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Effect of dosage and frequency of fertigation on quality of mango (*Mangifera indica* L.) cv. Banganpalli

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Abstract
A field experiment was carried out at Fruit Research Station, Sangareddy, Telangana State during the year 2015- 2017 to study the effect of dosage (T_1 –NK @ 100% RDF, T_2 - NK @ 80% RDF, T_3 - NK @ 60% RDF, T_4 - NK @ 50% RDF) and frequency of fertigation (F_1 - One time at marble stage, F_2 - Daily fertigation) on production and productivity of mango (*Mangifera indica* L.) cv. Banganpalli. The experiment results revealed that application of daily fertigation with 100% RD of NK + micronutrient mixture (D_1F_2) has recorded the maximum fruit TSS (17.12 °Brix), specific gravity (1.11), reducing sugars (6.96%), sugar acid ratio (85.08) and improved flavour with minimum titratable acidity (0.20 %) and maximum shelf life (15.13 days) of fruits, due to increase in the soil and leaf macro (N (kg/ha), K (kg/ha)) nutrient levels.

Keywords: Dosage and frequency, fertigation, *Mangifera indica* L., quality of mango

Introduction
Mango (*Mangifera indica* L.) belongs to the family Anacardiaceae considered as one of the most important fruits of the tropical and subtropical countries. India occupies the top position among mango growing countries of the world and produces 40.1% of the total world production. It is the premier and choicest fruit of India and undoubtedly one of the best fruits of the world. It is known as 'King of Fruits' due to its captivating flavour, irresistible taste and sweetness. Very aptly, Indians designated this fruit as the 'National Fruit' of the country. Mango is a highly nutritive fruit. It plays an important role in balancing the human diet by providing about 64-86 calories per 100 grams of ripe fruits (Rathore *et al.* 2007) [1]. It is a good source of vital protective nutrients like vitamins A, B, and C, niacin and is also rich in minerals including calcium, potassium and iron.

In general fertilizers are applied in two split doses for mango, one at the time of onset of monsoons and another dose at the time of flower initiation or during the fruit set stage. The second dose of fertilizer application plays key role in mango fruit production because it coincides with fruit growth and development. To improve fertilizer-use efficiency the available advance method is drip irrigation *i.e.*, fertigation. Fertigation refers to the application of solid or liquid mineral fertilizers via pressurized irrigation systems, thus forming irrigation water containing nutrients (Magen, 1995) [2]. Fertigation improves the nutrient uptake efficiency to an extent of 30-40 per cent, prevents soil degradation, reduces the cost of fertilizer and application besides improving the productivity and quality of the fruits. Water coupled with nutrient management is particularly important for improving input-use efficiency (Melgar *et al.*, 2008; Panigrahi *et al.*, 2010) [3, 4]. Further, fertigation ensures substantial saving in fertilizer usage and reduces leaching losses (Kumar *et al.*, 2007) [5].

Material and Methods
Plant Material and Treatment
The present investigation was carried out during two succeeding seasons *i.e.*, 2015-16 and 2016-17 at Fruit Research Station, Sangareddy, SKLTSHU, Telangana State is situated at an altitude of 560.3 meters above mean sea level on 18°.03 North latitude and 78°.18 East longitude, with an annual average temperature of 26.0 °C and rainfall of 910 mm. The climate of Sangareddy is tropical, semi-arid and dry.

Ten years old bearing trees of mango cv. Banganpalli, having uniform vigor and health were selected mango orchard.

Trees were spaced 8×8 m and received uniform pruning and cultural operations. Forty-eight selected trees were subjected to eight pre-harvest treatments *viz.* F_1T_1 - One time at marble stage + N_2 and K_2O @100% of RDF; F_1T_2 - One time at marble stage + N_2 and K_2O @80% of RDF; F_1T_3 - One time at marble stage + $N_2$and K_2O @60% of RDF; F_1T_4 - One time at marble stage + N_2 and K_2O @ 50 % of RDF; F_2T_1 - Daily fertigation+ $N_2$and K_2O @100% of RDF; F_2T_2 - Daily fertigation+ $N_2$and K_2O @80% of RDF; F_2T_3 - Daily fertigation+ $N_2$and K_2O @60% of RDF; F_2T_4 - Daily fertigation +N_2 and K_2O @ 50 % of RDF with three replications. One tree was taken as a unit for a replication of treatment.

Soil and leaf sampling

The soil and leaf samples were collected at two stages *viz.* before flowering (in October) and after harvesting (in August). Twenty healthy leaves from four sides of each selected tree were collected from the middle of the whorl, considering the fifth leaf in the whorl as the representative leaf, as described by Samra *et al.* (1978) [6]. Sampling was done between 9.00 am and 10.00 am as suggested by Singh (1960) [7]. Soil samples were collected from four sides of the plant at 1.0 m from the tree trunk at a depth of 0- 30 cm and mean values were calculated.

