability to diverse soil and climatic conditions and above all its attractive delicious wholesome fruits having multifarious uses. Papaya, which remained as a backyard crop hitherto, has become an important commercial crop over the years.

It is an excellent source of vitamin C and A. Demand is also high at consumers end for the attractive pulp colour, flavour, succulence and characteristic aroma (Desai and Wagh 1995). Papaya has occupied a unique place in the diet of people worldwide because of striking nutritional and medicinal value of fruits. It is grown all over India for its fresh and ripe fruits as well as for vegetable purposes which is available round the year in the country.

Papaya is highly problematic, complicated and interesting fruit crop from botanical, genetical, cytogenetical and horticultural point of view. Papaya is best suited in tropical climatic conditions having assured irrigation facilities. The mature fruits are available for harvesting after 150- 160 days of flowering and fruits remain available for four to five months. The papaya root system is shallow and roots are thin, which are responsible for the nutrient absorption. Nevertheless, the root can reach up to 1m depth, being important in the water uptake and for the maintenance. Therefore any management practice should encourage abundant root growth in the surface (25-30 cm) and thick roots in depth (30- 60 cm) (Reddy and Dinesh, 2013). Papaya is considered as an exhaustive crop as it is a heavy yielder besides demanding large quantity of nutrients. It yields 70 to 80 tonnes fruits per hectare under proper management. The fruits of excellent quality are produced under mild subtropical climates where as a dry warm sunny climate tends to add the sweetness of the fruit. The area under this crop is increasing steadily every year. Water and nutrients are the two important crucial basic sources for augmenting crop production.

Flexible and precise fertilizer application is another potential advantage of the drip system. Fertigation is the application of fertilizer through micro irrigation systems. Fertigation permits application of various fertilizer formulations directly at the site of active root zone area of plant. Elfving (1982) found that drip irrigation with fertilizer is much more precise than other methods at delivering nutrients to the root where it can be effectively utilized and therefore, resulting in greater uptake and use efficiency. In fertigation nutrient use efficiency could be as high as 90 per cent as compared to 40 per cent in conventional methods (Solaimalai *et al*., 2005). In addition it saves the fertilizers, time and labour. Generally crop response to fertilizer application through drip irrigation has been excellent.

So far as papaya is concerned, its demand for nitrogen, phosphorus and potassium under conventional method of fertilization is high, which can be considerably slashed when applied through drip in small quantities at frequent intervals in accordance to crop need. Chaudhri *et al.* (2001) found 50 per cent saving of fertilizer and 53 per cent water saving with substantial increase in yield of papaya. Papaya being indeterminate nature of crop, vegetative and reproductive stages overlaps and the plant needs nutrients even up to fruit ripening stage for better growth and fruit size, hence fertigation is very effective in papaya.

II. REVIEW

Effect of fertigation on growth

Srinivas (1997) studied on growth and yield response of banana to N fertigation through drip irrigation and direct soil application at IIHR, Bangalore during 1992-94. He reported that plant height, stem girth, leaf number and leaf area index increased with N application through soil and drip. However, this increase was not significant beyond 100 g N plant^{-1} applied through drip irrigation compared to direct soil application.

The field experiment was conducted at Bangalore to study the effect of levels of nitrogen and potassium fertigation on the performance of Robusta banana by Chadrakumar *et al.* (2001). They revealed that the maximum plant height, stem girth and number of leaves plant^{-1} at 180 days after planting were found under N and K_2O at 200 g plant^{-1} supplied through drip irrigation.

Pandey *et al.* (2001) conducted an experiment at Trichy, Tamil Nadu during 1999-2000 and concluded that different moisture regime and N fertigation in normal and paired row planting showed significant positive response on plant height and leaf area of Nendran banana.

Mahalakshmi *et al.* (2001a) studied the influence of fertigation on banana cv. Robusta (AAA) at the college orchards, Coimbatore during 1998-2000 and revealed that fertigation was effective in increasing the vigour of the plants as measured by the plant girth, number of leaves and phyllochron. Crop duration was significantly earlier in fertigation than the control plants.

Mahalakshmi *et al.* (2001b) working with fertigation under high density planting in banana cv. Robusta (AAA), reported that plants under fertigation exhibited improvement in plant morphology in terms of plant girth, number of leaves at harvest and phyllochron.

