International Journal of Research in Agronomy 2026; 9(1): 191-201

E-ISSN: 2618-0618
P-ISSN: 2618-060X
© Agronomy
NAAS Rating (2026): 5.20
www.agronomyjournals.com
2026; 9(1): 191-201
Received: 12-11-2025
Accepted: 15-12-2025

Guvvali Thirupathaiah
Sri Konda Laxman Telangana Horticultural University, Mulugu, Telangana, India

A Bhagwan
Sri Konda Laxman Telangana Horticultural University, Mulugu, Telangana, India

A Kiran Kumar
Sri Konda Laxman Telangana Horticultural University, Mulugu, Telangana, India

Corresponding Author:
Guvvali Thirupathaiah
Sri Konda Laxman Telangana Horticultural University, Mulugu, Telangana, India

Pre-harvest management of water, nutrients along with mulch: Implications for mango post-harvest quality

Guvvali Thirupathaiah, A Bhagwan and A Kiran Kumar

DOI: https://www.doi.org/10.33545/2618060X.2026.v9.i1c.4605

Abstract
A field experiment on mango cv. Banganpalli evaluated the combined effects of drip irrigation (control, 75%, 100%, and 125% ETc), fertigation (50%, 75%, 100% recommended N and K; 100% N-K via soil application) and mulching on fruit quality at harvest and post-harvest behaviour under ambient storage. Drip irrigation at 100–125% ETc with 75–100% N-K fertigation and mulching significantly improved fruit quality attributes: higher TSS (up to 19.60 °Brix), total sugars (up to 15.96%), non-reducing sugars, ascorbic acid (up to 7.56 to 10.4 and 5.00-6.28 mg 100 g^{-1}, respectively), Brix: acid ratio (up to 83.26), and lower titratable acidity. These treatments delayed the climacteric peak, suppressed respiration rate (O_2 uptake and CO_2 evolution), retained higher fruit firmness (up to 3.3 kg cm^{-2}), slowed chlorophyll degradation (higher DA-index), and extended shelf life up to 14.75 days compared to conventional flood irrigation and soil fertilization (shelf life ~10–11 days). The study demonstrates that integrated drip irrigation (100–125% ETc) and fertigation (75–100% N-K) with mulching offer an effective pre-harvest strategy to optimize both eating quality and post-harvest life of mango cv. Banganpalli.

Keywords: Ascorbic acid, climacteric, respiration rate, chlorophyll degradation, shelf life

Introduction
Mango (*Mangifera indica* L.), hailed as the "king of fruits", is one of the most important tropical and subtropical fruit crops and occupying approximately 5.5 million hectares worldwide with an annual production exceeding 55 million tonnes (FAO, 2023). India is the largest producer, contributing nearly 45% of global output (NHB, 2025). Among Indian commercial cultivars, Banganpalli (also known as Baneshan, Safeda, or Benishan) is highly valued for its attractive golden-yellow colour, fibreless flesh, pleasant aroma, excellent sweetness, and long shelf life under ambient conditions (NHM, 2022) [20]. However, Banganpalli fruits harvested from conventionally managed orchards (flood irrigation + soil application of fertilizers) often exhibit inconsistent quality, rapid post-harvest ripening, high respiration rate, quick softening, fast chlorophyll breakdown, and short marketable life (10–12 days at ambient temperature), leading to heavy post-harvest losses estimated at 25–40% (Jilen M. Mayani. 2016) [9].
Pre-harvest factors such as water and nutrient management play a vital role in determining fruit growth, biochemical composition at harvest, and subsequent post-harvest behaviour. Water deficit during fruit development reduces cell turgor, limits photosynthate translocation, impairs mineral uptake, and results in smaller fruits with lower sugar and vitamin C content (Jilen M. Mayani. 2016) [9]. Conversely, excessive or irregular irrigation causes cracking and poor colour development (Jilen M. Mayani. 2016) [9]. Similarly, imbalanced or untimely nutrient supply, especially nitrogen (N) and potassium (K), affects carbohydrate metabolism, cell wall strength, antioxidant accumulation, and resistance to physiological disorders (Jilen M. Mayani. 2016) [9].
In recent years, drip irrigation and fertigation have emerged as powerful water- and nutrient-saving technologies in perennial fruit crops. Drip irrigation maintains optimal soil moisture in the active root zone, minimizes hydrothermal stress, enhances root proliferation, and improves nutrient use efficiency. Fertigation (application of soluble fertilizers through drip) allows precise, split, and synchronized delivery of nutrients according to crop demand, resulting in higher leaf nutrient status and better partitioning of assimilates to the fruit. Mulching further conserves soil moisture, suppresses weeds, moderates soil temperature, and reduces fruit

cracking and sun scorch (Kaviyazhagan *et al*., 2015) [12]

Several workers have independently reported beneficial effects of drip irrigation and fertigation on fruit yield and quality of mango cultivars such as Alphonso, Dashehari, Totapuri, and Mallika (Prakash *et al*., 2015) [24]. However, very little information is available on their combined effect on post-harvest quality and shelf-life attributes of cv. Banganpalli, particularly under S.Emi-arid tropical conditions of southern India. Therefore, the present investigation was undertaken with the following objectives: To study the influence of different drip irrigation regimes (based on crop evapotranspiration, ETc) on fruit physico-chemical quality at harvest and during ambient storage. To evaluate the effect of varying levels of N and K applied through fertigation versus conventional soil application. To examine the synergistic effect of drip irrigation, fertigation, and mulching on biochemical constituents (TSS, sugars, ascorbic acid, acidity), respiration behaviour, fruit firmness, chlorophyll degradation, and shelf life of mango cv. Banganpalli.

Materials and Methods

Experimental site and plant material

The field experiment was conducted at the Mango Research station, Sangareddy, Sri Konda Laxman Telangana Horticultural University, Telangana, India (16° 30' N latitude and 78° 19' E longitude at an elevation of 550 m above MSL). The region has a hot S.Emi-arid climate with mean annual rainfall of 906 mm received mostly during south-west monsoon. The soil was red sandy loam with pH 7.4, low in organic carbon (0.38%), available N (182 kg ha^{-1}), P (23 kg ha^{-1}) and K (245 kg ha^{-1}). Uniform, healthy, 12-year-old mango trees cv. Banganpalli, grafted on local seedling rootstock, spaced at 10 m × 10 m, was selected for the study.

Treatments and experimental design

The experiment was laid out in a two-factor factorial randomized block design with three replications.

Factor A – Irrigation levels (drip)

- I_1: Conventional surface (flood-1200 liters once in 10 days per plant) irrigation (control)
- I_2: 75% of crop evapotranspiration (ETc)
- I_3: 100% ETc
- I_4: 125% ETc

Factor B – Fertigation / fertilization levels

- F_1: 100% recommended dose of N and K through soil application (control)
- F_2: 50% recommended dose of N and K through fertigation
- F_3: 75% recommended dose of N and K through fertigation
- F_4: 100% recommended dose of N and K through fertigation

Thus, there were 16 treatment combinations (4 irrigation × 4 fertilization levels) replicated thrice, making a total of 96 trees (two plants per treatment). Recommended dose of fertilizer for mango in the region is: 1000 g N, 1000 g P_2O_5, 1000 g K_2O and 50 kg FYM per tree per year. 500 g of N&K fertilizer applied along with phosphorus (1000 g P_2O_5) and 50 kg FYM was applied uniformly to all treatments as basal soil application during onset of Monsoon period and the remaining 500 g of N&K fertilizer applied in three splits for fertigation treatments. Urea and potassium nitrate (white) were used as sources of N and K, respectively, for both soil and fertigation treatments.

Drip irrigation was scheduled daily based on previous day's pan evaporation (Class A pan) adjusted by crop factor (Kc) and canopy coverage factor. Four drippers (8 L h^{-1} each) were placed around each tree. Black polyethylene mulch (100 micron) was spread in the tree basin (6 m diameter) in all drip-irrigated plots to conserve moisture and control weeds.

Observations recorded

Fully mature fruits (100–120 days after fruit set, shoulder development, slight yellowing at apex) were harvested in the morning hours during second week of May in both years. Representative samples of 30 fruits per treatment per replication were kept for storage studies at ambient condition (27 ± 2 °C, 65–75% RH).

Physico-chemical parameters recorded at harvest and at 3-day intervals during storage included:

- Total soluble solids (°Brix) – Hand Refractometer
- Titratable acidity (%) – NaOH titration
- Ascorbic acid (mg 100 g^{-1}) – 2,6-dichlorophenol dye method
- Total, reducing and non-reducing sugars (%) – Lane–Eynon method
- Respiration rate (O_2 uptake and CO_2 evolution,% kg^{-1} h^{-1}) – static head-space method using portable gas analyser (PBI Dan sensor)
- Fruit firmness (kg cm^{-2}) – penetrometer (8 mm probe)
- Chlorophyll degradation – DA-index using DA-meter (TR Turoni, Italy)
- Shelf life – number of days taken to reach eating-soft stage (firmness < 0.8 kg cm^{-2} with full yellow colour)

Statistical analysis

The data were subjected to two-way analysis of variance (ANOVA) using OPSTAT and WASP software. Duncan Multiple Range Test (DMRT) was used to distinguish means that were significantly different at $P \leq 0.05$. The results of both years followed similar trend; hence, pooled data are presented and discussed.

