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# Impact of irrigation and fertigation alongwith mulching on fruit yield, water use efficiency, nutrient use efficiency and economy of mango

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**ABSTRACT**

An investigation was carried out on sandy loam soils of semi-arid regions of the southern part of the Telangana to assess the potential of drip irrigation and fertigation alongwith mulch on fruit yield; recourses use efficiency as well as the economy of mango *cv.* Banganpalli. Treatments of the present study were comprised of four levels of irrigation [$I_1$ - control (farmer practice of irrigation 1.2 $m^3$ at 10 days intervals); $I_2$ - 75%, $I_3$ - 100% and $I_4$ - 125% ETc at daily intervals) and fertilization [$F_1$ - farmer practice of application of 100% (500 g) N&K through soil (fruits at marble size), $F_2$ - 50% (250 g), $F_3$ - 50% (375 g) and $F_4$ - 50% (500 g) N&K were applied through fertigation in three equal split doses at 15 days intervels after fruit set (from February 15$^{th}$ to end of March), alongwith mulching (silver polyethylene mulch of 100 micron thickness were used). The statistical design adopted was complete randomized block design (RCBD) in factorial with three replications. The application of 125% ETc + 75% N&K through fertigation resulted signiicantly 60% higher fruit yield, increased WUE (8.62 kg $m^{-3}$) and PFP (227 kg $kg^{-1}$) alongwith 12.5% fertilizers saving achived which had resulted to the increased economy (BCR 3.77) as compared to control. Further, underwater shortage condition application of 75% ETc + 100% N&K through fertigation alongwith mulching had resulted in 55% higher fruit yield, WUE (13.33 kg $m^{-3}$), PFP (161 kg $kg^{-1}$) and BCR (3.41) as compared to control (BCR 1.88).

## 1. INTRODUCTION

Mango (*Mangifera indica* L.) is one the most luscious fruit since time immemorial in the tropical and sub-tropical region of the world and is native to South East Asia (Indo-Burma region). It is designated as the 'King of Fruits' (Purseglove, 1972) because of its excellent flavour, attractive fragrance, beautiful shades of colour and delicious taste with high nutritive value. Presently, it is grown in India, China, Thailand, Mexico, Indonesia, Pakistan, Brazil, Egypt, Bangladesh and Nigeria (Pooja *et al*., 2019). India is the leader, sharing 41% of the world's mango production (Ganeshamurthy *et al*., 2018) with an area of 2.26 M ha with the production of 21.82 MMt. and average productivity is 9.7 t $ha^{-1}$ (NHB, 2018).

In Telangana mango occupies a prime position among the fruit crops, *i.e.* 70% of total fruit cultivated area and 56% of total production devoted to mango, but the average productivity of Telangana (9.3 t $ha^{-1}$) is very low compared to Uttar Pradesh (17.0 t $ha^{-1}$) it indicating that there is a potential to increasing the productivity of mango (NHB, 2018). However, the mango productivity has declined due to several biotic and abiotic factors. Out of several biotic and abiotic factors responsible, water and nutrient management are the most important factors that significantly influence the productivity and quality of fruit. Even though mango trees are tolerant to drought and occasional flooding, water stress during the critical stages of fruit growth and development is the main reason for low productivity (Adak *et al*., 2012). In such situation, water management, especially during the development stage plays an important role in improving yield and quality. But the amount and quality of available irrigation water in the arid and semi-arid regions are being main limiting factors for the productivity of mango (Adak *et al*., 2012).

Water and land are the important, indispensable resources for agricultural development and economic upgradation of any country. These natural resources cannot be regarded as available in abundance and free forever. The demand for these two resources will continue to grow due to ever increasing population and changing climate. Increased crop water demand during the fruit development stage is coincided with water shortage has enacted to investigate the sustainable use of irrigation water. For this, specific effective water-saving irrigation techniques without detrimentally affecting crop production need to be developed urgently. In this context, a shift in focus is indispensable for the development of additional water resources alongwith the efficient use of already existing water resources (Daniel and Eelco, 2017). As the mango is irrigated by basin and drip irrigation systems without any concern on crop water requirement and schedule; that has leds to inefficient utilization of available water. this system must be converted from the basin irrigation system to drip irrigation. With proper scheduling of irrigation that can save more water and also increase the acreage with available water (Panigrahi and Srivastava, 2011). Apart from the economic considerations, it is well known that the adverse effects of injudicious use of water and fertilizers can also have implications on the environment. Thus, there is a need for technological interventions that will help in minimizing the use of these precious resources and maximizing crop production, without any detrimental impact on the environment.

Among the various techniques of water application, the drip/trickle irrigation system has proved its superiority in fruit crops plantation. This is, owing to the precise and direct application of water in the root zone without wetting the entire area. The drip system synchronizes the plant water requirement and maintains an optimum soil moisture status around the vicinity of plant roots. The technology holds great potential in water scarce areas having shallow and coarse textured soils. Applying fertilizers through an efficient irrigation system, termed fertigation offers a vast potential for precision application and timely crop nutrition. Other advantages of fertigation lie in the saving of fertilizers and labour, uniform distribution of nutrients, minimize the leaching and volatilization losses, as a result, get higher fertilizer use efficiency besides higher crop yields (Raina, 2000 and Raina *et al*., 2005).

Though the Telangana region receives rainfall of 906.6 mm, however, 80% of the total rainfall is concentrated during monsoon (July-September) as such, pre and post-monsoon water stress is of common occurrence in the region. Under such conditions, the nutrient contents and availability within the rooting zone of the plant are scarce and it leading to inefficient utilization nutrient by the plants, when the ertilizers are applied through conventional methods under rainfed conditions. Undulating topography, shallow soil depth, poor retentivity of water and nutrients further aggravates the problem, consequently leading to low yields.

It is pertinent to add that moderation of soil moisture by application of mulch can enhance the yield and quality of crops. Soil moisture and nutrient availability play important role in root functions such as nutrient uptake, water absorption, metabolite production and carbohydrate storage. Mulches also affect various physical, chemical and biological reactions involved in plant growth and development, besides considerable savings in irrigation water (Gupta and Acharya, 1993). In addition to above, the mulching is another important soil and water conservation cultural practice. As many studies have shown that mulches can improve soil qualities, control weeds (Ross, 2010) and also help in efficient water management under such situation. Drip irrigation alongwith mulching is the best practice which saves 25-30% irrigation water. Singh *et al*. (2006) suggested that the irrigation requirement met through drip irrigation alongwith polyethylene mulch gave the 164% greater yield compared to ring basin irrigation in guava.

A gleaning of documented literature reveals that consequences of drip irrigation and fertigation especially, in conjunction with mulch, in mango orchards of Telangana region have not yet been established. Therefore the objective of the study is to investigate the effect of irrigation and fertigation scheduling alongwith mulching on yield, water use efficiency (WUE), partial factor productivity (nutrient use efficiency) and economy of mango *cv.* Banganpalli.