Jeyakumar *et al.* (2002) stated that application of 10 litres of water day^{-1} + 13.5 g urea and 10.5 g of muriate of potash week^{-1} through fertigation and soil application of super phosphate 278 g plant^{-1} at bimonthly intervals in papaya var. Co. 2 gave significantly higher plant height, number of leaves and minimum flowering height and bearing height.

Badgujar *et al.* (2004) evaluated Grand Naine banana with different planting densities under various fertigation levels at MPKV, Jalgaon. The results revealed that drip irrigation based on PE scheduled at daily basis and 75 per cent recommended dose of N and K_2O (200: 200 g N: K_2O plant^{-1}) at weekly intervals through drip in 38 doses, in addition to common dose of P @ 40 g plant^{-1} as soil application gave maximum pseudo stem girth and number of functional leaves at flowering as compared to other fertigation treatments and conventional method.

Sharma *et al.* (2005) compared five fertigation levels at PFDC, Raipur during 2000-2001 in papaya cv. Red Lady and reported that plant height, stem girth and number of functional leaves were higher under 100 per cent fertigation level. This treatment yielded an early flowering (25 days) and early fruit setting as compared to rest of the treatments.

Jeyakumar *et al.* (2010) revealed that fertigation of papaya with 100 per cent recommended dose of N and K_2O through drip (50 g N at 6.25 g plant^{-1} week^{-1} and 50 g K_2O at 6.25 g plant^{-1} week^{-1} for a two months period), in addition to soil application of 50 g P_2O_5 in bimonthly intervals resulted in flowering at the shortest height (96.32 cm). Plant height and stem girth were found more by registering 268 and 43.2 cm and maximum fruit yield. Number of leaves and leaf area were also observed high in fertigated plants by recording 34.2 and 3714 cm^2 leaf^{-1}, respectively. However, the first flowering height and first bearing height were recorded low in fertigated plants (91.5 and 108.3 cm).

Sadarunnisa *et al.* (2010) studied the effect of fertigation in papaya cv. Red Lady at Horticultural Research Station, Anantharajupeta, Andhra Pradesh and found the maximum plant height (220.50 cm), girth (44.25 cm), number of functional leaves (45.50), leaf area (4729.50 cm^2) and shortest height at first flowering under the treatment of 100 per cent recommended dose of N and K_2O through drip as compared to rest of the fertigation and conventional irrigation methods. However this treatment was comparable with lower dose of fertilizers i.e. 75 per cent recommended dose of N and K_2O through drip.

Tank *et al.* (2011) conducted an experiment to study the effect of fertigation on growth, yield and quality of papaya (*Carica papaya* L.) cv. Madhu bindu under South Gujarat conditions at the Regional Horticultural Research Station, ASPEE College of Horticulture and Forestry, Navsari, Gujarat with 9 fertigation treatments and a control having surface irrigation @ 1.0 IW/CPE ratio + 100 per cent fertilizer through soil. The results of experiment showed early flowering and maturity of first fruit, shortest bearing height, maximum plant height and stem girth, number of functional leaves and total leaf area were found maximum due to application of fertigation @ 0.8 PEF + N and K_2O @ 100 per cent recommended dose of fertilizer (RD) which remained at par with treatment of fertigation @ 0.8 PEF + N and K_2O @ 80 per cent RD.

Deshmukh and Hardaha (2014) conducted a field experiment in Chhindwara district of MP showed that the drip irrigation at 100 per cent CPE with 100 per cent recommended dose of fertilizer was found optimum for growth (139.17 cm), fruiting length (29.5 cm)

Panigrahi *et al.* (2015) carried out a field experiment at IGKV., Raipur to study the effect of different levels of fertigation through water-soluble fertilizers on growth, yield and quality of papaya cv. Red Lady and revealed that plant height and number of functional leaves were recorded maximum 200.72 cm and 35.50, respectively under 100 per cent RDF through fertigation while stem girth (51.72 cm) was found maximum under 80 per cent RDF through fertigation. Days required to first flowering and fruiting was recorded minimum under the same treatment.

Jadhav *et al.* (2016) conducted an experiment on, "Effect of fertigation, splitting and mulching on first flowering height (cm), days to first flower initiation and fruit maturity after planting of papaya (*Carica papaya* L.) cv. Red Lady" at two locations *i.e.* Regional Horticultural Research Farm, Navsari and Fruit Research Station, Gandevi, Navsari Agricultural University, Navsari (Gujarat) during 2012-13. The results of one year study inferred that, the application N and K_2O @ 100 % RDF (200: 200: 250 g palnt^{-1}) was favorable to influenced the first flowering height (cm), first flower initiation and days to fruit maturity after transplanting of papaya. In case of first flowering height (cm), days to first flower initiation and days to fruit maturity after transplanting were mostly influenced by 18 split application of N and K_2O @ 100 % RDF treatment after 15 days intervals application after transplanting the seedling of papaya cv. Red Lady.