Results and Discussion

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

Irrigation levels significantly influenced the fruit ascorbic acid content (Table-1). The highest value was recorded at 100% ETc (I3: 46.22 mg 100 g^{-1}), statistically similar to 75% ETc (I2: 45.42 mg 100 g^{-1}) and 125% ETc (I4: 43.75 mg 100 g^{-1}), whereas the control (I1) gave the lowest (39.42 mg 100 g^{-1}). Thus, drip irrigation at 75–125% ETc significantly increased ascorbic acid compared to conventional surface irrigation, consistent with findings in sapota cv. Kalipatti (Tiwari *et al*., 2016) [31], mango cv. Alphonso (Prakash *et al*., 2015) [24], citrus (Mathew and Ghosh, 2004) [18], sweet orange (Ghosh and Pal, 2010), and guava (Singh *et al*., 2015) [29]. This might be due to higher soil moisture under drip irrigation and mulching minimized root shrinkage, improved root–soil contact, and enhanced potassium uptake. Elevated leaf K promotes conversion of carbohydrates into amino acids and vitamins, including ascorbic acid (Borthakur and Bhattacharyya, 1996b) [4].

Fertilization treatments also significantly affected ascorbic acid content. The highest values were obtained with 100% N and K via fertigation (F4: 53.11 mg 100 g^{-1}), comparable to 75% via fertigation (F3: 49.20 mg 100 g^{-1}). The lowest was with 100% N and K via soil application (F1: 36.04 mg 100 g^{-1}). Fertigation markedly outperformed conventional soil application and the results are in agreement with Pankaj (2013) [23] in acid lime.

The irrigation × fertilization interaction was significant (Table-1). Maximum ascorbic acid was recorded in 75% ETc + 100% N and K via fertigation (I2F4: 56.67 mg 100 g^{-1}), followed closely by I3F4 (56.44), I4F4 (53.34), I2F3 (52.50), I3F3 (51.78), and I4F3 (50.00 mg 100 g^{-1}). The lowest value was in control + soil-applied 100% N and K (I1F1: 32.50 mg 100 g^{-1}). Combined higher irrigation and fertigation with mulching significantly increased ascorbic acid content. Which might be due to improved water and nutrient availability stimulated vegetative growth, enhanced solar energy capture, and promoted synthesis and accumulation of carbohydrates and secondary metabolites, including ascorbic acid (Sadarunnisa *et al*., 2010; Koo, 1984; Colapietra, 1987; Orphanos and Eliades, 1994) [25, 13, 5, 21]. These factors collectively explain the superior ascorbic acid levels observed in the present study.

TSS (° Brix)

Data revealed no significant main effect of irrigation or fertilization levels on TSS (°Brix) of mango cv. Banganpalli (Table-2). However, their interaction was significant. The highest TSS (19.60 °Brix) was recorded with 75% ETc + 50% N and K through fertigation (I2F2), which was statistically at par with I4F1 (19.42), I3F3 (19.35), I2F4 (18.93), I4F2 (18.83), I4F4 (18.82), I3F4 (18.55), and control I1F1 (18.72 °Brix). The lowest TSS was obtained with 75% ETc + 100% N and K through soil application (I2F1; 16.65 °Brix), which was at par with other low-performing treatments (17.08–17.50 °Brix) and I1F4 (17.33 °Brix). TSS significantly increased with higher irrigation and fertigation levels combined with mulching. Similar findings of increased TSS with higher irrigation were reported by Shirgure *et al*. (2016) [27] in Nagpur mandarin, Junaid *et al*. (2013) [10] in guava, Koo (1984) [13] in orange, Colapietra (1987) [5] in grapes, Orphanos and Eliades (1994) [21] in Valencia orange, and Sadarunnisa *et al*. (2010) [25] in papaya. The increase in TSS with higher irrigation, fertigation, and mulching is attributed to sustained soil moisture, reduced hydrothermal fluctuations, and active roots throughout the season. Drip irrigation and mulching minimized root shrinkage and improved root–soil contact. Fertigation enhanced nutrient availability, raising leaf NPK content. Higher nutrient reserves might have promoted conversion of carbohydrates into amino acids and proteins, increasing leaf area, carbon assimilation, and ultimately sugar accumulation and TSS (Borthakur and Bhattacharyya, 1996b) [4].

Titratable acidity (%)

Irrigation levels significantly affected titratable acidity (Table 2). The lowest acidity was recorded in the control (I1: 0.27%), statistically similar to 100% ETc (I3: 0.28%) and 125% ETc (I4: 0.29%), whereas the highest was with 75% ETc (I2: 0.33%). Titratable acidity decreased significantly with increasing irrigation levels, consistent with findings in mango cv. Alphonso (Prakash *et al*., 2015) [24].

Higher irrigation maintained consistent soil moisture, enhancing stomatal conductance and CO_2 assimilation (Taiz and Zeiger, 2009) [30]. This promoted photosynthates production and accumulation of carbohydrates and hydrolytic enzymes during fruit development, accelerating starch hydrolysis into sugars and thereby reducing acidity. In contrast, water stress at 75% ETc (I2) likely limited enzyme activity, slowing conversion of organic acids and starch to sugars, resulting in higher acidity.

Fertilization treatments also significantly influenced titratable acidity. The lowest values were with 100% N and K via fertigation (F4: 0.28%), on par with 50% (F2: 0.28%) and 75% (F3: 0.30%) through fertigation, while the highest was with 100% N and K via soil application (F1: 0.32%). Fertigation at 100% N and K significantly lowered acidity compared to conventional soil application, in agreement with Pankaj (2013) [23] in acid lime and Karuna *et al*. (2017) [11] in Kinnow mandarin.

The irrigation × fertilization interaction was significant. The lowest acidity was recorded in control + 100% N and K via fertigation (I1F4: 0.23%), comparable to I3F2 (0.24%), I4F2 (0.25%), and I1F1 (0.25%). The highest was in I3F1 (0.36%). Combined higher irrigation and fertigation with mulching consistently reduced titratable acidity, corroborating reports in orange (Koo, 1984) [13], grapes (Colapietra, 1987) [5], Valencia orange (Orphanos and Eliades, 1994) [21], papaya (Sadarunnisa *et al*., 2010) [25], Nagpur mandarin (Shirgure *et al*., 2016) [27], and guava (Junaid *et al*., 2013) [10]. Reduced acidity under higher irrigation and fertigation with mulching is attributed to improved soil moisture and nutrient availability, which enhanced source-to-sink translocation and plant growth (Prakash *et al*., 2015) [24]. This favored metabolite accumulation and starch hydrolysis into sugars during fruit ripening, thereby lowering titratable acidity.

Brix acid ratio

The Brix: acid ratio of mango cv. Banganpalli fruits as affected by irrigation and fertilization levels is shown in Table 2. Irrigation levels significantly influenced the Brix: acid ratio. The highest ratio was recorded in the control (I1: 72.39), statistically similar to 125% ETc (I4: 69.50) and 100% ETc (I3: 67.00), whereas the lowest was with 75% ETc (I2: 54.36). The ratio increased with higher irrigation levels, consistent with findings in mango cv. Alphonso (Prakash *et al*., 2015) [24].

Higher irrigation ensured consistent soil moisture, improved translocation of assimilates, and enhanced accumulation of carbohydrates and hydrolytic enzymes during fruit development. This accelerated starch hydrolysis into sugars, raising TSS and reducing acidity, thereby increasing the Brix: acid ratio. Fertilization treatments also significantly affected the Brix: acid ratio. The highest values were obtained with 100% N and K via fertigation (F4: 70.14), comparable to 50% via fertigation (F2: 69.19). The lowest ratio was with 100% N and K via soil application (F1: 58.60), similar to 75% via fertigation (F3: 59.88). Fertigation significantly improved the ratio over conventional soil application, in agreement with Pankaj (2013) [23] in acid lime and Karuna *et al*. (2017) [11] in Kinnow mandarin. Fertigation increased nutrient availability, boosted photosynthesis, and enhanced synthesis of carbohydrates and hydrolytic enzymes. These enzymes promoted hydrolysis of starch and organic acids into sugars, raising TSS and lowering acidity, which ultimately improved the Brix: acid ratio (Shirgure *et al*., 2016) [27].