Methods used for soil analysis

Table 1: Various soil parameters were analyzed by adopting the below-mentioned procedures

Sr. No	Parameters	Name of method	As suggested by
1	pH	Potentiometry	Jackson (1973) [8]
2	EC (dsm^{-1})	Conductometry	Jackson (1973) [8]
3	Available N Kg/ha	Alkaline permanganate method	Subbaiah and Asija (1956) [9]
4	Available P kg/ha	Calorimetric method	Jackson (1973) [8]
5	Available K kg/ha	Flame photometry method	Jackson (1973) [8]
6	Zn (ppm)	Atomic absorption spectrophotometer	Lindsay &Norvell 1969[10]
7	Fe (ppm)		
8	Mg (%)	Mg NH_4 $P0_4$ corresponds to the amount of magnesium present in the soil	Ishwaran 1980[11]

Methods used for leaf analysis

Table 2: Various leaf parameters were analyzed by adopting the below-mentioned procedures

Sr. No	Parameters	Name of method	As suggested by
3	Available N (%)	Kjeldahl method	Modified Kjeldahl's digestion method (Jackson, 2005) [9]
4	Available P (%)	Vanadomolybdate method	Jackson 1973[8]
5	Available K (%)	Atomic absorption spectrophotometer	Chapman and Pratt, 1961[13]
6	Zn (ppm)		
7	Fe (ppm)		
8	Mg (%)		

Fruit Quality Analysis

Fruit specific gravity determined by dividing the weight of the fruit in the air by the volume of the fruits obtained by the water displacement method (Gustafson, 1926) [14]. Total soluble solids (^{0}Brix) measured by using the 'Erma' hand refractometer. The total titratable acidity was calculated on the basis of one ml N/10 NaOH equivalent to 0.0064 g of anhydrous citric acid or per cent citric acid in juice. Sugar to acid ratio was calculated by dividing TSS (%) with titratable acidity (%). The total sugars were estimated by titrating the boiling mixture of 5 ml, each of Fehling A and Fehling B solution against the hydrolyzed aliquot by using methylene blue as an indicator. Non-reducing sugars were calculated by substracting reducing sugars from the total sugars and multiplying the difference by standard factor i.e., 0.95 and ascorbic acid was determined by AOAC (1980) [16] method. The shelf life was determined by recording the number of days the fruits remained in good condition without spoilage. The data obtained from the investigation were statistically analyzed according to the procedure out lined.

Results and Discussion

Soil nutrient status

The available soil nitrogen and soil potassium in the experimental site before the investigation was recorded (Table 3) as 192.26 and 290.87 kg/ha, respectively. At the end of each season of investigation, the available soil nitrogen and potassium were calculated to find out the effect of different fertigation dosages, frequencies and their interaction.

The perusal of data revealed that different doses and frequency of fertigation schedules have shown significant differences in NK levels in the soil whereas, P and micronutrient levels were found to be non-significant during both seasons *i.e.*, after the first season (before the second season) and after the second season of the investigation.

Regarding the effect of different fertigation dosages (D), the maximum N (249.99 kg/ha and 252.10kg/ha) and K (344.99 kg/ha and 346.37 kg/ha), was recorded with the application of 100% RDF + micronutrient mixture (D_1) whereas the minimum N (189.28 kg/ha and 204.91 kg/ha) and K (297.64 kg/ha and 300.55 kg/ha) was recorded with the application of 50 % RDF + micronutrient mixture (D_4) after the first season (before the second season) and after the second season of the investigation, respectively. From the results, it was found that application of 100% RDF + micronutrient mixture (D_1) has resulted in a 30.03% and 31.12% increase in available soil N and 18.16% and 19.08 % increase in K after the first season and after the second season of the investigation, respectively to the actual available soil N and K before investigation (Table 3).

Regarding the effect of different fertigation frequencies (F), the maximum N (243.77 kg/ha and 237.08 kg/ha) and K (330.70 kg/ha and 328.57 kg/ha) was recorded with the application of daily fertigation (F_2) whereas the minimum N

(214.46 kg/ha and 224.22 kg/ha) and K (313.85 kg/ha and 319.66 kg/ha) was recorded with one-time fertigation at marble stage (F_1) after the first season (before the second season) and after the second season of the investigation, respectively. Further, it was found that application of daily fertigation (F_2) has resulted in a 26.79 % and 23.31 % increase in available soil N and 13.69 % and 12.96 % increase in K after the first season and after the second season of the investigation, respectively to the actual available soil N and K before investigation (Table 3).

Regarding the interaction effect of different fertigation dosages and frequencies (D x F), maximum N (260.33 kg/ha and 260.68 kg/ha) and K (358.25 kg/ha and 353.81 kg/ha) was recorded with the application of daily fertigation with 100% RDF + micronutrient mixture (D_1F_2) whereas the minimum N (180.28 kg/ha and 200.62 kg/ha) and K (290.89 kg/ha and 296.92 kg/ha) was recorded with the application of one-time fertigation at marble stage with 50 % RDF + micronutrient mixture (D_4 F_1) after the first season (before the second season) and after the second season of the investigation, respectively. Further, the daily fertigation with 100% RDF + micronutrient mixture (D_1F_2) has resulted in a 35.41 % and 35.55 % increase in available soil N and 23.16 % and 21.64 % increase in K after the first season and after the second season of the investigation, respectively to the actual available soil N and K before investigation (Table 3).

This increased soil nutrient status with the application of daily fertigation with 100% RD of NK + micronutrient mixture in the present study can be attributed to the fact that fertigation enables the uniform and efficient application of fertilizers (Patel and Rajput, 2000) [34]. As a fertigation system aids in the application of water and nutrients directly in the root zone, it results in an increased level of soil nutrient status (Fares and Alva, 2000; Subramanian *et al.*, 2012) [35, 36]. Further, the application of fertilizers in split doses through drip irrigation minimizes the leaching losses in the soil and thus resulted in increased NK and micronutrients levels in soil (Basavaraju *et al.*, 2014) [37] in the present treatment. These results are in agreement with the findings of Tank and Patel (2013) [38] in papaya cv. Madhu Bindhu, Bandyopadhyay *et al.* (2019) [39] in coconut and Kavino *et al.* (2002) [40] in banana.