Singh *et al.* (2019) conducted an experiment on papaya cv. Red lady grown under protected conditions to evaluate the variations in plant growth, fruit production and quality parameters as induced by different fertigation levels in comparison to traditional fertilizer application. Among different treatments; least average plant height (313.50 cm), number of days taken for flower initiation (189) and fruit set (194), maximum average stem girth (47.53 cm), number of functional leaves per plant (32.0), height of first flowering (103.50 cm), fruits per node (1.66) were recorded in fertigation applied at 60% recommended dose of fertilizer treatment. Whereas, highest average plant spread (296.41 cm) were observed in treatment where fertigation at 80 percent RDF was applied.

Sesbastian and Bindu (2020) conducted an experiment at Instructional Farm, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala from 2018- 2020 to standardize the nutrient level for yield improvement through fertigation and foliar nutrition in papaya cv. Surya. Application of 100% RD of N and K through fertigation at weekly interval from one MAP to 20 MAP with foliar application of 19:19:19(1%) at bimonthly interval starting from 4 MAP to 16 MAP significantly improved the plant height, plant girth and number of leaves.

Effect of fertigation on yield attributes and yield

Berad *et al.* (1998) conducted a field experiment at Rahuri during 1995-97 with cv. Basrai banana on a clayey soil. Two fertilizer sources (liquid and solid), two irrigation methods (surface and drip) and two spacing (1.8 x 1.5 m and 0.9- 2.7 x 1.5 m) were compared. They revealed that the normal planting (1.8 x 1.5 m) with application of 100: 40: 200 g N, P_2O_5 and K_2O plant^{-1} in solid form and only N (urea) applied through the drip system in the drip irrigation treatments, performed well in respect of all yield attributes and registered 15 per cent higher yield as compared with surface irrigation for the same planting technique and fertilizer rate.

Chaudhri *et al.* (2001) conducted a field experiment on sandy clay loam soil at MPKV, Rahuri and observed that 50 per cent recommended dose of fertilizer in liquid form through drip irrigation was found efficient to achieve maximum number of fruits plant^{-1} (56.25), fruit yield plant^{-1} (60.34 kg) and fruit yield hectare^{-1} (67.04 t) as compared to higher levels of fertilizer dose in liquid form in papaya.

Chandrakumar *et al.* (2001) compared four levels of nitrogen and potassium (50,100,150 and 200 g plant^{-1}) through drip irrigation in Robusta banana. They observed that nitrogen and potassium level at 200 g plant^{-1} produced maximum hands bunch^{-1} (7.43), fingers bunch^{-1} (96.02), average finger weight (207.37 g) and yield (88.46 t ha^{-1}) as compared to rest of the levels.

Mahalakshmi *et al.* (2001a) conducted an experiment at Coimbatore (Tamil Nadu) and observed that the fertigation treatment at 25 l day^{-1} plant^{-1} with 100 per cent N and K (200: 300 g N: K_2O plant^{-1}) in addition to a common dose of P_2O_5 @ 30 g plant^{-1} applied through fertigation registered the maximum bunch weight of 44.53 kg with corresponding highest number of hands (10.52) and fingers (203.73).

Mahalakshmi *et al.* (2001b) concluded that among the different levels of irrigation and fertigation under high density planting of banana, irrigation at 50 l day^{-1} pit^{-1} through drip with 100 per cent (600 and 900 g, N and K_2O plant^{-1}) N and K_2O fertigation resulted in heavy bunch weight, maximum number of hands and number of fingers bunch^{-1} as compared to other fertigation treatments and conventional method at Coimbatore (Tamil Nadu).

Srinivas *et al.* (2001) conducted an experiment on growth and yield of Robusta banana in relation to N and K fertigation at Bangalore during 1997-98. They concluded that maximum fruit yield, average bunch weight, number of hands bunch^{-1} and average finger weight were found under the treatment of 200 g N and K_2O plant^{-1} applied through drip irrigation method at 0.80 PEF on daily basis in addition to uniform dose of P_2O_5 (247 g plant^{-1}) as soil application at 60 days after planting.