## 2. MATERIALS AND METHODS

The field experiment was conducted during two successive years (during 2017 to 2018 and 2018 to 2019) was executed in the grafted mango *cv.* Banganpalli of 12 years old and plants were planted with a spacing of 10 × 10 m at Sathapur (Kollapur area, Nagarkurnool district). The experimental farm is located at 16°30'N latitudes and 78°19'E longitudes at an elevation of 550 m above MSL, representing Southern Telangana zone, is mainly covered by red sandy soil, is locally known as 'Chelka soils' (Table 1). All plants were given similar cultural treatments except irrigation and fertilization. All the plants were mulched with silver

**Table: 1**
**Physical and chemical properties of experimental soil**

| Particulars | Value for 0-60 cm depth |
|---|---|
| A. Physical properties | |
| Sand (%) | 70 |
| Silt (%) | 19 |
| Clay (%) | 11 |
| Textural class | Red sandy loam |
| B. Chemical properties | |
| pH | 7.5 |
| Electrical conductivity (dS $m^{-1}$ at 25°C) | 0.33 |
| Organic carbon (%) | 0.56 |
| Available N (kg $ha^{-1}$ ) | 185 |
| Available $P_2O_5$ (kg $ha^{-1}$ ) | 23 |
| Available $K_2O$ (kg $ha^{-1}$ ) | 240 |

polyethylene of 100 micron thickness; irrigation treatments and the mulching were carried out in the month of January.

**Irrigation Scheduling**

Irrigation was scheduled by calculating crop evapo-transpiration rate (ETc) using pan evaporation measurements adjusted by crop coefficient and the irrigation water requirement was estimated by Pan "A" evaporation method, where the daily water requirement was calculated using the formula (Shukla *et al.*, 2001):

$$V = Ep.\ Kp.\ Kc.\ Sp.\ Sr.\ Wp.$$

Where, $V$ = Volume of water required (litters day$^{-1}$ plant$^{-1}$), $Ep$ = Pan evaporation as measured by Class-A pan evaporimeter mm day$^{-1}$, $Kc$ = Crop co-efficient (co-efficient depends but for fully grown plants is 0.85), $Kp$ = Pan co-efficient (0.7), $Sp$ = Plant to plant spacing (m), $Sr$ = Row to row spacing (m), $Wp$ = Fractional wetted area (0.3 for wider spaced crops).

The water requirement of the mango crops was estimated on daily basis during the fruit development period under study. The irrigation was started at the Principal flowering stage BBCH-510 (Buds closed and covered with green or brownish scales- Plate-2 BBCH scale descriptors) upto 15 days before harvest for both experiments. Daily time to operate drip irrigation system was worked out as mentioned below. Each plant was provided with 8 emitters of 4 l hr$^{-1}$ discharge rate which were placed uniformly at a 1 m distance.

$$\text{Time required to run the system} = \frac{\text{Quantity of water required (plant}^{-1}\text{day}^{-1})}{\text{Drip discharge (l hr}^{-1}\text{plant}^{-1})}$$

**Fertilizers Application**

**Control-farmer practice ($F_1$)**

The farmer practice (FP) of fertilizers application was done by conventional method (applied through the soil). The recommended dose of fertilizers (RDF *i.e.,* 1000 : 1000 : 1000 g of NPK and 50 kg of farm yard manure (FYM) plant$^{-1}$ yr$^{-1}$ for more than ten years old plants) were applied as per the package of the practice of Sri Konda Laxman Telangana State Horticultural University, Mulugu, Telangana (Research Achivements SKLTSHU, 2016). During the third week of June, the total FYM and phosphorus alongwith half of doses of nitrogen, potassium were applied as first dose. The remaining half dose of nitrogen and potassium were applied at fruit set stage (fruit at marble size in control) in the tree basin and it was mixed thoroughly with soil. Further, the micro-nutrients [ZnSO4 (50 g) + FeSO4 (25 g) + Borax (20 g) + MgSO4 (30 g) tree$^{-1}$] were applied through foliar method at marble size of fruit for both experiments.

**Fertigation**

The three fertigation levels namely $F_2$, $F_3$ and $F_4$ were followed. For $F_2$, $F_3$ and $F_4$ the initial 50% RDF and total FYM was applied through soil during the third week of June as in the case of $F_1$. The remaining 50% N&K were applied through fertigation as $F_2$ - 50%, $F_3$ - 75% and $F_4$ - 100% ($F_2$ - 250 g, $F_3$ - 375 g and $F_4$ - 500 g of N&K plant$^{-1}$, respectively) in three equal split doses at 15 days intervels after fruit set (from February 15$^{th}$ to end of March). In case of fertigation, the nutrient sources were applied in the form of Urea (46%) and Potassium Nitrate (13-00-45).

**Soil moisture content (%)**

In order to study the soil moisture content (%) under drip irrigation and conventional method, moisture content was determined using PDSR soil moisture sensor before starting the irrigation at BBCH (Biologische Bundesanstalt, Bundessortenamt und CHemische Industrie)-510, 619, 701, 703, 705 and 709 phenophases (Fig. 1) from 0-20 cm soil depth, under different irrigation and fertilization conditions. Soil moisture content was estimated at a lateral distance of 30 cm away from the emitter. Under conventional surface irrigation, soil moisture was recorded at 120 cm away from

BBCH-510 BBCH-619 BBCH-701 BBCH-703 BBCH-705 BBCH-709

*BBCH-510: Buds closed and covered with green or brownish scales, BBCH-619: End of flowering: all petals fallen and fruit set, BBCH-701: Fruits at 10% of final size, styles still visible (beginning of physiological fruit drop), BBCH-703: Fruits at 30% of final size (end of physiological fruit drop), BBCH-705: Fruits at 50% of final size BBCH-703-Fruits at 30% of final size, BBCH-705: Fruits at 50% of final size, BBCH-709: Fruits at standard cultivar size, shoulders fully developed*

**Fig. 1. Depiction of important phenophases in mango (Vijay Krishna, 2019)**

the tree trunk with the help of a digital soil moisture meter (PDSR soil moisture sensor Fig. 2). Average values of soil moisture were computed for different crop growth stages (Fig. 1).

### Water use efficiency (WUE) (kg m$^{-3}$)

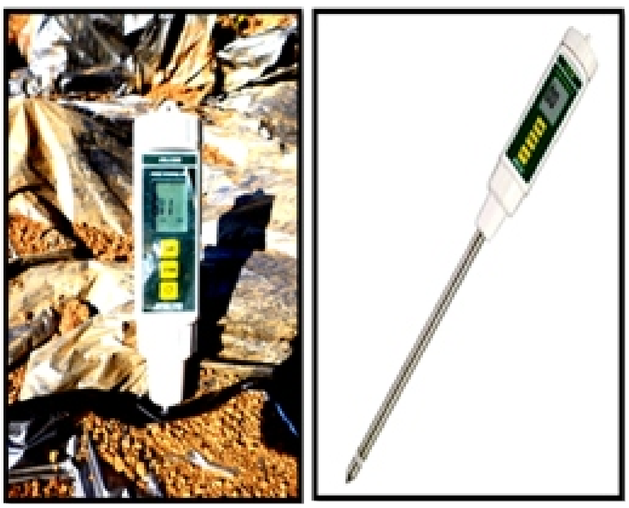
WUE was computed from the following relationship and has been expressed as kg m$^{-3}$ water.