Leaf nutrient status

The available leaf nitrogen and potassium in the leaves of experimental trees before the investigation was recorded as 0.73 % and 0.65 %, respectively. Regarding the effect of different fertigation dosages (D), maximum N (1.34 % and 1.33 %) and K (1.02 % and 1.20 %) was recorded with the application of 100% RDF + micronutrient mixture (D_1) whereas the minimum N (0.69 % and 0.70 %) and K (0.66 % and 0.66 %) was recorded with the application of 50 % RDF + micronutrient mixture (D_4) after the first season (before the second season) and after the second season of the investigation, respectively. Further, with the application of 100% RDF + micronutrient mixture (D_1), the increase in leaf N was 1.84 times and 1.82 times and the increase in leaf K was 1.57 times and 1.85 times after the first season and after the second season of the investigation, respectively to the actual available leaf N and K before investigation (Table 3).

Regarding the effect of different fertigation frequencies (F), maximum N (1.07% and 1.08%) and K (0.92% and 0.97%) was recorded with the application of daily fertigation (F_2) whereas the minimum N (0.86% and 0.85%) and K (0.76% and 0.75%) was recorded with one-time fertigation at marble stage (F_1) after the first season (before the second season) and after the second season of the investigation, respectively. Further, with the application of daily fertigation (F_2), the increase in leaf N was 1.47 times and 1.48 times and the increase in leaf K was 1.42 times and 1.49 times after the first season and after the second season of the investigation, respectively to the actual available leaf N and K before investigation (Table 3).

Regarding the interaction effect of different fertigation dosages and frequencies (D x F), maximum N (1.61% and 1.65%) and K (1.17% and 1.56%) was recorded with the application of daily fertigation with 100% RDF + micronutrient mixture (D_1F_2) whereas the minimum N (0.65% and 0.66%) and K (0.64% and 0.64%) was recorded with the application of one-time fertigation at marble stage with 50 % RDF + micronutrient mixture (D_4 F_1) after the first season (before the second season) and after the second season of the investigation, respectively. Further, with the application of daily fertigation with 100% RDF + micronutrient mixture (D_1F_2), the increase in leaf N was 1.84 times and 2.26 times and the increase in leaf K was 1.80 times and 2.40 times after the first season and after the second season of the investigation, respectively to the actual available leaf N and K before investigation (Table 3).

The significant effect of daily fertigation with 100% RD of NK + micronutrient mixture on leaf nutrient contents might be because fertigation enables the precise application of fertilizers directly in the active root zone reducing the leaching losses and losses through volatilization. These implications might have led to better nutrient availability and better uptake by the plants which eventually improved nitrogen and potassium use efficiency resulting in increased leaf nitrogen and potassium content. Further, higher leaf nutrient (N, K, Fe, Zn and Mg) content in daily fertigated trees might be attributed to the fact that fertigation helps in better uptake of nutrients due to frequent and timely application of fertilizers directly in the feeder root zone (Devi *et al.*, 2019) [41] in this treatment. Thus, the application of daily fertigation with 100% RD of NK + micronutrient mixture resulted in better absorption of these nutrients by mango trees which might have reflected as increased content of NK and micronutrients in leaves. These results are in close conformity with the findings of Devi *et al.* (2019) [41] in mango cv. Pant Sinduri, Kuchanwar *et al.* (2017) [42] in Nagpur mandarin, Naik *et al.* (2016) [43] in banana cv. Grand Naine, Pramanik *et al.* (2013) [44] in banana cv. Martaman, Tank and Patel (2013) [38] in papaya cv. Madhu Bindu, Jeyakumar*et al.* (2010) [26] in papaya cv. Co.7, Haneef*et al.* (2014) [21] in pomegranate cv. Bhagwa and Srinivas *et al.* (2010) [45] in passion fruit.

Specific gravity of fruit

The effect of different fertigation dosages (D), application of 100% RDF + micronutrient mixture (D_1) recorded maximum specific gravity of fruit (1.09) which was on par with that of application of 80% RDF + micronutrient mixture (D_2) (1.08) whereas minimum specific gravity of fruit (1.01) was recorded with the application of 50 % RDF + micronutrient mixture (D_4). In case of fertigation frequencies (F), daily fertigation (F_2) recorded maximum specific gravity of fruit (1.07) whereas one-time fertigation at marble stage (F_1) resulted in minimum specific gravity of fruit (1.04) (Table 7).

Regarding the interaction effect of different fertigation frequencies and dosages (D x F), the maximum specific gravity of fruit (1.11) was recorded with the application of daily fertigation with 100% RDF + micronutrient mixture (D_1F_2) whereas minimum (1.00) was recorded with the application of one-time fertigation at marble stage with 50% RDF + micronutrient mixture (D_4 F_1) (Table 7).

This increased specific gravity of fruit in D_1 and F_2 treatments and their interaction. It may be ascribed to the increased synthesis of metabolites and more uptake of nutrients and their translocation to the fruits (Kachwaya and Chandel, 2015) [17] resulting in increased fruit weight in those treatments. The uniform distribution of nutrients, coupled with its confinement in the root zone with increased soil nutrient content (N&K) (Table 3) under fertigation might have led to the increased nutrient uptake which reflected in increased leaf nutrient content (N&K) (Table 5) and better physiological activities of plants resulting into increased dry matter accumulation (Godara*et al.*, 2013; Kaur *et al.*, 2019) [18, 19] resulting in a better quality of fruits. These results are in conformity with the findings of Raina *et al.* (2011) [20] who reported good quality fruits with higher fruit size and weight with 100 per cent of the recommended dose of conventional fertilizers applied through fertigation in apricot.