Tumbare and Bhoite (2001) conducted an experiment on fertigation in banana at Rahuri (Maharashtra) to study the optimization of liquid fertilizer under drip irrigation with different levels of recommended doses of fertilizers (50, 75, 100 and 125 per cent of RDF). The results showed that banana crop responded to 125 per cent of recommended dose of fertilizer for achieving optimum fruit yield.

Madhava Rao *et al.* (2002) conducted an experiment at Kovvur, Andhra Pradesh and reported that fertigation at different levels of recommended dose of N and K_2O (200 g plant^{-1}) as urea and muriate of potash, respectively enhanced growth and yield of Robusta banana.

Kavino *et al.* (2002a) conducted a study to examine the efficacy of conventional fertilizers over water soluble fertilizers in influencing the yield and quality of banana cv. Robusta (AAA) at Coimbatore. The results showed that the application of water soluble fertilizers was very effective in producing the maximum bunch weight, hands bunch^{-1}, fingers bunch^{-1}, finger weight, pulp weight and yield.

Parikh *et al.* (2002b) conducted an experiment on fine texture soil to study the response of banana to nitrogen application through drip and reported that application of nitrogen through drip at 80 per cent of recommended dose gave significantly higher banana fruit yield compared with surface irrigation. They also observed that as high as 60 per cent of N requirement can be reduced without any adverse effect on banana fruit yield.

Reddy *et al.* (2002) conducted an experiment in Karnataka with nitrogen and potassium applied to Robusta banana at 50, 100, 150 and 200 g plant^{-1} by full drip irrigation, 50 per cent drip + 50 per cent soil application and full soil application. They observed that banana yield was increased with increasing N and K_2O fertigation levels and highest yield was recorded at 200 g N and K_2O plant^{-1} through fertigation as compared to soil application.

Jeyakumar *et al.* (2002) conducted an experiment using papaya cv. Co. 2 at Coimbatore during the year 2000-2001. They reported maximum number of fruit, fruit weight, fruit length, fruit circumference, fruit volume, pulp thickness and dry seed weight with the application of 10 l of water day^{-1} + 13.5 g urea and 10.5 g of muriate of potash week^{-1} through fertigation up to 8 months and soil application of super phosphate 278 g plant^{-1} at bimonthly intervals as compared to flood irrigation with 100 per cent recommended dose of N: P_2O_5: K_2O (200: 200: 200 g plant^{-1}) through soil application in four equal splits at bimonthly intervals.

Badgujar *et al.* (2004) conducted an experiment on influence of N and K_2O fertigation and different plant densities on yield of banana cv. Grand Naine at Jalgaon. Among the different levels of fertigation, 75 per cent recommended dose of fertilizer (200: 200 N: K_2O plant^{-1}) of N and K_2O at weekly intervals through drip on basis of PE scheduled at daily in addition to P_2O_5 (40 g plant^{-1}) as soil application produced maximum number of hands bunch^{-1} (8.17), number of fingers bunch^{-1} (116.24), bunch circumference (106.62 cm), finger girth (13.46 cm), bunch weight (14.03 kg) and yield (66.33 t ha^{-1}).

Vazquez *et al.* (2005) carried out a trial to evaluate the effect of drip irrigation and N: P: K fertilization through drip, conventional furrow irrigation system and soil N: P: K fertilization on yield, water use efficiency and economic productivity of papaya cv. Maradol, grown in a vertisol of Apatzingan Valley, Machoacan, Mexico. They found maximum average yield under fertigation treatment (30.4 t ha^{-1}) as compared to conventional system (13.3 t ha^{-1}).

Sharma *et al.* (2005) observed that maximum fruit length (31.12 cm), circumference (68.72 cm), fruit number (32.45), weight (1.810 g), pulp thickness (3.21 cm) and yield (140 t ha^{-1}) were obtained under the treatment of 100 per cent recommended dose of fertilizers through drip.

Singh and Singh (2006) conducted an experiment to study the effect of fertigation on papaya cv. Pusa Delicious at Pusa, Samastipur, Bihar during 1998-99 with three fertigation treatments and conventional cultivation. They concluded that the fruit length, number, circumference and weight under fertigation treatment were significantly superior to conventional method of fertilizer application. They also recorded 43 per cent yield increase with 100 per cent urea application through fertigation compared to conventional cultivation.