The irrigation × fertilization interaction was significant. The highest Brix: acid ratio was recorded in control + 100% N and K via fertigation (I1F4: 80.47), followed closely by I4F2 (83.26), I1F1 (75.48), I3F2 (74.46), I4F4 (74.19), and I4F3 (69.70). The lowest was in 75% ETc + 100% N and K via soil (I2F1: 48.99), comparable to several other low-performing combinations (49.14–60.77). Combined higher irrigation and fertigation with mulching markedly increased the Brix: acid ratio, corroborating observations in Nagpur mandarin (Shirgure *et al*., 2016) [27] and pomegranate cv. Bhagwa (Haneef *et al*., 2014) [8]. The superior Brix: acid ratio under higher irrigation and fertigation with mulching resulted from greater soil moisture and nutrient availability, which strengthened source-to-sink transport and plant growth. This favored accumulation and hydrolysis of starch into sugars, increasing TSS and reducing acidity, leading to a higher Brix: acid ratio.

Total sugars, non-reducing sugars, and reducing sugars

Total sugars

Irrigation levels significantly affected total sugar content (Table 3). The highest values were recorded at 100% ETc (I3) and 125% ETc (I4) (both 12.98%), statistically similar to control (I1: 12.48%), while the lowest was at 75% ETc (I2: 12.09%).

Fertilization treatments showed significant differences. Maximum total sugars were obtained with 100% N and K via fertigation (F4: 14.98%), comparable to 75% via fertigation (F3: 14.26%). The lowest was with 100% N and K via soil application (F1: 10.22%).

The interaction was significant. Highest total sugars were recorded in I3F4 (15.96%), followed by I4F4 (15.35%), I3F3 (14.98%), I4F3 (14.48%), and I1F4 (14.75%). The lowest was in I4F1 (9.43%), similar to several soil-applied treatments (9.93–10.58%), (Table 3).

Non-reducing sugars

Irrigation significantly influenced non-reducing sugars. Highest content was at 100% ETc (I3: 8.09%), comparable to 125% ETc (I4: 7.53%). Lowest values were at 75% ETc (I2) and control (I1) (~7.35–7.53%). Fertigation at 100% N and K (F4: 9.51%) gave the highest non-reducing sugars, followed by 75% (F3: 8.71%), while soil application (F1: 5.24%) recorded the lowest. The interaction effect was significant, with I3F3 (10.42%), I3F4 (10.14%), and I4F4 (9.51%) showing the highest values, and I4F1 (4.15%) the lowest (Table 3).

Reducing sugars

Surprisingly, highest reducing sugars were observed at 75% ETc (I2: 5.59%), comparable to 125% ETc (I4: 5.45%), while 100% ETc (I3) gave the lowest (4.89%). Among fertilization treatments, 100% N and K via fertigation (F4: 5.93%) recorded the highest reducing sugars, followed by 75% (F3: 5.41%). Lowest values were with 50% via fertigation (F2: 4.74%) and soil application (F1: 4.97%). Interaction showed I2F4 (6.28%) as the highest, followed by I4F4, I3F4, I4F3, and I1F4 (5.77–5.84%). The lowest was I1F2 (3.90%), (Table 3).

Higher irrigation (100–125% ETc) through drip, combined with mulching, significantly increased total and non-reducing sugars compared to the control or deficit irrigation (75% ETc). This is attributed to sustained soil moisture, reduced hydrothermal stress, enhanced surface rooting, and efficient uptake of N and K- key activators of enzymes involved in photosynthesis and carbohydrate metabolism. These conditions promoted assimilate translocation and starch hydrolysis into sugars during ripening (Kulkarni and Yewale, 2012; Prakash *et al*., 2015; Bhusan *et al*., 2015) [14, 24, 2].

Fertigation, especially at 75–100% N and K (F3 and F4), consistently outperformed soil application, resulting in higher total, non-reducing, and reducing sugars. Improved nutrient availability and use efficiency enhanced photosynthetic activity and enzyme-mediated conversion of starch to sugars (Dinesh *et al*., 2008; Boora and Singh, 2000; Sadarunnisa *et al*., 2010; Sandip *et al*., 2016; Karuna *et al*., 2017) [7, 3, 25, 26, 11].

The combined effect of higher irrigation and fertigation with mulching maximized sugar accumulation through better source-to-sink strength, sustained moisture, and nutrient supply, leading to efficient starch hydrolysis during ripening. Similar results have been reported in orange (Koo, 1984) [13], grapes (Colapietra, 1987) [5], Valencia orange (Orphanos and Eliades, 1994) [21], and papaya (Sadarunnisa *et al*., 2010) [25].

Respiration rate (O_2 and CO_2% kg fresh mass^{-1} h^{-1})

Respiration is a fundamental metabolic process that provides energy for various biochemical reactions in plant tissues. Aerobic respiration involves the oxidative breakdown of organic reserves into simpler molecules, primarily carbon dioxide (CO_2) and water, with the concomitant release of energy. The substrates utilised in respiration include carbohydrates, lipids, and organic acids. This process consumes oxygen (O_2) through a series of enzymatic reactions.

In climacteric fruits such as mango, ripening is marked by a dramatic increase in respiration rate (the climacteric rise), characterised by a sharp rise in CO_2 evolution and a corresponding decline in internal O_2 concentration. This climacteric rise is triggered by an autocatalytic increase in ethylene production and sensitivity (Lyons and Pratt, 1964) [17].

Under ambient conditions, a relatively constant respiratory quotient (ratio of CO_2 evolved to O_2 consumed) is typically observed, indicating the presence of physiologically active ethylene within the fruit tissues (James *et al*., 1961). A secondary rise in respiration, often termed "induced" respiration, may occur later during storage and is primarily caused by microbial proliferation rather than the ripening process itself (Palmer and McGlasson, 1969) [22]. Freshly harvested fruits are virtually free of microbes; however, microbial populations increase as ripening progresses (Palmer and McGlasson, 1969) [22]. Unripe fruits generally exhibit low microbial counts, possibly due to the presence of antimicrobial compounds in green tissues (Simmonds, 1963) [28]. In ripe fruits, loss of cellular integrity makes them more susceptible to infection, which can trigger secondary (microbially induced) respiration (McGlasson and Pratt, 1964) [19]. The extent of this secondary rise depends largely on cellular integrity, which is influenced by both pre-harvest and post-harvest factors.

Respiration Rate of Mango cv. Banganpalli Fruits during Storage

Respiration rate was measured as oxygen uptake (O_2% kg^{-1} fresh mass h^{-1}) and carbon dioxide evolution (CO_2% kg^{-1} fresh mass h^{-1}). The data (Tables 4 to 6) exhibited a typical climacteric pattern, with a sharp rise in CO_2 evolution and a corresponding decline in internal O_2 concentration between the 3rd and 6th day after harvest, followed by a gradual decline thereafter.

Oxygen Uptake (O_2% kg^{-1} fresh mass h^{-1}); (Table 4&5)

On the day of harvest

Significant differences were observed among irrigation levels. The highest O_2 uptake was recorded with 75% ETc (I_2: 15.3), which was statistically at par with 125% ETc (I_4: 15.1) and control (I_1: 15.1). The lowest was with 100% ETc (I_3: 14.4). Among fertigation treatments, the highest O_2 uptake occurred with 75% N and K through fertigation (F_3: 15.5), followed by 100% N and K through fertigation (F_4: 14.9) and 100% N and K applied through soil (F_1: 14.9). The lowest was with 50% N and K through fertigation (F_2: 14.5). Interaction effects were significant. The highest value was recorded in I_4F_3 (125% ETc + 75% N and K fertigation: 16.5), at par with I_3F_3 (100% ETc + 75% N and K fertigation: 15.8). The lowest was in I_3F_2 (100% ETc + 50% N and K fertigation: 13.8).

3rd day of storage
The highest O_2 uptake among irrigation levels was in the control (I_1: 12.7), followed by 100% ETc (I_3: 9.4), at par with 75% ETc (I_2: 9.5). The lowest was with 125% ETc (I_4: 8.4). Among fertigation treatments, the highest value was with 100% N and K applied through soil (F_1: 10.6), followed by 50% N and K through fertigation (F_2: 10.2). The lowest was with 75% N and K through fertigation (F_3: 9.2). The highest interaction value was in I_1F_1 (control + 100% N and K through soil: 14.4), at par with I_2F_2 (75% ETc + 50% N and K fertigation: 14.3). The lowest was in I_4F_2 (125% ETc + 50% N and K fertigation: 7.0).

6th day of storage
The highest O_2 uptake among irrigation levels was in the control (I_1: 11.8), followed by 100% ETc (I_3: 9.4), at par with 75% ETc (I_2: 9.2). The lowest was with 125% ETc (I_4: 8.3). Among fertigation treatments, the highest value was with 100% N and K applied through soil (F_1: 10.1), followed by 50% N and K through fertigation (F_2: 10.0). The lowest was with 75% N and K through fertigation (F_3: 9.0). The highest interaction value was in I_1F_1 (13.7), at par with I_2F_2 (13.2). The lowest was in I_2F_3 (75% ETc + 75% N and K fertigation: 5.9).

