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# Yield response of watermelon to varying levels of fertigation, drip irrigation and vertical training under rain shelter

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## Abstract

An experiment was conducted at the Department of Olericulture, College of Agriculture, Vellayani, Kerala, to study the effect of fertigation, drip irrigation, and training levels on the yield and quality of watermelon under rain shelter. The treatments were factorial combinations of three fertigation levels (75, 100 and 125 % recommended dose (RD) of 70:50:120 NPK ha$^{-1}$), two irrigation levels (0.6 and 0.8 evapotranspiration (ET) rates) and two training levels (nipping to one vine, nipping to two vines) arranged in randomized block design with two replications and control with surface irrigation, soil application of fertilizer and horizontal training of vines. Levels of fertigation and irrigation exerted a significant influence on fruit weight and yield plant$^{-1}$. Total yields were highest at 100 % RD (115.68 t ha$^{-1}$) as compared to 125 % RD (94.81 t ha$^{-1}$). The number of fruits plant$^{-1}$ was unaffected by fertigation and irrigation treatments. Vertical training of two vines in watermelon resulted in the highest number of fruits plant$^{-1}$ (6.09). TSS was unaffected by fertilization, irrigation, or training levels. Under a rain shelter, lycopene and ascorbic acid levels were affected by a lack of irrigation.

**Key words:** *Citrullus lanatus*, fertigation, irrigation, training, rain shelter, watermelon, evapotranspiration

## Introduction

Watermelon [*Citrullus lanatus* (Thunb.) Matsum. & Nakai] is a popular fruit of the family Cucurbitaceae, cultivated all over the world. In India, it is grown in an area of 1.01 lakh hectare with a production of 25.2 lakh tonnes (GOI, 2018). Hi-tech interventions like protected cultivation and precision farming in vegetables is gaining momentum in Kerala. These are mainly adopted in few crops like cucumber, capsicum, tomato, cowpea and some leafy vegetables. Compared to polyhouses, rain shelters are low cost structures and are more suited to hot humid conditions. Yield of vegetables per unit area is 2-4 times higher in rain shelters compared to open field production (Sharif *et al.*, 2008).

Watermelon is one of the highly priced vegetables having great market potential. It is the most sought after fruit during the summer season. It contains more than 91% water and therefore, water supply during critical stages of plant growth and fruit development is very important. Water availability for irrigation will be a major constraint for agriculture in coming years. So strategies to reduce water loss are the need of the hour. Use of micro irrigation facilities like drip system can play a major role towards this end. Fertigation can improve nutrient use efficiency by supplying nutrients and water precisely avoiding excess concentrations of fertilizer in the soil and consequent leaching. At the same time marketable yield is maintained or improved (Monaghan *et al.*, 2010).

Mineral nutrition is one of the important factors contributing to watermelon yield. However, the suggested rates varied considerably. Goreta *et al.* (2005) found that total and marketable yields did not increase with nitrogen rates above 115 kg ha$^{-1}$. Increased use of fertilizer led to rise in yield and dry weight of watermelon fruits (Hendericks *et al.*, 2007) but stronger infestation of gummy stem blight and downy mildew is reported with increased nitrogen fertigation (Santos *et al.*, 2009).

Generally, in watermelon deficit irrigation (Leskovar *et al.*, 2004) and various levels of fertilizers supplied through fertigation had no influence on fruit quality like lycopene and vitamin C (Andrade Junior *et al.,* 2009; Prabhakar *et al.*, 2013). But, Wakindiki and Kirambia (2011) reported decrease in soluble solids with increase in irrigation. Marketable yield decreased linearly in response to an increase in water stress (Fernandes *et al.*, 2014).

Watermelon is traditionally cultivated horizontally on the ground. Recently plants are trained upwards on vertical supports with branch pruning and fruit thinning. These practices increase the plant density, fruit quality, yield (Campagnol *et al.*, 2012; Watanabe, 2014), number of marketable fruits, improves colour and avoids yellow bellies in fruits (Oga and Umekwe, 2015). Vertical training facilitates easy application of pesticides, better ventilation and distribution of light (Gomes *et al.,* 2017). But fruit weight decreased in vertically trained plants (Watanabe *et al.*, 2001; Watanabe, 2014).