TSS (ºBrix)

The effect of different fertigation dosages (D), application of 100% RDF + micronutrient mixture (D_1) recorded maximum fruit TSS (16.81 ºBrix) which was on par with that of application of 80% RDF + micronutrient mixture (D_2) (16.50 ºBrix) whereas minimum fruit TSS (15.09 ºBrix) was recorded with the application of 50 % RDF + micronutrient mixture (D_4). In case of fertigation frequencies (F), daily fertigation (F_2) recorded maximum fruit TSS (17.12 ºBrix) whereas one-time fertigation at marble stage (F_1) resulted in minimum fruit TSS (14.93 ºBrix) (Table 7).

This increase in fruit TSS is due to daily fertigation (F_2) and higher dose of fertilizers (D_1) and their interaction (D_1F_2) might have provided a consistent moisture regime in the soil due to which root remains active throughout the season resulting in higher availability of nutrients in the soil (N&K) (Table 3) and leaf (N&K) (Table 5) and proper translocation of food materials which accelerated the fruit growth and development of quality characters in the fruits. Application of higher levels of fertigation daily improved the growth of the plant and facilitated in accumulation of more carbohydrates into the fruit further, during the subsequent fruit development. Such metabolites (starch) will hydrolyse into sugar and increases the TSS (Haneef*et al.*, 2014) [21]. These results are in conformity with those of Thakur and Singh (2004) [22], who recorded the highest TSS in mango cv. Amrapali with 100% of the recommended dose of NPK applied through drip irrigation. A similar increase in TSS of fruits by fertigation with the full dose of fertilizer was reported in pomegranate (Haneef*et al.*, 2014) [21], strawberry (Kachwaya and Chandel, 2015) [17] and litchi (Tyagi and Singh, 2018) [23].

Total Sugars (%)

The effect of different fertigation dosages (D), application of 100% RDF + micronutrient mixture (D_1) recorded maximum total sugars (13.90 %) in fruit whereas minimum total sugars (10.50 %) was recorded with the application of 50 % RDF + micronutrient mixture (D_4). In case of fertigation frequencies (F), daily fertigation (F_2) recorded maximum total sugars (12.82 %) whereas one-time fertigation at marble stage (F_1) resulted in minimum total sugars (11.89 %) (Table 7).

This increase in total sugar per cent in fruits is due to the availability of higher nitrogen and potassium in soil (N and K) (Table 3) and their uptake resulting in increased leaf nutrient status (N and K) (Table 5). Being considered as a quality element, potassium promotes the carbohydrate accumulation in developing fruits and their subsequent hydrolysis into sugars through enzyme activation thus, resulting in improved sugar content (Ganeshamurthy *et al.*, 2011) [24]. A similar increase in total sugars of fruits by fertigation with 100% RDF was also reported by Sarker and Rahim (2012) [25] in mango cv. Amrapali, Jeyakumar *et al.* (2010) [26] in papaya and Kachwaya and Chandel (2015) [17] in strawberry.

However, the interaction effect of different fertigation frequencies and dosages (D x F) was found nonsignificant.

Reducing and non-reducing sugars (%)

The effect of different fertigation dosages (D), application of 100% RDF + micronutrient mixture (D_1) recorded maximum reducing sugars (6.40 %) of fruits whereas minimum reducing sugars (3.30 %) was recorded with the application of 50 % RDF + micronutrient mixture (D_4).

In case of fertigation frequencies (F), daily fertigation (F_2) recorded maximum reducing sugars (5.41 %) whereas one-time fertigation at the marble stage (F_1) resulted in minimum reducing sugars (4.56 %) of fruits (Table 7. and Table 8).

Further, regarding the interaction effect of different fertigation frequencies and dosages (D x F), maximum reducing sugars (6.96 %) was recorded with the application of daily fertigation with 100% RDF + micronutrient mixture (D_1F_2) whereas minimum reducing sugars (3.01 %) was recorded with the application of one-time fertigation at marble stage with 50 % RDF + micronutrient mixture (D_4 F_1) (Table 7. and Table 8).

This increase in sugar content of fruits harvested from D_1, F_2 treatments and their interaction might be due to more availability of nutrients in the soil (Table 3) and its accumulation in leaf (Table 5). Especially nitrogen which might have further exerted the regulatory role in affecting the fruit quality (Haneef *et al.*, 2014) [21]. These results are in conformity with the findings of Thakur and Singh (2004) [22] in mango cv. Amrapali and Haneef *et al.*, (2014) [21] in pomegranate, who recorded the highest reducing sugar with 100% of RDF applied through drip irrigation. Jeyakumar *et al.* (2010) [26] also found that total sugars were comparatively higher in papaya fruits harvested from 100% recommended dose of N and K_2O through drip irrigation. A similar increase in reducing sugars by fertigation with the higher dose of RDF was also reported by Sarker and Rahim (2012) [25] in mango cv. Amrapali, Kachwaya and Chandel (2015) [17] in strawberry and Tyagi and Singh (2018) [23] in litchi.

However, the individual effect of different fertigation dosages (D) and frequency (F) and their interaction effect (DxF) was found non-significant.

Titratable Acidity (%)

The effect of different fertigation dosages (D), application of 100% RDF + micronutrient mixture (D_1) recorded minimum titratable acidity (0.24 %) of fruit whereas maximum titratable acidity (0.47 %) was recorded with the application of 50 % RDF + micronutrient mixture (D_4).

In case of fertigation frequencies (F), daily fertigation (F_2)

recorded minimum titratable acidity (0.32 %) whereas one-time fertigation at marble stage (F_1) resulted in maximum titratable acidity (0.38 %) (Table 8).

Further, regarding the interaction effect of different fertigation frequencies and dosages (D x F), minimum titratable acidity (0.20 %) was recorded with the application of daily fertigation with 100% RDF + micronutrient mixture (D_1F_2) whereas maximum titratable acidity (0.50 %) was recorded with the application of one-time fertigation at marble stage with 50 % RDF + micronutrient mixture (D_4 F_1) (Table 8).

