RESPONSE OF MUSKMELON (*Cucumis melo* L.) TO DRIP IRRIGATION AND FERTIGATION UNDER MULCH CONDITIONS

Thesis

**Submitted to the Punjab Agricultural University
in partial fulfillment of the requirements
for the degree of**

**MASTER OF SCIENCE
in
HORTICULTURE (VEGETABLE SCIENCE)**
(Minor Subject: Soil and Water Engineering)

By

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(L-2017-A-162-M)**

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LUDHIANA – 141 004**

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CERTIFICATE – I

This is to certify that the thesis entitled, **"Response of muskmelon (*Cucumis melo* L.) to drip irrigation and fertigation under mulch conditions"** submitted for the degree of **Master of Science,** in the subject of **Vegetable Science** (Minor subject: **Soil and Water Engineering**) to the Punjab Agricultural University, Ludhiana, is a bonafide research work carried out by **Jaspreet Kaur (L-2017-A-162-M)** under my supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged.

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CERTIFICATE – II

This is to certify that the thesis entitled, **"Response of muskmelon (*Cucumis melo* L.) to drip irrigation and fertigation under mulch conditions"** submitted by **Jaspreet Kaur (L-2017-A-162-M)** to the Punjab Agricultural University, Ludhiana, in partial fulfillment of the requirements for the degree of **M.Sc.** in the subject of **Vegetable Science** (Minor subject: **Soil and Water Engineering**) has been approved by the Student's Advisory Committee along with External Examiner after an oral examination on the same.

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ABSTRACT

The present investigation was conducted at Vegetable Research Farm and Biochemical Laboratory, Department of Vegetable Science, Punjab Agricultural University, Ludhiana to standardize the optimum moisture regime, NPK levels under drip irrigation and mulch for crop establishment, growth, yield and quality fruit production in muskmelon. Hybrid 'MH-27' comprised as a plant material. The treatments included three levels of drip irrigation regimes i.e. at 100 per cent crop evapotranspiration (ET_c), 80 per cent ET_c and 60 per cent ET_c along with mulch treatment (silver black polythene mulch and no mulch) under main plot treatments and three level of fertigation i.e. 100 per cent recommended dose of fertilizer (RDF), 80 per cent RDF and 60 per cent RDF was considered under sub plot treatments resulting in eighteen treatments combinations which were compared with the conventional practices. Drip irrigation at 100 per cent ET_c and 100 per cent RDF under mulch improved vine length, number of primary branches, average fruit weight and yield which was statistically at par with drip irrigation at 80 per cent ET_c and 80 per cent RDF. Further, it was noticed that yield from different treatments of drip fertigation varied from 168.8 q/ha to 201.8 q/ha which was 16 per cent higher from conventional system. Various quality parameters i.e. ascorbic acid and dry matter content were found to increase with increase in depth of irrigation and fertilizer dose. However, maximum total soluble solids (TSS) were observed with drip irrigation at 80 per cent ET_c and 100 per cent RDF. The economic analysis revealed that highest net returns (Rs 130023/ha) were obtained under drip fertigation along with mulch application which was 17.2 per cent higher from conventional system. Thus, it may be concluded from the present investigation that drip fertigation at 80 per cent ET_c level and 80 per cent RDF along with mulch application is beneficial to improve productivity and quality of muskmelon with saving of 80.85 water and 20 per cent fertilizer over the conventional method.

Keywords: Drip irrigation, Fertigation, Mulch, Muskmelon, Crop evapotranspiration

Signature of Major Advisor **Signature of Student**

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ਸਾਰ ਅੰਸ਼

ਮੌਜੂਦਾ ਅਧਿਐਨ ਪੰਜਾਬ ਐਗਰੀਕਲਚਰਲ ਯੂਨੀਵਰਸਿਟੀ, ਲੁਧਿਆਣਾ ਦੇ ਸਬਜ਼ੀ ਵਿਗਿਆਨ ਵਿਭਾਗ ਦੇ ਸਬਜ਼ੀ ਖੋਜ ਫਾਰਮ ਅਤੇ ਜੀਵ-ਰਸਾਇਣਕ ਪ੍ਰਯੋਗਸ਼ਾਲਾ ਵਿਖੇ ਤੁਪਕਾ ਸਿੰਚਾਈ ਅਧੀਨ ਨਮੀ ਦੀ ਮਿਕਦਾਰ, NPK ਦੀ ਮਾਤਰਾ ਦਾ ਮਿਆਰੀਕਰਨ ਕਰਨ ਲਈ ਅਤੇ ਖਰਬੂਜੇ ਵਿੱਚ ਫ਼ਸਲ ਦੇ ਵਿਕਾਸ, ਝਾੜ ਅਤੇ ਗੁੱਣਵਤਾ ਦਾ ਮੁਲਾਂਕਣ ਕਰਨ ਲਈ ਕੀਤਾ ਗਿਆ। ਅਧਿਐਨ ਲਈ ਖਰਬੂਜੇ ਦੀ ਦੋਗਲੀ ਕਿਸਮ 'MH-27' ਨੂੰ ਚੁਣਿਆ ਗਿਆ। ਅਧਿਐਨ ਦੌਰਾਨ ਮੁੱਖ ਪਲਾਟ ਵਿੱਚ ਤੁਪਕਾ ਸਿੰਚਾਈ ਦੇ ਤਿੰਨ ਪੱਧਰਾਂ ਭਾਵ 100% ਫ਼ਸਲ ਵਾਸ਼ਪ ਉਤਸਰਜਨ (ET_c), 80% ਅਤੇ 60% ET_c ਅਤੇ ਮਲਚਰ ਉਪਚਾਰਾਂ (ਚਾਂਦੀ ਰੰਗੇ ਕਾਲੇ ਰੰਗ ਦੀ ਪੌਲੀਥੀਨ ਸ਼ੀਟ ਅਤੇ ਮਲਚ ਰਹਿਤ) ਨੂੰ ਰੱਖ ਕੇ ਅਤੇ ਉਪ ਪਲਾਟ ਵਿੱਚ ਖਾਦਾਂ ਦੇ ਤਿੰਨ ਪੱਧਰਾਂ ਭਾਵ ਖਾਦਾਂ ਦੀ ਸਿਫਾਰਸ਼ ਕੀਤੀ ਮਾਤਰਾ (RDF), 80% RDF, 60% RDF ਦੀ ਵਰਤੋਂ ਕਰਕੇ ਕੁੱਲ ਅਠਾਰਾਂ ਉਪਚਾਰਾਂ ਦੀ ਵਰਤੋਂ ਕੀਤੀ ਗਈ ਅਤੇ ਰਿਵਾਇਤੀ ਵਿਧੀਆਂ ਨਾਲ ਇਹਨਾਂ ਦੀ ਤੁਲਨਾ ਕੀਤੀ ਗਈ। ਮਲਚ ਦੀ ਵਰਤੋਂ ਕਰਕੇ 100% ET_c ਉਪਰ ਤੁਪਕਾ ਸਿੰਚਾਈ ਅਤੇ 100% RDF ਵਾਲੇ ਉਪਚਾਰ ਅਧੀਨ ਵੇਲ ਦੀ ਲੰਬਾਈ, ਪ੍ਰਮੁੱਖ ਸ਼ਾਖਾਵਾਂ ਦੀ ਗਿਣਤੀ, ਫ਼ਲ ਦੇ ਔਸਤਨ ਭਾਰ ਅਤੇ ਝਾੜ ਵਿੱਚ ਵਾਧਾ ਹੋਇਆ ਜੋ ਕਿ 80 % ET_c ਤੁਪਕਾ ਸਿੰਚਾਈ ਅਤੇ 80% RDF ਵਾਲੇ ਉਪਚਾਰ ਦੇ ਸਮਰੂਪ ਸੀ। ਤੁਪਕਾ ਫਰਟੀਗੇਸ਼ਨ ਦੇ ਵੱਖੋ-ਵੱਖਰੇ ਉਪਚਾਰਾਂ ਅਧੀਨ ਫ਼ਸਲ ਦਾ ਝਾੜ 168.8 ਕੁਟਿੰਟਲ/ਹੈਕਟੇਅਰ ਤੋਂ 201.8 ਕੁਟਿੰਟਲ/ਹੈਕਟੇਅਰ ਸੀ ਜੋ ਕਿ ਰਿਵਾਇਤੀ ਵਿਧੀ ਤੋਂ ਪ੍ਰਾਪਤ ਹੋਣ ਵਾਲੇ ਝਾੜ ਤੋਂ 16 ਪ੍ਰਤੀਸ਼ਤ ਜ਼ਿਆਦਾ ਸੀ। ਸਿੰਚਾਈ ਦੀ ਡੂੰਘਾਈ ਅਤੇ ਖਾਦਾਂ ਦੀ ਮਾਤਰਾ ਵਿੱਚ ਵਾਧਾ ਹੋਣ ਨਾਲ ਗੁੱਣਵਤਾ ਦੇ ਵੱਖੋ-ਵੱਖਰੇ ਮਾਪਦੰਡਾਂ ਜਿਵੇਂ ਕਿ ਐਸਕਾਰਬਿਕ ਐਸਿਡ ਅਤੇ ਸੁੱਕੇ ਮਾਦੇ ਦੀ ਮਾਤਰਾ ਵਿੱਚ ਵਾਧਾ ਹੋਇਆ। ਹਾਲਾਂਕਿ, 80% ET_c ਤੁਪਕਾ ਸਿੰਚਾਈ ਅਤੇ 100% RDF ਉਪਚਾਰ ਅਧੀਨ ਕੁੱਲ ਘੁਲਣਸ਼ੀਲ ਸੋਲਿਡਸ (TSS) ਦੀ ਮਾਤਰਾ ਸਭ ਤੋਂ ਜ਼ਿਆਦਾ ਦਰਜ ਕੀਤੀ ਗਈ। ਆਰਥਿਕ ਮੁਲਾਂਕਣ ਤੋਂ ਪਤਾ ਚੱਲਿਆ ਕਿ ਮਲਚ ਦੀ ਵਰਤੋਂ ਕਰਕੇ ਤੁਪਕਾ ਫਰਟੀਗੇਸ਼ਨ ਵਾਲੇ ਉਪਚਾਰ ਨਾਲ ਸਭ ਤੋਂ ਜ਼ਿਆਦਾ ਮੁਨਾਫਾ (130025 ਰੁਪਏ/ਹੈਟਕੇਅਰ) ਹੋਇਆ ਜੋ ਕਿ ਰਿਵਾਇਤੀ ਵਿਧੀ ਤੋਂ 17.2 ਪ੍ਰਤੀਸ਼ਤ ਜ਼ਿਆਦਾ ਸੀ। ਇਸ ਲਈ, ਮੌਜੂਦਾ ਅਧਿਐਨ ਤੋਂ ਇਹ ਤੱਥ ਸਾਹਮਣੇ ਆਏ ਕਿ ਮਲਚ ਦੀ ਵਰਤੋਂ ਕਰਕੇ 80% ET_c ਪੱਧਰ ਉਪਰ ਤੁਪਕਾ ਫਰਟੀਗੇਸ਼ਨ ਅਤੇ 80% RDF ਵਾਲਾ ਉਪਚਾਰ, ਖਰਬੂਜੇ ਦੀ ਗੁੱਣਵਤਾ ਅਤੇ ਉਤਪਾਦਕਤਾ ਨੂੰ ਵਧਾਉਣ ਵਿੱਚ ਸਹਾਈ ਹੈ ਅਤੇ ਇਸ ਨਾਲ ਰਿਵਾਇਤੀ ਵਿਧੀ ਦੇ ਮੁਕਾਬਲੇ ਇਸ ਉਪਚਾਰ ਨਾਲ 80.85% ਪਾਣੀ ਅਤੇ 20% ਖਾਦਾਂ ਦੀ ਬੱਚਤ ਹੁੰਦੀ ਹੈ।

ਮੁੱਖ ਸ਼ਬਦ: ਤੁਪਕਾ ਸਿੰਚਾਈ, ਖਾਦ ਪਾਉਣਾ, ਮਲਚ, ਖਰਬੂਜਾ, ਫ਼ਸਲ ਵਾਸ਼ਪ ਉਤਸਰਜਨ

ਪ੍ਰਮੁੱਖ ਸਲਾਹਕਾਰ ਦੇ ਹਸਤਾਖਰ **ਵਿਦਿਆਰਥੀ ਦੇ ਹਸਤਾਖਰ**

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CHAPTER I

INTRODUCTION

Muskmelon (*Cucumis melo* L.) is one of the most important commercial cucurbit, cultivated in both tropical and sub-tropical regions of the world. Muskmelon belongs to genus *Cucumis* and family *Cucurbitaceae* with a chromosome number of 2n=24. Around the globe, muskmelon ranks third among the cultivated cucurbits after watermelon and cucumber (Nunez-Palenius *et al* 2008). Both south-eastern Africa and peninsular India have been considered as place of origin of muskmelon (Mallick and Masui 1986).

In India, melons covered an area of about 54 thousand ha with a production of 1231 thousand MT (Anonymous 2018). Muskmelon is mainly cultivated in Tamil Nadu, Uttar Pradesh, Punjab, Gujrat, Telangana, Maharashtra and Andhra Pradesh. In Punjab, area under muskmelon is about 5.67 thousand ha with an average production of 100.90 thousand MT (Anonymous 2019a).

Muskmelon is juicy, musky, beautifully coloured and very tasty fruit with both nutritive and medicinal values (Milind and Kulwant 2011). Melons are rich source of essential nutrients such as vitamin A (beta-carotene), C and K with very low content of fat and sodium (Lester 1997). Ripened fruits of melons are very much beneficial in curing diseases related to human kidneys. Seeds of the fruit are diuretic and nutritive whereas pulp of the fruit is beneficial to cure chronic or acute eczema (Rahman *et al* 2008). Melons ensures in promoting individuals health and reducing the risk of cancer and some chronic diseases (Lester 1997).

The productivity of melon crop highly depends upon the agronomic practices followed during the cultivation, out of which, irrigation and nutrient management plays an important role. It is accepted that total amount of irrigation water applied have great impact on production and quality of muskmelon (Fabiero *et al* 2002). An excessive amount of irrigation applied have resulted in effect on marketable yield in a negative direction, majorly due to increased number of rotten fruits (Pew and Gardner 1983) whereas smaller fruits (Fabeiro *et al* 2002, Long *et al* 2006) and lower yields (Kirnak *et al* 2005 and Sensoy *et al* 2007) were observed under water deficit conditions. Along with the yield and crop productivity, fruit quality is also considered to be an important parameter. Quality of muskmelon is majorly influenced by total soluble solids i.e. TSS. There is well established relationship between muskmelon quality and soil moisture regime. Late fruit development stage is the critical period for the accumulation of sugars in melons. Excess or deficient irrigation at this stage tends to reduce the soluble solids content in melons (Long *et al* 2006). Therefore, to improve the yield, quality and to conserve water, optimum amount of water application to muskmelon plants is utmost important (Mirabad *et al* 2014). Conventional irrigation method is most widely accepted method all over the world for producing melons (Mustafa *et al* 2003) but water use efficiency (WUE) in this method is very low as major proportion of irrigation water is lost by runoff, deep percolation and surface evaporation. In order to improve water use efficiency (WUE), nutrient use efficiency (NUE), yield and quality in muskmelon, drip fertigation and mulching can play important role.

Drip irrigation, also known as trickle irrigation, saves water and fertilizers both by allowing the water and nutrients to emit slowly only in the root zone of the plant (Yohannes and Tadesse 1998). The work done on drip irrigation revealed that beside improved yield and water saving, drip irrigation is very effective in improving the quality of vegetable crops (Sivanappan 1994). Drip irrigation saves water to the degree of 50 to 60 per cent, decreases the inter-cultivation cost by 30 to 40 per cent, increase the yield by 15 to 20 per cent and enhances the harvest quality (Kumar 2013, Kulecho and Weatherhead 2005, Narayanamoorhty1997; 2003, Qureshi *et al* 2001 and Verma *et al* 2004). Improved growth, increased fruit weight and size along with earliness have been observed under drip irrigation system in muskmelon (Leskovar *et al* 2001, Hartz 1997 and Bhella 1988). Nutrients can also be applied along with the irrigation water and hence known as fertigation. Fertigation has the potential of supplying optimum mixture of nutrients into the plants root zone, thus, resulting in higher productivity and good quality of the produce. High fertilizer use efficiency, uniform distribution of nutrients into the soil, decreased volatilization of nitrogen from soil surface are some of the advantages of fertigation (Papadopoulos 1985). Enhanced responses of vegetable crops to fertigation have been observed in tomato, lettuce, potato, pepper and many more (Clough *et al* 1990, Bar-Yosef and Sagiv 1982, Mohammad *et al* 1999 and Qawasmi *et al* 1999).