In Kerala, watermelon is cultivated only in a very limited area of 100 ha (GOI, 2018), even though the demand for the fruit is very high. Being a high value crop, its exploitation on commercial scale under protected structures like rain shelters can generate handsome income to farmers. Currently the preference is for mini watermelon with fruits weighing 1-3 kg to cater the needs of nuclear families, which can be very well grown in trellises. Generally watermelon is cultivated horizontally using surface irrigation with soil application of fertilizers. No studies have been made on training watermelon vertically under rain shelter. The effects of irrigation strategies and interaction with fertigation rates are also not well investigated under sandy clay loam soils of southern Kerala. Hence, this study was performed to explore the effects of different levels of fertigation, drip irrigation and vertical training on yield and quality of watermelon under rain shelter.

## Materials and methods

The experiment was conducted in rain shelter of 266 $m^2$ area (38 m x 7 m) at Department of Olericulture, College of Agriculture, Vellayani, Kerala Agricultural University during 2015-2016. The site was located at 08º 25`53.7`` N and 76º 59`15.8`` E at an altitude of 29 m above mean sea level. The watermelon hybrid Prachi, with mini sized fruit was used. Mechanical composition and moisture characteristics of the soil are provided in Table 1. The treatments were factorial combinations of three fertigation levels (75 %, 100 % and 125 % recommended dose (RD) of 70:50:120 NPK $ha^{-1}$) and two irrigation levels (0.6 and 0.8 evapotranspiration (ET) rates) and two training levels (nipping to one vine, nipping to two vines) arranged in randomized block design with two replications and control with basin irrigation, soil application of fertilizer and horizontal training of vines.

Table 1. Mechanical composition and moisture characteristics of the soil

| Particulars | Value |
|---|---|
| A. Mechanical composition | |
| Coarse sand (%) | 17.30 |
| Fine sand (%) | 29.50 |
| Silt (%) | 25.80 |
| Clay (%) | 26.10 |
| Textural class | Sandy clay loam |
| B. Soil moisture characteristics | |
| Particle density (g $cc^{-1}$) | 2.30 |
| Bulk density (g $cc^{-1}$) | 1.40 |
| Maximum water holding capacity (%) | 23.70 |
| Porosity (%) | 31.10 |
| Field capacity (%) | 21.90 |
| Permanent wilting point (%) | 9.10 |

The experimental area was deeply ploughed up to 50 cm and weeds and stubbles were removed. Farm yard manure @ 25 t $ha^{-1}$ was applied before last ploughing. Raised beds of one meter width and one foot height were taken with channels of 50 cm between beds; so that the row to row spacing was 1.5 m. Drip lines were laid with a lateral per bed and drippers with a discharge rate of 2 L $hour^{-1}$ spaced every 60 cm. The beds were covered with silver on black polyethylene mulch of 50 μ thickness. Twelve days old seedlings at 2-3 true leaf stage were transplanted at 60 cm spacing. The plants were trained vertically under rain shelter. In plants with two vines, the tip of the main vine was nipped off at about 10-12 days after transplanting and two vigorously growing laterals were allowed to grow and in plants with one vine, only the main vine was allowed to grow. The first three secondary branches were removed as soon as they appeared and the rest were pruned periodically after the third leaf (Campagnol *et al.*, 2012). In control no pruning was adopted and plants were trailed horizontally over dried coconut fronds.

Uniform irrigation was given to the seedlings up to one week after transplanting and irrigation scheduling was started after first week. Drip irrigation was scheduled daily to meet the crop water requirement based on the pan evaporation data of previous day from Class A open pan evaporimeter near the trial plot. Total irrigation applied was 179.63 mm, 272.27 mm and 344.50 mm for 0.6 ET, 0.8 ET and control respectively. Fertigation was done at three days interval using fertigation pump. The data was analysed statistically by applying the techniques of analysis of variance.