The possible explanation for the decrease in titratable acidity of fruits in D_1, F_2 treatments and their interaction might be due to increased nutrient availability in the soil as well as leaf (N&K) (Table 3 and 5) throughout the entire fruit development stage which might have promoted the enzymatic activity and further favoured the hydrolysis of metabolites (such as organic acids) resulting into reduced acidity level (Tyagi and Singh, 2018) [23]. A similar decrease in titratable acidity by fertigation with higher RDF was also reported in mango cv. Amrapali (Sarker and Rahim, 2012) [25], Nagpur mandarin (Goud*et al.*, 2017) [27] and pomegranate (Tanari*et al.*, 2019) [28]. Haneef*et al.*, (2014) [21] also recorded lower titratable acidity in fertigation with 100% RDF and reported that fertigation with a high dose of fertilizers led to better growth of the plant which facilitated in accumulation of more carbohydrates into the fruit during fruit development that will hydrolyze into sugar further during subsequent fruit development stages in pomegranate.

Sugar: Acid ratio

The effect of different fertigation dosages (D), application of 100% RDF + micronutrient mixture (D_1) recorded maximum sugar and acid ratio (71.48) of fruits whereas minimum sugar and acid ratio (31.88) was recorded with the application of 50 % RDF + micronutrient mixture (D_4). In case of fertigation frequencies (F), daily fertigation (F_2) recorded maximum sugar and acid ratio (57.66) whereas one-time fertigation at marble stage (F_1) resulted in minimum sugar and acid ratio (43.81).Further, regarding the interaction effect of different fertigation frequencies and dosages (D x F), maximum sugar and acid ratio (85.08) was recorded with the application of daily fertigation with 100% RDF + micronutrient mixture (D_1F_2) whereas minimum sugar and acid ratio (30.13) was recorded with the application of one-time fertigation at marble stage with 50 % RDF + micronutrient mixture (D_4 F_1) (Table 8).

The higher sugar to acidity ratio is the indicator of the sweetness of the fruit. If the sugar to acidity ratio is high means that the fruits have more sugars and less acidity. The increased sugar to acid ratio of fruits from D_1, F_2 treatments and their interaction in the present study is because of the increased sugars content (Table 7) and reduced acidity of fruits (Table 8). Higher levels of fertigation might have improved the growth of the plant that facilitated in accumulation of more carbohydrates into the fruit further, during the subsequent fruit development. Such metabolites (starch) will hydrolyze into sugar that increases the TSS and decreases the acidity (Haneef *et al.*, 2014) [21] resulting in better quality and flavour of fruits. These results are in conformity with the findings of Sarker and Rahim (2012) [25] in mango cv. Amrapali and in the case of pomegranate Haneef *et al.*, (2014) [21] reported increased TSS to acidity ratio by fertigation with 100% RDF. Similar results are also reported in Nagpur mandarin (Goud *et al.*, 2017) [27] and litchi (Tyagi and Singh, 2018) [23].

Fruit ascorbic acid (mg / 100 g)

The effect of different fertigation dosages (D), application of 100% RDF + micronutrient mixture (D_1) recorded maximum fruit ascorbic acid (47.31 mg / 100 g) whereas minimum fruit ascorbic acid (35.58 mg / 100 g) was recorded with the application of 50 % RDF + micronutrient mixture (D_4). In case of fertigation frequencies (F), daily fertigation (F_2) recorded maximum fruit ascorbic acid (43.58 mg / 100 g) whereas one-time fertigation at marble stage (F_1) resulted in minimum fruit ascorbic acid (40.38 mg / 100 g) (Table 8).

From the results, it is evident that the daily fertigation (F_2) and fertigation with 100% RDF (D_1) significantly increased the ascorbic acid content of fruits in the present study due to the availability of high levels of nutrients in the soil as well as leaf (Table 3 and 5) particularly nitrogen which might have increased the synthesis and catalytic activity of several enzymes and co-enzymes which are instrumental in ascorbic acid synthesis (Boora and Singh, 2000; Kachwaya and Chandel, 2015) [17]. These findings were in accordance with that of Ramniwas *et al.* (2013) [30] in guava, Tanari*et al.* (2019) [28] in pomegranate and Kachwaya and Chandel, (2015) [17] in strawberry who found maximum ascorbic acid under fertigation at 100 % RDF compared to lower levels of fertigation. Similar results of increased ascorbic acid content with fertigation were reported by Sarker and Rahim (2012) [25] in mango cv. Amrapali and Tyagi and Singh (2018) [23] in litchi.

However, the interaction effect of different fertigation frequencies and dosages (D x F) was found not significant.

Shelf life of fruits (days)

The effect of different fertigation dosages (D), the application of 100% RDF + micronutrient mixture (D_1) recorded the maximum shelf life of fruits (14.42 days) whereas minimum shelf life (10.51 days) was recorded with the application of 50 % RDF + micronutrient mixture (D_4). In case of fertigation frequencies (F), daily fertigation (F_2) recorded the maximum shelf life of fruits (13.18 days) whereas one-time fertigation at the marble stage (F_1) resulted in the minimum shelf life of fruits (12.11 days). Further, regarding the interaction effect of different fertigation frequencies and dosages (D x F), maximum shelf life (15.13 days) was recorded with the application of daily fertigation with 100% RDF + micronutrient mixture (D_1F_2) whereas minimum shelf life (10.16 days) was recorded with the application of one-time fertigation at marble stage with 50 % RDF + micronutrient mixture (D_4 F_1) (Table 9).