Mulching combined with drip irrigation and fertigation can be helpful in increasing the efficiency of the individual systems (Tiwari *et al* 2003). Mulching is the process of covering the soil so as to make favourable conditions for the plant growth. Mulching is one of the agricultural practices which proves to be beneficial for increasing the water use efficiency of the crop (Rashidi and Keshavarzpour 2011). Drip irrigation can also be used along with mulching to further improve the water use efficiency (WUE) for the production of muskmelon. Mulches are basically organic and inorganic in nature. Leaves, compost, straws are organic in nature whereas plastic mulches are categorized under inorganic mulches. Plastic mulches are available in different colours but their usage mainly depends upon the purpose and climatic conditions. Some of the advantages of using mulch includes reduced leaching of nutrients, lower soil evaporation, suppression of unwanted plants, increasing/decreasing the temperature of soil surface and conserving the soil moisture (Lamont 2005, Kumar and Lal 2012 and Ban *et al* 2009). Use of plastic mulches in vegetable production have resulted in early and higher yield of the crop (De Pascale *et al* 2011, Ban *et al* 2009 and Hochmuth *et al* 2012).

Thus, drip irrigation, fertigation and mulching may improve water and nutrient use efficiency along with muskmelon production and quality. Under Punjab conditions, no such study indicating the effects of drip irrigation, fertigation and mulching in muskmelon have been reported. Thus, by keeping in view the above benefits, the present research was carried out to obtain the following objectives:

a) To find out the optimum moisture regime for muskmelon under mulch and drip irrigation.

b) To find out the optimum level of NPK fertilizers for growth, yield and quality of muskmelon.

c) To find the economic viability of drip fertigation system along with usage of mulch.

CHAPTER II

REVIEW OF LITERATURE

Efforts are made to present a brief summary of studies related to the investigation carried out in the field at various places under the subheads:

- Effect of drip irrigation on growth, yield and quality
- Effect of fertigation on growth, yield and quality
- Effect of mulch on growth, yield and quality
- Integrated effect of drip irrigation, mulch and fertigation
- Effect of drip irrigation and mulch on water use efficiency
- Economics of drip irrigation, fertigation and mulch

2.1 Effect of drip irrigation on growth, yield and quality

With the increasing population, the availability of water resources is decreasing day by day and efficient usage of such resources is of utmost importance. Now a days, drip irrigation is becoming popular for the production of vegetable crops and it has been observed 40 per cent lesser usage of water with this method of irrigation compared to other methods of irrigation (Tyson and Harrison 2009). Many losses such as runoff, deep percolation and evaporation can be minimized and greater efficiency in using water can be achieved. Production of muskmelons is highly affected by amount of irrigation water applied (Fabeiro *et al* 2002). Water should be supplied according to the crop requirements in muskmelon, as, remarkable effect on the marketable yield in a negative way have been observed (Pew and Gardner 1983). Small fruit size and lower yield are the outcomes when lesser irrigation water than the crop requirement is supplied to the crop. In addition to this, soluble solid content in the fruits also gets affected, thereby, decreasing the quality of the produce. Excess or deficient irrigation tends to reduce the soluble solids content in melons (Long *et al* 2006). In order to improve the production, quality and water usage efficiency, drip irrigation should be adopted. Complete information regarding the water requirements of the crop and water holding capacity of the soil is required to manage the water application in crops produced by trickle irrigation technology. While adopting this technology, special attention should be given, as, irrigation in excess results in leaching down of nutrients beyond the root zone, whereas, deficiency of moisture in the soil leads to stress in crop.

Improved plant growth, increased fruit size and early fruit yield have been observed when muskmelon is grown under drip irrigation system (Hartz 1997 and Leskovar *et al* 2001). Drip irrigated melon plants tends to produce higher yield (upto 35 per cent), higher soluble solids content and higher titrable acidity in fruits (Antunez *et al* 2011). Hartz (1997) conducted an experiment to investigate the effects of drip irrigation on the yield and quality of muskmelon and observed that marketable yield, fruit size and per cent of cull fruit was unaffected by drip irrigation and good quality fruits with equal amount of total soluble solids. Zeng *et al* (2009) studied the appropriate irrigation water amounts for melons growing under green-house conditions. Four different irrigation levels i.e. 100, 90, 80 and 70 per cent were applied for different treatments based on the percentage of field water capacity. Sufficiently greater impact was found on plant growth, fruit production and quality under different irrigation water amounts. Plant height and stem diameter decreased from T100 to T70 whereas quality of the fruit was found to be best under T90 treatment. Li *et al* (2012) and Yi *et al* (2012) conducted an experiment with different levels of irrigation in muskmelon under greenhouse conditions and observed that the plant growth, production of the fruits and their quality were significantly affected by different levels of irrigation. Increasing the level of irrigation tends to increase the leaf area, yield, dry weight, number of leaves and height in cantaloupes (Mirabad *et al* 2014). Rudich *et al* (1977) reported that the impact of irrigation was not that much at vegetative growth, flowering and fruit set stage. However, irrigation at fruit development stage (which continued for 1.5 months) resulted in increasing yield of muskmelon, but the quality of fruit remain unaffected. Fabeiro *et al* (2001) studied the effect of controlled deficit irrigation in muskmelon crop at blooming, setting and ripening stage and reported that lowest production was observed in the treatment which suffered from deficit at blooming stage and the produce of the crop was mainly affected at this stage and both quality and quantity of the produce was affected when the crop suffered stress at the setting stage whereas at ripening stage, only quality was found to be affected i.e. sugar content was not desirable. Yi *et al* (2012) further reported that thickness of the flesh, soluble sugars, total soluble solids, free amino acid content, ascorbic acid content and soluble protein content were remarkably affected by different irrigation levels. The impact of water deficit stress levels on growth, sugar content and yield in muskmelon was observed and it was demonstrated that different deficit irrigation treatments have notable impact on height, dry weight, leaf area, yield, sugar content and number of leaves per plant. Lester *et al* (1994) studied about the impact of pre-harvest drip irrigation schedule on post-harvest quality of muskmelon cultivar and found that method of irrigation doesn’t showed any greater impact on the post-harvest quality of melons, but the application time showed significant impact. Melons irrigated 4 days prior to harvest produced fruits with lower soluble solids content, greater volume and greater moisture content.

Drip irrigation have also been reported to improve yield, quality and growth in other cucurbits. A comparative study between drip irrigation and conventional basin method of irrigation conducted by Gebremedhin (2001) revealed increment in yield by 20 per cent along with 37 per cent saving of irrigation water in oriental pickling melon. Simsek *et al* (2004) and Rouphael *et al* (2008) studied the effects of different levels of irrigation on yield and yield attributing characters of watermelon. They reported significant reduction in yield when the application of irrigation water was reduced. Accelerated development of seedling resulting in early yield in cucumber was observed by Kunzelomann and Paschold (1999) in a comparative study between drip and sprinkler irrigation system. They also reported that 50 per cent saving of water and yield of about 547 tonnes per hectare was observed under drip irrigation compared with sprinkler system of irrigation, showing yield around 400 tonnes per hectare. Higher yield from drip irrigated cucumber compared with furrow irrigated plant was also reported by Guler and Ibrikci (2002). Simsek *et al* (2005) conducted an experiment to study the effect on yield components in cucumber under different levels of irrigation. They reported highest fruit yield under treatment with Irrigation water/Cumulative pan evaporation (IW/CPE) ratio of 1.00 and also concluded that yield was significantly reduced with reduction in irrigation water regime. Zhang *et al* (2011) conducted an experiment to compare subsurface drip irrigation scheduling in cucumber. They found that yield of cucumber significantly increase with increase in amount of irrigation water applied. However, vitamin C content and soluble solids sugar were found to decrease with increase in water application.

Drip irrigation have furthermore been represented to improve yield, quality and advancement in other vegetables moreover. Gupta *et al* (2010) reported noteworthy impact on different development and yield traits of tomato hybrid SH-TH-1 with trickle water system and fertigation treatments. Among the irrigation levels (100, 80 and 60 per cent ETc), 80 per cent delivered greatest plant stature (130.1 cm), number of branches per plant (8.4), average fruit weight (49.8 g) and yield (89.3 t ha^{-1}). Yadav and Choudhary (2012) explored that drip irrigation treatment demonstrated essentially better growth in plant development over flood irrigation in tomato. Among different levels of drip irrigation, 85 per cent ET_c delivered most extreme plant stature (88.9 cm) and number of branches per plant (10.7). Bahadur *et al* (2006) revealed that 100 per cent ET_o recorded the highest number of fruits (35.2), fruit weight (151.3 g), fruit yield (4 kg per plant) and marketable fruit yield (63.8 t ha^{-1}) in tomato. Increased tomato yield by 8-15 per cent and increase in number of fruits by 12-14 per cent was observed by Ngouajio *et al* in (2007) under the trickle irrigation system. Significantly higher production of dry matter and fruit yield have been observed in tomato under drip system (Hebbar *et al* 2002). Yadav and Choudhary (2012) researched the impact of trickle water system in tomato and found essentially better execution in yield traits and yield than conventional irrigation. Among the different irrigation levels, drip at 85 per cent ET_c resulted in better performance. Drip irrigation system with 100, 85, 70 and 55 per cent of ET increased the fruit yield by 42.8, 44.3, 36.9 and 25.2 per cent, individually, over surface irrigation system. Kahlon *et al* (2007) assessed the impact of drip and furrow system on tomato under two different levels of irrigation (IW/CPE=1.0 and 0.7). Results demonstrated that IW/CPE=1.0 recorded highest fruit weight (48.0 and 42.2 g) and yield (84.5 and 78.9 t ha^{-1}) when contrasted with IW/CPE = 0.7 and furrow system (IW/CPE=1.0 and 0.7) during both the years. Increase in TSS content in tomato at 60 per cent ET_c level in tomato was reported by Al- Qerem *et al* (2012).

Antony and Singandhupe (2004) studied the impact of drip irrigation on yield, growth and water use efficiency (WUE) of capsicum and demonstrated that improvement in root length, root fineness, plant height, more number of branches and yield was observed under the drip system when compared to other methods of irrigation. They also reported that more yield, more plant height and more number of branches can be obtained when crop is irrigated at 100 per cent level of drip irrigation. Kumar *et al* (2006) considered the impact of variable irrigation system and fertigation on yield, WUE and net returns in potato and announced that the most astounding tuber yield (29.3 t ha^{-1}) was recorded with trickle water system at 1.20 IW/CPE, though the least tuber yield (19.2 t ha^{-1}) was recorded at 0.60 IW/CPE ratio. Bisht *et al* (2012) demonstrated that maximum tuber yield (39.4 t ha^{-1}) was acquired under treatment 80 per cent ET.

Remarkable effect on the marketable yield of bulb crops i.e. onion and garlic have been reported under different levels and methods of irrigation, of which, drip irrigation at 100 per cent level resulted in the maximum yield (Anonymous 2001). Shankar *et al* (2010) preformed an experiment to study the impact of different methods of irrigation i.e. drip, sprinkler and surface on yield and growth in bulb crops and showed that application of water through drip system resulted in highest yield. Bagali *et al* (2012) uncovered that, among the various levels (60, 80 and 100 per cent E_{pan}), 100 per cent E_{pan} recorded higher bulb yield (50.9 t ha^{-1}) in onion more than 80 (47.2 t ha^{-1}) and 60 per cent (38.16 t ha^{-1}) pan evaporation. Expanded bulb yield with 100 per cent E_{pan} might be credited to huge increment in yield ascribing characters. They also reported that 100 per cent of E_{pan} recorded essentially higher plant stature (66.6 cm), number of leaves (9.6), leaf region (506.2 cm^2), leaf area index (LAI) (4.5) and neck size (1.3 cm) of onion when contrasted with 60 and 80 per cent E_{pan}.

Drip irrigation system of cabbage at 100 per cent of E_{pan} recorded fundamentally most noteworthy plant stature (19.4 cm), number of leaves (13.1) per plant, head diameter (13.1 cm), net head weight (1.7 kg), gross head weight (1.2 kg) and head yield (30.6 t ha^{-1}) when contrasted with other levels (40, 60 and 80 per cent E_{pan}) and furrow irrigation (1.2 IW/CPE) (Kumar and Sahu 2013). Gupta *et al* (2009) announced that 80 per cent ET through drip was discovered better over others with highest yield per plot (13.2 kg) and yield per hectare (20.3 t ha^{-1}) in broccoli. 100 per cent ET_c irrigation level resulted in high TSS value in lettuce (Acar *et al* 2008).

2.2 Effect of fertigation on growth, yield and quality parameters

Application of fertilizers and irrigation are two of the factors having utmost importance, as quality and yield of the crop cultivated is notably affected (Goldberg *et al* 1976, Dasberg and Bresler 1985 and Bar-Yosef 1999). Applying the fertilizers according to the crop needs and at proper growth stage, proper placement of the fertilizers in the most efficient manner holds a considerable importance, but, our traditional methods of fertilizer application are not able to improve fertilizer use efficiency (FUE) and posseses some serious limitations. Nutrients loss due to leaching, fixation and volatalization are some of the drawbacks of applying fertilizers through traditional methods. In addition to this, excessive leaching of nutrients leads to groundwater pollution, leading to a major concern for the environment (Papadopoulos 1995). In order to overcome these limitations, fertigation play an important role. Dissolving the fertilizer into the irrigation water and delivering it to the plant root zone area through irrigation system is refers to as the process of fertigation (Hagin and Lowengart 1995). Application of the mineral nutrition precisely, both spatially and temporally, can be achieved through application of fertilizers along with the irrigation water. The very first application of this operation, scientifically, was done in U.S.A with the help of sprinkler system of irrigation (Bryan and Thomas 1958) while drip fertigation was practiced in tomato in Israel (Sagiv and Kafkafi 1976). Generally, higher efficiency of the nutrients usage, in terms of more nutrient recovery by the plants, with much higher results (upto 90 per cent) when compared with other methods of fertilizer application (40-45 per cent) have been remarkably noticed under fertigation process (Agostini *et al* 2010 and Solaimalai *et al* 2005). Additionally, fertigation allows for higher yield, good quality produce and environment conservation. Sandal and Kapoor (2015) reviewed the work done regarding fertigation in different vegetable crops like cucumber, brinjal, chilli and reported 25-40 per cent saving of fertilizer along with more returns and reduced nutrient leaching. Yield increment of about 8-41 per cent have been observed in horticulture crops due to fertigation (Singh *et al* 2010). Usage of poor quality fertilizers and improperly designed irrigation systems results in disadvantages of the fertigation process (Koo 1980).

Harnandez and Aso (1991) observed increased weight of the fruits (1.1kg) and higher yield (29.83 t ha^{-1}) in melons when NPK @ 70 kg, 60 kg and 90 kg respectively, were applied along with the irrigation water. Greater fruit production seasonly, have also been reported in muskmelon when potassium (K) was applied with irrigation water in comparison with pre plant application. Higher yield was also observed by Raman *et al* (2000) in gherkins when 75 per cent recommended dose of fertilizer (RDF) was applied through drip irrigation system. Application of nitrogen through fertigation was found to increase fruit yield, number, weight and length significantly in watermelon (Alkhader *et al* 2019). They reported maximum yield in 100 per cent RDF treatment, which was statistically at par with 75 per cent RDF treatment. Application of NPK fertilizers through fertigation in cucumber was found to increase yield of the crop, which was about 81.2 per cent higher over the control (Choudhari and More 2002). Al- Wabel *et al* (2006) also reported that nitrogen fertigation was more effective over the conventional method for improving the yield of cucumber under greenhouse conditions. Beyaert *et al* (2007) conducted an experiment in cucumber with different methods of irrigation and fertilizer application and concluded that drip irrigation along with fertigation resulted in increased dry matter content, fruit yield and economic returns. Sikarwar and Hardaha (2016) conducted a study with four different fertigation treatments viz. (60, 80, 100 and 120 per cent RDF) and found maximum height under 120 per cent RDF whereas number of fruits and yield was found to be highest in 100 per cent RDF in cucumber. Application of micro and macro nutrients in bitter gourd at 100 per cent RDF through drip irrigation was found to increase the growth rate of the crop (Meenakshi and Vadivel 2005). Meenakshi *et al* (2007) reported improvement in growth and quality attributes in bitter gourd when macro and micro nutrients were applied along with irrigation water. Singandhupe *et al* (2006) reported that maximum fruit yield in pointed gourd was obtained when fertilizer was applied with irrigation water at 80 per cent RDF. They also reported that yield was similar to treatment when 100 per cent RDF was applied using soil application. Singandhupe *et al* (2007) reported saving of 25 per cent fertilizer through the process of fertigation in pointed gourd.