## Results and discussion

The effects of different levels of fertigation, drip irrigation and training on vegetative, flowering and yield characters of watermelon are presented in Tables 2 and 3. Fertigation and irrigation treatments had significant influence on vine length in watermelon under rain shelter. Increasing the fertilizer dose resulted in significant increase in vine length. Fertigation at 125 % RD recorded the longest vine length of 5.62 m. Among the irrigation treatments, drip irrigation at 0.8 ET significantly increased the length of vine and it was lowest in basin irrigation. Cucurbits require considerable amount of moisture during their most vigorous growth phase and it extends up to the maturity of fruits. The reduced growth in basin irrigation could be attributed to the movement of water and nutrients beyond the effective root zone leading to a reduction in the uptake of nutrients.

Table 2. Effect of fertigation, drip irrigation and training on vegetative and flowering characters of watermelon under rain shelter

| Treatments | Vine length (m) | Days to first male flower | Node to first male flower | Days to first female flower | Node to first female flower |
|---|---|---|---|---|---|
| Fertigation | | | | | |
| 75 % RD | 4.79 | 15.88 | 5.13 | 23.00 | 13.48 |
| 100 % RD | 4.99 | 15.25 | 4.57 | 23.88 | 14.63 |
| 125 % RD | 5.62 | 17.63 | 6.57 | 22.10 | 13.19 |
| SE(m)± | 0.144 | 0.219 | 0.157 | 0.192 | 0.254 |
| CD at 5 % | 0.447 | 0.680 | 0.490 | 0.596 | 0.789 |
| Irrigation level | | | | | |
| 0.6 ET | 4.89 | 16.20 | 5.67 | 22.92 | 13.70 |
| 0.8 ET | 5.36 | 16.30 | 5.17 | 23.07 | 13.83 |
| SE(m)± | 0.116 | 0.178 | 0.130 | 0.155 | 0.207 |
| CD at 5% | 0.360 | NS | 0.406 | NS | NS |
| Training | | | | | |
| 1 vine | 5.20 | 16.08 | 5.58 | 22.95 | 13.78 |
| 2 vines | 5.05 | 16.42 | 5.25 | 23.03 | 13.75 |
| SE(m)± | 0.116 | 0.178 | 0.130 | 0.155 | 0.207 |
| CD at 5 % | NS | NS | NS | NS | NS |
| Control | 4.31 | 18.50 | 6.25 | 25.75 | 16.75 |

NS-Non significant

Fertigation at 100 % RD recorded earliness in male flower anthesis as well as flower production in the lowest node. In the case of female flowering, 125 % RD registered early flowering. Similar observation was also made by Maluki *et al.* (2016). The early appearance of male and female flowers at higher levels of nitrogen application might be attributed to fast growth of vine which favoured flower forming hormone like gibberellic acid thereby inducing production of more female flowers. The levels of irrigation and training had no significant influence on flowering.