From the results, it is found that daily fertigation (F_2), fertigation with 100% RDF (D_1) treatments and their interaction (D_1F_2) have significantly increased the shelf life of fruits. This could be due to better availability of water and more quantity of nutrients in the soil as well as leaves (N&K) (Table 3 and 5).throughout the fruiting period and improvement in quality parameters of fruits in these treatments. The nutrient supply and its assimilation by crop are known to have a significant influence on fruit quality parameters. Potassium is required for translocation of photosynthates from source (leaves) to sink (fruit) (Khayyat *et al.* 2012) [31]. Similarly, the optimum nitrogen is required for the accumulation of protein and fleshiness of fruit (Rao

&Subramanyam 2009) [32]. The fruit maturation stage requires relatively higher K to improve fruit quality (Tanari *et al.*, 2019) [28] which might have been fulfilled in present fertigation treatments. All these factors might have contributed to better quality parameters in these treatments resulting in the better shelf life of fruits. A similar increase in the shelf life of fruits by fertigation with 100% RDF was also reported by Sarker and Rahim (2012) [25] in mango cv. Amrapali and Panwar *et al.*, (2007) [33] in mango cv. Dashehari.

Table 3: Effect of dosage and frequency of fertigation on Nitrogen (kg/ha.), P (kg/ha.) and K (kg/ha.) levels in soil of mango cv. Banganpalli

	N (kg/ha.)						**P (kg/ha.)**						**K (kg/ha.)**					
	After first season or before second season			**After second season**			**After first season and before second season**			**After second season**			**After first season and before second season**			**After second season**		
Treatments	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**
D_1	239.65^{d}	260.33^{a}	249.99^{a}	243.52^{c}	260.68^{a}	252.1^{a}	18.12	18.92	18.52	18.42	20.25	19.33	331.73^{c}	358.25^{a}	344.99^{a}	338.94^{b}	353.81^{a}	346.37^{a}
D_2	229.31^{e}	249.99^{c}	239.65^{b}	234.94^{d}	252.1^{b}	243.52^{b}	17.73	18.53	18.13	18.5	19.66	19.08	324.89^{d}	342.1^{b}	333.5^{b}	329^{d}	335.54^{c}	332.27^{b}
D_3	208.62	266.49^{b}	237.56^{c}	217.78^{f}	226.36^{e}	222.07^{c}	16.94	17.35	17.15	17.34	17.92	17.63	307.89^{f}	318.06^{e}	312.98^{c}	313.79^{f}	320.73^{e}	317.26^{c}
D_4	180.28	198.28	189.28^{d}	200.62^{h}	209.2^{g}	204.91^{d}	16.16	16.57	16.36	16.17	16.75	16.46	290.89^{h}	304.39^{fg}	297.64^{d}	296.92^{h}	304.19^{g}	300.55^{d}
Mean of F	214.46^{b}	243.77^{a}	229.12	224.22^{b}	237.08^{a}	230.65	17.24	17.84	17.54	17.61	18.65	18.13	313.85^{b}	330.7^{a}	322.28	319.66^{b}	328.57^{a}	324.11
	S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%	
Frequency (F)	0.31	0.93		0.34	1.02		0.5	NS		0.56	NS		1.13	3.42		0.11	0.33	
Dosage (D)	0.43	1.31		0.48	1.44		0.71	NS		0.79	NS		1.6	4.84		0.15	0.47	
FXT	0.61	1.86		0.67	2.04		1.01	NS		1.12	NS		2.26	6.85		0.22	0.66	

*Figures with same alphabet did not differ significantly

F_1 - One time at marble stage

F_2 - Daily fertigation (total dosage divided per day)

D_1 – N_2 and K_2O @ 100% of RDF

D_2 - N_2 and K_2O @80% of RDF

D_3 - N_2 and K_2O @ 60 % of RDF

D_4 - N_2 and K_2O @ 50 % of RDF

Table 4: Effect of dosage and frequency of fertigation on Mg (%), Zn (ppm) and Fe (ppm) levels in soil of mango cv. Banganpalli.

	Mg (%)						**Zn (ppm)**						**Fe (ppm)**					
	After first season and before second season			**After second season**			**After first season and before second season**			**After second season**			**After first season and before second season**			**After second season**		
Treatments	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**
D_1	0.17	0.2	0.18	0.08	0.09	0.09	1.35	1.5	1.43	0.77	0.8	0.79	11.69	12	11.85	8.89	9.2	9.04
D_2	0.16	0.19	0.17	0.08	0.09	0.08	1.28	1.43	1.35	0.76	0.79	0.77	11.54	11.85	11.69	8.73	9.04	8.89
D_3	0.13	0.14	0.14	0.07	0.07	0.07	1.13	1.2	1.17	0.73	0.74	0.74	11.23	11.38	11.31	8.41	8.57	8.49
D_4	0.11	0.12	0.11	0.06	0.06	0.06	0.98	1.05	1.02	0.7	0.71	0.71	10.92	11.07	11	8.1	8.26	8.18
Mean of F	0.14	0.16	0.15	0.07	0.08	0.08	1.18	1.3	1.24	0.74	0.76	0.75	11.34	11.58	11.46	8.53	8.77	8.65
	S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%	
Frequency (F)	0.01	NS		0	NS		0.1	NS		0.03	NS		0.43	NS		0.4	NS	
Dosage (D)	0.02	NS		0.01	NS		0.14	NS		0.04	NS		0.6	NS		0.57	NS	
FXT	0.03	NS		0.01	NS		0.2	NS		0.06	NS		0.85	NS		0.8	NS	

*Figures with same alphabet did not differ significantly

F_1 - One time at marble stage

F_2 - Daily fertigation (total dosage divided per day)

D_1 – N_2 and K_2O @ 100% of RDF

D_2 - N_2 and K_2O @ 80% of RDF

D_3 - N_2 and K_2O @ 60 % of RDF

D_4 - N_2 and K_2O @ 50 % of RDF

Table 5: Effect of dosage and frequency of fertigation on Nitrogen (%), P (%) and K (%) levels in leaves of mango cv. Banganpalli.