Application of fertilizers along with irrigation water have also been reported to improve growth, yield and quality parameters in other vegetables. More efficient utilization of nitrogen and higher yield of tomato and egg plant was found when applied along with the irrigation water (Papadopoulos and Ristimaki 2000). Higher yield in tomato and lesser number of plants with blossom end rot disorder was reported by Tu *et al* (2000) when drip fertigation was adopted. Mahajan and Singh (2006) conducted an experiment to study about the response of greenhouse grown tomatoes to irrigation and fertigation. They reported that drip irrigation at 0.5 pan evaporation along with fertigation at 100 per cent N recommended dose of fertilizer resulted in increased TSS i.e. upto 5.7 °Brix in the fruit. Increased TSS can be attributed to lesser amount of water application, resulting in more sugar import via phloem was concentrated. Pawar *et al* (2013) examined the impact of water soluble fertilizers (WSF) with drip water system on development, yield and quality of tomato cultivar ‘Vaibhav’ when compared with conventional method. They found that highest plant stature (228 cm), number of branches/plant (13) and plant spread (78.8 cm) were seen in 100 per cent WSF which was statistically at par with 80 per cent WSF, though, the conventional method delivered the minimum plant stature (199.6 cm), number of branches per plant (9.7) and plant spread (67.4 cm). Gupta *et al* (2010) found that, fertigation at 60 per cent of prescribed NPK through fertigation recorded greatest plant stature (132.4 cm), number of essential branches per plant (8.2), number of fruits per plot (1456) and average fruit weight (48.4 g) in tomato. Prabhakar *et al* (2012) found that fertigation treatments brought about better tomato development as shown by higher plant tallness, number of branches per plant when contrasted with conventional method. Pandey *et al* (2013) explored the impact of nitrogen fertigation on yield of chilli. Increment in yield of chilli were observed by Veeranna *et al* (2001). The fertigation of nitrogen had recorded 34.5 per cent higher yield when contrasted with top dressing method of fertilizer application.

Improvement in yield and yield attributing parameters like plant height, number of umbels per plant, number of umbels per plot, diameter of umbels was reported by Bhakare and Fatkal (2008) in onion on application of 125 per cent RDF with irrigation water. Savitha *et al* (2010) reported that utilization of 75 per cent RDF recorded the highest plant stature (55.4 cm), number of leaves per plant (8.8) and root length (6 cm) trailed by 100 and 125 per cent RDF respectively in onion. Brahma *et al* (2010a) considered that the impact of various nitrogen levels fertigation on development and yield characteristics of broccoli and uncovered that 100 per cent fertigation of recommended dose of nitrogen (200 kg ha^{-1}) delivered the most astounding plant stature, leaves per plant, plant spread and head diameter over conventional method, keeping pace with 80 per cent fertigation level of recommended dose of N. Fertigation with 150 per cent recommended dose of nitrogen (RDN) brought about higher yield of cabbage head (29.7 tons ha^{-1}) over other nitrogen levels (25, 50, 75, 100 and 125 per cent RDN). This expansion in yield may be credited to higher plant height (19.6 cm), gross weight (1.6 kg), net weight (1.3 kg) (Kumar and Sahu 2013). Increase in marketable yield of cauliflower by 21.3 per cent with fertigation compared to conventional method of fertilizer application was reported by Kapoor *et al* (2014). Patel and Rajput (2004) found that 40 per cent saving of the fertilizer can be achieved if applied through fertigation without any significant impact on the yield of okra crop.

2.3 Effect of mulching on growth, yield and quality parameters

Mulching can be defined as a protective covering, organic (grass mulch, straw mulch) or inorganic (polythene sheets) in nature, which offers barrier against loss of moisture and nutrients, unwanted plants, and various stresses such as biotic and abiotic, resulting in positive impact on plant establishment and yield (Mugalla *et al* 1996). Improvement in physical, chemical and biological properties of soil, leading to more addition of nutrients into the soil have been observed under mulch conditions. Mulching leads to increase in soil temperature, resulting in fast growth and earliness in crop (Clarkson and Frazier 1957). Vegetable crops developed under plastic mulches have resulted in 7 to14 days earlier and expanded yield to multiple times over vegetable crops developed on uncovered soil (Lamont 1993). A general rise in the growth of the crops like tomato, brinjal and pepper by 21-28, 16-32 and 19-39 per cent respectively was reported by Pakyurek *et al* in (1994) under mulch application. Mulching has huge impact on yield and economics of production and depends on climatic conditions and type of mulch material used and market demand. Natural or synthetic soil mulches impact the crop in various ways, moreover it altogether increases yield and quality of the crop. Wein and Minotti (1988) announced that development, yield and assimilation of nutrients are influenced by mulch application.

Beneficial effects of mulching on muskmelon production have been reported by various workers. Increased weight of fruits i.e. 1.09 kg was reported by Hemphill and Mansour (1986) when mulching technology was adopted for muskmelon cultivation. TSS of about 11.44 °Brix have been reported in muskmelon under transparent mulch (Vani *et al* 1989). Also, increase in TSS content under mulch application in muskmelon when compared with no mulch conditions was reported by Mohamedien *et al* (1992). Thicker and stronger plants with good quality and earliness by 20 days was reported in muskmelon, brinjal, pepper, tomato, watermelon and cucumber (Immirzi *et al* 1998). Taber (1993) concluded that early production in muskmelon can be achieved using the plastic mulches along with the beneficial effects on yield. Loy and Wells (1975) observed earliness in flowering of pistillate flowers in muskmelon hybrids under black plastic mulch conditions. Additionally, experimental hybrids also showed earliness in flowering with mulch covers when compared with commercial hybrids. Maturity was about seven days sooner for the commercial hybrids and 12-13 days sooner for the experimental hybrids with dark polyethylene mulch. Ibarra *et al* (2001) carried out an experiment to study the impact of plastic mulch on plant biomass, development parameters, and yield of muskmelon plants (*Cucumis melo* L.) and reported that plants developed utilizing soil mulch exhibited higher estimations of plant biomass, early and higher yield. Gerber *et al* (1982) discovered earlier and superior quality of muskmelon produce (*Cucumis melo* L.) with the usage of row covers and plastic mulch. Munguia *et al* (1998) studied the spatial distribution of solutes and water in soil profile and its relation with the crop growth under plastic mulch in muskmelon and found that under mulch, concentration of solutes and soil moisture, which in turn favours the plant growth was higher. Length of the shoot was also found to be significantly high under mulch treatment over the control. TSS was also reported to be high with application of mulch. Weibe (1973) reported considerable earliness in flowering under plastic mulch application. They also reported lower content of

TSS under the un-mulched treatment. Greater yield under the mulch treated plots was reported by Lamont *et al* (1993) in muskmelon.

Mulching have additionally been accounted for to improve yield, quality and development in different cucurbits. An experiment was conducted by Parmar *et al* (2013) to study the influence of mulching on yield, growth and quality in watermelon. They concluded that growth of the plant, yield and quality characters were positively influenced under silver or black plastic mulch. Nwokwo and Aniekwe (2014) reported increase in soil moisture content which in turn increased yield in watermelon under the application of mulch. Andino and Motsenbocker (2004) conducted an experiment on watermelon to consider the impact of different coloured mulches on development of watermelon and inferred that there was increment in vine length of the mulched plots when contrasted with uncovered plots. Parmar *et al* (2013) reported superiority in terms of growth, yield and quality in watermelon when compared with bare soils. Bhella (1988) found that drip irrigation and mulching, individually or combined, results in higher and early yield in watermelon. Higher fruit yield under plastic mulches compared to untreated plots or straw mulch covered plots was reported by Qadir (1992) in watermelon. Baker *et al* (1998) also reported increment in yield and yield components in watermelon under the application of polyethylene mulch. Maged and Nemar (2006) revealed higher vegetative growth, leaf area and dry weight in cucumber under the black plastic mulch when contrasted with silver and transparent mulches. Hallidri (2001) revealed that plant stature and number of leaves were higher in black and transparent polythene mulch than control (uncovered soil) while no significant distinction was seen in case of stem diameter in cucumber. Spizewski *et al* (2010) observed no significant differences in the total and marketable yield of fruits, dry matter content and total carbohydrate content when cucumber was grown under mulched and non-mulched conditions. However, the efficiency of irrigation was found to be higher in the soil, mulched with black polyethylene sheet than non-mulched soil. Wolfe *et al* (1989) found that cucumber (*Cucumis sativus*) showed a positive increment in earliness and total yield when both row covers and plastic mulch was used. Hallidri *et al* (2001) reported that plant height and number of leaves were found to be significantly increased with mulch application in cucumber. Mahadeen (2014) studied the effect of black plastic mulch on growth and yield of summer squash and reported that early and overall yield was notably increased when grown under mulch conditions. Likewise, weight of the fruit, dry weight and fruit number also gets increased. Gordon *et al* (2010) reported that dark mulch colours, black and blue polythene mulches resulted in highest earlier and total yield respectively in *Cucurbita pepo*. Black plastic mulches were also found to increase plant height (38.11 cm), plant spread (142.39 cm), total number of leaves per plant (41.85), yield (62.72 t ha^{-1}) and root length (36.83 cm) in summer squash (Bhatt *et al* 2011).

Khan *et al* (2015) studied the impact of different mulching material on growth and yield attributing characters of sponge gourd and found superiority in characters with mulch application when compared with control (no mulch) treatment.

Valuable impacts of mulching on other vegetables have been accounted for by different specialists. Agarwal *et al* (2010) reported a positive impact on flowering, vegetative growth and quality attributes in tomato when red coloured plastic mulch was used. Additionally WUE was also found to be best under the red mulch conditions. Increased number of branches and leaves were observed by Rajablariani *et al* in (2010) in tomato. Changes in temperature of the root zone under mulch conditions, leads to better uptake and transport of the nutrients, leading to increased root shoot ratio in tomato crop (Tindall *et al* 1990). Moursy *et al* (2015) found notable increase in the vegetative characters of tomato. Early flowering and better establishment of the crops is the result of growing vegetable crops under black plastic mulch (Djigma and Deimkouma 1986). Wahome *et al* (2005) found that tomato plants mulched with grass accomplished higher tallness pursued by dark polythene sheet and the most reduced plant stature was seen in the non-mulch plants. Likewise, Hudu *et al* (2005) watched a noteworthy increment in plant stature in mulched tomatoes when contrasted with plants developed on exposed soil. Hassan *et al* (2005) reported that plant stature, number and length of roots, dry weight of roots and number of flowers were fundamentally higher in plants developed on mulch when contrasted with exposed soil in tomato. Ojeniyi *et al* (2007) reported that cocoa husk increased number of branches of tomato plant. Increase in tomato yield from 20.7 to 29.8 per cent was reported by Singh and Kamal (2012) when grown under black polythene sheets. Amid preliminaries led on tomato grown on papered mulch plots, the first picking of tomato crop was twelve days sooner in Russia when contrasted with bare plots (Diev 1985). As indicated by Gandhi and Bains (2006) tomato plants grown under straw mulch resulted in highest fruit weight. Wahome *et al* (2005) found that highest number of fruits per plant and most noteworthy yield per hectare was seen in tomatoes that were mulched with grass pursued by those mulched with dark polythene. In a similar investigation, it was seen that plant mulched with grass and dark polythene sheet had higher fruit mass and duration of harvesting was longest when tomatoes were mulched with grass. Znidarcic *et al* (2004) inferred that higher tomato yield were accounted when dark plastic mulch and row covers were utilized together. This increase can be attributed to increment in air and soil temperatures around the plant developing conditions and thus enhancing stand establishment. Trials led by Standen (1980) on tomato reported the first picking nine days sooner in Canada. The hotter conditions under paper mulch would have been the possible reasons under early ripening. Thakur *et al* (2000) revealed that plant height, leaf area, leaf area index (LAI), number of flowers and fruit yield was considerably higher under mulch conditions compared with un-mulched ones upto 75 per cent water deficits in capsicum. Under mulch conditions, availability of cleaner bell pepper gets increased (Brown and Butcher 2001). Increased content of vitamin C was observed under mulch application in chilli by Ashrafuzzaman *et al* (2011). Hassan *et al* (1994) reported the beneficial effects of mulching in chilli production and concluded that increased height in mulched plants may be related to soil moisture content. Venkanna (2008) recorded number of branches at various phases of yield development in chilli and observed significantly higher branch number with utilization of glyricidia mulch over no mulch. Sekhon *et al* (2008) demonstrated that chilli plants developed in straw mulch produce higher yield when contrasted with the non-mulched plants. Panchal *et al* (2001) found that mulch had huge impact on chlorophyll content in chilli and dark coloured plastic mulch was the best among the mulches. Mahmood *et al* (2002) studied the effect of mulching in potato with five different treatments i.e. white polythene sheet, black polythene sheet, perforated black polythene sheet, grass and bare soil and observed that emergence of the crop is affected in a positive direction on mulching, with highest emergence recorded in white polythene sheet (78.5 per cent). Highest growth rate and yield was also observed under white polythene sheet. Chandra *et al* (2002) found increased potato yield under mulching. On application of pine mulch in potato, tuber weight, number of tubers per plant and total yield was increased to 0.29 kg, 5.4 and 222.7 q/ha respectively.

Bulb crops such as onion also responded positively in terms of plant height and number of leaves per plant, with black polythene mulch at the top, followed by transparent polythene mulch and water hyacinth (Anisuzzaman *et al* 2009). Antonious and Kasperbauer (2002) found greater concentration of phenolics in carrot when grown under black and yellow plastic mulches. They also reported higher β-carotene and ascorbic acid content was observed under white and yellow coloured mulches when contrasted with other colours or non-mulched soil. Growing vegetable crops under mulch conditions leads to lesser damage and thereby, improves the quality of the crop. Growing of turnips in green and blue coloured plastic mulches leads to sweet and sharp taste, respectively (Antonious *et al* 1996). Better results in context of TSS, chlorophyll content and total sugars were reported by Franquera (2015) in lettuce. Mohammed and Mamkagh (2009) found double increase in total yield and fruit number in okra (*Abelmoschus esculenus*).

2.4 Integrated effect of drip irrigation, mulch and fertigation

Imamsaheb *et al* (2014) reported positive impacts on growth, yield and quality of different vegetable crops under drip irrigation and fertigation. High WUE and FUE, lesser N losses due to leaching, application of nutrients directly into root zone of the crops, reduction in application cost are some of the beneficial effects of using the combination of drip irrigation and fertigation (Solamalai *et al* 2005). Cabello *et al* (2008) conducted an experiment to study the impact of different irrigation and nitrogen rates on yield and quality of muskmelon. They found significant interaction between irrigation and nitrogen for fruit weight, WUE and crop yield. Combination of water application @ 100 per cent ET_c with nitrogen @ 93 kg ha^{-1} resulted in best yields. Majid and Fereydoun (2011) investigated the effects of different methods of irrigation on crop yield and yield components of muskmelon. Treatments comprised of surface irrigation, drip irrigation and drip irrigation + mulching. Combination of drip irrigation and mulching resulted in highest values for fruit weight, yield and thickness. Abumani *et al* (2017) studied the water profitability and productivity of growing melons under drip irrigation, fertigation and mulching. They reported that drip fertigation along with mulching with polyethylene sheets results in high yield and quality characters. High fruit yield in melons was observed under drip fertigation + mulching. Mulching in combination with sub surface drip irrigation in muskmelon resulted in increased fruit mass, yield, growth rate, fruit diameter and thickness of pulp (Rodrigo *et al* 2008). Alenazi *et al* (2015) reported higher production of muskmelon cultivar 'Velta' with drip irrigation at 100 per cent ET_c level along with mulch application.

Reddy *et al* (2018) reported highest yield and fruit weight when combination of drip irrigation (80 per cent ET_c) and mulch was used. Yaghi *et al* (2013) found that combination of transparent mulch with drip irrigation resulted in high yield i.e. 63.9 t ha^{-1} in cucumber when compared with surface irrigation treatment. This increase can be attributed to increased soil moisture and temperature, leading to improved vegetative growth and hence productivity. Impact of different type of mulches along with different levels of drip irrigation on performance of bottle gourd was studied by Deshmukh *et al* (2013). They reported maximum yield was observed in black plastic mulch along with 80 per cent level of drip irrigation. Singh *et al* (2009) found increment in yield of tomato crop when drip irrigation + mulching was used.