9th day of storage
The highest O_2 uptake among irrigation levels was in the control (I_1: 13.7), followed by 125% ETc (I_4: 12.1). The lowest was with 100% ETc (I_3: 11.5). Among fertigation treatments, the highest value was with 100% N and K applied through soil (F_1: 14.1), followed by 50% N and K through fertigation (F_2: 12.7). The lowest was with 75% N and K through fertigation (F_3: 10.1). The highest interaction value was in I_1F_1 (15.3), at par with I_2F_2 (15.1). The lowest was in I_2F_3 (7.3).

12th day of storage
The highest O_2 uptake among irrigation levels was in the control (I_1: 11.4), followed by 100% ETc (I_3: 10.5), at par with 125% ETc (I_4: 10.4). The lowest was with 75% ETc (I_2: 8.7). Among fertigation treatments, the highest value was with 100% N and K applied through soil (F_1: 12.0), followed by 50% N and K through fertigation (F_2: 10.5). The lowest was with 75% N and K through fertigation (F_3: 9.1). The highest interaction value was in I_1F_1 (14.1), at par with I_3F_1 (14.0). The lowest was in I_2F_3 (7.0).

Carbon Dioxide Evolution (CO_2% kg^{-1} fresh mass h^{-1}); (Table 6&7)
On the day of harvest
The lowest CO_2 evolution among irrigation levels was with 75% ETc (I_2: 4.8), at par with 100% ETc (I_3: 4.9). The highest was in the control (I_1: 5.6). Among fertigation treatments, the lowest was with 50% N and K through fertigation (F_2: 4.8), followed by 75% N and K through fertigation (F_3: 5.0). The highest was with 100% N and K applied through soil (F_1: 5.4). The lowest interaction value was in I_3F_2 (100% ETc + 50% N and K fertigation: 4.2), at par with I2F3 (4.3). The highest values (5.8) were recorded in I3F1, I1F3, and I4F4.

3rd day of storage
The lowest CO_2 evolution among irrigation levels was with 100% ETc (I3: 7.1), followed by control (I1: 7.6). The highest was with 125% ETc (I4: 8.4). Among fertigation treatments, the lowest was with 100% N and K through fertigation (F4: 6.7), followed by 75% N and K through fertigation (F3: 7.6). The highest was with 50% N and K through fertigation (F2: 8.9). The lowest interaction values were in I2F4 (6.1) and I4F4 (6.0). The highest was in I4F2 (125% ETc + 100% N and K through soil: 11.2).

6th day of storage (climacteric peak)
The lowest CO_2 evolution among irrigation levels was in the control (I1: 6.6), followed by 100% ETc (I3: 7.7), at par with 125% ETc (I4: 7.8). The highest was with 75% ETc (I2: 8.0). Among fertigation treatments, the lowest was with 75% N and K through fertigation (F3: 5.5), followed by 100% N and K through fertigation (F4: 6.3). The highest was with 100% N and K applied through soil (F1: 9.4). The lowest interaction value was in I1F3 (3.0), followed by I2F4 (4.2). The highest was in I4F2 (12.1).

9th day of storage
The lowest CO_2 evolution among irrigation levels was in the control (I1: 5.5). The highest was with 100% ETc (I3: 6.5), at par with 125% ETc (I4: 6.4). Among fertigation treatments, the lowest was with 75% N and K through fertigation (F3: 5.6). The highest (6.5) was recorded in both F1 and F2. The lowest interaction values (4.1) were in I4F3 and I2F4. The highest was in I4F2 (8.2).

12th day of storage
The lowest CO_2 evolution among irrigation levels was in the control (I1: 6.8), followed by 75% ETc (I2: 7.2). The highest was with 100% ETc (I3: 8.7). Among fertigation treatments, the lowest was with 75% N and K through fertigation (F3: 6.7), followed by 100% N and K through fertigation (F4: 7.3). The highest was with 50% N and K through fertigation (F2: 8.5). The lowest interaction value was in I4F3 (5.1), followed by I1F3 (5.9). The highest was in I3F1 (9.9).
The results on gas composition (O_2 and Co_2% kg fresh mass^{-1} h^{-1}) of mango fruits after application of different levels irrigation and fertilization treatments are presented in the Table 4.2.14-17 and Fig 4.2.3-4. In the present study almost all fruits of present investigation has shown climacteric peak (respiratory peak) from three (3) to six (6) days after fruit harvest. This might be due to the fruit ripening has progress in these days which has resulted in increased CO_2 and reduced O_2 concentration in the present investigation. However nine days after fruit harvest the respiration rate has shown significant difference with different levels irrigation and fertilization treatments.
Different levels of irrigation treatments has shown significant effect on (in O_2 consumption and CO_2 release) respiration rate. In the present investigation the I_1 (control) treatment has shown reduced respiration rate compared to other treatments. However, the I_3 and I_4 (100and 125% ETc) treatments has shown delayed climacteric peak (constant raise in respiration rate). The minimum respiration rate in control is due to the minimum crop load. The minimum crop load might have resulted in increased source to sink strength as compared to other treatments in the present investigation. The increased source strength might have helped in increased assimilates in fruits. These food reserves play major role in synthesis of pectin's, lipid compounds and other antimicrobial and antioxidant compounds. This might have resulted in increased cell wall integrity lead to increased fruit firmness (1.7 kg cm^{-2}) (Table-8&9) in the present investigation. This ultimately resulted in reduced respiration rate (CO_2 release and O_2 consumption) in the present investigation. The maximum respiration rate was recorded with application of 75% ETc (I_2), which might be due to reduced photosynthetic rate as a result of reduced stomatal conductivity and CO_2 assimilation, which

might have negatively influenced the synthesis of pectin's, lipid compounds and other antimicrobial and antioxidant compounds has led to the maximum respiration rate in the present investigation.

Different levels of fertilization treatments has shown significant effect on (in O_2 consumption and CO_2 release) respiration rate. The control (F_1) has shown reduced respiration rate compared to other treatments, where as F_2 (50% N and K through fertigation) has shown increased respiration rate. However the F_3 and F_4 (75 and 100% N and K through fertigation) has shown delayed climacteric peak (constant raise in respiration rate). The minimum respiration rate in control due to treatment has the minimum crop load might have resulted in increased source to sink strength as compared to other treatments in the present investigation. The increased source strength might have helped in increased assimilates in fruits. These food reserves play major role in synthesis of pectin's, lipid compounds and other antimicrobial and antioxidant compounds. This might have resulted in better cell wall integrity lead to increased fruit firmness (3.0 kg cm^{-2}) (Table 8&9) in the present investigation. This ultimately resulted in reduced respiration rate (CO_2 release and O_2 consumption) in the present investigation.

The combined application increased irrigation and fertigation levels have significantly reduced the respiration rate (in O_2 consumption and CO_2 release) of mango fruits as compared to conventional method of irrigation and fertilization. The treatments I_2F_3, I_4F_3, I_4F_4, I_3F_2, I_3F_3 and I_1F_1 did not shown secondary respiratory peak in (CO_2 release) up to 12th day of fruit storage, fruit has shown lower and constant respiration rate. The same has resulted increased soil moisture, this might have helped in increased nutrient solubility and availability. The increased water and nutrients might have resulted in increased food reserves accumulation through enhanced plant physiological activities. These food reserves play major role in synthesis of pectin's, lipid compounds and other antimicrobial and antioxidant compounds. This might have resulted in better cell wall integrity and increased fruit firmness, reduced chlorophyll degradation in the present investigation. This ultimately resulted in reduced CO_2 release (respiration rate) and O_2 consumption. Whereas the interactions of I_2F_2, I_3F_1 and I_4F_1 has shown increased respiration rate along with early second raise in O_2 consumption, it means fruits ripened early and there after fruits started degrading due to it the induced respiration triggered. This may be due to poor cell wall integrity affected by improper irrigation and nutrition has resulted in reduced synthesis of antimicrobial and antioxidant compounds. Further, the reduced fruit firmness, increased chlorophyll degradation which ultimately increased the respiration rate led to reduced shelf life of fruits in the present investigation.

Fruit firmness (kg cm^{-2})

The data revealed that there is no significant difference among different levels of irrigation with respect to firmness of fruit on 12th day of storage.

Fertilization treatments significantly affected fruit firmness on day 12 of storage. Highest firmness occurred with 75% N-K fertigation (F3: 2.65 kg cm^{-2}), followed by 100% fertigation (F4: 1.58 kg cm^{-2}); lowest was with 50% fertigation (F2: 0.97 kg cm^{-2}). Higher fertigation levels markedly retained firmness compared to conventional soil fertilization. This is attributed to greater nutrient reserves from improved uptake via fertigation, enhanced photosynthesis, increased food reserves, and higher pectin synthesis - all strengthening cell-wall integrity (Junaid *et al*., 2013 in guava) [10].