	N(%)						**P(%)**						**K(%)**					
	After first season and before second season			**After second season**			**After first season and before second season**			**After second season**			**After first season and before second season**			**After second season**		
Treatments	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**
D_1	1.07^{b}	1.61^{a}	1.34^{a}	1.01^{b}	1.65^{a}	1.33^{a}	0.18	0.21	0.2	0.18	0.22	0.2	0.87^{b}	1.17^{a}	1.02^{a}	0.84	1.56	1.2
D_2	0.93^{c}	1.07^{b}	1^{b}	0.94^{b}	1.08^{b}	1.01^{b}	0.16	0.2	0.18	0.17	0.2	0.18	0.8^{bc}	1.07^{a}	0.93^{a}	0.8	0.89	0.84
D_3	0.79^{e}	0.86^{d}	0.83^{c}	0.8	0.87^{b}	0.84^{c}	0.13	0.15	0.14	0.13	0.15	0.14	0.72	0.76^{bcd}	0.74^{b}	0.72	0.76	0.74
D_4	0.65^{g}	0.72^{f}	0.69^{c}	0.66	0.73	0.7^{c}	0.1	0.12	0.11	0.1	0.12	0.11	0.64	0.68	0.66^{b}	0.64	0.68	0.66
Mean of F	0.86^{b}	1.07^{a}	0.97	0.85^{b}	1.08^{a}	0.97	0.14	0.17	0.16	0.15	0.17	0.16	0.76^{b}	0.92^{a}	0.84	0.75^{b}	0.97^{a}	0.86
	S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%	
Frequency (F)	0.03	0.1		0.04	0.11		0.02	NS		0.02	NS		0.03	0.08		0.03	0.1	
Dosage (D)	0.05	0.14		0.05	0.15		0.03	NS		0.03	NS		0.04	0.12		0.04	0.14	

FXT	0.07	0.2		0.07	0.21		0.04	NS		0.04	NS		0.05	0.16		0.06	0.19	

*Figures with same alphabet did not differ significantly

F_1 - One time at marble stage

F_2 - Daily fertigation (total dosage divided per day)

D_1 – N_2 and K_2O @ 100% of RDF

D_2 - N_2 and K_2O @ 80% of RDF

D_3 - N_2 and K_2O @ 60 % of RDF

D_4 - N_2 and K_2O @ 50 % of RDF

Table 6: Effect of dosage and frequency of fertigation on Mg (%), Zn (ppm) and Fe (ppm) levels in leaves of mango cv. Banganpalli.

	Mg (%)						Zn (ppm)						Fe (ppm)					
	After first season and before second season			After second season			After first season and before second season			After second season			After first season and before second season			After second season		
Treatments	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**
D_1	0.24	0.25	0.24	0.18	0.19	0.19	15.59	16.15	15.87	13.1	13.5	13.3	93.9	95.3	94.6	83.81	85.3	84.56
D_2	0.23	0.24	0.24	0.18	0.19	0.18	15.31	15.87	15.59	12.9	13.3	13.1	93.2	94.6	93.9	83.07	84.56	83.81
D_3	0.21	0.22	0.22	0.17	0.17	0.17	14.76	15.04	14.9	12.5	12.7	12.6	91.8	92.5	92.15	81.59	82.33	81.96
D_4	0.2	0.21	0.2	0.16	0.16	0.16	14.2	14.48	14.34	12.1	12.3	12.2	90.4	91.1	90.75	80.1	80.84	80.47
Mean of F	0.22	0.23	0.23	0.17	0.18	0.18	14.97	15.38	15.17	12.65	12.95	12.8	92.32	93.37	92.85	82.14	83.26	82.7
	S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%	
Frequency (F)	0.01	NS		0.01	NS		0.51	NS		0.4	NS		0.9	NS		1	NS	
Dosage (D)	0.02	NS		0.02	NS		0.73	NS		0.56	NS		1.27	NS		1.42	NS	
FXT	0.02	NS		0.03	NS		1.03	NS		0.8	NS		1.79	NS		2.01	NS	

*Figures with same alphabet did not differ significantly

F_1 - One time at marble stage

F_2 - Daily fertigation (total dosage divided per day)

D_1 – N_2 and K_2O @ 100% of RDF

D_2 - N_2 and K_2O @ 80% of RDF

D_3 - N_2 and K_2O @ 60 % of RDF

D_4 - N_2 and K_2O @ 50 % of RDF

Table 7: Effect of dosage and frequency of fertigation on fruit specific gravity at the time of harvest, TSS (^{0}Brix), total sugars (%) and reducing sugars (%) of mango cv. Banganpalli.