There was significant difference among fertigation treatments for fruit weight and yield $plant^{-1}$. Fertigation at 100 % RD recorded highest fruit weight of 2.13 kg which was on par with 75 % RD (1.98 kg). Number of fruits $plant^{-1}$ was not influenced by the treatments. Fertigation at 100 % RD significantly increased fruit weight, yield $plant^{-1}$ and yield $hectare^{-1}$. Fertigation at 100 % RD recorded the highest yield of 115.68 t $ha^{-1}$. Nitrogen promotes vegetative growth and P stimulates root development. Better vegetative growth leads to enhanced chlorophyll content along with higher stomatal conductance and thereby increased photosynthesis. Moreover, sufficient availability of K might have encouraged increased transport of photosynthates to the sink leading to higher yield (Maluki *et al.*, 2016). Under open condition, fruit weight was not influenced by fertilizer dose (Andrade Junior *et al.*, 2009; Nisha *et al*, 2020), where fruit yield was more influenced by number of fruits than fruit weight. The yield attributes like fruit weight, fruits plant$^{-1}$ and yield plant$^{-1}$ were decreased at the highest fertilizer level (125 % RD) tried. This might be attributed to early fruit set in lower nodes which resulted in competition between the fruit and vegetative parts during early fruit development. Moreover early formed fruits also recorded reduced fruit weight (Watanabe, 2014). Increased concentration of soluble fertilizers increases the osmotic potential of soil solution, causing reduction in water uptake by the plant roots (Maluki *et al.*, 2016). The application of fertilizer through drip was found superior to conventional solid fertilizer application. Fertigation treatments recorded higher values for number of fruits plant$^{-1}$ and yield ha$^{-1}$ than conventional soil application of fertilizers. Similar observation was also made by Prabhakar *et al.* (2013).

Table 3. Effect of fertigation, drip irrigation and training on yield characters of watermelon under rain shelter

| Treatments | Fruits plant$^{-1}$ | Fruit weight (kg) | Yield plant$^{-1}$ (kg) | Yield (t ha$^{-1}$) |
|---|---|---|---|---|
| Fertigation | | | | |
| 75 % RD | 5.49 | 1.98 | 10.02 | 106.23 |
| 100 % RD | 5.64 | 2.13 | 10.99 | 115.68 |
| 125 % RD | 5.37 | 1.77 | 9.10 | 94.81 |
| SE(m)± | 0.515 | 0.088 | 0.424 | 4.39 |
| CD at 5% | NS | 0.273 | 1.321 | 13.68 |
| Irrigation level | | | | |
| 0.6 ET | 5.21 | 1.84 | 8.97 | 93.66 |
| 0.8 ET | 5.77 | 2.09 | 11.1 | 117.49 |
| SE(m)± | 0.209 | 0.071 | 0.347 | 3.59 |
| CD at 5 % | NS | 0.220 | 1.079 | 11.17 |
| Training | | | | |
| 1 vine | 4.9 | 2.04 | 9.34 | 98.49 |
| 2 vines | 6.09 | 1.88 | 10.73 | 112.68 |
| SE(m)± | 0.209 | 0.071 | 0.347 | 3.59 |
| CD at 5 % | 0.651 | NS | 1.079 | 11.17 |
| Control | 4.14 | 1.61 | 6.13 | 37.59 |

NS-Non significant

The highest fruit yield of 11.10 kg plant$^{-1}$ was recorded at 0.8 ET against 8.97 kg with irrigation at 0.6 ET. Proper balance of moisture in plants not only increases the photosynthesis but also helps in higher uptake of nutrients to meet accelerated rate of growth and ultimately yield. The drip irrigation levels gave higher yield of watermelon than surface irrigation. The increased yield under drip irrigation system might have resulted due to excellent soil-water-air relationship with higher oxygen concentration in the root zone, higher uptake of nutrients and continuous maintenance of higher soil moisture content to fulfil the evapotranspirational need of the crop. Leskovar *et al.* (2003) reported highest total yield at 1.0 ET (53.9 t ha$^{-1}$) compared to 0.5 ET (26.8 t ha$^{-1}$). Reduction in total yield caused by deficit irrigation are similar to those obtained by Erdem *et al.* (2001), Bang *et al.* (2004), Rouphel *et al.* (2008) and Kirnak and Dogan (2009). However, McCann *et al.* (2007) reported that irrigation levels had no significant effect on yield of seedless watermelon.

The results revealed that number of fruits plant$^{-1}$ increased significantly with increasing training level from one to two vines in rain shelter. Training to two vines registered 6.09 fruits plant$^{-1}$ compared to one vine (4.90). The fruit weight was not influenced by training methods but it was lower in control. However, Watanabe *et al.* (2001) and Watanabe (2014) observed that fruit weight in vertically trained plants were significantly lighter than that of horizontally trained plants. Highest yield of 112.68 t ha$^{-1}$ was recorded in training to two vines than one vine (98.49 t ha$^{-1}$). Vertically trained watermelon gave significantly higher yield than horizontally trained control as more number of plants can be accommodated per unit area. Oga and Umekwe (2015) also reported increased number of fruits plant$^{-1}$ and marketable yield in staked watermelon.