*Water use efficiency (WUE) = Y / LWA*

Where, *Y* - Yield (kg tree$^{-1}$), *LWA* - liters of water applied tree$^{-1}$.

### Partial factor productivity (PFP) kg kg$^{-1}$

In the present study the PFP was calculated with the following formula of PFP (Dobermann, 2007).



*Measurement range: 0% to 50% moisture content of soil sample with 0.1% resolution*

**Fig. 2. Measurement of soil moisture with PDSR soil moisture sensor**

*NEU (kg kg$^{-1}$) = Fruit yield in treated plant / Nutrient applied for treated plant*

### Economics

The cost of cultivation of mango was worked out for one hectare area and the details of economics are presented in Table 10.

## 3. RESULTS AND DISCUSSION

### Fruit Yield (kg tree$^{-1}$)

The results on average fruit yield of mango *cv.* Banganpalli after the application of irrigation and fertilization treatments are presented in the Table 2. The data revealed that there was a significant difference among different levels of irrigation with respect to fruit yield of mango *cv.* Banganpalli. Maximum fruit yield per tree was recorded with the application of 125% ETc ($I_4$) (131 kg tree$^{-1}$) followed by application of 100 % ETc ($I_3$) (127 kg tree$^{-1}$) which was on par with an application of 75% ETc ($I_2$) (123 kg tree$^{-1}$), while minimum fruit yield tree$^{-1}$ was observed in control ($I_1$) (77 kg tree$^{-1}$). In the present investigation, the increased irrigation level through drip alongwith mulching has resulted significantly 41.22% higher fruit yield per tree over conventional method of irrigation ($I_1$). Similar increase in fruit yield per tree with increased irrigation through drip alongwith mulching was earlier reported by Panigrahi *et al.* (2010) in mango *cv.* Dashehari; Dinesh *et al.* (2008) in mango *cv.* Lat Sinduri; Kumar *et al*. (2008) in mango *cv.* Arka Anmol; Prakash *et al.* (2015) in mango *cv.* Alphonso and Goramnagar *et al.* (2017) in acid lime.

Increased fruit yield with increased irrigation level ($I_4$ - 125% ETc) might be due to the increased fruit and number of fruits per tree as compared to control ($I_1$) in the present investigation. Further, these increased fruit weight and a number of fruits per tree with 125% ETc alongwith mulching

**Table: 2**
**Effect of irrigation and fertigation on fruit yield (kg tree$^{-1}$) of mango *cv.* Banganpalli**

| Treatments | Fruit yield (kg tree$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean |
| $I_1$ (Control) | $72^{ef}$ | $57^{f}$ | $79^{de}$ | $102^{c}$ | $77^{c}$ |
| $I_2$ (75% ETc) | $93^{c}$ | $102^{c}$ | $135^{b}$ | $161^{a}$ | $123^{b}$ |
| $I_3$ (100% ETc) | $77^{de}$ | $92^{cd}$ | $164^{a}$ | $175^{a}$ | $127^{b}$ |
| $I_4$ (125% ETc) | $79^{de}$ | $94^{cd}$ | $174^{a}$ | $178^{a}$ | $131^{a}$ |
| Mean | $80^{c}$ | $86^{c}$ | $138^{b}$ | $154^{a}$ | |
| Factors | F-Test | | SEm± | | CD (P=0.05) |
| Irrigation (I) | * | | 3.140 | | 9.06 |
| Fertigation (F) | * | | 3.140 | | 9.06 |
| Interaction (I × F) | * | | 6.27 | | 18.12 |

*Each data point is average of two years*

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

might have resulted in maximum fruit yield per tree as compared to conventional method irrigation in the present investigation. Similar results were earlier reported by Haneef *et al.* (2014) in pomegranate *cv.* Bhagwa where in 100% drip irrigation alongwith mulch which has recorded 10-25% more fruit yield compared to 50% irrigation alongwith silver polythene mulch due to increased fruit weight and number of fruits per tree. However, the minimum fruit yield was recorded in control ($I_1$) might be due to under conventional method of irrigation, a loss of water through seepage loss, deep percolation losses lead to decreased WUE (5.12 kg $m^{-3}$) (Table 5), which might have resulted in reduced fruit weight and number of fruits per tree, which ultimately resulted in minimum fruit yield per tree as compared to $I_4$ (125% ETc alongwith mulching) in the present investigation.

The significant difference was observed with different levels of fertilization treatments with respect to fruit yield of mango. Maximum fruit yield per tree was recorded with the application of 100% N&K through fertigation ($F_4$) (154 kg $tree^{-1}$) followed by application of 75% N&K through fertigation ($F_3$) (127 kg $tree^{-1}$), while minimum fruit yield $tree^{-1}$ was recorded with the application of 100% N&K through soil application ($F_1$) (80 kg $tree^{-1}$), which was on par with an application of 50% N&K through fertigation ($F_2$) (86 kg $tree^{-1}$). In the present investigation, the fertigation treatment $F_4$ has resulted significantly 48% higher fruit yield $tree^{-1}$ as compared to the conventional method of fertilization ($F_1$). Further, the application of 50% N&K through fertigation ($F_2$) (86 kg $tree^{-1}$) was effective than the application of 100% N&K through soil application ($F_1$). The application of $F_2$ has also saved in 25% (when compared to total RDF) fertilizers through increased FUE (Table 6) as compared to $F_1$ treatment. A similar increase in fruit yield $tree^{-1}$ with increased fertigation through drip alongwith mulching was earlier reported by Prakash *et al.* (2015) in mango *cv.* Alphonso.

Furthermore, the increase in the fruit yield per tree with an application of 100% N&K through fertigation ($F_4$) might be due to increased PFP (Table 6) in the present investigation, which might have helped in increased nutrient reserves. These increased nutrient reserves might have helped in synthesis of enough food reserves alongwith hormones like auxins and gibberellins (Tromp, 1983), which resulted in increased fruit yield attributing characters like increased fruit weight and number of fruits per tree, which ultimately resulted in increased fruit yield $tree^{-1}$ in the present investigation. A similar increase in fruit yield per tree with increased fertigation through drip alongwith mulching was earlier reported by Sandip *et al.* (2016) in mango *cv.* Kesar. Similarly, Firake and Deolankar (2000) also reported in pomegranate increase in fruit yield per tree with fertigation of 100% RDF might be due to uniform distribution of nutrients coupled with confinement in the root zone under fertigation and also the higher dose of NPK through fertigation resulting in increased fruits yield per tree. Similar findings were also earlier reported by Prakash *et al.* (2015) in mango *cv.* Alphonso; Puneshwer *et al.* (2016) in guava; Singh *et al*. (2006) and Haneef *et al*. (2014) in pomegranate.