The irrigation × fertilization interaction significantly affected fruit firmness on day 12 of storage. Highest firmness occurred with 125% ETc + 75% N-K fertigation (I4F3: 3.3 kg cm^{-2}), comparable to 100% ETc + 75% N-K fertigation (I3F3: 3.1 kg cm^{-2}), control + 75% N-K fertigation (I1F3: 3.1 kg cm^{-2}), and control + 100% soil-applied N-K (I1F1: 3.0 kg cm^{-2}). Lowest firmness was in control + 50% fertigation (I1F2: 0.3 kg cm^{-2}). Combined higher irrigation and fertigation markedly improved firmness retention compared to conventional practices. This resulted from sustained soil moisture, enhanced nutrient availability and uptake, higher nutrient reserves, increased photosynthesis, greater photosynthate accumulation, and elevated pectin synthesis — all strengthening cell-wall integrity (Junaid *et al*., 2013 in guava) [10].

DA-index

The results on DA-index of mango fruits after application of different levels irrigation and fertilization treatments are presented in the Table-10 to 11. The changes in fruit colour can be assessed with the DA-index (difference of absorbance-index), which measures the level of chlorophyll-a in the flesh of the fruit just under the skin. Generally DA index values decreases with fruit ripens as chlorophyll degrades (Amaya and Janet, 2018) [1].

Irrigation levels significantly influenced DA-index of mango cv. Banganpalli on day 12 of storage (Table 4.2.21). Highest chlorophyll retention occurred at 125% ETc (I4: 0.49), comparable to 100% ETc (I3: 0.45); lowest was in control (I1: 0.40). Drip irrigation at higher levels markedly delayed chlorophyll degradation compared to conventional flooding. Similar findings were reported by David *et al*. (2012) [6] in blueberry. This delay is attributed to sustained soil moisture, which enhanced nutrient uptake, photosynthesis, carbon assimilation, sugar accumulation (Borthakur and Bhattacharyya, 1996b) [4], cell-wall integrity, fruit firmness, antioxidant synthesis (ascorbic acid), and suppressed respiration. These factors collectively slowed chlorophyll breakdown (DA-index ≥0.45 on day 9; Tables 10&11).

Fertilization treatments significantly affected DA-index on day 12 of storage. Highest values occurred with 75% N-K fertigation (F3: 0.58), comparable to 100% fertigation (F4: 0.51); lowest was with 50% fertigation (F2: 0.29, mislabeled as F1 in original). Fertigation markedly increased DA-index (delayed chlorophyll degradation) compared to conventional soil fertilization. This is attributed to readily available nutrients via fertigation, which boosted photosynthesis, photosynthates accumulation, pectin-like substance production, ascorbic acid levels, antioxidant activity, and cell-wall integrity — collectively slowing chlorophyll breakdown and improving fruit quality. Similar results were reported by Kumar *et al*. (2010) [15] in papaya.

The irrigation × fertilization interaction significantly affected DA-index on day 12 of storage (Table 4.2.21). Highest values occurred in 100% ETc + 75% N-K fertigation (I3F3: 0.70), comparable to 125% ETc + 75% N-K fertigation (I4F3: 0.68) and 75% ETc + 100% N-K fertigation (I2F4: 0.60). Lowest DA-index was in a low-nutrient control treatment (I3F2: 0.23). Combined higher irrigation and fertigation markedly increased DA-index (delayed chlorophyll degradation) compared to conventional practices. This is attributed to sustained soil moisture promoting nutrient mineralization and mobilization, timely nutrient supply via split fertigation doses, enhanced photosynthesis, greater photosynthate accumulation, pectin synthesis, higher fruit firmness, suppressed respiration, and elevated antioxidant levels — all slowing chlorophyll breakdown in mango fruits.

Shelf life (days)

The data (Table 12) revealed significant differences in shelf life of mango cv. Banganpalli among irrigation levels. Maximum shelf life was recorded at 125% ETc (I4: 12.73 days), statistically similar to 100% ETc (I3: 12.69 days), while minimum was at 75% ETc (I2: 10.96 days). Higher irrigation levels significantly extended shelf life compared to the control. Similar results were reported by David *et al*. (2012) [6] in blueberry. Longer shelf life under higher drip irrigation is attributed to sustained soil moisture, which improved mineral nutrient availability, enhanced photosynthesis and carbon assimilation, and increased accumulation of sugars and other metabolites (Borthakur and Bhattacharyya, 1996b) [4]. This led to greater fruit firmness, slower chlorophyll degradation, and suppressed respiration, collectively delaying ripening and senescence. Shorter shelf life in the control resulted from water stress, which reduces fruit quality relative to well-watered trees.

Fertilization treatments significantly affected shelf life of mango fruits. Maximum shelf life was recorded with 75% N-K fertigation (F3: 13.04 days), statistically similar to 100% fertigation (F4: 12.68 days). Minimum values occurred with 50% fertigation (F2: 11.07 days) and soil application (F1: 11.43 days). Similar extensions in shelf life with higher fertigation have been reported by Kumar *et al*. (2010) [15] in papaya. Fertigation markedly prolonged shelf life compared to conventional soil fertilization. This is attributed to higher nutrient reserves from improved uptake via fertigation, leading to enhanced photosynthesis, greater accumulation of food reserves, increased pectin synthesis, stronger cell-wall integrity, higher fruit firmness, slower chlorophyll degradation, and suppressed respiration. These factors collectively delayed senescence and extended shelf life.

The combined application of irrigation and fertilization significantly affected shelf life of mango cv. Banganpalli. Maximum shelf life was recorded in 100% ETc + 100% N-K fertigation (I3F4: 14.75 days), statistically similar to 125% ETc + 75% N-K fertigation (I4F3: 14.45 days) and 125% ETc + 100% N-K fertigation (I4F4: 14.00 days). Minimum shelf life occurred in 75% ETc + 50% N-K fertigation (I2F2: 10.58 days). This study demonstrates that higher irrigation and fertigation levels, combined with mulching, significantly extended shelf life compared to conventional practices. The extension is attributed to optimal soil moisture and timely nutrient supply via split fertigation, which enhanced nutrient uptake, leaf nutrient reserves, photosynthesis, photosynthates accumulation, pectin synthesis, and cell-wall integrity. These factors increased fruit firmness, slowed chlorophyll degradation, and suppressed respiration, collectively delaying senescence has resulted in prolonging shelf life of mango.

Table 1: Effect of irrigation and fertigation on ascorbic acid content (mg $100g^{-1}$) of mango cv. Banganpalli.

Treatments	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	32.50^{e}	36.67^{cde}	42.50^{cd}	46.00^{bc}	39.42^{b}
I_2 (75% ETc)	38.34^{cde}	34.17^{e}	52.50^{a}	56.67^{a}	45.42^{a}
I_3(100% ETc)	36.67^{cde}	40.00^{cde}	51.78^{a}	56.44^{a}	46.22^{a}
I_4(125% ETc)	36.67^{cde}	35.00d^{e}	50.00^{a}	53.34^{ab}	43.75^{ab}
Mean	36.04^{b}	36.46^{b}	49.20^{a}	53.11^{a}	
Factors	F-Test		S.Em±		CD (P=0.05)
Irrigation (I)	*		1.43		4.13
Fertigation (F)	*		1.43		4.13
Interaction (IxF)	*		2.86		8.26

(Each data point is average of two years)

Note: Figures with same alphabets did not differ significantly.

F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water $tree^{-1}$ at 10 days intervals.

Table 2: Effect of irrigation and fertigation on TSS (° Brix), titratable acidity (%) and Brix acid ratio of mango cv. Banganpalli

Treatments	TSS (°Brix)					Titratable acidity (%)					Brix acid ratio				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	18.72^{abc}	18.27^{cde}	18.50^{bcd}	17.33^{ef}	18.20	0.25^{e}	0.31^{cd}	0.31^{cd}	0.23^{e}	0.27^{c}	75.48^{ab}	64.72^{bcde}	68.90 ^{cd}	80.47^{a}	72.39^{a}
I_2 (75% ETc)	16.65^{f}	19.60^{ab}	17.50^{def}	18.93^{abc}	18.17	0.35^{abc}	0.34^{abc}	0.31^{cd}	0.35^{abc}	0.33^{a}	48.99^{f}	56.00^{ef}	58.23^{def}	56.19^{def}	54.36^{b}
I_3(100% ETc)	17.08^{f}	17.13^{f}	19.35^{ab}	18.75^{abc}	18.08	0.36^{ab}	0.24^{e}	0.26^{de}	0.27^{de}	0.28^{ab}	49.14^{f}	74.76^{abc}	52.62^{def}	69.70 ^{cd}	67.00^{a}
I_4(125% ETc)	18.42^{ab}	18.83^{abc}	18.55^{abc}	18.82^{abc}	18.55	0.32^{bcd}	0.25^{e}	0.32^{cd}	0.27^{de}	0.29^{bc}	60.77^{bcdef}	83.26^{a}	59.78^{cdef}	74.19^{abc}	69.50^{a}
Mean	17.19	18.46	18.48	18.46		0.32^{ab}	0.28^{b}	0.30^{a}	0.28^{b}		58.60^{b}	69.19^{a}	65.32^{a}	70.14^{a}	
Factors	F-Test		S.Em±		CD (p=0.05)	F-Test		S.Em±		CD (p=0.05)	F-Test		S.Em±		CD (p=0.05)
Irrigation (I)	NS		0.18		-	*		0.01		0.03	*		2.66		7.68
Fertigation (F)	NS		0.18		-	*		0.01		0.03	*		2.66		7.68
Interaction (IxF)	*		0.36		1.05	*		0.02		0.05	*		5.32		15.35

(Each data point is average of two years)

Note Figures with same alphabets did not differ significantly.