Drip irrigation @ 0.5 pan evaporation with fertigation of nitrogen at 100 per cent RDF resulted in increased fruit yield in tomato (Mahajan and Singh 2006). Singandhupe *et al* (2003) found that 20-40 per cent saving of nitrogen is possible when applied through trickle irrigation system in tomato. Enhanced uptake of nitrogen i.e. about 8-11 per cent was also reported under drip system. Application of water through drip system @ 80 per cent ET and fertigation with 60 per cent RDF leads to remarkable increase in fruit yield (989.3 q/ha). However, biochemical parameters i.e. ascorbic acid, lycopene content, TSS was found to be improved under 80 per cent ET through drip system with 80% RDF of NPK (Gupta *et al* 2015). Drip system + polythene mulch (black) increased fruit yield in tomato (57.87 t ha^{-1})

when compared with drip system alone (45.57 t ha^{-1}). Combination of both also resulted in high water use efficiency (1.23 t/ ha-cm) (Singh *et al* 2009). Paul *et al* (2013) found that drip irrigation system with LLDPE mulch results in better plant growth, increased number of fruits per plant and high yield (28.7 t ha^{-1}) in capsicum. Singh *et al* (2009) found increment in yield of tomato crop when drip irrigation along with mulching was used. Choudhary *et al* (2012) studied about the effects of drip irrigation and mulches on different parameters in capsicum and found that vegetative and physiological parameters were increased with combination of drip irrigation @1.0 pan evaporation plus mulching with black polythene sheet. Additionally, early picking was also reported under this treatment in comparison with flood irrigation and without mulch conditions.

Savitha *et al* (2010) studied the effect of fertigation with drip system in onion and found that fertigation with 75 per cent RDF recorded highest yield of the bulbs when compared with conventional method of fertilizer application. Increase in nutrient uptake was also observed.

2.5 Effect of drip irrigation and mulch on water use efficiencY

Seyfi and Rashidi (2007) conducted an experiment in which effect of plastic mulch and drip irrigation on WUE was studied in cantaloupe. They reported that the combination of drip irrigation and mulch significantly increased the WUE over the other treatments. Leskovar *et al* (2001) reported 53 per cent lower water applied under drip irrigation system when compared with conventional furrow systems along with 2-3 times more water use efficiency (WUE) in muskmelon. Zeng *et al* (2009) and Kirnak *et al* (2005) reported increase in irrigation water use efficiency (IWUE) with lowering the amount of irrigation water. On the contrary, IWUE was found to decrease with lowering the amount of irrigation water applied in muskmelon (Li *et al* 2012 and Fabeiro *et al* 2002).

Simsek *et al* (2004) studied the effect of different levels of irrigation of drip irrigation i.e. 125, 100, 75 and 50 in watermelon and found that WUE ranged between 9.6 to 11.7 kg m^{-3} and 10.8 to 13.1 kg m^{-3} in 2002 and 2003 respectively. Increase in the efficiency of water usage with decrease in irrigation regime levels was concluded by Simsek and Comlekcioglu (2011) in watermelon. They reported WUE of 5.84 kg m^{-3} and 9.26 kg m^{-3} with highest and lowest level of irrigation regime respectively. Kirnak *et al* (2009) reported improved WUE with moderate deficit irrigation in watermelon. Increase in WUE and NUE under mulch i.e. about 60 per cent over the bare soil was observed by Rao *et al* (2016) in watermelon. Zhang *et al* (2011) conducted a study in cucumber with different levels of drip irrigation (I_1- 0.6 E_{pan}, I_2 - 0.8 E_{pan} and I_3 – 1.0 E_{pan}) and observed lowest WUE in I_1, with highest reported in I_2. Simsek *et al* (2005) observed WUE ranging between 7.37 and 6.32 kg m^{-3} and 9.40 and 9.9 kg

m^{-3} in IW/CPE ratio of 1.25 and 1.00 respectively in cucumber. Hakkim and Chand (2014) found 35 per cent saving of water over control with maximum WUE at 65 per cent irrigation level in cucumber. Yaghi *et al* (2013) reported increase and decrease in WUE under the mulch condition and no mulch or furrow irrigation treatments in cucumber respectively. WUE was reported to be 0.262 t/ha/mm. Kirnak and Demirtas (2006) reported that WUE can be increased with usage of drip irrigation and mulching in cucumber.

In tomato, drip fertigation resulted in higher water use efficiency at 40 per cent ET_c (53.85 q/ha/cm). Saving of water i.e. 45.8 and 56.5 per cent under 100 and 80 per cent irrigation regimes respectively over control was reported (Bahadur *et al* 2006). Increased WUE under 40 per cent PE level of drip irrigation over furrow method was reported by Kumar and Sahu (2013) in cabbage. Trickle fertigation indicated practically 28 per cent more water use efficiency when contrasted with treatment involving conventional method of fertilizer application and trickle irrigation and 87 per cent more when compared with combination of furrow irrigation and soil application of fertilizers in tomato (Tanaskovik *et al* 2011).

2.6 Economics of drip irrigation, fertigation and mulch

Higher net returns and high cost-benefit ratio was observed under black plastic mulch in watermelon by Parmar *et al* (2013). Chand (2014) studied about the economics of adopting drip fertigation in cucumber and reported that application of water and fertilizers @ 100 per cent recommended dose resulted in highest B:C ratio i.e. 3.42. Jadhav *et al* (1990) found the B:C ratio of 5.15 and 2.96 from drip irrigation and furrow irrigation methods, respectively in tomato. Dunage *et al* (2009) studied about the economics of tomato using drip irrigation and found that application of FYM using drip irrigation @ 100 per cent ET resulted in highest net returns of about Rs 3,62,016 per ha with benefit cost ratio of 5.19. Application of water @ 50 per cent ET_c through drip irrigation along with straw mulch resulted in maximum net returns and higher benefit- cost ratio (7.03) in tomato (Biswas *et al* 2015). Brahma *et al* (2010b) studied about the economics of applying fertilizers along with irrigation water and found that 100 per cent recommended dose of nitrogen (120 kg ha^{-1}) and potassium (60 kg ha^{-1}) fertilizer resulted in highest cost benefit ratio i.e. 1: 1.72 in early season capsicum. Application of fertilizers @ 80 per cent RDF and 0.8 PET water application resulted in maximum B:C ratio (2.55:1) in bell pepper. Choudhary and Bhambri (2012) found that both black polythene mulch and paddy straw mulch resulted in maximum gross and net returns, with minimum returns found under bare soil i.e. no mulch conditions in capsicum. Singh *et al* (2011) reported gross income of about Rs 2,83,905 per ha and Rs 2,30,475 per ha from drip and conventional method of irrigation in bell pepper. Reduction in the cost of labour for weeding purpose under black polythene mulch condition was observed by Kumara *et al* (2016) while studying the economics of chilli. Kumar *et al* (2006) conducted an experiment to study about the impact of irrigation and fertigation treatments on yield, production efficiency and economic returns in case of potato grown under drip irrigation. They revealed that highest gross returns and net returns were found when drip irrigation at 120 ET_c along with fertilizers @ N:P:K (187: 63: 125) kg/ha was applied. Saini and Singh (2006) concluded that drip irrigation in different vegetable crop sequences (Cauliflower-Hybrid chilli) resulted in higher net returns, as water saved can be used to irrigate more and more area. Also, net returns were almost 3.6 times higher when contrasted with conventional method of irrigation. A benefit cost ratio of 2.99 was found when drip fertigation @ 100 per cent RDF was adopted as a treatment in hybrid bhendi (Rajaraman and Pugalendhi 2013). Tiwari *et al* (1998) concluded that net seasonal income, benefit-cost ratio was recorded to be highest under combination of drip irrigation and black plastic mulch in okra. Vijayakumar *et al* (2010) reported maximum benefit-cost ratio under drip irrigation at 75 per cent of PE along with fertigation @ 75 per cent RDF of N and K in brinjal. Kaur (2015) while conducting an experiment to study the impact of mulch on brinjal, found that plastic mulch usage resulted in maximum gross returns whereas higher net returns and high B:C ratio was recorded on usage of organic mulch.

CHAPTER III

MATERIALS AND METHODS

A field experiment entitled "Response of muskmelon (*Cucumis melo* L.) to drip irrigation and fertigation under mulch conditions" was conducted during summer season of 2017-18 and 2018-19. The details regarding the experimental site, experimental materials, procedures followed and techniques adopted to attain the experimental objectives are presented in this chapter.

3.1 Experimental site

The experiment was conducted at Vegetable Research Farm and Biochemistry Laboratory, Department of Vegetable Science, Punjab Agricultural University, Ludhiana, located at 30°-54' N latitude and longitude of 75°- 48' E and at an altitude of 247 m above the sea level.

3.2 Weather and climate

The weather in Ludhiana is characterized by period of hot and dry summers (April-June) followed by rainy season with hot and humid weather (June-Aug) and cold winters (Nov-Jan). During summers, temperature may go as high as 45-46°C, while minimum temperature of 0°C or even less, is observed during winter season. The average precipitation of the area is 600 mm, which mostly occurs during monsoon period. The meteorological data recorded during the crop season 2017-18 and 2018-19 is presented in Fig. 1 and 2.

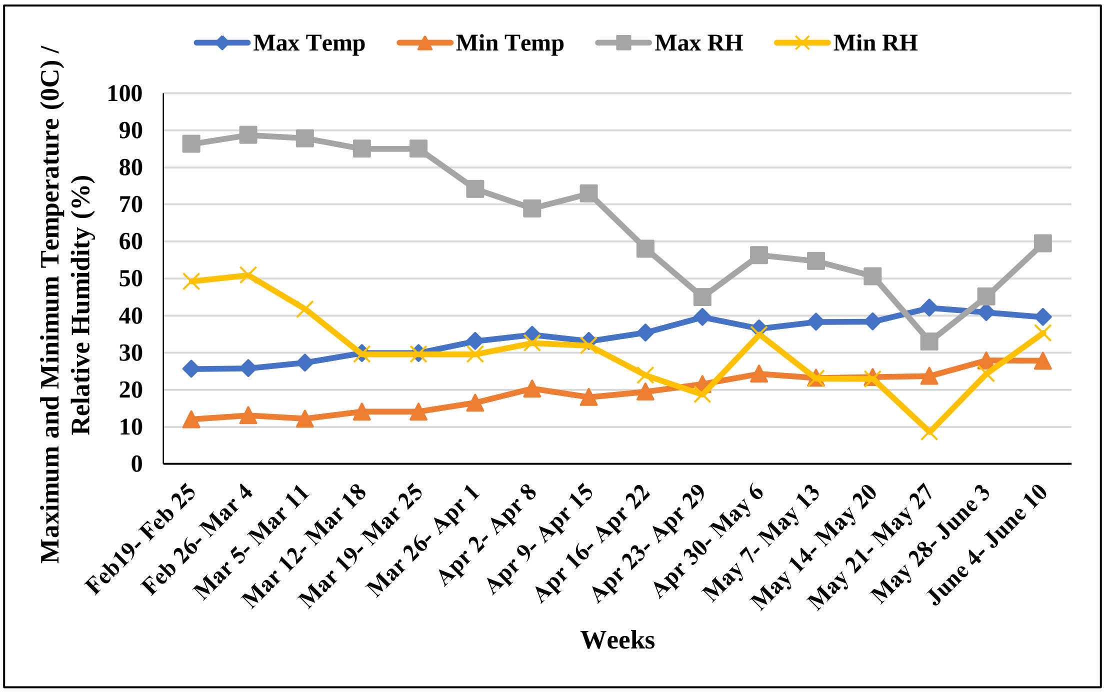


Fig. 1: Weekly Maximum Temperature (^{o}C), Minimum Temperature (^{o}C), Maximum Relative Humidity (%) and Minimum Relative Humidity (%) recorded during crop season 2017-18

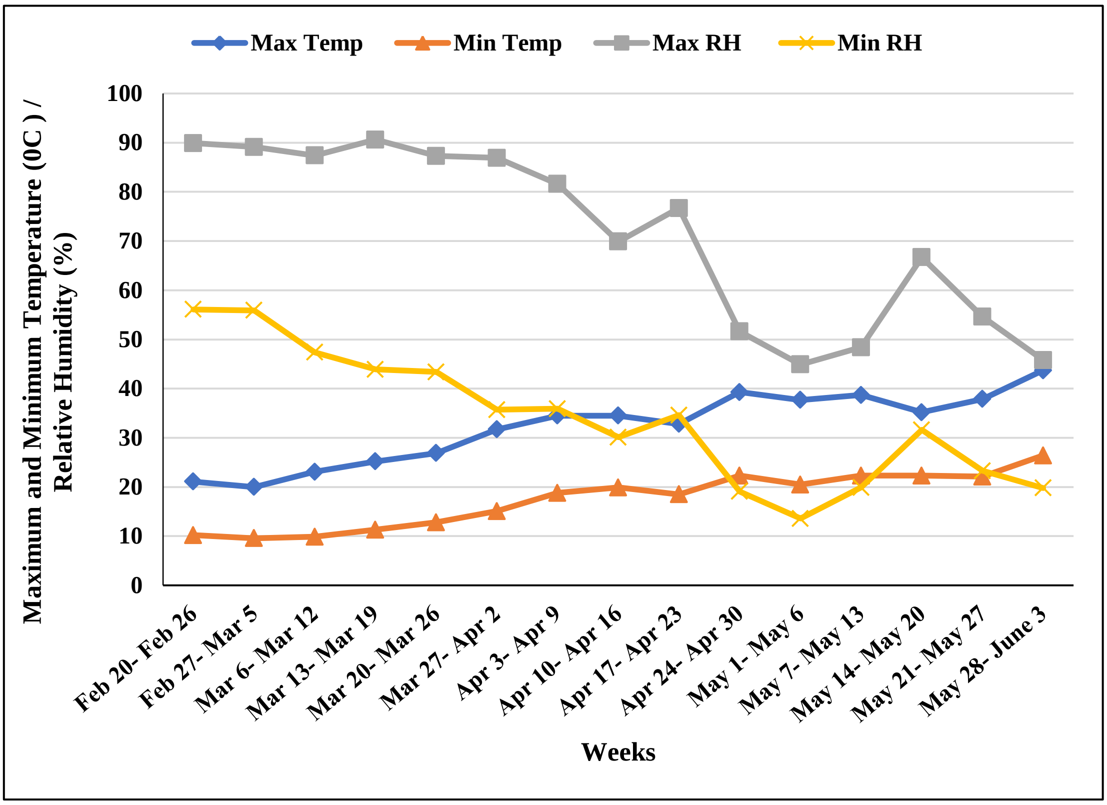


Fig. 2: Weekly Maximum Temperature (°C), Minimum Temperature (°C), Maximum Relative Humidity (%) and Minimum Relative Humidity (%) recorded during crop season 2018-19

3.3 Soil analysis

Samples from three different locations from a depth of 0-15 cm were taken within the experimental area and were subjected to physio-chemical analysis before crop plantation to access the basic physical and chemical properties of soil. The particulars of analysis are presented in Table 1.

Table 1: Physical and chemical properties of the soil in the experimental field

Sr. No.	Soil Characteristics	2017-18	2018-19
1	Soil Texture	Loamy sand	Loamy sand
2	pH	7.12	7.12
3	Organic Carbon (%)	0.18	0.20
4	Electrical Conductivity (dS/m)	0.31	0.33
5	Available Nitrogen (kg ha^{-1})	140	132
6	Available Phosphorus (kg ha^{-1})	20.02	18.16
7	Available Potassium (kg ha^{-1})	157.82	163

3.3.1 Soil texture

International pipette method proposed by Piper (1966) was used for the determination of the texture of soil. For the separation of the sand particles (0.02-2.0 mm) gravity sedimentation method was adopted, given by Day (1965). Separation of the sand content was done using 70-mesh size. The clay (<0.002 mm) content was separated from silt using 0.1 N solution of sodium hexametaphosphate as dispersing agent.

3.3.2 pH

The soil pH was determined in 1:2 soil-water suspensions using a glass electrode pH meter (Jackson 1967).

3.3.3 Soil organic carbon (SOC) (%)

SOC was determined through wet combustion by Walkley and Black (1934) rapid titration method. 2 g of soil sample was taken in a conical flask and 10 ml 1N $K_2Cr_2O_7$ was added as an oxidizing agent and the reaction is facilitated by the heat generated when concentrated H_2SO_4 was added to the mixture. Excess of $K_2Cr_2O_7$ was determined by titration with 0.5 N ferrous ammonium sulphate in the presence of diphenylamine indicator and NaF which gives a clear solution.