The interaction between irrigation and fertilization treatments had shown statistically significant differences among the treatments. The maximum fruit yield $tree^{-1}$ was recorded with application of 125 % ETc + 100% N&K ($I_4F_4$) (178 kg $tree^{-1}$) which was on par with application of 100% ETc + 100% N&K through fertigation ($I_3F_4$) (175 kg $tree^{-1}$), 125% ETc + 75% N&K through fertigation ($I_4F_3$) (174 kg $tree^{-1}$), 100% ETc + 75% N&K through fertigation ($I_3F_3$) (164 kg $tree^{-1}$) and 75% ETc + 100% N&K through fertigation ($I_2F_4$) (161 kg $tree^{-1}$). Minimum fruit yield per tree was recorded with control + 50% N&K through fertigation ($I_1F_2$) (57 kg $tree^{-1}$) which was on par with control + 100% N&K through soil application and ($I_1F_1$) (72 kg $tree^{-1}$). In the present investigation increased irrigation and fertigation along mulching has resulted significantly 55 to 60% higher fruit yield per tree over conventional method of irrigation and fertilization. Increased the fruit yield per tree kg $tree^{-1}$ with increased irrigation and fertigation along mulching might be due to increased soil moisture availability (20-21%) (Table's 3 to 4). These increased soil moisture availability might have resulted in increased surface rooting and the root remains active throughout the fruit growing period. Further, when plants irrigated with 100% ETc alongwith fertigation and mulching has enhanced the WUE (Table 5) and PFP (Table 6) due to synergistic effect of increased level of irrigation and fertigation alongwith mulching.

Further, increased soil moisture might have helped in proper translocation of food materials and nutrients throughout the crop growth period due to increased stomatal conductivity and transpiration rate, which might have resulted in increased fruit yield attributing characters like fruit weight and number of fruits. Furthermore, the increased plant physiological activities, enhanced water and PFP has cumulatively resulted in increased fruit weight and number of fruits per tree, which ultimately resulted in increased fruit yield per tree in the present investigation. Similar findings were also earlier reported by Prakash *et al.* (2015) in mango *cv.* Alphonso; Panwar *et al.* (2007) in mango *cv.* Dashehari; Vijay *et al.* (2017) in Kinnow mandarin; Torres *et al.* (2004), Panigrahi and Srivastava (2017) and Shirgure *et al.* (2016) in Nagpur mandarin; Suman and Raina (2014) in apple; Sharma and Mursaleen (2014) in guava.

**Soil Moisture Content (%)**

The data on soil moisture content influenced by different irrigation and mulching treatments during different phenophases (*i.e.* form BBCH-510 to BBCH-709 stage) of

**Table: 3**
**Effect of irrigation and fertigation on soil moisture content (%) of mango *cv.* Banganpalli [Data based on PDSR soil moisture sensor readings at BBCH-510, 619 and 701 (From flowering to fruit set)]**

| Treatments | Soil moisture content during different crop growth stages (From flowering to fruit set) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BBCH - 510 | | | | | BBCH - 619 | | | | | BBCH - 701 | | | | |
| | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean |
| $I_1$ (Control) | 10.6 | 10.2 | 10.9 | 10.6 | 10.6 | 8.4 | 8.4 | 9.2 | 9.1 | 8.8 | 9.5 | 9.3 | 9.7 | 9.6 | 9.5 |
| $I_2$ (75% ETc) | 9.4 | 9.6 | 9.9 | 9.9 | 9.7 | 8.4 | 8.7 | 9.3 | 9.0 | 8.9 | 8.9 | 9.2 | 9.0 | 9.4 | 9.1 |
| $I_3$ (100% ETc) | 15.6 | 14.5 | 15.5 | 14.35 | 15.0 | 15.0 | 14.5 | 14.8 | 14.3 | 14.7 | 15.1 | 14.5 | 14.8 | 14.7 | 14.8 |
| $I_4$ (125% ETc) | 20.6 | 21.4 | 21.2 | 20.8 | 20.8 | 20.6 | 21.4 | 21.2 | 20.8 | 20.4 | 20.1 | 20.3 | 20.5 | 21.0 | 20.5 |
| Mean | 14.1 | 13.9 | 13.4 | 13.7 | | 13.1 | 13.1 | 13.3 | 13.2 | | 13.4 | 13.3 | 13.5 | 13.7 | |
| Factors | F - Test | | Sem± | | CD (p = 0.05) | F - Test | | Sem± | | CD (p = 0.05) | F - Test | | Sem± | | CD (p = 0.05) |
| Irrigation (I) | * | | 0.14 | | 0.40 | * | | 0.15 | | 0.45 | * | | 0.16 | | 0.46 |
| Fertigation (F) | * | | 0.14 | | NS | * | | 0.15 | | NS | * | | 0.16 | | NS |
| Interaction (I × F) | * | | 0.28 | | NS | * | | 0.31 | | NS | * | | 0.32 | | NS |

*$F_1$ - 100% (500 g) N&K applied through soil; $F_2$ - 50% (250 g) N&K applied through fertigation; $F_3$ - 75% (375 g) N&K applied through fertigation; $F_4$ - 100% (500 g) N&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 soil moisture content (%) of mango cv. Banganpalli [Data based on PDSR soil moisture sensor readings at BBCH-703, 705 and 709 (From fruit set fruit maturity)]**

| Treatments | Soil moisture content during different crop growth stages (From fruit set to fruit maturity) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | BBCH - 703 | | | | | BBCH - 705 | | | | | BBCH - 709 | | | | |
| | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean |
| $I_1$ (Control) | 11.6 | 11.5 | 10.3 | 10.4 | 11.0 | 9.5 | 10.7 | 9.8 | 9.5 | 9.9 | 9.0 | 10.2 | 9.3 | 9.1 | 9.4 |
| $I_2$ (75% ETc) | 9.4 | 9.3 | 9.8 | 9.7 | 9.6 | 9.1 | 9.0 | 9.6 | 8.9 | 9.2 | 9.0 | 8.8 | 8.5 | 8.0 | 8.6 |
| $I_3$(100% ETc) | 16.9 | 14.7 | 15.8 | 14.2 | 15.4 | 16.6 | 14.0 | 14.8 | 14.4 | 15.0 | 15.6 | 13.0 | 14.2 | 13.9 | 14.2 |
| $I_4$ (125% ETc) | 21.5 | 22.2 | 20.1 | 19.2 | 20.8 | 20.5 | 20.9 | 19.5 | 18.6 | 19.9 | 20.6 | 20.8 | 18.8 | 18.1 | 19.6 |
| Mean | 14.9 | 14.4 | 14.0 | 13.4 | | 13.9 | 13.7 | 13.4 | 12.9 | | 13.6 | 13.2 | 12.7 | 12.3 | |
| Factors | F - Test | | Sem± | | CD (p = 0.05) | F - Test | | Sem± | | CD (p = 0.05) | F - Test | | Sem± | | CD (p = 0.05) |
| Irrigation (I) | * | | 0.10 | | 0.29 | * | | 0.15 | | 0.43 | * | | 0.15 | | 0.45 |
| Fertigation (F) | * | | 0.10 | | 0.29 | * | | 0.15 | | 0.43 | * | | 0.15 | | 0.45 |
| Interaction (I × F) | * | | 0.20 | | 0.58 | * | | 0.29 | | 0.85 | * | | 0.31 | | 0.89 |