F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water $tree^{-1}$ at 10 days intervals.

Table 3: Effect of irrigation and fertigation on fruit total, non-reducing and reducing sugars (%) content of mango cv. Banganpalli.

Treatments	Total sugars (%)					Non-reducing sugars (%)					Reducing sugars (%)				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	10.48^{ef}	11.13^{e}	13.55^{cd}	14.75^{ab}	12.48^{ab}	5.48^{gh}	7.23^{ef}	7.72^{de}	8.98^{bcd}	7.35^{b}	5.00^{de}	3.90^{g}	5.83^{b}	5.77^{ab}	5.12^{b}
I_2 (75% ETc)	10.57^{ef}	9.93^{ef}	14.01^{b}	13.85^{bcd}	12.09^{b}	5.31^{gh}	4.59^{hi}	8.54^{cde}	7.56^{e}	6.50^{c}	5.26^{cde}	5.34b^{cde}	5.48^{bcd}	6.28^{a}	5.59^{a}
I_3(100% ETc)	10.39^{ef}	10.58^{ef}	14.98^{ab}	15.96^{a}	12.98^{a}	6.03^{fg}	5.76^{gh}	10.42^{a}	10.14^{ab}	8.09^{a}	4.35^{fg}	4.82^{ef}	4.56^{ef}	5.82^{ab}	4.89^{c}
I_4(125% ETc)	9.43^{f}	12.66^{d}	14.48^{abc}	15.35^{a}	12.98^{a}	4.15^{i}	7.75^{de}	8.71^{cd}	9.51^{abc}	7.53^{ab}	5.28^{d}	4.91^{e}	5.78^{abc}	5.84^{ab}	5.45^{a}
Mean	10.22^{c}	11.08^{b}	14.26^{a}	14.98^{a}		5.24^{c}	6.33^{b}	8.85^{a}	9.05^{a}		4.97^{b}	4.74^{b}	5.41^{a}	5.93^{a}	
Factors	F-Test	S.Em±	CD (p=0.05)			F-Test	S.Em±	CD (p=0.05)			F-Test	S.Em±	CD (p=0.05)		
Irrigation (I)	*	0.23	0.66			*	0.23	0.66			*	0.09	0.26		
Fertigation (F)	*	0.23	0.66			*	0.23	0.66			*	0.09	0.26		
Interaction (IxF)	*	0.46	1.32			*	0.46	1.32			*	0.18	0.52		

(Each data point is average of two years)

Note: Figures with same alphabets did not differ significantly.

F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water tree^{-1} at 10 days intervals.

Table 4: Effect of irrigation and fertigation on O_2 content (% kg fresh mass^{-1} h^{-1}) of mango cv. Banganpalli.

Treatments	On the day of fruit harvest					3rd day					6th day				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	15.5^{bc}	15.3^{bcd}	15.1^{c}	14.5^{def}	15.1^{a}	14.4^{a}	10.9^{c}	12.8^{b}	12.8^{b}	12.7^{a}	13.7^{a}	10.6^{cd}	11.7^{b}	11.0^{c}	11.8^{a}
I_2 (75% ETc)	15.5^{bc}	15.8^{ab}	14.8^{cde}	15.3^{bcd}	15.3^{a}	9.0^{e}	14.3^{a}	5.9^{h}	9.0^{e}	9.5^{b}	8.6^{gh}	13.2^{a}	5.9^{k}	9.0^{gh}	9.2^{b}
I_3 (100% ETc)	14.2^{ef}	13.3^{g}	15.8^{ab}	14.5^{def}	14.4^{b}	10.8^{c}	8.8^{ef}	8.4^{f}	9.7^{d}	9.4^{b}	10.3^{de}	9.3^{fg}	8.4^{hi}	9.7^{ef}	9.4^{b}
I_4 (125% ETc)	14.5^{def}	13.8^{fg}	16.5^{a}	15.5^{bc}	15.1^{a}	8.2^{f}	7.0^{g}	9.8^{d}	8.4^{f}	8.4^{c}	7.9^{i}	6.7^{j}	9.8^{ef}	8.8^{gh}	8.3^{c}
Mean	14.9^{b}	14.5^{b}	15.5^{a}	14.9^{b}		10.6^{a}	10.2^{b}	9.2^{c}	10.0^{b}		10.1^{a}	10.0^{a}	9.0^{c}	9.6^{b}	
Factors	F-Test	S.Em±	CD (p=0.05)			F-Test	S.Em±	CD (p=0.05)			F-Test	S.Em±	CD (p=0.05)		
Irrigation (I)	*	0.14	0.40			*	0.09	0.27			*	0.11	0.32		
Fertigation (F)	*	0.14	0.40			*	0.09	0.27			*	0.11	0.32		
Interaction (IxF)	*	0.28	0.80			*	0.19	0.55			*	0.22	0.64		

Note: Figures with same alphabets did not differ significantly.

F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water tree^{-1} at 10 days intervals.

Table 5: Effect of irrigation and fertigation on O_2 content (% kg fresh mass^{-1} h^{-1}) of mango cv. Banganpalli

Treatments	9th day					12th day				
Irrigation levels	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	15.3^{a}	12.5^{c}	12.5^{c}	14.6^{b}	13.7^{a}	14.1^{a}	10.4^{e}	10.2^{ef}	11.1^{d}	11.4^{a}
I_2 (75% ETc)	10.8^{d}	15.1^{a}	7.3^{h}	9.2^{g}	10.6^{d}	7.6^{i}	11.7^{c}	7.0j	8.7^{h}	8.7^{c}
I_3(100% ETc)	14.9^{ab}	10.6^{d}	10.3^{de}	10.2^{ef}	11.5^{c}	14.0^{a}	9.6^{g}	9.7^{fg}	8.6^{h}	10.5^{b}
I_4(125% ETc)	15.3^{a}	12.8^{c}	10.3^{de}	9.9^{f}	12.1^{b}	12.3^{b}	10.2^{ef}	9.5^{g}	9.7^{fg}	10.4^{b}
Mean	14.1^{a}	12.7^{b}	10.1^{d}	11.0^{b}		12.0^{a}	10.5^{b}	9.1^{d}	9.5^{c}	
Factors	F-Test	S.Em±	CD (p=0.05)			F-Test	S.Em±	CD (p=0.05)		
Irrigation (I)	*	0.09	0.26			*	0.08	0.23		
Fertigation (F)	*	0.09	0.26			*	0.08	0.23		
Interaction (IxF)	*	0.18	0.52			*	0.16	0.47		

Note: Figures with same alphabets did not differ significantly.

F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water tree^{-1} at 10 days intervals.

Table 6: Effect of irrigation and fertigation on Co_2 content (% kg fresh mass^{-1} h^{-1}) of mango cv. Banganpalli.

Treatments	On the day of fruit harvest					3rd day					6th day				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	5.8^{e}	5.4^{d}	5.8^{e}	5.4^{d}	5.6^{c}	6.5^{bc}	7.2^{ef}	8.6^{hi}	8.0^{g}	7.6^{b}	7.5^{f}	7.2^{e}	3.0^{a}	8.8^{hi}	6.6^{a}
I_2 (75% ETc)	4.9^{b}	4.7^{b}	4.3^{a}	5.2^{cd}	4.8^{a}	8.8^{i}	9.2^{j}	8.2^{g}	6.1^{ab}	8.1^{c}	11.2^{k}	8.4^{g}	8.2^{g}	4.2^{b}	8.0^{c}
I_3(100% ETc)	5.8^{e}	4.2^{a}	4.9^{b}	4.9^{b}	4.9^{a}	7.5^{f}	8.2^{gh}	6.8^{cde}	6.0^{a}	7.1^{a}	9.8^{j}	8.2^{g}	6.8^{d}	5.9^{c}	7.7^{b}
I_4(125% ETc)	5.1^{bc}	4.9^{b}	5.1^{bc}	5.8^{e}	5.2^{b}	9.0^{j}	11.2^{k}	6.7^{cd}	6.8^{cde}	8.4^{d}	9.0^{i}	12.1^{l}	3.9^{b}	6.1^{c}	7.8^{b}
Mean	5.4^{c}	4.8^{a}	5.0^{b}	5.3^{c}		7.9^{c}	8.9^{d}	7.6^{b}	6.7^{a}		9.4^{d}	9.0^{c}	5.5^{a}	6.3^{b}	
Factors	F-Test	S.Em±	CD (p=0.05)			F-Test	S.Em±	CD (p=0.05)			F-Test	S.Em±	CD (p=0.05)		
Irrigation (I)	*	0.05	0.15			*	0.07	0.20			*	0.05	0.15		
Fertigation (F)	*	0.05	0.15			*	0.07	0.20			*	0.05	0.15		
Interaction (IxF)	*	0.10	0.29			*	0.14	0.40			*	0.11	0.31		

Note: Figures with same alphabets did not differ significantly.