Agrawal *et al.* (2010) carried out the experiment of study the effect of fertigation through water-soluble fertilizers on growth, yield and quality of papaya cv. Red Lady. Fruit length (32.12 cm), circumference (68.72 cm), fruit number (56.32) weight (1748.33 g), pericarp thickness (3.21 cm) and per cent TSS (12.38 ^oB) and fruit yield (140.80 t ha^{-1}) were higher under the treatment i.e. application of 100 per cent fertilizers of recommended dose through drip irrigation. further it was reported also reported that number of fruits plant^{-1} (56.32), fruit weight (1748.33 g) and maximum yield of 144.80 t ha^{-1} were obtained in F_1 treatment i.e. 100 per cent fertilizer of recommended dose applied.

Jeyakumar *et al.* (2010) assessed the influence of fertigation on nutrient use and yield improvement in papaya cv. Co. 7 during 2006-2008 at Horticultural College and Research Institute, Coimbatore. They compared 100, 75, and 50 per cent of recommended dose of N and K_2O (200: 200 g plant^{-1}) at weekly intervals up to 8 months with soil application of recommended dose of fertilizers (200: 200: 200 g N: P_2O_5: K_2O plant^{-1}) at bimonthly intervals resulted maximum fruit yield. Number of fruits and fruit weight were observed high (40.2

and 1.84 kg) in fertigated plants. The increase in number of fruits and fruit weight attributed for higher fruit yield tree^{-1} (73.97 kg) and the resultant total fruit yield hectare^{-1} (184.9 t)

Sadarunnisa *et al.* (2010) studied on the effect of fertigation on yield and quality of papaya cv. Red Lady to standardize the optimum dose for papaya through fertigation at Ananthrajupet, Andhra Pradesh. They compared 100, 75, 50 per cent RDF (250: 250: 500 g N: P_2O_5: K_2O) of N and K_2O through drip, 100 per cent RDF of N and K_2O through soil and irrigation by drip and 100 per cent RDF of N and K_2O through soil and conventional irrigation. The P_2O_5 was applied to soil once in two months. The results indicated that 75 per cent N and K_2O when applied through drip, recorded a yield of 100.42 kg plant^{-1} which was on par with the yield of plants supplied with 100 per cent RDF (102.60 kg plant^{-1}). The yield components like number of fruits plant^{-1}, fruit weight were superior in the treatment where fertilizers were applied through drip compared to the treatments in which soil application of fertilizers was done. Moreover, they concluded that there was no significant difference between 100 and 75 per cent N and K_2O treatments through drip regarding yield and yield attributes, the later dosage is economical over the former.

Tank *et al.* (2011) recorded the higher yield of papaya fruits in application of fertigation @ 0.8 PEF + N and K_2O @ 100 per cent recommended dose of fertilizer (RD) which was about 31.90 over control treatment which was attributed to higher number and weight of fruits.

Singh and Singh (2012) in the experiment conducted to study the effect of fertigation on papaya (Pusa delicious) at the experimental farm of Horticultural Research Station, Birauli (RAU, Bihar, Pusa) reported that fruit characteristics of papaya were found superior with 100 per cent fertigation followed by 80 per cent, the control treatment and 60 per cent fertigation treatment. The highest value of fruiting length was recorded as 0.88 meter and number of fruits plant^{-1} was 39 under 100 per cent fertigation treatments.

Pawar and Dingre (2013) revealed that drip with fertigation resulted into 24 to 46 per cent increase in banana yield with equal amount of water saving as compared to conventional method. Drip fertigation significantly increased yield contributing as compared to conventional fertilizers. Fertigation as per the growth stages proved superior as compared to uniform splits for all the characters including yield. The 100 per cent recommended dose of fertilizer through drip as per crop growth stages showed 46.22 per cent increase in yield (83.62 t ha^{-1}). However, it was on par with 80% fertigation treatments (79 t ha^{-1}). The banana fruit yield obtained under 60% fertigation (68 t ha^{-1}) produced 19 % more yield as compared to conventional fertilizer application through soil (57.4 t ha^{-1}) indicating 40 per cent fertilizer saving due to fertigation.

Deshmukh and Hardaha (2014) reported that the drip irrigation at 100 per cent CPE with 100 per cent recommended dose of fertilizer was found optimum for papaya production (112.55 kg plant^{-1}) as well as fruiting length (29.5 cm). Data showed that up to 61.59 per cent more yield was found with drip fertigation system as compared to conventional method of irrigation.