Total soluble solids (TSS) is the most important quality parameter of watermelon. TSS content was not affected by the fertilizer, irrigation and training levels (Table 4). Battilani and Solimando (2006) and Andrade Junior *et al.* (2009) reported that total soluble solids was unaffected by fertigation levels in watermelon. However, increased TSS content with increase in application P was reported by Maluki *et al.* (2016). According to Davis *et al.* (2006) withholding irrigation prior to harvesting increases sugar content and avoid fibrous flesh. Fernandes *et al.* (2014) also reported significant influence of irrigation frequencies on soluble solids content.

Table 4. Effect of fertigation, drip irrigation and training on quality of watermelon under rain shelter

| Treatments | TSS (ºBrix) | Lycopene (mg 100g$^{-1}$) | Ascorbic acid (mg 100g$^{-1}$) | Reducing sugar (%) | Non reducing sugar (%) |
|---|---|---|---|---|---|
| Fertigation | | | | | |
| 75 % RD | 12.70 | 7.56 | 4.69 | 3.32 | 4.25 |
| 100 % RD | 13.08 | 7.82 | 4.83 | 3.36 | 4.24 |
| 125 % RD | 12.77 | 7.58 | 4.85 | 3.34 | 4.24 |
| SE(m)± | 0.240 | 0.076 | 0.097 | 0.040 | 0.024 |
| CD at 5 % | NS | NS | NS | NS | NS |
| Irrigation level | | | | | |
| 0.6 ET | 12.83 | 7.77 | 4.95 | 3.32 | 4.24 |
| 0.8 ET | 12.87 | 7.53 | 4.63 | 3.35 | 4.24 |
| SE(m)± | 0.195 | 0.059 | 0.077 | 0.035 | 0.021 |
| CD at 5 % | NS | 0.184 | 0.240 | NS | NS |
| Training | | | | | |
| 1 vine | 12.88 | 7.63 | 4.83 | 3.33 | 4.26 |
| 2 vines | 12.80 | 7.66 | 4.75 | 3.35 | 4.23 |
| SE(m)± | 0.195 | 0.059 | 0.077 | 0.035 | 0.021 |
| CD at 5 % | NS | NS | NS | NS | NS |
| Control | 13.00 | 7.56 | 4.70 | 3.28 | 4.19 |

NS-Non significant

Lycopene, ascorbic acid, reducing sugar and non reducing sugar contents were not influenced by fertigation and training levels. Among the treatments, only irrigation levels had influence on lycopene and ascorbic acid contents, where 0.6 ET recorded higher contents than 0.8 ET under rain shelter. Rajasekar *et al.* (2014) reported higher ascorbic acid content in field grown vegetables compared to protected condition. Leskovar *et al.* (2004) reported that vitamin C and lycopene content was unaffected by deficit irrigation in watermelon. Lycopene content in watermelon is related to growth conditions, harvest maturity, accession and ploidy level. In contrast to this, drip irrigation with saline ground water improved quality of watermelon in terms of total sugars and vitamin C (Tingwu *et al.*, 2003).

The results of the present study revealed that the yield of watermelon increased under drip irrigation and fertigation than the conventional surface irrigation and soil application of fertilizer. Training the vines vertically under rain shelter increased the yield of watermelon compared to conventional horizontal training. Training to two vines plant$^{-1}$ showed better performance for number of fruits plant$^{-1}$ and yield of mini watermelon. TSS was not affected by fertigation, irrigation and training levels. For precision farming of watermelon, the fertigation level of 70:50:120 NPK ha$^{-1}$ was found ideal.

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