F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water tree^{-1} at 10 days intervals.

Table 7: Effect of irrigation and fertigation on Co₂ per cent (kg fresh mass^{-1} h^{-1}) of mango cv. Banganpalli.

Treatments	9th day					12th day				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	5.5^{b}	5.2^{b}	5.1^{b}	6.4^{e}	5.5^{a}	6.3^{b}	8.0^{d}	5.9^{b}	7.2^{c}	6.8^{a}
I_2 (75% ETc)	6.1^{de}	5.2^{b}	7.2^{f}	4.2^{a}	5.7^{a}	7.0^{c}	7.1^{c}	8.8^{e}	6.0^{b}	7.2^{b}
I_3 (100% ETc)	7.2^{f}	7.2^{f}	5.7^{cd}	5.8^{cd}	6.5^{b}	9.9^{g}	9.1^{e}	7.0^{c}	8.9^{e}	8.7^{d}
I_4 (125% ETc)	7.1^{f}	8.2^{g}	4.1^{a}	6.1de	6.4^{b}	7.8^{d}	9.8^{f}	5.1^{a}	7.1^{c}	7.5^{c}
Mean	6.5^{b}	6.5^{b}	5.5^{a}	5.6^{a}		7.7^{c}	8.5^{d}	6.7^{a}	7.3^{b}	
Factors	F-Test		S.Em±		CD (p=0.05)	F-Test		S.Em±		CD (p=0.05)
Irrigation (I)	*		0.07		0.22	*		0.08		0.23
Fertigation (F)	*		0.07		0.22	*		0.08		0.23
Interaction (IxF)	*		0.15		0.43	*		0.15		0.43

Note: Figures with same alphabets did not differ significantly.
F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water tree^{-1} at 10 days intervals.

Table 8: Effect of irrigation and fertigation on fruit firmness (kg cm^{-2}) of mango cv. Banganpall*.

Treatments	On the day of fruit harvest					3rd day of storage					6th day of storage				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	11.3	12.8	11.6	12.5	12.1	10.6^{bcd}	10.7^{bcd}	10.6^{bcd}	11.6^{ab}	10.9	8.8^{ab}	4.5^{efg}	9.2^{a}	6.0^{cdef}	7.1
I_2 (75% ETc)	12.1	12.1	13.0	12.0	12.3	9.9^{de}	10.5^{cde}	11.2^{abc}	11.7^{ab}	10.8	4.5^{efg}	8.7^{abc}	5.7^{de}	6.3^{bcdf}	6.3
I_3(100% ETc)	12.3	12.5	11.5	12.3	12.2	12.0^{a}	8.8^{e}	9.9^{d}	11.4^{abc}	10.5	2.3^{g}	5.0^{defg}	7.8^{cv}	6.8^{cvf}	5.5
I_4(125% ETc)	12.0	12.3	12.2	11.2	11.9	10.0^{de}	10.0^{de}	11.2^{abc}	10.9^{abc}	10.5	5.2^{d}	4.2^{fg}	9.3^{a}	7.0^{cve}	6.4
Mean	12.0	12.5	12.1	12.0		10.6^{b}	10.0^{c}	10.7^{b}	11.4^{a}		5.2^{b}	5.6^{b}	8.0^{a}	6.5^{b}	
Factors	F-Test		S.Em±		CD (p=0.05)	F-Test		S.Em±		CD (p=0.05)	F-Test		S.Em±		CD (p=0.05)
Irrigation (I)	*		0.15		NS	*		0.19		NS	*		0.48		NS
Fertigation (F)	*		0.15		NS	*		0.19		0.56	*		0.48		1.37
Interaction (IxF)	*		0.30		NS	*		0.39		1.12	*		0.95		2.75

Note: Figures with same alphabets did not differ significantly.
F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water tree^{-1} at 10 days intervals.

Table 9: Effect of irrigation and fertigation on fruit firmness (kg cm^{-2}) of mango cv. Banganpalli.

Treatments	9th day of storage					12th day of storage				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	4.0^{a}	1.2^{d}	5.0^{a}	2.2^{cd}	3.1	3.0^{a}	0.3^{d}	3.1^{a}	1.1^{b}	1.7
I_2 (75% ETc)	1.8^{cd}	4.0^{b}	2.1^{cd}	4.3^{b}	3.1	1.0^{cd}	1.8^{b}	1.1^{b}	1.6^{b}	1.4
I_3 (100% ETc)	1.2^{d}	2.3^{cd}	6.9^{a}	3.3^{bc}	3.4	0.5^{cd}	1.1^{b}	3.1^{a}	2.0^{b}	1.7
I_4 (125% ETc)	2.7^{c}	1.8^{cd}	7.5^{a}	2.9^{bc}	3.7	1.2^{bc}	0.6^{cd}	3.3^{a}	1.6^{b}	1.7
Mean	2.4^{b}	2.3^{c}	5.4^{a}	3.2^{b}		1.14^{b}	0.97^{c}	2.65^{a}	1.58^{b}	
Factors	F-Test		S.Em±		CD (p=0.05)	F-Test		S.Em±		CD (p=0.05)
Irrigation (I)	*		0.26		NS	*		0.13		NS
Fertigation (F)	*		0.26		0.76	*		0.13		0.38
Interaction (IxF)	*		0.53		1.53	*		0.26		0.76

Note: Figures with same alphabets did not differ significantly.
F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water tree^{-1} at 10 days intervals.

Table 10: Effect of irrigation and fertigation on fruit chlorophyll index of peel (DA-index) of mango cv. Banganpalli.

Treatments	1st day					4rd day				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	1.10	1.12	1.09	1.14	1.11	1.01^{a}	1.08^{a}	0.97^{ab}	1.01^{a}	1.02^{a}
I_2 (75% ETc)	1.24	1.21	1.18	1.21	1.21	0.78^{c}	1.06^{a}	1.04^{a}	1.02^{a}	0.97^{ab}
I_3(100% ETc)	1.12	1.13	1.14	1.10	1.12	0.72^{c}	0.74^{c}	1.02^{a}	0.92^{ab}	0.85^{c}
I_4(125% ETc)	1.16	1.19	1.12	1.11	1.15	0.98^{a}	0.80^{bc}	0.88^{abc}	0.90^{ab}	0.89^{bc}
Mean	1.16	1.16	1.13	1.14		0.87	0.92	0.98	0.96	
Factors	F-Test		S.Em±		CD (p=0.05)	F-Test		S.Em±		CD (p=0.05)
Irrigation (I)	*		0.04		NS	*		0.04		0.11
Fertigation (F)	*		0.04		NS	*		0.04		NS
Interaction (IxF)	*		0.08		NS	*		0.7		0.21

Note: Figures with same alphabets did not differ significantly.
F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water tree^{-1} at 10 days intervals.

Table 11: Effect of irrigation and fertigation on fruit chlorophyll index of peel (DA-index) of mango cv. Banganpalli.

Treatments	8th day					12th day				
	F_1	F_2	F_3	F_4	Mean	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	0.78^{abc}	0.79^{ab}	0.80^{ab}	0.77^{abc}	0.78	0.45^{cde}	0.30^{ghj}	0.49^{cd}	0.37^{efg}	0.40^{b}
I_2 (75% ETc)	0.75^{bc}	0.73^{bc}	0.84^{a}	0.77^{abc}	0.78	0.36^{efgh}	0.36^{egh}	0.44^{def}	0.60^{ab}	0.44^{ab}
I_3(100% ETc)	0.70^{c}	0.72^{bc}	0.80^{ab}	0.73^{bc}	0.74	0.34^{fgh}	0.23^{j}	0.70^{a}	$0.52b^{cd}$	0.45^{ab}
I_4(125% ETc)	0.77^{abc}	0.76^{abc}	0.78^{abc}	0.76^{abc}	0.77	0.46^{cde}	0.26^{hj}	0.68^{a}	$0.55b^{c}$	0.49^{a}
Mean	0.75^{b}	0.75^{b}	0.81^{a}	0.76^{ab}		0.41^{c}	0.29^{d}	0.58^{a}	0.51^{b}	
Factors	F-Test		S.Em±	CD (p=0.05)		F-Test	S.Em±		CD (p=0.05)	
Irrigation (I)	*		0.01	NS		*	0.02		0.05	
Fertigation (F)	*		0.01	0.04		*	0.02		0.05	
Interaction (IxF)	*		0.03	0.08		*	0.16		0.50	

Note: Figures with same alphabets did not differ significantly

F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water tree^{-1} at 10 days intervals.