Panigrahi *et al.* (2015) revealed that application of water-soluble fertilizers through fertigation was quite effective on fruit set and yield of papaya. Number of fruit plant^{-1} (76.27), fruit weight (1.42 kg) and yield (145.23 t ha^{-1}) were found maximum under 80 per cent RDF through fertigation.

Singh *et al.* (2019) conducted an experiment on papaya cv. Red lady to evaluate the variations in plant growth, fruit production and quality parameters as induced by different fertigation levels in comparison to traditional fertilizer application. Among different treatments; least average fruits node^{-1} (1.66) were recorded in fertigation applied at 60% recommended dose of fertilizer treatment. Whereas, highest average number of fruits plant^{-1} (46.26), fruit length (20.67 cm), fruit circumference (40.53 cm) and fruit yield (42.79 kg plant^{-1}) were observed in treatment where fertigation at 80 per cent RDF was applied. Under protected cultivation; 80 per cent of recommended fertilizer dose given through drip irrigation resulted in maximum yield and quality fruits of 'Red lady' papaya cultivar.

Sesbastian and Bindu (2020) reported that application of 100% RD of N and K through fertigation at weekly interval from one MAP to 20 MAP with foliar application of 19:19:19 (1%) at bimonthly interval starting from 4 MAP to 16 MAP significantly improved number of fruits plant^{-1}, fruit weight and yield plant^{-1} in papaya cv. Surya. Also it was found that application of 100% RD of N and K through fertigation at weekly interval from one MAP to 20 MAP with foliar application of ZnSo4 (0.5%) and Borax (0.3%) at 4th, 8th, 12th and 16th MAP was on par with the above treatment on number of fruits plant^{-1}, fruit weight and yield plant^{-1} in papaya cv. Surya.

Effect of fertigation on fruit quality

Srinivas (1996a) compared daily and alternate day drip irrigation at 0.6 PEF level in papaya cv. Coorg Honey Dew and noted highest total soluble solids under alternate day drip irrigation at 0.6 PEF.

Srinivas *et al.* (2001) noted the highest TSS (24 ^{0}Brix) and pulp: peel ratio (2.84) when 150 g N and K_2O was applied through drip at 0.8 PEF on daily basis in addition to 247 g P_2O_5 plant^{-1} as soil application as compared to higher and lower level of fertilizer doses.

Jeyakumar *et al.* (2001) found graded doses of K (0, 150, 300 and 450 Kg K_20 ha^{-1}) were applied with two cultivars (CO 2 and CO 7) at four locations of Tamil Nadu and found that potassium nutrition significantly influenced fruit weight, fruit yield $plant^{-1}$ and the quality of fruits.

Kavino *et al.* (2002a) stated that the treatment receiving drip irrigation at 200 per cent of PE and 75 per cent recommended dose of fertilizer pit^{-1} using normal fertilizer registered the highest value of TSS and sugars as compared to water soluble fertilizers.

Jeyakumar *et al.* (2002) recorded higher TSS (12.4 ^{0}Brix) under fertigation treatment as compared to control in Co. 2 variety of papaya.

Ravichandrane *et al.* (2002) were recommended twelve splits instead of six as it resulted application of 400 g each of NPK $plant^{-1}$ $year^{-1}$ gave higher yield and number of fruits, TSS 14.40 (^{0}Brix), carotene enzyme 3.64 mg 100 g^{-1} pulp and fruits weight 2.11 kg in papaya cv. CO 2.

Sharma *et al.* (2005) noted maximum TSS (12.38 ^{0}Brix) under the treatment of 100 per cent recommended dose of fertilizer through drip as compared to rest of the treatments.

Zaman *et al*. (2006) reprted that maximum fruit weight was observed in cv. Bombai and lowest in cv. Shahi (Red), while TSS (9.0-13.0 %) and total sugars (6.96-10.50 %) were observed in cv. Bombai and cv. Shahi, respectively.

Agrawal *et al.* (2010) observed that TSS (12.38 ^{o}B) higher under the treatment i.e. application of 100 per cent fertilizers of recommended dose through drip irrigation in papaya cv. Red Lady.

Jeyakumar *et al.* (2010) noted maximum TSS, total sugars and ascorbic acid in fertigation treatment at 100 per cent recommended dose of N and K_2O through drip, in addition to soil application of 50 g P_2O_5 at Coimbatore in papaya cv. Co. 7.