*$F_1$ - 100% (500 g) N&K applied through soil; $F_2$ - 50% (250 g) N&K applied through fertigation; $F_3$ - 75% (375 g) N&K applied through fertigation; $F_4$ - 100% (500 g) N&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 water use efficiency (kg m$^{-3}$) of mango *cv.* Banganpalli**

| Treatments | Water use efficiency (kg m$^{-3}$) | | | | |
|---|---|---|---|---|---|
| | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean |
| $I_1$ (Control) | 4.73$^{de}$ | 3.76$^{e}$ | 5.21$^{d}$ | 6.78$^{de}$ | 5.12$^{d}$ |
| $I_2$ (75% ETc) | 7.71$^{cd}$ | 8.46$^{c}$ | 11.15$^{b}$ | 13.33$^{a}$ | 10.16$^{a}$ |
| $I_3$ (100% ETc) | 4.77$^{de}$ | 5.71$^{ed}$ | 10.19$^{b}$ | 10.84$^{b}$ | 7.88$^{b}$ |
| $I_4$ (125% ETc) | 3.94$^{e}$ | 4.66$^{de}$ | 8.62$^{c}$ | 8.84$^{c}$ | 6.51$^{c}$ |
| Mean | 5.29$^{c}$ | 5.65$^{c}$ | 8.79$^{b}$ | 9.95$^{a}$ | |
| Factors | F-Test | | SEm± | | CD (P=0.05) |
| Irrigation (I) | * | | 0.21 | | 0.61 |
| Fertigation (F) | * | | 0.21 | | 0.61 |
| Interaction (I × F) | * | | 0.42 | | 1.22 |

*Note: Figures with same alphabets did not differ significantly Pat P≤ 0.05; $F_1$ - 100% (500 g) N&K applied through soil; $F_2$ - 50% (250 g) N&K applied through fertigation; $F_3$ - 75% (375 g) N&K applied through fertigation; $F_4$ - 100% (500 g) N&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 fertilizer (nitrogen and potassium) use efficiency (kg kg$^{-1}$) of mango *cv.* Banganpalli**

| Treatments | Fertilization | | | | |
|---|---|---|---|---|---|
| | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean |
| $I_1$ (Control) | 72$^{fg}$ | 101$^{g}$ | 103$^{fg}$ | 103$^{dc}$ | 95$^{b}$ |
| $I_2$ (75% ETc) | 93$^{d}$ | 181$^{c}$ | 176$^{bc}$ | 161$^{c}$ | 153$^{a}$ |
| $I_3$ (100% ETc) | 77$^{ef}$ | 164$^{d}$ | 214$^{ab}$ | 175$^{bc}$ | 157$^{a}$ |
| $I_4$ (125% ETc) | 79$^{fg}$ | 167$^{ef}$ | 227$^{a}$ | 178$^{bc}$ | 163$^{a}$ |
| Mean | 80$^{d}$ | 153$^{b}$ | 180$^{a}$ | 154$^{b}$ | |
| Factors | F-Test | | SEm± | | CD (P=0.05) |
| Irrigation (I) | * | | 3.86 | | 11.14 |
| Fertigation (F) | * | | 3.86 | | 11.14 |
| Interaction (I × F) | * | | 7.71 | | 22.28 |

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

fruit development are presented in Table's 3 and 4. The main effect of irrigation had shown significant effect on soil moisture content during different phenophases (from BBCH 510 to 709; Fig. 1) of fruit development. Maximum soil moisture content (19.6 to 20.8%) was recorded with application of 125% ETc ($I_4$) followed by application of 100% ETc ($I_3$) (14.2 to 15.4%). Minimum soil moisture content was noted with application of 75% ETc ($I_2$) (8.6 to 9.7%) which was on par with control ($I_1$). The higher soil moisture in the surface (0-30 cm) soil layers may be attributed to the fact that under drip irrigation, water was applied at daily intervals in smaller quantities, which remained confined in the upper layers. Under surface irrigation, higher hydraulic gradient was created owing to application of bulk volume of water per irrigation with quite wider irrigation frequency, which resulted in more rapid downward movement of water and more soil moisture fluctuations were recorded. But the soil moisture content in $I_2$ was on par with control ($I_1$) because drip irrigation of 75% ETc ($I_2$) at daily intervals, which confined in the upper layers, however, the quantity of water applied (14.40 m$^3$ tree$^{-1}$) equal as that of 100% ETc (14.00 to 15.00 m$^3$ tree$^{-1}$). This advocated that under water shortage conditions application of minimum quantity (75% ETc) most effective than of control. Further, application of 75% ETc alongwith mulching had also saved 25% water without adversely affecting the fruit yield and it is also possible to increase the acreage with available water. The similar results were earlier reported by Sharma *et al*. (2007) in grape *cv.* Thomson seedless; Tiwari *et al.* (2016) in sapota *cv.* Kalipatti and Sharma (2007) in apricot.

The data pertaining effect of different fertilization treatments on soil moisture content (%) of mango *cv.* Banganpalli had shown the significant difference. The soil moisture content at BBCH-510, BBCH-619 and BBCH-701 did not vary significantly because the fertilization treatment were applied after the BBCH 701 phenophase of fruit development (fruits at marble size) and thereafter the soil moisture content was shown the significant difference with different fertilization treatments. The highest soil moisture content (14.9%) at BBCH-703 was recorded in $F_1$ which was on par with $F_2$ (14.4%), followed by $F_3$ (14.0%) and lowest was noted in $F_4$ (13.4%). Similarly, at BBCH-705 and BBCH-709 phenophase the highest soil moisture content (13.9 and 13.6%, respectively) was recorded in $F_1$ (500 g of N&K applied through soil) which was on par with and $F_2$ (13.4 and 13.2%) and minimum soil moisture content was observed in $F_4$ (500 g N&K through fertigation).

Minimum soil moisture content was observed in $F_3$ and $F_4$ treatments which might be due to the fertilizers applied through fertigation in split doses might have increased the plant physiological activity in the presence of required nutrients at timely availability lead to increased water absorption. Further, the split dose of fertilizer application through drip might have helped in the efficient utilization of nutrients (Table 6) which might have helped in production of photosynthates. These increased physiological activity might have resulted in increased fruit yield (Table 2), in this instance water might have played major role in various physiological activities and translocation of food materials through which water utilization might have increased which ultimately resulted in reduced soil moisture content in the present investigation (Table 4). However, the maximum soil moisture (%) availability was recorded in $F_1$ and $F_2$, which may be due to suboptimal nutrition or inefficient utilization of nutrients supplied through conventional method, which might have reduced growth and development as a result the soil moisture may not utilize efficiently.