.

Table 12: Effect of irrigation and fertigation on shelf life of mango cv. Banganpalli.

Treatments	F_1	F_2	F_3	F_4	Mean
I_1 (Control)	11.35^{def}	11.62^{def}	11.98^{de}	12.42^{cd}	11.84^{b}
I_2 (75% ETc)	11.45^{def}	10.58^{f}	10.98^{ef}	10.83^{ef}	10.96^{c}
I_3 (100% ETc)	11.75^{de}	11.08^{ef}	14.45^{ab}	13.48^{bc}	12.69^{a}
I_4 (125% ETc)	11.15^{ef}	11.00^{ef}	14.75^{a}	14.00^{ab}	12.73^{a}
Mean	11.43^{b}	11.07^{b}	13.04^{a}	12.68^{a}	
Factors	F-Test		S.Em±		CD (p=0.05)
Irrigation (I)	*		0.20		0.57
Fertigation (F)	*		0.20		0.57
Interaction (IxF)	*		0.40		1.15

(**Each data point is average of two years)**

Note: Figures with same alphabets did not differ significantly.

F_1- 100% (500 g) N and K applied through soil; F_2- 50% (250 g) N and K applied through fertigation; F_3- 75% (375 g) N and K applied through fertigation; F_4- 100% (500 g) N and K applied through fertigation; I_1-(Control) irrigated with 1200 liters of water tree^{-1} at 10 days intervals.

Conclusion

Pre-harvest management through drip irrigation at 100–125% ETc combined with 75–100% recommended N and K applied via fertigation and mulching consistently produced mango cv. Banganpalli fruits of superior physicochemical quality and markedly extended post-harvest shelf life under ambient conditions. These practices enhanced TSS, total and non-reducing sugars, ascorbic acid content, and Brix: acid ratio while reducing titratable acidity. During storage, they delayed the climacteric peak, suppressed respiration rate, maintained higher fruit firmness, slowed chlorophyll degradation, and prolonged marketable life by 3–4 days compared to conventional flood irrigation and soil fertilization. The beneficial effects are primarily due to optimal and continuous soil moisture, improved nutrient availability and uptake, higher leaf nutrient status, enhanced photosynthesis and assimilate partitioning, increased synthesis of structural and protective compounds, and better cellular integrity. Therefore, adoption of drip irrigation at 100–125% ETc along with 75–100% N-K fertigation and mulching is strongly recommended as a sustainable pre-harvest practice to achieve premium fruit quality and longer post-harvest life in mango cv. Banganpalli.

References

1. Amaya A, Janet VZ. Determination of the optimal apple harvest date (A4156). University of Wisconsin System; 2018. p. 1-5.
2. Bhusan PL, Panda C, Dash KA. Effect of pre-harvest chemical treatments and mulching on marketability of mango (*Mangifera indica* L.) cv. Amrapali. J Crop Weed. 2015;11(1):216-219.
3. Boora RS, Singh D. Effect of NPK on growth, yield and quality of (*Manilkara achras* (Mill) Forberg) cv. Cricket Ball. Haryana J Hortic Sci. 2000;29(3-4):188-189.
4. Borthakur PK, Bhattacharyya RK. Organic mulches in guava orchard. India J Hortic. 1996;37:43-44.
5. Colapietra M. The effect of increasing rate of plant nutrients on the qualitative and quantitative yield of grape wine. A comparison of fertigation and manually applied fertilizers. Rivista di Viticoltura e di Enologie. 1987;40:223-249.
6. David L, Ehret B, Frey B, Forge T, Helmer T. Effects of drip irrigation configuration and rate on yield and fruit quality of young high bush blueberry plants. HortScience. 2012;47(3):414-421.
7. Dinesh K, Pandey V, Vishal N. Effect of drip irrigation regimes on growth, yield and quality of mango hybrid Arka Anmol. Indian J Hortic. 2008;65(4):409-412.
8. Haneef M, Kaushik RA, Sarolia DK, Mordia A, Dhakar M. Irrigation scheduling and fertigation in pomegranate cv. Bhagwa under high density planting system. Indian J Hortic. 2014;71(1):45-48.
9. Jilen MM. Post-Harvest Management of Horticultural Crops. Jaya Publishing House; 2016.
10. Junaid NK, Jain AK, Sharda R, Singh N, Gill PPS, Kaur S. Growth, yield and nutrient uptake of guava (*Psidium guajava* L.) affected by soil matric potential, fertigation and mulching under drip irrigation. Agric Eng Int. 2013;15(3):17-28.
11. Karuna K, Mankar A, Nirgude V, Patel VB, Sinha R. Effects of NPK fertigation on physico-chemical attributes and leaf nutrient status of Citrus reticulata Blanco cv. Kinnow. Chem Sci Rev Lett. 2017;6(23):1583-1586.
12. Kaviyazhagan S, Gurusamy A, Subramanian E, Prabhaharan J, Amutha R, Sivasankari B, *et al.* Drip fertigation of water-soluble fertilizers: A tool to enhance nutrient and water use efficiency- A comprehensive review.

Plant Sci Today. 2025;12(sp3):1-12.
13. Koo RCJ. The importance of ground coverage by fertigation for citrus on sandy soils. Fertilizer Issues. 1984;1:75-78.
14. Kulkarni SS, Yewale PH. Effect of mulching and chemicals for improving yield and quality of mango cv. Keshar. Int J For Crop Improv. 2012;3(2):137-139.
15. Kumar N, Soorianathasundaram K, Meenakshi N, Manivannan MI, Suresh J, Nosov V. Balanced fertilization in papaya for higher yield and quality. Acta Hortic. 2010;851:357-362.
16. Kumar P, Banik BC, Reshma VS, Gupta T. Effect of mulching and supplementary irrigation on fruit quality characteristics of karonda. Int J Pure Appl Biosci. 2017;5(3):118-122.
17. Lyons JM, Pratt HK. Effect of stage of maturity and ethylene treatment on respiration and ripening of tomato fruits. J Am Soc Hortic Sci. 1964;84:491-500.
18. Mathew B, Ghosh SN. Effect of drip irrigation on sweet orange cv. Mosambi grown in rain shadow laterite soils. Proc Int Soc Magn Reson Med. 2004:200-202.
19. McGlasson WB, Pratt HK. Effects of wounding on respiration and ethylene production by cantaloupe fruit tissue. Plant Physiol. 1964;39:128-132.
20. NHM. 2022. https://nhb.gov.in/pdf/MahabubnagarBrochure.pdf
21. Orphanos PI, Eliades G. Nitrogen fertigation of Valencia orange irrigated by drip or mini-sprinkler. Acta Hortic. 1994;365:105-120.
22. Palmer JK, McGlasson WB. Respiration and ripening of banana fruit slices. Aust J Biol Sci. 1969;22:87-99.
23. Pankaj B. Yield, fruit quality and water productivity of drip fertigated Assam Lemon (*Citrus limon*). Int J Agric Eng. 2013;6(2):339-344.
24. Prakash K, Vijayakumar RM, Balamohan TN, Sundhar Singh SD. Effect of drip irrigation regimes and fertigation levels on yield and quality of mango cultivar ‘Alphonso’ under ultra high density planting. Proc Global Conf Augment Prod Util Mango: Biotic Abiotic Stress. 2015;1066.
25. Sadarunnisa S, Madhumathi C, Hari Babu K, Sreenivasulu B, Rama Krishna M. Effect of fertigation on growth and yield of papaya cv. Red Lady. Proc IInd IS Papaya. 2010;851.
26. Sandip M, Makwana A, Kore P, Barad A. Effect of different fertigation treatments on yield and quality of mango cv. Kesar raised under ultra high density planting system. Int J Farm Sci. 2016;6(4):1-7.
27. Shirgure PS, Srivastava AK, Huchche AD, Patil P. Interactive effect of irrigation schedules and fertigation levels on fruit yield, quality and plant nutrition of Nagpur mandarin (Citrus reticulata Blanco). Indian J Agric Sci. 2016;86:1509-1514.
28. Simmonds JH. Studies in the latent phase of Oolletotrichum species causing ripe rots of tropical fruits. Queensland Agric J. 1963;20:373-424.
29. Singh VK, Soni MK, Singh A. Effect of drip irrigation and polyethylene mulching on fruit yield and quality of guava cv. Allahabad Safeda under meadow orcharding. Indian J Hortic. 2015;72(4):479-484.
30. Taiz L, Zeiger E. Fisiologia vegetal. 4th ed. Porto Alegre: Artmed; 2009. p. 848.
31. Tiwari KN, Kumar M, Singh VK, Santosh DT. Response of drip irrigation and plastic mulch on quality of sapota (*Achras zapota*) fruits. Int J Agric Environ Biotechnol. 2016;9(4):699-710.