Treatments	**Fruit specific gravity at the time of harvest**			**TSS (^{0}Brix)**			**Total sugars (%)**			**Reducing sugars (%)**		
	POOLED			**POOLED**			**POOLED**			**POOLED**		
	F_1	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**
D_1	1.08^{b}	1.11^{a}	1.09^{a}	16.50^{c}	17.12^{a}	16.81^{a}	13.28	14.52	13.90^{a}	5.83^{c}	6.96^{a}	6.40^{a}
D_2	1.03^{c}	1.08^{b}	1.05^{b}	16.17^{d}	16.81^{b}	16.49^{b}	12.67	13.9	13.28^{b}	5.27^{d}	6.40^{b}	5.83^{b}
D_3	1	1.05^{c}	1.02^{c}	15.68^{f}	15.87^{e}	15.78^{c}	11.43	12.05	11.74^{c}	4.14	4.71	4.42^{c}
D_4	0.98	0.99	0.99^{d}	14.93	15.24	15.08^{d}	10.19	10.81	10.50^{d}	3.01	3.58	3.30^{d}
Mean of F	1.02^{b}	1.06^{a}	1.04	15.82^{b}	16.26^{a}	16.04	11.89^{b}	12.82^{a}	12.36	4.56^{b}	5.41^{a}	4.99
	S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%	
Frequency (F)	0	0.01		0.03	0.08		0.1	0.3		0.04	0.13	
Dosage (D)	0	0.01		0.04	0.11		0.15	0.43		0.06	0.18	
FXT	0.01	0.02		0.05	0.16		0.21	NS		0.09	0.25	

*Figures with same alphabet did not differ significantly

F_1 - One time at marble stage

F_2 - Daily fertigation (total dosage divided per day)

D_1 – N_2 and K_2O @ 100% of RDF

D_2 - N_2 and K_2O @ 80% of RDF

D_3 - N_2 and K_2O @ 60 % of RDF

D_4 - N_2 and K_2O @ 50 % of RDF

Table 8: Effect of dosage and frequency on fertigation on non-reducing sugars (%), titratable Acidity (%), TSS and acid ratio and ascorbic acid (mg/100 g of F.W.) of mango cv. Banganpalli

Treatments	**Non reducing sugars (%)**			**Titratable Acidity (%)**			**TSS and Acid ratio**			**Ascorbic acid (mg/100 g of F.W.)**		
	POOLED			**POOLED**			**POOLED**			**POOLED**		
	F_1	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**	**F_1**	**F_2**	**Mean of D**
D_1	7.45	7.56	7.51	0.29^{c}	0.20^{a}	0.24^{a}	57.88^{c}	85.08^{a}	71.48^{a}	45.18	49.44	47.31^{a}
D_2	7.4	7.51	7.45	0.33^{d}	0.24^{b}	0.29^{b}	49.41^{d}	68.97^{b}	59.19^{b}	43.04	47.31	45.18^{b}
D_3	7.28	7.34	7.31	0.41	0.37^{e}	0.39^{c}	37.83	42.94	40.38^{c}	38.78	40.91	39.84^{c}
D_4	7.17	7.23	7.2	0.5	0.45	0.47^{d}	30.13	33.64	31.88^{d}	34.51	36.65	35.58^{d}
Mean of F	7.33	7.41	7.37	0.38^{b}	0.32^{a}	0.35	43.81^{b}	57.66^{a}	50.74	40.38^{b}	43.58^{a}	41.98
	S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%		S.Em±	C.D. at 5%	
Frequency (F)	0.11	NS		0	0.01		0.73	2.13		0.35	1.03	
Dosage (D)	0.15	NS		0	0.01		1.03	3.02		0.5	1.46	
FXT	0.22	NS		0.01	0.01		1.46	4.27		0.71	NS	

*Figures with same alphabet did not differ significantly

F_1 - One time at marble stage

F_2 - Daily fertigation (total dosage divided per day)

D_1 – N_2 and K_2O @ 100% of RDF

D_2 - N_2 and K_2O @ 80% of RDF

D_3 - N_2 and K_2O @ 60 % of RDF

D_4 - N_2 and K_2O @ 50 % of RDF

Table 9: Effect of dosage and frequency on Fruit shelf life of mango cv. Banganpalli

Treatments	Fruit shelf life		
	POOLED		
	F_1	F_2	Mean of D
D_1	13.73^c	15.12^a	14.43^a
D_2	12.99^d	14.42^b	13.71^b
D_3	11.58	12.29^e	11.94^c
D_4	10.16	10.87	10.51^d
Mean of F	12.12^b	13.18^a	12.65
	S.Em±	C.D. at 5%	
Frequency (F)	0.07	0.2	
Dosage (D)	0.1	0.29	
FXT	0.14	0.41	

*Figures with same alphabet did not differ significantly
F_1 - One time at marble stage
F_2 - Daily fertigation (total dosage divided per day)
D_1 – N_2 and K_2O @ 100% of RDF
D_2 - N_2 and K_2O @ 80% of RDF
D_3 - N_2 and K_2O @ 60 % of RDF
D_4 - N_2 and K_2O @ 50 % of RDF

Summery and Conclusions

Both soil and leaf nutrient status (NPK, Mg, Zn and Fe) due to fertigation, the individual effect of different dosages (D) and frequency of fertigation (F) and their interaction (DxF) resulted in a significant increase in N and K levels whereas, P and Mg, Zn and Fe levels were found non-significant. Regarding the individual effect of different fertigation dosages with 100% RDF + micronutrient mixture (D_1) and fertigation frequency with daily fertigation resulted in good quality fruits with maximum specific gravity, TSS, total sugars, reducing sugars, fruit ascorbic acid and sugar-acid ratio with improved flavour recording minimum titratable acidity and maximum shelf life of fruits. However, the effect of different fertigation dosages was found non-significant on non-reducing sugars. However, the treatment *i.e.*, daily fertigation with 100% RDF + micronutrient mixture (D_1F_2) has shown significant influence resulting in good quality fruits with maximum TSS, specific gravity, reducing sugars, the sugar-acid ratio with improved flavour recording minimum titratable acidity and maximum shelf life. Overall, it can be concluded that application of 100% RDF+ micronutrient mixture in daily splits is beneficial for improvement in available N and K in both soil and leaf of the plant and quality of the fruit.

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