The interaction between irrigation and fertilization had a non significant difference in soil moisture content among the treatments during BBCH-510, BBCH-619 and BBCH-701 phenophases, the soil moisture content did not shown significantly difference because of the fertilization treatment were applied after the BBCH 701 phenophase of fruit development (fruits at marble size) and there after (from BBCH 703-709 phenophase of fruit development) the soil moisture content had shown the significant difference. The maximum soil moisture content (20.5%) was recorded with application of $I_4F_1$ (125% ETc + 500 g N&K through soil) which was on par with $I_4F_2$ (20.9 cm) followed by application of $I_4F_3$ (19.5%), $I_4F_4$ (18.6%) while the lowest soil moisture content (8.9%) was recorded with application of $I_2F_4$ (75% ETc + 500g N&K through fertigation) at BBCH - 703 phenophase. Similarly, at BBCH-705 and BBCH-709 phenophase also, the higher soil moisture content (20.9 and 20.8%) was noticed in $I_4F_2$ (125% ETc + 250 g N&K through soil) which was on par with application of $I_4F_1$ (20.5 and 20.6%) treatment, while minimum soil moisture content (8.9 and 8.0%) was noticed in $I_2F_4$ (75% ETc + 500g N&K through fertigation). From the present study the interaction of increased irrigation alongwith different fertilization treatment combinations had significantly increased the soil moisture content. But the same level of irrigation with increased level of fertigation has significantly reduced the soil moisture content. This indicating that, application of fertilizers through fertigation might have helped in increased fruit yield (Table 2) through increased water absorption from the soil, which might have resulted in effective utilization of available soil moisture there by the WUE (Table 5) and PFP (Table 6) may be increased, which might have resulted in reduced soil moisture content in the present investigation.

**Water Use Efficiency (WUE) (kg m$^{-3}$)**

The WUE (kg m$^{-3}$) of mango *cv.* Banganpalli influenced by different irrigation and fertilization treatments are presented in Table 5. The data revealed that there is a significant difference among different irrigation treatments with respect to WUE (kg m$^{-3}$) of mango *cv.* Banganpalli. Maximum WUE was recorded with the application of 75% ETc ($I_2$) (10.16 kg m$^{-3}$) followed by 100% ETc ($I_3$) (7.88 kg m$^{-3}$). Minimum WUE was observed in the application of control ($I_1$) (5.12 kg m$^{-3}$). In the present investigation reduced irrigation (75% ETc) alongwith mulching ($I_2$) has resulted significantly highest WUE as compared to control. This might be due to the treatment having resulted highest yield per unit water consumption as compared to control ($I_1$). The highest WUE under $I_2$ treatment might be due to the drip irrigation at daily intervals has helped in reducing soil moisture fluctuation. Further, the same treatment has ensured the improved soil microclimate, weed free environment and low evaporation as compared to control ($I_1$). This has resulted in higher productivity per unit water consumption with reduced irrigation (75% ETc) alongwith mulching. Similar findings were earlier reported by Panigrahi *et al.* (2010) in mango *cv.* Dashehari, Srivastava *et al.* (1999) in banana, Tiwari *et al.* (2014) in sapota *cv.* Kalipatti. However, minimum WUE was recorded in (control-$I_1$) basal irrigation. This might be due to an imbalance in soil moisture availability. Further, the same treatment has resulted in depletion of soil moisture availability and high soil moisture fluctuation due to the plants irrigated at long intervals. Depletion of soil moisture availability and high soil moisture fluctuation might have resulted in leaching loss of water and nutrient has resulted in inefficient utilization of applied water in the present investigation.

Maximum WUE was recorded with the application of 100% of N&K through fertigation ($F_4$) (9.95 kg m$^{-3}$) followed by with application of 75% of N&K through fertigation ($F_3$) (8.79 kg m$^{-3}$). Minimum WUE was observed with application of 100% of N&K through soil ($F_1$) (5.29 kg m$^{-3}$). The increased fertigation levels have significantly increased WUE as compared to the conventional method of fertilization ($F_1$). In the present experiment the WUE has increased upto 6.37 to 47% more over conventional method of fertilization ($F_1$). The maximum WUE (9.95 kg $m^{-3}$) was recorded with the application of 100% N&K through fertigation. The increased WUE might be due to the fact that fertigation aids increased flexibility in application and multiple reduced rate applications timed to more closely coincide with plant nutrient demand. Furthermore, the mobility of N&K is much greater when fertigated than broadcasted (Neilsen *et al.,* 2003) has enabled the efficient utilization of applied nutrients ultimately resulting in increased WUE in the present investigation. Similar increase in WUE was earlier recorded by Pankaj (2013) in Assam lemon and Haneef *et al.* (2014) in pomegranate.

The data revealed that there is a significant difference among different interactions of irrigation and fertilization treatments with respect to WUE (kg $m^{-3}$) of mango *cv.* Banganpalli. Maximum WUE was recorded in application of 75% ETc alongwith fertigation of 100% of N&K ($I_2F_4$) (13.33 kg $m^{-3}$) followed by 75% ETc alongwith fertigation of 75% of N&K ($I_2F_3$) (11.15 kg $m^{-3}$) which was on par with application of 100% ETc alongwith fertigation of 100% of N&K ($I_3F_4$) (10.84 kg $m^{-3}$) and 100% ETc alongwith fertigation of 75% of N&K ($I_3F_3$) (10.19 kg $m^{-3}$). Minimum WUE was recorded in control + 50% of N&K through fertigation ($I_1F_2$) (3.76 kg $m^{-3}$). The combined application of an increased level of irrigation and fertigation has significantly increased the WUE compared to conventional methods of irrigation and fertilization in the present investigation. The application of 75% ETc + 100 N&K through fertigation alongwith mulching has resulted significantly highest WUE as compared to other treatments. This is might be due to increased fruit yield per unit water application. High WUE under drip irrigation and fertigation along mulching might be due to an adequate amount of available soil moisture (14-20%) (Table's 3 to 4) during the fruit development stage. Further, the depletion of available soil moisture from the same soil depth was quite low due to frequent applications of irrigation alongwith mulching has created an adequate environment in soil-plant-atmosphere system. Further, the mobility of N&K is much greater when fertigated than broadcasted (Neilsen *et al.*, 2003). This might have contributed to increased fruit yield (161-178 kg $tree^{-1}$) (Table 10) through increased PFP (163-166 kg $kg^{-1}$) (Table 6) which ultimately resulted in increased WUE as compared to control ($I_1F_1$) in the present investigation. Similar findings are earlier suggested by Pankaj (2013) in Assam lemon and Kumawat *et al*. (2019) in guava *cv.* Lalith.

**Partial factor productivity (PFP) (kg $kg^{-1}$)**

The results on PFP (kg $kg^{-1}$) of mango *cv.* Banganpalli has been influenced by different levels of irrigation and fertilization treatments are presented in Table 6.