Kumar *et al.* (2010) recommended the application of balanced fertilization with N 300, P_2O_5 300 and K_2O 300 kg ha^{-1} $year^{-1}$ for papaya to get maximum pulp thickness in papaya in content in yellow and red fleshed varieties.

Sadarunnisa *et al*. (2010) indicated that the quality characters of fruits like fruit length, circumference, volume and TSS, in fertigated treatments were superior to treatments in which soil application of fertilizers was done. Treatments provided with drip recorded lower TSS compared to flood irrigated plants.

Tank *et al.* (2011) revealed that fertigation had significant influence on quality parameters by recording higher levels of TSS, total sugars, reducing sugars, non- reducing sugars and ascorbic acid. However, total carotenoids content in fruit was remain unchanged.

Singh and Singh (2012) reported that the quality of fruits in terms of length, circumference and weight under fertigation treatment was significantly superior to conventional cultivation.

Panigrahi *et al.* (2015) reported that quality of papaya cv. Red Lady with application of water-soluble fertilizers through fertigation was quite effective on qualitative parameter total soluble solid (13.38 %).

Singh *et al.* (2019) reported desirable levels of fruit quality parameters such as total soluble solids, acidity and sugars were observed in treatment where fertigation at 80 per cent RDF was applied. Under protected cultivation 80 per cent of recommended fertilizer dose given through drip irrigation resulted in quality fruits of 'Red lady' papaya cultivar.

Effect of fertigation on leaf nutrient content

Veerannah and Selvaraj (1984) found that uptake of N, P, K, Ca and Mg on papaya cv. CO 1 were higher between flowering (53.37, 15.41, 203.36, 4.10 and 2.30 kg ha^{-1}, respectively) and harvesting stages (305.58, 103.68, 524.02, 327.40 and 183.34 kg ha^{-1}, respectively), but uptake is specifically higher between fruit development and harvest stages more so with potassium.

Jeyakumar *et al.* (2002) concluded that phosphorus content in leaf was not affected while significantly higher nitrogen and potassium were recorded under fertigation treatments. The application of 100 per cent recommended dose of N and K_2O through drip irrigation recorded significantly higher leaf N (1.72 %) and leaf K (2.91 %) as compared to lower doses of fertigation and 100 per cent recommended dose of N and K_2O by soil application. Leaf P was not affected due to the different treatments.

Kavino *et al.* (2002b) revealed that fertigation treatment resulted in higher leaf N (3.30 %) at three months after ratooning and at harvesting stage (2.65 %) and higher levels of K at five and seven months after ratooning (4.63 and 4.48 %) while P level in the leaf was not affected.

Mellado *et al.* (2005) conducted an experiment to evaluate the effect of drip irrigation and N-P-K fertilization under fertigation and conventional furrow irrigation system and soil N-P-K fertilization on yield, water use efficiency and economic productivity of papaya (*Carica papaya* L.), cv. Maradol grown in a Vertisol of Mexico and found that the concentration of K in plant under drip and furrow irrigation and fertilization systems was low, the concentration of Ca and B was high, and the concentration of N, P, Mg, Fe, Cu, Zn, and Mn was within sufficiency range.

Jeyakumar *et al.* (2010) revealed that higher N (1.72 %) and K (2.91 %) content in the fertigated plant. But, P did not show any significant variation between control and fertigated plants as phosphorus was applied directly in soil taking into account its nature of precipitation and clogging in drippers.

Effect of fertigation on soil nutrient status

Srinivas *et al.* (2001) observed that the N uptake was highest with leaves followed by fruits and stem. The P uptake was highest in fruit followed by stem and leaves, where K uptake was highest in fruits followed by leaves and stem.

Kavino *et al.* (2002b) conducted trial on the effect of fertigation on changes of leaf as well as soil N, P_2O_5 and K_2O content in banana crop cv. Robusta and reported that significantly higher levels of available soil N and K_2O were noted in normal fertilizers application through drip as compared to liquid fertilizers while soil P_2O_5 did not show much variation.

Effect of fertigation on saving of water and fertilizer

Chaudhari *et al*. (2001) concluded that water saving to the tune of 53 per cent was observed in drip irrigation as compared to surface irrigation method. Moreover, 50 per cent fertilizer saving was noted in fertigation treatment as compared to conventional method of recommended fertilizer dose.

Savani *et al.* (2002) at Soil and Water Management Research Unit, Navsari, Gujarat found that fertigation was beneficial for banana along with 40 per cent fertilizer saving and 35 per cent reduced irrigation water requirement without any adverse effect on growth, yield and quality of banana.