3.3.4 Electrical conductivity (EC) (dS m^{-1})

Electrical conductivity of the soil samples was determined from 1:2 soil-water suspension equilibrated for 24 h using a conductivity bridge (Jackson 1967). The EC was expressed as deci siemens per meter (dS m^{-1}).

3.3.5 Available nitrogen (kg ha^{-1})

Alkaline potassium permanganate method was used to determine available nitrogen (Subbiah and Asija 1965). Five gram soil was taken in a Kjeldahl distillation flask and moistened with 20 ml of distilled water. After adding 25 ml of 0.32% $KMnO_4$ and 25 ml of 2.5% NaOH solution, the flask was fitted to Kjeldahl assembly. The NH_3 evolved was absorbed in 10 ml of 0.02 N H_2SO_4 taken in a conical flask. About 30 ml distillate was collected. Three drops of methyl red indicator were added to conical flask. The excess of H_2SO_4 in the conical flask was titrated against 0.02 N NaOH with change in colour from pink to yellow.

3.3.6 Available phosphorus (kg ha^{-1})

Soil was analysed for available phosphorous by using 0.5 M $NaHCO_3$ (pH 8.5) as an extracant by the method given by Olsen *et al* 1954, suitable for neutral, alkaline and calcareous soils. The extract was treated with ammonium molybdate as complexing agent and ascorbic acid as reducing agent to produce blue colour with is determined calorimetrically at 760 nm using red filter.

3.3.7 Available potassium (kg ha^{-1})

5 g soil was shaken with 25 ml of neutral normal ammonium acetate (Merwin and Peech 1950) and the extract was diluted and readings were taken on a flame photometer.

3.4 Land preparation

Ploughing of the land with mould board plough along with harrowing twice was done to obtain the fine tilth of the soil. Laying out of the plots as per the plan was done before transplanting. Weeds and stubbles were collected and disposed off.

3.5 Plant material

The muskmelon hybrid 'MH-27' was used in the study. The vines are dark green and vigorous. Fruits are round, light yellow coloured, netted and sutured in nature. Flesh is thick, salmon orange and medium juicy. Average fruit weight is 856 g. The fruit is harvested at full slip stage and its first picking is done 63 days after transplanting. The hybrid is tolerant to wilt and root knot nematodes and have long shelf life, suitable for long distance transportation.

3.6 Treatments

The whole plot was divided into 57 sub plots and dimensions of each plot was 10 × 03 m. The experiment was laid out in split plot design with three levels of irrigation and mulching in the main plot and three fertigation treatments in sub plots and replicated thrice as shown in Fig. 3 and 4. Additionally, conventional method of cultivation was also included as control.

3.6.1 Irrigation levels

The three levels of irrigation treatments were

I_1 : Drip irrigation at 100 per cent ET_c (Evapotranspiration of the crop)

I_2 : Drip irrigation at 80 per cent ET_c (Evapotranspiration of the crop)

I_3 : Drip irrigation at 60 per cent ET_c (Evapotranspiration of the crop)

3.6.2 Mulching treatments

M_1 : Silver black polythene mulch

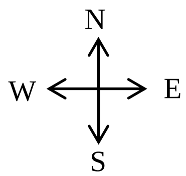
M_0 : No mulch

3.6.3 Fertigation levels (RDF : Recommended dose of fertilizer)

F_1 : 100 per cent RDF of NPK

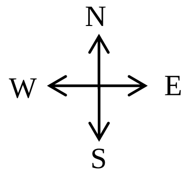
F_2 : 80 per cent RDF of NPK

F_3 : 60 per cent RDF of NPK



Water Channel								
Non Experimental Area								
$M_1I_1F_2$ (R_3)		**$M_1I_1F_1$ (R_3)**		**$M_1I_2F_3$ (R_3)**		**$M_1I_3F_3$ (R_3)**		**$M_1I_3F_2$ (R_3)**
$M_0I_1F_2$ (R_3)		**$M_0I_1F_1$ (R_3)**		**$M_0I_2F_3$ (R_3)**		**$M_0I_3F_3$ (R_3)**		**$M_0I_3F_2$ (R_3)**
$M_1I_1F_3$ (R_3)		**$M_1I_2F_2$ (R_3)**		**$M_1I_2F_1$ (R_3)**		**$M_1I_3F_1$ (R_3)**		**(Control)**
$M_0I_1F_3$ (R_3)		**$M_0I_2F_2$ (R_3)**		**$M_0I_2F_1$ (R_3)**		**$M_0I_3F_1$ (R_3)**		**Non experimental area**
$M_0I_1F_1$ (R_2)		**$M_0I_1F_2$ (R_2)**		**$M_0I_2F_3$ (R_2)**		**$M_0I_2F_1$ (R_2)**		**$M_0I_3F_2$ (R_2)**
$M_1I_1F_1$ (R_2)		**$M_1I_1F_2$ (R_2)**		**$M_1I_2F_3$ (R_2)**		**$M_1I_2F_1$ (R_2)**		**$M_1I_3F_2$ (R_2)**
(Control)	**Furrow**	**$M_0I_1F_3$ (R_2)**	**Furrow**	**$M_0I_2F_2$ (R_2)**	**Furrow**	**$M_0I_3F_3$ (R_2)**	**Furrow**	**$M_0I_3F_1$ (R_2)**
Non experimental area		**$M_1I_1F_3$ (R_2)**		**$M_1I_2F_2$ (R_2)**		**$M_1I_3F_3$ (R_2)**		**$M_1I_3F_1$ (R_2)**
$M_1I_3F_1$ (R_1)		**$M_1I_1F_3$ (R_1)**		**$M_1I_1F_2$ (R_1)**		**$M_1I_2F_3$ (R_1)**		**Non experimental area**
$M_0I_3F_1$ (R_1)		**$M_0I_1F_3$ (R_1)**		**$M_0I_1F_2$ (R_1)**		**$M_0I_2F_3$ (R_1)**		**(Control)**
$M_1I_3F_2$ (R_1)		**$M_1I_3F_3$ (R_1)**		**$M_1I_1F_1$ (R_1)**		**$M_1I_2F_2$ (R_1)**		**$M_1I_2F_1$ (R_1)**
$M_0I_3F_2$ (R_1)		**$M_0I_3F_3$ (R_1)**		**$M_0I_1F_1$ (R_1)**		**$M_0I_2F_2$ (R_1)**		**$M_0I_2F_1$ (R_1)**

Fig. 3: Layout of the field for the experiment during 2017-18



Water Channel								
Non Experimental Area								
$M_1I_2F_3$ (R_3)		**$M_1I_2F_2$ (R_3)**		**$M_1I_3F_3$ (R_3)**		**$M_1I_1F_1$ (R_3)**		**Non experimental area**
$M_0I_2F_3$ (R_3)		**$M_0I_2F_2$ (R_3)**		**$M_0I_3F_3$ (R_3)**		**$M_0I_1F_1$ (R_3)**		**(Control)**
$M_1I_2F_1$ (R_3)		**$M_1I_3F_1$ (R_3)**		**$M_1I_3F_2$ (R_3)**		**$M_1I_1F_3$ (R_3)**		**$M_1I_1F_2$ (R_3)**
$M_0I_2F_1$ (R_3)		**$M_0I_3F_1$ (R_3)**		**$M_0I_3F_2$ (R_3)**		**$M_0I_1F_3$ (R_3)**		**$M_0I_1F_2$ (R_3)**
$M_0I_3F_2$ (R_2)		**$M_0I_3F_3$ (R_2)**		**$M_0I_2F_3$ (R_2)**		**$M_0I_1F_2$ (R_2)**		**$M_0I_1F_1$ (R_2)**
$M_1I_3F_2$ (R_2)		**$M_1I_3F_3$ (R_2)**		**$M_1I_2F_3$ (R_2)**		**$M_1I_1F_2$ (R_2)**		**$M_1I_1F_1$ (R_2)**
$M_0I_3F_1$ (R_2)	**Furrow**	**$M_0I_2F_2$ (R_2)**	**Furrow**	**$M_0I_2F_1$ (R_2)**	**Furrow**	**$M_0I_1F_3$ (R_2)**	**Furrow**	**(Control)**
$M_1I_3F_1$ (R_2)		**$M_1I_2F_2$ (R_2)**		**$M_1I_2F_1$ (R_2)**		**$M_1I_1F_3$ (R_2)**		**Non experimental area**
Non experimental area		**$M_1I_1F_1$ (R_1)**		**$M_1I_3F_3$ (R_1)**		**$M_1I_2F_3$ (R_1)**		**$M_1I_2F_1$ (R_1)**
(Control)		**$M_0I_1F_1$ (R_1)**		**$M_0I_3F_3$ (R_1)**		**$M_0I_2F_3$ (R_1)**		**$M_0I_2F_1$ (R_1)**
$M_1I_1F_3$ (R_1)		**$M_1I_1F_2$ (R_1)**		**$M_1I_3F_1$ (R_1)**		**$M_1I_3F_2$ (R_1)**		**$M_1I_2F_2$ (R_1)**
$M_0I_1F_3$ (R_1)		**$M_0I_1F_2$ (R_1)**		**$M_0I_3F_1$ (R_1)**		**$M_0I_3F_2$ (R_1)**		**$M_0I_2F_2$ (R_1)**

Fig. 4: Layout of the field for the experiment during 2018-19

3.6.1.1 Irrigation application

Irrigation water @ 60, 80 and 100 per cent ET_c (evapotranspiration of the crop) was applied at an interval of 1 day for the whole season. On the basis of ET_c and area commanded per plant, estimation of treatment wise volume of irrigation water applied per plant was done through drip irrigation system. Based upon the discharge capacity of the drippers, system was operated for a particular time to apply a given volume of water per plant. The initial, mid and end season crop coefficient values for muskmelon are 0.5, 0.85 and 0.65 respectively (Allen *et al* 1998).

Using Modified Penman method, daily PET values for the crop season, based upon daily meteorological data collected were calculated. Daily data was collected from the meteorological observatory of Punjab Agricultural University, Ludhiana.

Total volume of water applied per irrigation was calculated as given below:

The evapotranspiration had been calculated using the FAO Penman- Monteith equation (Allen *et al* 1998) in the following formula:

$$PET=\frac{0.408(Rn - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$

where,

PET is the potential evapotranspiration (mm)

Rn is the net radiation (MJ m^{-2} day^{-1})

G is the soil heat flux density (MJ m^{-2} day^{-1})

T is the mean daily air temperature at 2m height (°C)

Δ is the slope of saturated vapour pressure curve (kPa C^{-1})

γ is the psychrometric constant (Pa ° C^{-1})

es is the saturated vapour pressure at air temperature (kPa)

ea is the prevailing vapour pressure (kPa)

u_2 is the wind speed at 2m height (m s^{-1})

ET_c (Crop evapotranspiration) was calculated as

$ET_c = ET_0 (K_c)$

where,

K_c is crop coefficient

The calculation of the irrigation time for the operating drip irrigation system was calculated using the given formula:

$$T(drip) = \frac{ET_c \times A \times N}{N_e \times q \times n}$$

where,

T (drip) is the drip irrigation time (hr)

ET_c is the crop evapotranspiration (mm)

N_e is the number of the emitters per lateral (52)

q is the discharge of each emitter (2.2 lph)

n is the efficiency of drip irrigation system (0.8)

A is the area commanded per plant

N is the number of plants per row

3.6.2.1 Mulch application

Application of mulch was done manually before transplanting of the crop. Silver black plastic mulch was used and round holes of about 7 cm diameter were cut off with the help of sharpened edge paper cutter keeping a distance of 60 cm between them. Both end of the mulch was anchored upto 75 mm in the soil.

3.6.3.1 Dose and frequency of application

The recommended dose of nitrogen (N), phosphorus (P) and potassium (K) is 125 kg, 62.5 kg and 62.5 kg/ ha respectively for muskmelon. Fertigation was given at a frequency of 4 days with the help of ventury system. Considering the length of the crop season, fertilizer application was completed in total 14 splits. 259.3 g of Urea (46% N), 170.45 g Urea phosphate (18% N and 44% P) and 156.25 g Sulphate of potash (48% K) were applied throughout the whole season per plot as source of N, P and K respectively. Quantity of fertilizer applied per split is presented in Table 2.

Table 2: Quantity of fertilizer applied (g) per plot per split for the whole season

Treatments	Quantity of fertilizer required in each split		
	Urea (46% N) (g)	Urea phosphate (18% N, 44% P) (g)	Sulphate of potash (48% K) (g)
F_1 (100% RDF)	18.52	12.17	11.16
F_2 (80% RDF)	14.81	9.74	8.93
F_3 (60% RDF)	11.11	7.30	6.69

3.7 Crop raising

The crop nursery was raised in plug trays in the month of February and was transplanted 25-30 days after sowing. Seedlings were protected from cold winds. The hybrid 'MH-27' was transplanted in the field for two seasons 2017-18 and 2018-19 at different dates and according to the experimental details seedlings of muskmelon were transplanted on both sides of 3m wide bed at a distance of 60 cm between the two hills. The crop was irrigated with drip irrigation system with two laterals per bed having drippers spaced at 40 cm and discharge of 2.2 litres per hour. The normal cultural practices for crop raising were followed as per standard agronomic practices (Anonymous 2019b).

3.8 Layout of experiment

- Number of treatments: 19
- Design: Split plot design
- Replications: 3
- Total number of plots: 19×03=57
- Plot size: 10×03m

3.9 Observations

A) Meteorological observations

For the whole experimental period, daily data for rainfall, minimum and maximum air temperatures, minimum and maximum relative humidity, wind velocity and total sunshine hours were collected from Department of Agrometeorology, PAU Ludhiana.

3.9.1 Soil temperature (^oC)

Maximum and minimum temperature of the soil under mulch (M_1) and no mulch (M_0) treatment was measured at a depth of 10 cm using soil thermometer. Minimum temperature was rerecorded at 8:30 a.m. and maximum temperature at 2:30 p.m. each day.

B) Growth characters

3.9.2 Length of the main shoot (cm)

Selection of five plants from each replication in each treatment was done to measure the length of the main shoot at regular intervals viz. 30 and 60 days after transplanting. Measurement of the main shoot was done from base to the highest point of the vine using a meter rod and an average value was computed out for each treatment. To calculate the final value, mean value of observations in each treatment was calculated.

3.9.3 Number of primary branches per plant

To determine the number of primary branches per plant, five plants from each replication in each treatment were selected. For determination of vegetative growth of plants under different treatments, number of primary branches arising from the main stem of the vine were counted. To get the final value, an average value of observations for each treatment was computed out.

C) Fruit characters

3.9.4 Number of fruits per vine

Selection of five plants in each replication of the treatment was done to determine the number of fruits per plant and then average of selected plants was taken. For the final value, mean value of observations in each treatment was calculated.

3.9.5 Average weight of fruit (g)

Selection of five random fruits in each treatment was done and weight of the fruits from selected plants was noted during each picking and was divided by five to get the average fruit weight. Average fruit weight is average weight through all the pickings.

3.9.6 Fruit diameter (cm)

The diameter of the fruit was measured after harvesting stage with the help of the vernier calliper. Five healthy fruits from each treatment were selected at each picking and diameter was determined. After last picking, average was computed to get the final value.

3.9.7 Total yield (q/ha)

Yield of crop was worked out on the basis of number of fruits, fruit weight and yield per plant and data was recorded.

3.9.8 Marketable yield (q/ha)

Yield contributed by fruits free from disease and deformation out of the total yield was considered as marketable yield.

D) Quality parameters

3.9.9 Total soluble solids (ºBrix)

Five fruits were randomly picked from each treatment and TSS was determined using a digital refractometer. Squeezing of the central portion of the flesh was done to get few drops of juice. Juice was placed on refractometer and readings were noted in ºBrix.

3.9.10 Vitamin C (mg/100g)

The method suggested by AOAC (1990) involving the usage of 2, 6-dicholorophenol indophenol dye was used for the determination of Ascorbic acid.

Reagents

1. **Metaphosphoric acetic acid solution (MPA):** 15 g metaphosphoric acid was taken and

dissolved in 40 ml glacial acetic acid and volume was made to 500 ml with distilled water.

2. **Dye:** 62.5 mg of 2, 6-dichlorophenol indophenol was dissolved in 100 ml of distilled water. Then added 52.5 mg sodium bicarbonate and volume was made to 250 ml with distilled water. It was filtered and kept in the dark.
3. **Standardization of dye:** Took 50 mg of pure ascorbic acid and dissolved in 50 ml of MPA solution. Took 1 ml of solution and titrated against dye to know the volume of dye used for 1 mg of ascorbic acid.