The data revealed that there is a significant difference among different irrigation levels with respect to PFP of mango *cv.* Banganpalli. Maximum PFP was observed with the application of 125% ETc ($I_4$) (163 kg $kg^{-1}$) which was on par with the application of 100 and 75% ETc (153 and 157 kg $kg^{-1}$, respectively), whereas minimum PFP observed in control ($I_1$) (95 kg $kg^{-1}$). In the present investigation, the increased level of irrigation has significantly increased the PFP as compared to basin irrigation (F1-control). Similarly in sweet orange *cv.* Phule Mosambi the increased irrigation level has also increased the PFP of irrigation (Hendre *et al.,* 2020). Similar results were also earlier reported in mango *cv.* Kesar (Sujatha *et al.,* 2006), in guava *cv.* Lalith (Kumawat *et al*., 2019) and in grape *cv.* Thomson Seedless (Sharma *et al.*, 2008). Increased PFP with increased irrigation level might be due to drip irrigation at frequent intervals providing a consistent moisture regime (20%) (Table's 3 to 4) in the soil and therefore, roots remain active for a longer period. Further, the proper and continuous moisture in the soil also increased the availability of nutrients through active mineralization (Kumawat *et al*., 2019) which ultimately resulted in increased PFP in the present investigation.

Application 75% of N&K through fertigation ($F_3$) has resulted in maximum PFP (179.86 kg $kg^{-1}$) followed by 100% of N&K through fertigation ($F_4$) (153.94 kg $kg^{-1}$), whereas minimum PFP was observed with the application of 100% of N&K through soil ($F_1$) (80.12 kg $kg^{-1}$). Increased fertigation levels significantly increased the PFP as compared to soil application. Similar results were earlier reported in sweet orange *cv.* Phule Mosambi (Hendre *et al.,* 2020), Ranghaswami *et al*. (2006) in mulberry and Sharma *et al*. (2008) in grape. Increased PFP might be due to the fertigation aids increased flexibility in application with similar plant response possible at reduced N rates. Further, the mobility of N&K is much greater when fertigated than broadcasted (Neilsen *et al.,* 2003). The increased mobility of N&K which has enabled the efficient utilization of applied nutrients ultimately resulted in increased nutrient uptake in the present investigation. This ultimately resulted in increased PFP in the present investigation.

The interaction of different irrigation and fertilization treatments alongwith mulching has shown significant differences in PFP of mango *cv.* Banganpalli. Maximum PFP was observed with application 125% ETc and 100% N&K through fertigation $I_3F_4$ (226.50 kg $kg^{-1}$) which was on par with application of 100% ETc +75% N&K through fertigation ($I_3F_3$) (214 kg $kg^{-1}$) which was also on par with application of 125% ETc +100% N&K through fertigation ($I_4F_4$) (178 kg $kg^{-1}$), 75% ETc +75% N&K through fertigation ($I_2F_3$) (175.79) and 75% ETc +100% N&K through fertigation ($I_2F_4$) (161 kg $kg^{-1}$). Minimum PFP was obtained in control +100% N&K through soil application ($I_1F_1$) (101 kg $kg^{-1}$). The present investigation suggested that increased level of irrigation and fertilization alongwith mulching has significantly increased the PFP as compared to basin irrigation (control) +100% N&K through soil application ($I_1F_1$). Similar findings are earlier reported by Ranghaswami *et al.* (2006) in mulberry, Sharma *et al.* (2008) in grape and sweet orange *cv.* Phule Mosambi (Hendre *et al.,* 2020).

The PFP of mango *cv.* Banganpalli considerably increased with increased drip irrigation and fertigation compared to soil application of N&K fertilizers. This could be attributed due to the regular application of N&K (as high as three splits in drip fertigation) combined with irrigation water in the active root zone of the crop and their interaction in even N&K distribution in the soil. Further, drip irrigation and fertigation have minimum leaching of nutrients away from the root zone. The increased FUE) recorded with irrigation, fertigation and mulching treatment was mainly due to better crop growth and increased yield by effective utilization of available nutrients, that was supplied during principle fruit growing periods met the crop demand (Bangar and Chaudhari, 2004). Whereas, minimum PFP was recorded with a conventional method of irrigation and fertilization ($I_1F_1$). Minimum PFP in the conventional method of irrigation and fertilization might be due to a decrease in PFP as a result of loss of water and nutrients through leaching, restricted mineralization and nutrient mobility.

**Gross Return, Net Return and Benefit Cost Ratio (BCR)**

The mean values of gross and net return influenced by different levels of irrigation and fertilization has been worked out based on prevalent wages, rate of critical inputs and average selling price of produce during the cropping season of 2017 - 2019, data is presented in Table's 7 to 9 and details of the cost of cultivation is given in Table 10.

The increased level of irrigation through drip alongwith mulch was proved to be better than the conventional method of irrigation alongwith mulching in receiving higher gross and net return. The maximum gross (₹ 262,060 ha$^{-1}$), net returns (₹ 1,74,712 ha$^{-1}$) and BCR (3.0) was obtained with application of 125% ETc alongwith mulching ($I_4$). However,

**Table: 7**
**Effect of irrigation and fertigation on gross returns (₹ ha$^{-1}$) of mango *cv.* Banganpalli**

| Treatments | Gross returns (₹ ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean |
| $I_1$ (Control) | 142,940.00 | 113,740.00 | 157,580.00 | 205,080.00 | 154,840.00 |
| $I_2$ (75% ETc) | 186,080.00 | 204,100.00 | 269,180.00 | 321,900.00 | 245,320.00 |
| $I_3$ (100% ETc) | 153,540.00 | 183,880.00 | 328,020.00 | 348,900.00 | 253,580.00 |
| $I_4$ (125% ETc) | 158,420.00 | 187,380.00 | 348,820.00 | 355,620.00 | 262,060.00 |
| Mean | 160,240.00 | 172,280.00 | 275,400.00 | 307,880.00 | |

**Table: 8**
**Effect of irrigation and fertigation on net returns (₹ ha$^{-1}$) of mango *cv.* Banganpalli**

| Treatments | Net returns (₹ ha$^{-1}$) | | | | |
|---|---|---|---|---|---|
| | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean |
| $I_1$ (Control) | 66,867.00 | 27,162.00 | 65,164.50 | 1,10,757.00 | 67,492.63 |
| $I_2$ (75% ETc) | 1,10,007.00 | 1,17,522.00 | 1,76,764.50 | 2,27,577.00 | 1,57,972.63 |
| $I_3$ (100% ETc) | 77,467.00 | 97,302.00 | 2,35,604.50 | 2,54,577.00 | 1,66,232.63 |
| $I_4$ (125% ETc) | 82,347.00 | 1,00,802.00 | 2,56,404.50 | 2,61,297.00 | 1,74,712.63 |
| Mean | 84,167.00 | 85,702.00 | 1,82,984.50 | 2,13,557.00 | |

**Table: 9**
**Effect of irrigation and fertigation on benefit cost ratio of mango *cv.* Banganpalli**

| Treatments | Benefit cost ratio | | | | |
|---|---|---|---|---|---|
| | $F_1$ | $F_2$ | $F_3$ | $F_4$ | Mean |
| $I_1$ (Control) | 1.88 | 1.31 | 1.71 | 2.17 | 1.77 |
| $I_2$ (75% ETc) | 2.45 | 2.36 | 2.91 | 3.41 | 2.81 |
| $I_3$ (100% ETc) | 2.02 | 2.12 | 3.55 | 3.70 | 2.90 |
| $I_4$ (125% ETc) | 2.08 | 2.16 | 3.77 | 3.77 | 3.00 |
| Mean | 2.11 | 1.99 | 2.98 | 3.26 | |