Shinde *et al.* (2005) at PFDC, Rahuri reported that paired row planting technique along with application of 75 per cent recommended dose of fertilizer in liquid form through drip irrigation is equally good as 100 per cent recommended dose of fertilizer as liquid form with additional benefit of 25 and 47.88 per cent fertilizer and water saving, respectively.

Singh and Singh (2012) in the experiment conducted to study the effect of fertigation on papaya (Pusa delicious) at the experimental farm of Horticultural Research Station, Birauli (RAU, Bihar, Pusa) reported that fertilizer expense efficiency was found maximum in water applied through drip with 60 per cent of recommended dose of nitrogenous fertilizer (16.75).

Deshmukh *et al.* (2017) reported that the fertilizer use efficiency recorded was 24.69, 25.85 and 32.56 kg of yield kg^{-1} of nutrient applied for drip irrigation treatments with 0.6, 0.8 and 1.0 IW/CPE ratio, respectively, where as it was 29.53, 26.55 and 27.01 kg of yield kg^{-1} of nutrient applied for treatments 60, 80 and 100 per cent recommended dose of fertilizers, respectively over control (14.79 kg of yield kg^{-1} of nutrient applied).

Effect of fertigation on economics

Chandrakumar *et al.* (2001) studied the effect of levels and ratios of nitrogen and potassium fertigation on the performance of Robusta banana at Indian Institute of Horticultural Research, Hessaraghatta, Bangalore. They noted the higher profit $rupee^{-1}$ invested (` 2.82) with 150 g of nitrogen and potassium fertigation as compared to higher and lower levels of nitrogen and potassium fertigation.

Mahalakshmi *et al.* (2001a) stated that fertigation has proved economies water and fertilizer levels with a corresponding lower expenditure in cost of production with labour saving towards weeding, fertilization and water application.

The economic analysis of the treatments based on cost of production kg^{-1} of banana and benefit cost ratio revealed that the application of irrigation at 40 litres day^{-1} pit^{-1} through drip irrigation with 75 per cent (450: 675 g N and K_2O $plant^{-1}$) N and K_2O fertigation in addition to common dose of P_2O_5 @ 90 g $plant^{-1}$ through fertigation was found superior over the other treatments under high density planting system (Mahalakshmi *et al.* 2001b).

Kavino *et al.* (2002a) compared conventional fertilizers and water soluble fertilizers application through fertigation in banana and reported that even though plants fertigated with water soluble fertilizers gave highest yields, plant fertigated with normal fertilizers have been found better for adoption by farmer owing to its low cost (high benefit cost ratio i.e. 3.42) and easy market availability.

Kadam *et al.* (2005) at Precision Farming Development Centre, Rahuri revealed that optimum yield and maximum net profit of banana can be achieved with spacing 1.75 m X 1.75 m , 80 per cent recommended dose of N: P_2O_5: K_2O fertigation and 0.80 PE irrigation level.

Sharma *et al.* (2005) tested five fertigation levels at PFDC, Raipur during 2000- 2001 in papaya cv. Red Lady. Among the various fertigation treatments, 100 per cent fertigation level recorded the highest yield of 140 tones ha^{-1} with maximum benefit cost ratio of 2.43.

Jeyakumar *et al.* (2010) revealed that higher B: C ratio (1: 1.97) in plants treated with 100 per cent recommended dose of N & K_2O plant^{-1} through drip (50 g N & 50 g K_2O), in addition to soil application of 50 g P_2O_5.

Sadarunnisa *et al.* (2010) observed that the benefit cost ratio was high in the treatment where 75 per cent recommended dose of N and K_2O through drip was applied as compared to higher and lower levels of fertilizer doses and conventional method as well.

Deshmukh *et al.* (2014) observed the least B: C ratio (1.19) in the control, whereas was maximum (1.725) for 1.0 IW/CPE ratio and 60 per cent recommended dose of fertilizer.

Deshmukh *et al.* (2017) conducted a field experiment for three consecutive years from 2011 to 2013 to study the effect of different fertigation levels on papaya production in sandy loam soil and reported that maximum benefit of ` 1164700 ha$^{-1}$ was obtained with 100 per cent of recommended dose of fertilizer over control treatment (` 694700 ha^{-1}) with B: C ratio of 2.62 and 1.86, respectively.

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