Procedure

5 g of the fresh fruit sample was taken and extraction was done using ascorbic acid with 6 per cent metaphosphoric acid and volume is made to 50 ml. 5 ml of this solution was taken in the titration flask and titrated it against dye (2, 6-dichlorophenol indophenol) sodium salt. The end was indicated by the appearance of light pink colour, which persisted for about 15 seconds. The calculations were made as under and expressed as milligram vitamin C per 100 g of fresh weight.

$$\text{Vitamin C (mg/100 g of fresh weight)} = \text{ml of dye used} \times 50 \times X$$

where, value of X was taken from standard curve.

3.9.11 Dry matter (g/100g)

For the calculation of dry matter content, 50 g of flesh was scooped out of the fruit and was grinded. Initial weight of the sample and petri dish was noted. Sample was placed in the oven with airflow of 70°C for drying purpose until constant weight was attained. After the drying process, final weight of sample and petri dish was noted. The dry matter content was calculated as

$$\text{Dry matter (g/100 g)} = \frac{(C - A)}{(B - A)} \times 2$$

Where,

A = Weight of petri dish

B = Total weight of fresh sample and petri dish

C = Total weight of dry sample and petri dish.

E) Water use efficiency (q/ha-cm)

Estimation of water use efficiency was done by dividing the total yield obtained under different treatments with the depth of water applied for each treatment. Water use efficiency was expressed in q/ha-cm of water used.

$$\text{Water use efficiency (q/ha-cm)} = \frac{\text{Total yield (q/ha)}}{\text{Total amount of water used (cm)}}$$

F) Economic parameters

3.9.12 Net- returns

For the analysis of economics, net returns is calculated.

Net returns= Gross returns-Total cost of cultivation

3.10 Statistical analysis

The data was collected regarding the various parameters and was statistically analysed as per the procedure given by "Gomez and Gomez (1984) and adapted by Cheema and Singh (1991) in statistical package CPCS1-I. At 5% level of significance, various comparisons were made. The analysis of variance (ANOVA) is as follows:

ANOVA

Source of variation	Degrees of freedom
Replications	2
Irrigation	2
Mulching	1
Main plot (Irrigation × Mulch)	2
Error a	10
Sub- plot (Fertigation)	2
Irrigation × Fertigation	4
Fertigation × Mulch	2
Irrigation × Mulch × Fertigation	4
Error b	24
Total	53

Plate 1: Nursery sowing

Plate 2: Field preparation

Plate 3: Harvesting

CHAPTER IV

RESULTS AND DISCUSSION

The results observed from the present investigation entitled "Response of Muskmelon (*Cucumis melo* L.) to drip irrigation and fertigation under mulch conditions" are presented in this chapter.

A) Meteorological observations

B) Growth characteristics

C) Yield characteristics

D) Quality characteristics

E) Economic parameters

A) Meteorological observations

Data collected daily for the whole experimental period for rainfall, minimum and maximum air temperatures, minimum and maximum relative humidity, wind velocity and total sunshine hours is presented in Annexure I and II.

4.1 Soil temperature (^oC)

Soil temperature is one of the most important parameter which affects the plant growth and establishment significantly. Germination, availability of nutrients, moisture content of soil and organic matter decomposition gets affected with the temperature of soil. Change in soil temperature is the most significant change by which mulch impact crop generation. During 2017-18 and 2018-19, similar trend was observed in context of soil temperature under mulch (M_1) and no mulch (M_0) conditions. Maximum soil temperature under silver-black polythene mulch was lower than those of no mulched soil whereas minimum temperature was recorded to be more under mulch application (M_1) (Fig. 5 and 6). The results are in line with the findings of Diaz- Perez (2009) in broccoli. Weekly data for soil temperature during the crop season is presented in Annexure III and IV.

B) Growth characteristics

4.2 Vine length (cm)

4.2.1 Vine length 30 days after transplanting

Vine length is one of the important trait agronomically which affects the yield potential of the crop. Length of the main vine was measured at 30 days after transplanting (DAT). Data regarding the effect of different irrigation, mulch and fertigation levels on vine length is presented in Table 3.

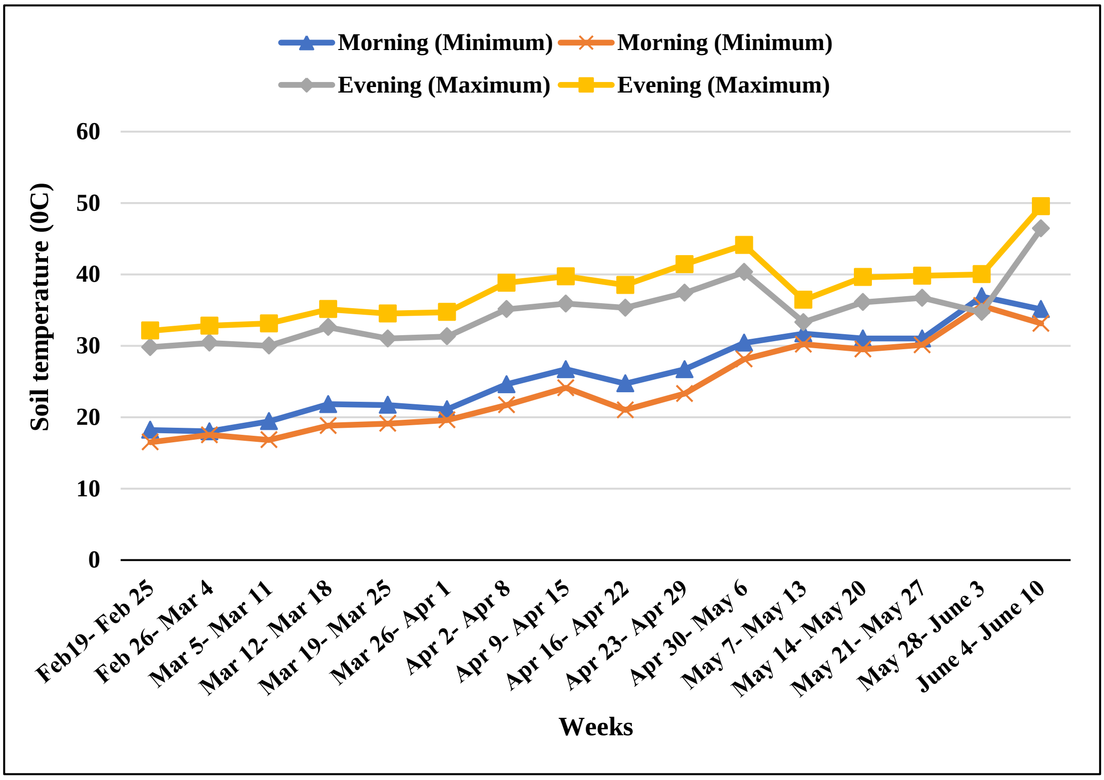


Fig. 5: Minimum and maximum soil temperature (°C) at depth of 10 cm under mulch and no mulch treatment during 2017-18

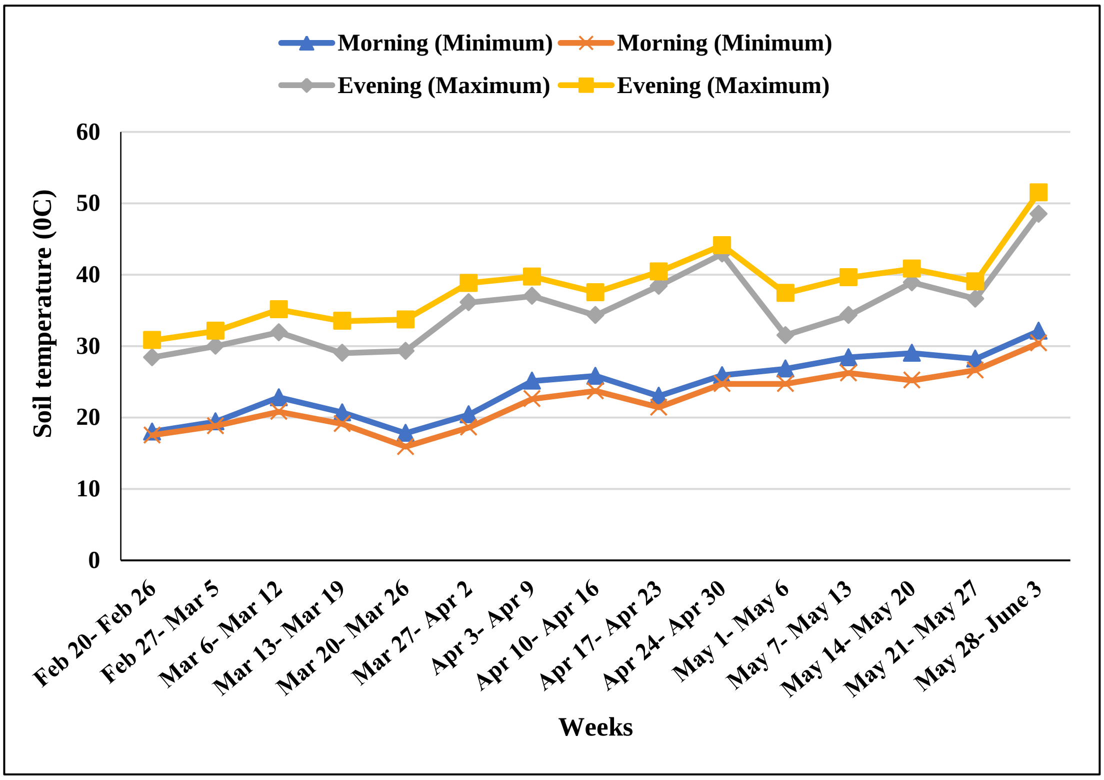


Fig. 6: Minimum and maximum soil temperature (°C) at depth of 10 cm under mulch and no mulch treatment during 2018-19

Table 3: Vine length (cm) at 30 days after transplanting as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	Length of main vine (30 DAS) in cm		
	2017-18	2018-19	Pooled
Control	90.9	92.7	91.8
Irrigation (I)			
I_1 (100% ET_c)	98.0	99.5	98.7
I_2 (80% ET_c)	93.5	95.9	94.7
I_3 (60% ET_c)	82.7	85.3	84.0
CD (p= 0.05)	6.3	6.2	6.2
Mulch (M)			
M_1 (Mulch)	95.4	97.8	96.6
M_0 (No mulch)	87.4	89.4	88.4
CD (p=0.05)	5.1	5.0	5.1
Fertigation (F)			
F_1 (100% RDF)	94.9	96.9	95.9
F_2 (80% RDF)	92.7	95.2	93.9
F_3 (60% RDF)	86.7	88.6	87.6
CD (p=0.05)	3.4	3.5	3.5
Interaction			
I × M	NS	NS	NS
I × F	NS	NS	NS
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop
RDF: Recommended dose of fertilizers
Control: Conventional method
NS: Non significant

Overall analysis of the data revealed maximum length of vine in treatment I_1 (1.0 ET_c) (98.7 cm) with statistically at par relation with I_2 (0.8 ET_c) (94.7 cm) and significantly lower vine length in treatment I_3 (0.6 ET_c) (84.0 cm). Length of the main vine at 30 days after transplanting (DAT) was significantly affected by different levels of irrigation during both the years i.e. 2017-18 and 2018-19. During 2017-18, significantly higher vine length was observed in treatment I_1 (1.0 ET_c) (98.0 cm) when compared to treatment I_3 (0.6 ET_c) (82.7 cm). Treatment I_2 (0.8 ET_c) was found to be statistically at par with treatment I_1 (1.0 ET_c) with vine length of 93.5 cm. Similar trend was followed during the year 2018-19, where mean vine length for treatments I_1 (1.0 ET_c), I_2 (0.8 ET_c) and I_3 (0.6 ET_c) were 99.5 cm, 95.9 cm and 85.3 cm respectively, in which treatment I_2 was statistically at par with treatment I_1. Increase in vine length with increased depth of irrigation might be attributed to retention of soil moisture near field capacity, leading to improvement in absorption rate of nutrients and moisture and increase in turgidity and elongation of cell.

Significant impact on vine length in a positive direction was observed when soil was covered with silver black polythene mulch (M_1). Mean data presented in Table 3 revealed that length of the main branch increased with mulch treatment (M_1) in comparison to without mulch treatment (M_0). The length of the main vine recorded under treatment M_1 was 95.4 cm and 97.8 cm during 2017-18 and 2018-19 respectively, which were significantly more as compared to without mulch treatment (M_0). The results are in line with the findings of Parmar *et al* (2013) in watermelon. Increase in the vine length under mulch may be attributed to enhancement in conservation of soil moisture and improve micro-climate of the vines.

Significant differences in vine length at 30 DAT were also observed due to different levels of fertilizers applied. Pooled data depicted increase in vine length with increase in dose of fertilizers. Maximum length of the vine was recorded in treatment F_1 (100 per cent RDF) (95.9 cm), followed by F_2 (80 per cent RDF) (93.9 cm) and F_3 (60 per cent RDF) (87.6 cm). Both F_1 and F_2 were found to be statistically at par. During 2017-18, highest vine length was recorded under the treatment F_1 (100 per cent RDF) (94.9 cm), which was statistically at par with treatment F_2 (80 per cent RDF) (92.7 cm) but significantly more from treatment F_3 (60 per cent RDF) (86.7 cm). Similar trend was followed during 2018-19 in which 96.9 cm, 95.2 cm and 88.6 cm length was recorded with treatments F_1 (100 per cent RDF), F_2 (80 per cent RDF) and F_3 (60 per cent RDF) respectively.

Vine length recorded under the control was 90.9 and 92.7 cm during 2017-18 and 2018-19 which was lower compared to the treatments where drip fertigation was given at its 80 per cent level and mulch was applied. Interactions among various levels of irrigation, mulch and fertigation was found to be non-significant, stating independent role of each factor

4.2.2 Vine length 60 days after transplanting

Length of the main vine at 60 days after transplanting as affected by different irrigation treatments is presented in Table 4. Pooled data analysis depicted significant differences among the different irrigation treatments for vine length at 60 DAS with I_1 (1.0 ET_c) recording the highest plant height (199.2 cm) which was statistically at par with I_2 (0.8 ET_c) (191.6 cm) and lowest in treatment I_3 (0.6 ET_c) (180.9 cm). During 2017-18, significantly increased length of the main vine was observed under treatment I_1 (1.0 ET_c) (196.9 cm) which was significantly higher from treatment I_2 (0.8 ET_c) (188.7 cm) and I_3 (0.6

Table 4: Vine length (cm) at 60 days after transplanting as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	Length of main vine (60 DAS) in cm		
	2017-18	2018-19	Pooled
Control	185.6	187.7	186.7
Irrigation (I)			
I_1 (100% ET_c)	196.9	201.6	199.2
I_2 (80% ET_c)	188.7	194.5	191.6
I_3 (60% ET_c)	176.9	183.9	180.9
CD (p= 0.05)	7.7	10.0	8.3
Mulch (M)			
M_1 (Mulch)	192.3	198.4	195.3
M_0 (No mulch)	182.7	188.9	185.8
CD (p=0.05)	6.3	8.2	6.8
Fertigation (F)			
F_1 (100% RDF)	191.9	197.7	194.8
F_2 (80% RDF)	188.4	194.5	191.4
F_3 (60% RDF)	181.0	188.7	185.5
CD (p=0.05)	7.0	NS	NS
Interaction			
I × M	NS	NS	NS
I × F	NS	NS	NS
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop
Control: Conventional method
RDF: Recommended dose of fertilizers
NS: Non significant

ET_c) (176.9 cm). However, during the year 2018-19, highest plant height was observed in treatment I_1 (1.0 ET_c) (201.6 cm) which was at par with treatment I_2 (0.8 ET_c) (194.5 cm). Significantly lower plant height was recorded in I_3 treatment (0.6 ET_c) (183.9 cm). These results are in accordance with the findings of Zeng *et al* (2009) in muskmelon. Decrease in vine length with water stress may be due to adverse effect on photosynthetic activity due to stomatal closure and reduced availability of CO_2 for chroloplast (Lawlor and Cornic 2002, Flexas *et al* 2004 and Bertamini *et al* 2007). Shao *et al* (2007) reported decrease in plant growth under water stress conditions due to reduced water content and turgor pressure in the cell, resulting in inhibition of cell division and enlargement.