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

**Table: 10**
**Cost of cultivation for mango *cv.* Banganpalli for different levels of irrigation, fertigation and mulching treatments**

| No. | Materials / Works | Hectare (100 plants) |
|---|---|---|
| I. | Inputs | 37273 |
| | 1. Recommended dose (RDF) is 1000:1000: 1000 g of NPK and 50 kg FYM plant$^{-1}$yr$^{-1}$ for >10 years old plants (1.33 kg of Urea; 2.2 kg of DAP and 2.0 kg of SOP plant$^{-1}$) | 17273 |
| | a. Urea ₹ 5.52 kg$^{-1}$ | 985 |
| | b. DAP ₹ 10.4 kg$^{-1}$ | 2261 |
| | c. SOP ₹ 17.44 kg$^{-1}$ | 2907 |
| | d. FYM ₹ 2.00 kg$^{-1}$ | 10000 |
| | e. Zinc ₹ 100 kg$^{-1}$ | 500 |
| | f. Iron ₹ 80 kg$^{-1}$ | 200 |
| | g. Boron ₹ 90 kg$^{-1}$ | 180 |
| | h. Magnesium ₹ 80 kg$^{-1}$ | 240 |
| | I. Mulch material 2000 ₹ Roll$^{-1}$ (400 × 0.9 m) to cover 20 m canopy area plant$^{-1}$ha$^{-1}$ | 10000 |
| II. | Cultural operations, plant protection and labour charges | 10000 |
| | 2. Spraying of micronutrients 4 labour (300 ₹ day$^{-1}$) | 48,800 |
| | 3. Bunds formation, Weeding, irrigation and fertilizer application 75 labours | 1200 |
| | 4. Plant protection chemicals and measures (700 litres water$^{-1}$ ha$^{-1}$) | 21,000 |
| | a. 16 labours for 4 sprays (300 ₹ day$^{-1}$) | 8,800 |
| | b. Neem oil @ 2.5 ml l$^{-1}$ (1.75 l Neem oil and 400 ₹ l$^{-1}$) | 4,800 |
| | c. Thiomethoxam @ 0.5 ml l$^{-1}$ (0.35 l ha$^{-1}$ and 1,600 ₹ l$^{-1}$) | 700 |
| | d. Imidachloprid @ 0.5 ml l$^{-1}$ (0.35 l ha$^{-1}$ and 2,000 ₹ l$^{-1}$) | 560 |
| | e. Profenophos + cypermetrin 0.5 ml l$^{-1}$ (0.35 l ha$^{-1}$ and 1,200 ₹ l$^{-1}$) | 700 |
| | f. SAF (Carbendazim 12% + Mancozeb 63% wp) @ 2.0 g l$^{-1}$ (2.00 kg l ha$^{-1}$ (600 ₹ kg$^{-1}$) | 420 |
| | g. Hexaconazole @ 0.5 ml l$^{-1}$ (0.35 l ha$^{-1}$ and 1,200 ₹ l$^{-1}$) | 1200 |
| | 5. 15 - Labours for each harvesting in control (4,500 ₹ harvest$^{-1}$) | 420 |

*Note: Marke Table price of mango cv. Banganpalli 20 ₹ kg$^{-1}$*

the minimum gross (₹ 1,54,840 ha$^{-1}$), net returns (₹ 67,492 ha$^{-1}$) and BCR (1.77) was obtained in conventional method of irrigation ($I_1$-control). In the present investigation increasing irrigation, levels have significantly increased the productivity of mango thereby increased the net returns and BCR observed with application of 125% ETc + mulching as compared to control ($I_1$) in the present investigation. Similar findings were earlier reported by Joshi *et al*. (2011) in litchi, Ramniwas *et al*. (2012) in guava *cv.* Shweta, Sharma *et al*. (2012) in guava and Tiwari *et al*. (2014) in sapota *cv.* Kalipatti.

The increased level of fertigation through drip alongwith mulch was proved to be better than the conventional method of fertilization alongwith mulching in receiving higher gross and net returns. The maximum gross (₹ 3,07,880 ha$^{-1}$), net returns (₹ 2,13,557 ha$^{-1}$) and BCR (3.26) was obtained with application of 100% N&K supplied through fertigation alongwith mulching ($F_4$). However, the minimum gross (₹ 1,60,240 ha$^{-1}$) net return (₹ 84,167 ha$^{-1}$) were obtained in conventional method of fertilization (F1 - 100% N&K applied through soil) and minimum BCR was recorded in $F_1$ (1.99). The increasing fertigation levels have significantly increased the productivity of mango thereby increasing the net returns and BCR observed ($I_4$). Similar findings are earlier reported by Ramniwas *et al*. (2012) in guava *cv.* Shweta.

The interaction of irrigation and fertigation has shown increased gross and net returns compared to conventional methods of irrigation and fertilization. The application of 125% ETc +100% N&K through fertigation ($I_4F_4$) has resulted in maximum gross and net returns (₹ 3,55,620 and 2,13,557 lakh ha$^{-1}$, respectively) but the highest BCR was observed in application of 125% ETc + 75% N&K trough fertigation ($I_4F_3$) (3.77) which was on par with application of 125% ETc + 100% N&K trough fertigation ($I_4F_4$) (3.77). However, minimum gross and net returns (₹ 1,13,740 and 65,164 lakh ha$^{-1}$, respectively) and BCR (1.31) was observed in the application of control + 50% N&K through fertigation ($I_1F_2$). The maximum BCR with application of 125% ETc + 75% N&K trough fertigation ($I_4F_3$) might be due to the same treatment having shown the highest PFP (226.50 kg kg$^{-1}$) with minimum fertilizers application as compared to $I_4F_4$ treatment. This has resulted in reduced fertilizer cost which ultimately resulted in an increased BCR in the present investigation. A similar result was earlier noted by Pankaj (2013) in Assam lemon and Ramniwas *et al*. (2012) in guava *cv.* Shweta.

## 4. CONCLUSIONS

From the present investigation, conjugated application of 125% ETc + 75% N&K through fertigation (375 g of N&K) in three equal split doses at 15 days intervels after fruit set (from February 15$^{th}$ to end of March) alongwith mulching has significantly increased the fruit yield (60% higher fruit yield over control), WUE, PFP and economy (BCR 3.77) alongwith 12.5% fertilizers saving as compared to farmer practice. Further, underwater scarced condition with application of 75% ETc + 100% N&K (500 g of each) through fertigation in three equal split doses at 15 days intervels after fruit set (from February 15$^{th}$ to end of March) alongwith mulching had resulted 55% higher fruit yield, maximum WUE (13.33 kg m$^{-3}$), PFP (161 kg kg$^{-1}$) and BCR (3.41) as compared to farmer practice (BCR 1.88).

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