Mulch (M_1) application leads to significantly higher length of main branch when compared with no mulch treatment (M_0). Vine length recorded during 2017-18 and 2018-19 under M_1 was 192.3 and 198.4 cm respectively, which was significantly higher over no mulch treatment (M_0). The results are in conformity with the findings of Mahadeen (2014) in summer squash.

Pooled data analysis depicted no significant differences on vine length with different levels of fertilizers. However, significant differences on length of the main branch at 60 DAT under various levels of fertilizers were observed during 2017-18. Treatment F_1 (100 per cent RDF) showed the maximum plant height (191.9 cm) which was statistically at par with treatment F_2 (80 per cent RDF) (188.4 cm) but significantly higher from treatment F_3 (60 per cent RDF) (181.0 cm). Higher fertilizer dose resulting in enhancement of chlorophyll and carbohydrate synthesis might have resulted in higher vegetative growth. During 2018-19, no significant difference among the treatments F_1 (100 per cent RDF), F_2 (80 per cent RDF) and F_3 (60 per cent RDF) were observed.

Conventional method of cultivation resulted in vine length of 185.6 and 187.7 cm during 2017-18 and 2018-19 respectively while drip irrigation and fertigation at 80 per cent level resulted in vine length of 191.6 and 191.4 cm during these years. The reduction of vine length under conventional cultivation might be attributed to lesser availability of water and nutrients due to runoff, evaporation, deep percolation, volatilization and leaching of nutrients, thereby affecting the crop growth. None of the interactions were found to be significant in both the years and pooled analysis.

4.3 Number of primary branches

Data regarding the total number of primary branches per plant as affected by different treatments of irrigation, mulch and fertigation is presented in Table 5. Data presented in Table 5 depicts the significant influence of different levels of irrigation on number of primary branches. Overall mean data revealed maximum number of primary branches in treatment with 100 per cent ET_c (I_1) (3.1), which was significantly higher from treatment with 60 per cent ET_c (2.5). Treatment with 80 per cent ET_c (2.8) was statistically at par with 100 per cent ET_c. During 2017-18, highest number of primary branches were recorded under the treatment in which irrigation was applied at 100 per cent ET_c (I_1) (2.9), followed by irrigation at 80 per cent ET_c (I_2) (2.8) and drip irrigation at 60 per cent ET_c treatment (I_3) (2.5). However, treatment I_1 and I_2 were found to be statistically at par. Similar trends were followed during 2018-19, with number of primary branches viz. 3.2, 2.9, 2.6 under the treatments where irrigation was applied at 100 per cent ET_c (I_1), 80 per cent ET_c (I_2) and 60 per cent ET_c (I_3) respectively. The results are in conformity with the findings of Ningaraju and Joseph (2014) in pickling melon.

Plate 4: Comparative crop growth under silver black polythene mulch (M_1) and no mulch (M_0) treatment

Plate 5: Comparative crop growth under drip irrigation at 100 per cent ET_c and 100 per cent RDF (left) with 60 per cent ET_c and 60 per cent RDF (right)

Table 5: Number of primary branches as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	Number of primary branches		
	2017-18	2018-19	Pooled
Control	2.6	2.9	2.8
Irrigation (I)			
I_1 (100% ET_c)	2.9	3.2	3.1
I_2 (80% ET_c)	2.8	2.9	2.8
I_3 (60% ET_c)	2.5	2.6	2.5
CD (p= 0.05)	0.2	0.2	0.2
Mulch (M)			
M_1 (Mulch)	2.9	3.1	3.0
M_0 (No mulch)	2.6	2.8	2.7
CD (p=0.05)	0.1	0.2	0.1
Fertigation (F)			
F_1 (100% RDF)	2.9	3.2	3.1
F_2 (80% RDF)	2.7	3.0	2.9
F_3 (60% RDF)	2.4	2.6	2.6
CD (p=0.05)	0.2	0.2	0.2
Interaction			
I × M	NS	NS	NS
I × F	NS	NS	NS
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop   **RDF:** Recommended dose of fertilizers
Control: Conventional method   **NS:** Non significant

Overall pooled data showed a significant increase in number of primary branches in those treatment where silver black polythene mulch (M_1) (3.0) was applied. During 2017-18 and 2018-19, significantly more number of branches were observed when mulch was applied (M_1) viz. 2.9 and 3.1 respectively. Improvement in plant growth under silver or black plastic mulch was also reported by Parmar *et al* (2013) in watermelon. This distinction may be contributed by the congenial microclimatic and soil moisture conditions under mulches, prompting better vegetative development.

The number of primary branches recorded were significantly influenced under different levels of fertilizers applied (Table 5). Statistical analysis of pooled data showed significantly more number of primary branches with 100 per cent RDF (F_1) (3.1), with statistically at par relation with 80 per cent RDF treatment (F_2) (2.9). Significantly lower branch number was observed with 60 per cent RDF (F_3) (2.6). During 2017-18, highest number of branches were observed with 100 per cent RDF (F_1) (2.9), which was statistically at par with 80 per cent RDF (F_2) (2.7). 60 per cent RDF (F_3) recorded significantly lowest number of branches (2.4). During 2018-19, number of primary branches observed with 100 per cent RDF (F_1), 80 per cent RDF (F_2) and 60 per cent RDF (F_3) were 3.2, 3.0 and 2.6 respectively, with statistically at par relation between F_1 and F_2. The results are in line with findings of Feleafel *et al* (2014) in cucumber.

Number of primary branches recorded in control during 2017-18 and 2018-19 were 2.6 and 2.9 respectively. During both the years, none of the interactions were found to be significant for number of primary branches per plant. Pooled mean data also depicted no significant interactions among various factors.

C) Yield characteristics

4.4 Fruit number

Fruit number is an important attribute which significantly influences the yield of the crop. Data recorded regarding the number of fruits per vine as influenced by various treatments of irrigation, fertigation and mulch is depicted in Table 6. Statistical analysis of overall data depicted no significant differences in number of fruits when different levels of irrigation were given. During both the years, maximum number of fruits were observed under treatment I_1 (1.0 ET_c), trailed by I_2 (0.8 ET_c) and I_3 (0.6 ET_c) i.e. 3.94, 3.80 and 3.68 respectively during 2017-18 and 3.94, 3.84 and 3.71 respectively during 2018-19. However, statistical analysis of data revealed that there was no significant difference among different levels of irrigation.

Data presented in Table 6 depicts that fruit number was higher under the mulch treatment (M_1) (3.87 and 3.89) during 2017-18 and 2018-19 respectively but no significant difference was observed upon statistical analysis.

Number of fruits per vine as affected by different fertigation levels is presented in Table 6. Pooled mean data analysis revealed highest number of fruits with 100 per cent RDF (F_1) (3.91), however both the treatments i.e. 100 per cent RDF (F_1) and 80 per cent RDF (F_2) (3.82) were found to be at par. Significantly lower number of fruits were obtained with 60 per cent RDF (F_3) (3.71). In 2017-18, among different fertilizer levels, 100 per cent RDF (F_1) recorded the highest number of fruits (3.90), followed by 80 per cent RDF (F_2) (3.79) and 60 per cent RDF (F_3) (3.73) but statistically, all the three treatments were found to be non-significant. During 2018-19, treatment where 100 per cent RDF was applied (F_1) exhibited the highest number of fruits (3.91) which was statistically at par with treatment in which 80 per cent RDF was given (F_2) (3.84). Lowest fruit number was observed under treatment with 60 per cent RDF (F_3) (3.70).

Table 6: Fruit number as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	Fruit number		
	2017-18	**2018-19**	**Pooled**
Control	3.45	3.50	3.48
Irrigation (I)			
I_1 (100% ET_c)	3.94	3.94	3.94
I_2 (80% ET_c)	3.80	3.84	3.82
I_3 (60% ET_c)	3.68	3.71	3.70
CD (p= 0.05)	NS	NS	NS
Mulch (M)			
M_1 (Mulch)	3.87	3.89	3.88
M_0 (No mulch)	3.74	3.77	3.76
CD (p=0.05)	NS	NS	NS
Fertigation (F)			
F_1 (100% RDF)	3.90	3.91	3.91
F_2 (80% RDF)	3.79	3.84	3.82
F_3 (60% RDF)	3.73	3.70	3.71
CD (p=0.05)	NS	0.13	0.10
Interaction			
I × M	NS	NS	NS
I × F	NS	NS	NS
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop   **RDF:** Recommended dose of fertilizers
Control: Conventional method   **NS:** Non significant

During 2017-18 and 2018-19, fruit number observed under control was lower than various drip irrigation, fertigation and mulch treatments i.e. 3.45 and 3.50 in the corresponding years. Among the interactions between irrigation, mulch and fertilizer treatments, none of the interactions were found to be significant.

4.5 Average fruit weight

The statistical analysis of data presented in Table 7 and Fig. 7 depicted significant differences among the irrigation, fertigation and mulching treatment on fruit weight. Further perusal of data revealed no significant interactions between the various factors viz. irrigation, mulch and fertigation.

Table 7: Average fruit weight (g) as affected irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	Average fruit weight (g)		
	2017-18	**2018-19**	**Pooled**
Control	878	880	879
Irrigation (I)			
I_1 (100% ET_c)	902	902	902
I_2 (80% ET_c)	884	882	883
I_3 (60% ET_c)	803	807	805
CD (p= 0.05)	51	52	49
Mulch (M)			
M_1 (Mulch)	915	918	917
M_0 (No mulch)	810	809	810
CD (p=0.05)	42	42	40
Fertigation (F)			
F_1 (100% RDF)	891	889	890
F_2 (80% RDF)	871	873	872
F_3 (60% RDF)	826	825	828
CD (p=0.05)	32	46	35
Interaction			
I × M	NS	NS	NS
I × F	NS	NS	NS
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop **RDF:** Recommended dose of fertilizers
Control: Conventional method **NS:** Non significant

Table 7 and Fig. 7 depict the significant differences among the different levels of irrigation treatments on average weight of the fruit. In pooled mean analysis, drip irrigation at 100 per cent ET_c, 80 per cent ET_c and 60 per cent ET_c resulted in average weight of 902 g, 883 g and 805 g respectively with significant differences among them. During both the years, maximum fruit weight was recorded when irrigation was applied at 100 per cent ET_c (I_1), followed by irrigation at 80 per cent ET_c (I_2) and lowest was observed under irrigation at 60 per cent ET_c treatment (I_3). However, I_1 and I_2 were found to be statistically at par. The weight of the fruit recorded was 902 g and 902 g when irrigation was applied at 100 per cent ET_c (I_1), 884 g and 882 g at 80 per cent ET_c and 803 g and 807 g at 60 per cent ET_c during

2017-18 and 2018-19 respectively. Maintenance of soil moisture near field capacity with increasing frequency of irrigation might have resulted in maximum absorbed PAR (Photosynthetically Active Radiation) along with increment in photosynthetic rate and dry matter production with efficient translocation helped in increasing weight of the fruits. The results are in line with the findings of Di Gioia *et al* (2009) and Kirnak and Dogan (2009) in watermelon.

Significant differences regarding the weight of the fruit were observed when crop was grown under the mulch (M_1) conditions (Table 7 and Fig. 7). Analysis of mean data depicted maximum fruit weight of 917 g with mulch (M_1) treatment, which was significantly higher over the treatment where no mulch (M_0) was applied. During 2017-18 and 2018-19, mulch (M_1) treatment significantly improved the fruit weight (915g and 918g respectively) of muskmelon. The percentage increment in fruit weight under silver black polythene mulch over the bare soil was 13.2. Increase in the average fruit weight of muskmelon was also observed by Hemphill and Mansour (1986) and Maiero *et al* (1987), when mulching was used for cultivation. Improved microclimate around the crop, thereby resulting in better crop establishment and growth, leading to higher photosynthetic activity and net assimilates production, might be the reason for significant increase in average fruit weight.

Table 7 and Fig. 7 depict the effect on fruit weight with different levels of fertilizers applied. Pooled mean data analysis depicted maximum fruit weight in treatment F_1 (100 per cent RDF) (890 g) which was at par with F_2 (80 per cent RDF) (872 g) and significantly more as compared to F_3 (60 per cent RDF) (828 g). In 2017-18, among the various fertilizer levels, significant differences for fruit weight were observed with maximum in F_1 (100 per cent RDF), followed by F_2 (80 per cent RDF) and F_3 (60 per cent RDF) (891 g, 871 g and 826 g respectively). Similar patterns were followed in year 2018-19 in which 889 g, 873 g and 825 g of fruits obtained with F_1 (100 per cent RDF), F_2 (80 per cent RDF) and F_3 (60 per cent RDF) treatments of fertilizer respectively. Both F_1 and F_2 were statistically at par. Increase in fruit weight with F_1 (100 per cent RDF) and F_2 (80 per cent RDF) might be attributed to increased dose of fertilizer, resulting in increased uptake of nutrients, dry matter production and yield components. More dry matter production and nutrient uptake leads to increased synthesis of assimilates which might have translocated efficiently to the fruit, hence increasing the average fruit weight.

Irrigation and fertigation treatment at 80 per cent level and mulch application resulted in increased fruit weight when compared with the control. During 2017-18 and 2018-19, weight recorded under control was 878 and 880 g respectively. Interaction among different factors was discovered to be non-significant during both the years and pooled mean data.

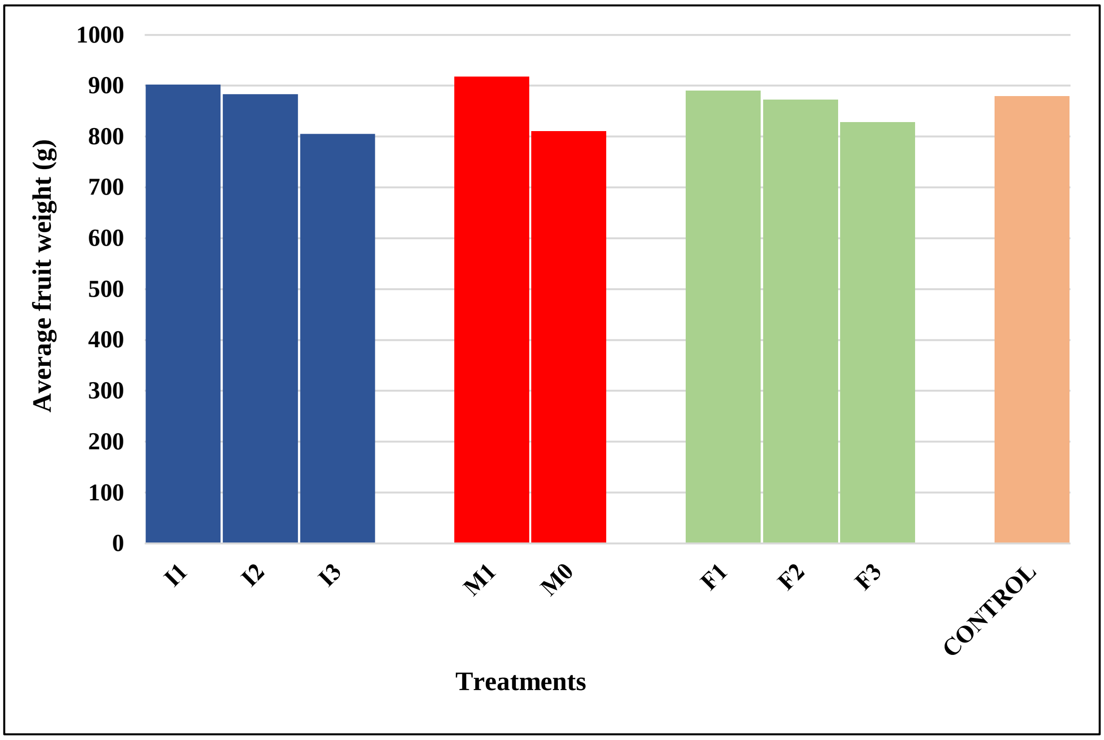


Fig. 7: Average fruit weight (g) as affected irrigation (I), fertigation (F) and mulching (M) in muskmelon

I_1: 100% ET_c **I_2:** 80% ET_c. **I_3:** 60% ET_c
F_1: 100% RDF **F_2:** 80% RDF **F_3:** 60% RDF
ET_c: Evapotranspiration of the crop

M_1: Silver black mulch **M_0:** No mulch
Control: Conventional method
RDF: Recommended dose of fertilizers

4.6 Fruit diameter

Data furnished in Table 8 shows the significant impact of irrigation levels on diameter of the fruit. Overall data depicted highest diameter in I_1 (1.0 ET_c) (18.1 cm), followed by I_2 (0.8 ET_c) (17.8 cm) and significantly lowest diameter in I_3 (0.6 ET_c) (16.8 cm). Treatment I_1 (1.0 ET_c) and I_2 (0.8 ET_c) were found to be statistically at par. During 2017-18, significant differences among the three levels of irrigation were recorded. Diameter of fruit recorded under treatment I_1 (1.0 ET_c), I_2 (0.8 ET_c), and I_3 (0.6 ET_c) was 17.3, 16.9 and 15.9 cm respectively. However, during 2018-19, I_1 (1.0 ET_c) and I_2 (0.8 ET_c) were found to be statistically at par with each other with I_1 (1.0 ET_c) showing diameter of 19.0 cm and I_2 (0.8 ET_c) with diameter of 18.8 cm. Treatment I_3 (0.6 ET_c) recorded significantly lower fruit diameter of 17.7 cm.

Covering of the soil with silver black polythene mulch (M_1) resulted in increased fruit diameter. Mean data analysis depicted increased in fruit diameter under the mulch (M_1) application (18.0 cm). Further, diameter of the fruit recorded under mulch conditions was 17.1 and 19.0 cm during 2017-18 and 2018-19 respectively.

Table 8: Fruit diameter (cm) as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	Fruit diameter (cm)		
	2017-18	**2018-19**	**Pooled**
Control	15.9	16.8	16.3
Irrigation (I)			
I_1 (100% ET_c)	17.3	19.0	18.1
I_2 (80% ET_c)	16.9	18.8	17.8
I_3 (60% ET_c)	15.9	17.7	16.8
CD (p= 0.05)	0.3	0.3	0.3
Mulch (M)			
M_1 (Mulch)	17.1	19.0	18.0
M_0 (No mulch)	16.2	18.0	17.1
CD (p=0.05)	0.3	0.3	0.3
Fertigation (F)			
F_1 (100% RDF)	17.2	18.9	18.1
F_2 (80% RDF)	16.9	18.8	17.8
F_3 (60% RDF)	15.9	17.9	16.9
CD (p=0.05)	0.4	0.3	0.3
Interaction			
I × M	NS	NS	NS
I × F	NS	NS	NS
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop
RDF: Recommended dose of fertilizers
Control: Conventional method
NS: Non significant

Significant differences in fruit diameter on application of different levels of fertilizer were observed. Pooled mean analysis depicted maximum diameter with 100 per cent RDF (18.1 cm), which was at par with 80 per cent RDF (17.8 cm) and significantly lower diameter in 60 per cent RDF (F_3) (16.9 cm). When 100 per cent RDF (F_1) was applied, highest diameter was recorded (17.2 cm and 18.9 cm), which was statistically at par with 80 per cent RDF (F_2) (16.9 cm and 18.8 cm) during 2017-18 and 2018-19 respectively. Lowest diameter was observed with 60 per cent RDF (F_3) (15.9 and 17.9 cm) during 2017-18 and 2018-19 respectively, which was significantly lower from the treatment where 100 and 80 per cent RDF was applied.

Conventional method resulted in diameter of 15.9 and 16.8 cm during 2017-18 and 2018-19 respectively which was comparatively lower from the treatment when drip irrigation and fertigation was given at 80 per cent ET_c and RDF respectively. Application of mulch also resulted in higher diameter over the control. Further perusal of data revealed no significant interactions among irrigation, fertigation and mulch treatments, stating that these factors do not influence each other.

4.7 Total yield

Data provided in Table 9 and Fig. 8 indicates the effect of different irrigation, mulch and fertilizer levels on total yield of the crop.

Table 9 and Fig. 8 revealed that total yield of the crop varied significantly with different levels of irrigation. Overall data depicted that significantly higher crop yield was observed with I_1 i.e. Drip irrigation at 100 per cent ET_c (199.6 q/ha), which was at par with I_2 i.e. drip irrigation at 80 per cent ET_c (191.8 q/ha), with lowest yield recorded under I_3 i.e. drip irrigation at 60 per cent ET_c (170.0 q/ha). During 2017-18, treatment with 100 per cent ET_c (I_1) (197.5 q/ha) resulted in maximum yield, followed by 80 per cent ET_c (I_2) (191.1 q/ha) and significantly lower yield in 60 per cent ET_c (I_3) (168.8 q/ha). I_1 and I_2 were statistically at par with each other. Similarly, during 2018-19, maximum yield was recorded in those treatments where drip irrigation was applied at 100 per cent ET_c (I_1) (201.8 q/ha) which was statistically at par with treatment where irrigation at 80 per cent ET_c was given (I_2) (192.6 q/ha) and significantly higher from irrigation at 60 per cent ET_c (I_3) (171.3 q/ha). The results are in agreement with findings of Yildiram *et al* (2009) in muskmelon. Treatment I_1 and I_2 might have resulted in keeping moisture soil content near field capacity for maximum time, resulting in higher NUE, maximum absorption of nutrients, thereby favouring positive impact on growth attributes i.e. vine length, primary branches, dry matter content, fruit weight, diameter in muskmelon, ultimately increasing the yield of the crop. Reduction in the crop yield under water stress conditions might have resulted in negative impact on growth and plant development.

Pooled analysis showed the significant differences among the mulch (M_1) and no mulch (M_0) treatment, with significantly higher yield with mulch application (M_1) (200.6 q/ha). Treatments where no mulch (M_0) was applied, significantly lower yield was recorded. During 2017-18, yield observed under mulch (M_1) was 198.5 q/ha which was significantly higher over the yield obtained under no mulch treatment (M_0) (171.4 q/ha). Similarly, notable differences among the mulch (M_1) and no mulch (M_0) treatments were observed during 2018-19 with mulch (M_1) application recording yield of 202.8 q/ha and bare soil (M_0) resulting in yield of 176.0 q/ha. Yield observed during first year and second year under mulch was 15.8

and 15.22 per cent higher over the non-mulch respectively. The results are in conformity with the earlier findings of Bonnano and Lamont (1987) and Ibbara *et al* (2001) in muskmelon and Romic *et al* (2003) and Ban *et al* (2009) in watermelon. Increase in crop yield under mulch application have also been reported by Ekinci and Dursun (2009) and Gordon *et al* (2010).

Table 9: Total yield (q/ha) as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	Total yield (q/ha)		
	2017-18	**2018-19**	**Pooled**
Control	170.9	167.8	169.3
Irrigation (I)			
I_1 (100% ET_c)	197.5	201.8	199.6
I_2 (80% ET_c)	191.1	192.6	191.8
I_3 (60% ET_c)	168.8	171.3	170.0
CD (p= 0.05)	14.1	15.7	13.2
Mulch (M)			
M_1 (Mulch)	198.5	202.8	200.6
M_0 (No mulch)	171.4	176.0	173.7
CD (p=0.05)	11.5	12.8	10.8
Fertigation (F)			
F_1 (100% RDF)	193.5	197.9	196.7
F_2 (80% RDF)	187.9	191.1	189.5
F_3 (60% RDF)	173.5	178.7	176.1
CD (p=0.05)	8.8	12.2	9.4
Interaction			
I × M	NS	NS	NS
I × F	NS	NS	NS
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop **RDF:** Recommended dose of fertilizers
Control: Conventional method **NS:** Non significant

Different fertilizer levels were also found to be affect the total yield significantly (Table 9 and Fig. 8). Statistical analysis of mean data revealed significantly higher yield with 100 per cent RDF (F_1) (196.7 q/ha) when compared with 60 per cent RDF (F_3) (176.1 q/ha). Treatment with 80 per cent RDF (F_2) (189.5 q/ha) was statistically at par with 100 per cent RDF (F_1). During 2017-18, maximum yield was obtained with 100 per cent RDF (F_1) (193.5

q/ha), followed by 80 per cent RDF (F_2) (187.9 q/ha) and significantly lower yield with 60 per cent RDF (F_3) (173.5 q/ha). During 2018-19, 100 per cent RDF (F_1) (197.9 q/ha) resulted in significantly higher yield, followed by 80 per cent RDF (F_2) (191.1 q/ha) and significantly more when compared to 60 per cent RDF (F_3) (178.7 q/ha). Treatment F_1 and F_2 were statistically at par with each other. The results are in agreement with findings of Bhakare and Fatkal (2008) and Eifediyi and Remison (2009). Higher nutrient use efficiency (NUE) and water use efficiency (WUE) might be the reason for increased yield when fertilizers were applied along with irrigation water (Bafna *et al* 1993 and Manfrinato 1971).

Mean yield recorded under control was 170.9 and 167.8 q/ha during 2017-18 and 2018-19 respectively which was lower when compared with drip fertigation and mulch treatments. Conventional method involves many losses such as runoff, evaporation, deep percolation, volatalization and leaching of nutrients might have contributed to lesser availability of nutrients and moisture to the plants for growth and development and to meet the potential evapotranspiration requirements of the crop, thereby resulting in lower yield.

Further perusal of the data indicated that no interaction was found to be significant during both the years, stating that each of the factor involved behaves independently.

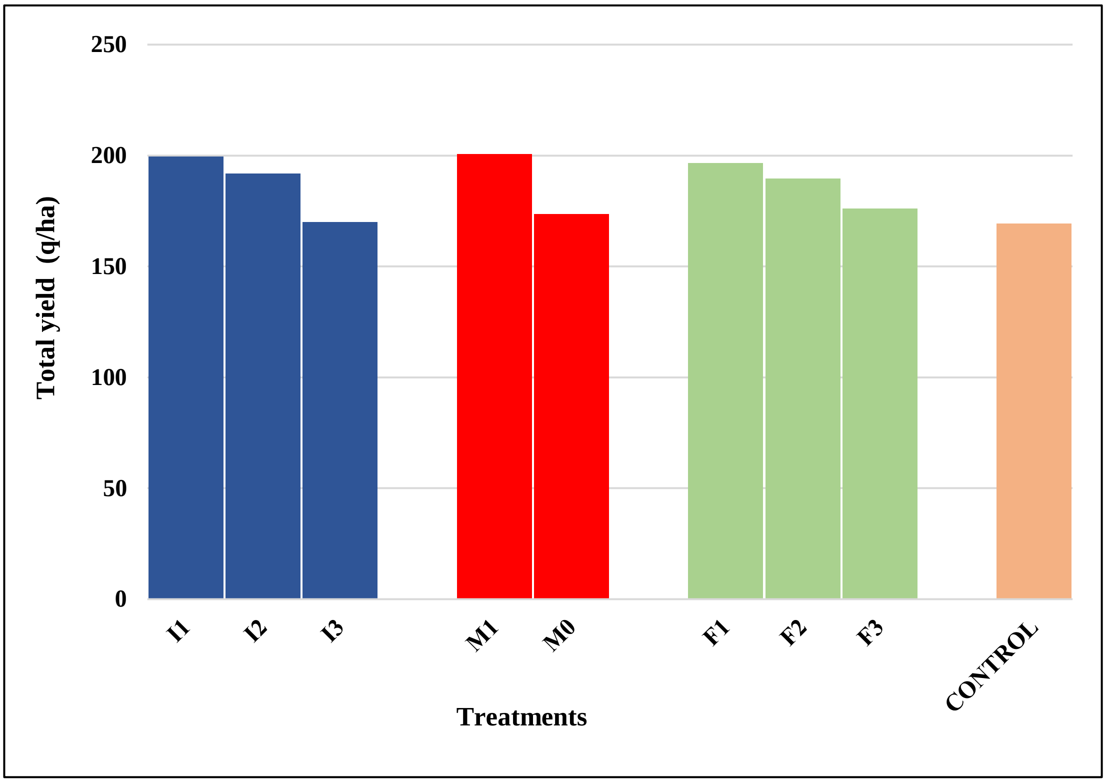


Fig. 8: Total yield (q/ha) as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

I_1: 100% ET_c **I_2:** 80% ET_c. **I_3:** 60% ET_c **M_1:** Silver black mulch **M_0:** No mulch
F_1: 100% RDF **F_2:** 80% RDF **F_3:** 60% RDF **Control:** Conventional method
ET_c: Evapotranspiration of the crop **RDF:** Recommended dose of fertilizers

4.8 Marketable yield

Data presented in Table 10 depicted the impact of different irrigation, fertigation and mulch levels on marketable yield during 2017-18, 2018-19 and pooled analysis. Pooled data depicted significantly higher marketable yield in I_1 (1.0 ET_c) (186.8 q/ha), followed by I_2 (0.8 ET_c) (175.8 q/ha) and I_3 (0.6 ET_c) (152.4 q/ha). Both I_1 (1.0 ET_c) and I_2 (0.8 ET_c) were statistically at par. During 2017-18, I_1 (1.0 ET_c) treatment recorded significantly higher marketable yield (182.7 q/ha), followed by I_2 (0.8 ET_c) treatment (174.0 q/ha) and significantly lower yield was observed under I_3 (0.6 ET_c) (151.3 q/ha).

Table 10: Marketable yield (q/ha) as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	Marketable yield (q/ha)		
	2017-18	2018-19	Pooled
Control	153.9	150.3	152.1
Irrigation (I)			
I_1 (100% ET_c)	182.7	190.9	186.8
I_2 (80% ET_c)	174.0	177.5	175.8
I_3 (60% ET_c)	151.3	153.5	152.4
CD (p= 0.05)	12.9	14.3	12.1
Mulch (M)			
M_1 (Mulch)	184.7	188.8	186.8
M_0 (No mulch)	156.3	156.8	156.6
CD (p=0.05)	10.5	11.7	9.9
Fertigation (F)			
F_1 (100% RDF)	175.3	183.6	179.4
F_2 (80% RDF)	172.3	175.2	173.8
F_3 (60% RDF)	161.5	162.1	161.8
CD (p=0.05)	8.1	11.2	8.6
Interaction			
I × M	NS	NS	NS
I × F	NS	NS	NS
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop **RDF:** Recommended dose of fertilizers

Control: Conventional method **NS:** Non significant

Both I_1 and I_2 treatments were found to be statistically at par. Similar trends with I_1 (1.0 ET_c) (190.9 q/ha) treatment recording significantly higher marketable yield and statistically equivalent with I_2 (0.8 ET_c) treatment (177.5 q/ha) and lowest in I_3 (0.6 ET_c) (153.5 q/ha) was observed during 2018-19.

Cultivating the crop under mulch conditions resulted in notably higher yield over no mulch condition. During both the years, significantly higher yield was observed under mulch application (M_1). Mean yield recorded under mulch (M_1) application was 184.7 q/ha and 188.8 q/ha during 2017-18 and 2018-19 respectively. Increment in yield under mulch (M_1) over the bare soils was 19.31 per cent. The results are in agreement with the findings of Kirnak and Demirates (2006) in cucumber.

Among the various treatments of fertilizer application, pooled data analysis showed significantly higher yield under 100 per cent RDF, followed by 80 per cent RDF and significantly more from 60 per cent RDF. Treatment F_1 and F_2 were found to be statistically at par with each other. During 2017-18, 100 per cent RDF (F_1) (175.3 q/ha) showed maximum marketable yield which was at par with 80 per cent RDF (F_2) (172.3 q/ha), but significantly higher from treatment with 60 per cent RDF (F_3) (161.5 q/ha). Similarly, during 2018-19, 100 per cent RDF (F_1) resulted in maximum marketable yield (183.6 q/ha), followed by 80 per cent RDF (F_2) (175.2 q/ha) and significantly lower yield was observed in 60 per cent RDF (F_3) (162.1 q/ha).

Marketable yield under control recorded was lower when compared with treatments when drip irrigation and fertigation was given at 80 per cent of ET_c and RDF respectively. Application of mulch also resulted in higher marketable yield in comparison with control. Yield of about 153.9 and 150.3 q/ha was observed under conventional method of cultivation during 2017-18 and 2018-19 respectively. Further data analysis revealed no significant interactions during both the years and pooled data.

4.9 Irrigation water saving using drip irrigation

Quantity of water applied under different levels of irrigation is presented in Table 11 and Fig. 9. Maximum depth of water was applied under conventional method of irrigation (71.58 and 71.06 cm) during 2017-18 and 2018-19 respectively. Among the various drip irrigation treatments considerable amount of water was saved. Mean data analysis depicted maximum saving of water in I_3 i.e drip irrigation at 60 per cent ET_c (80.85 per cent), followed by I_2 i.e drip irrigation at 80 per cent ET_c (74.43 per cent) and lowest in I_1 i.e drip irrigation at 100 per cent ET_c (68.00 per cent). During 2017-18 and 2018-19, the maximum percentage of water saving over conventional method of irrigation was recorded in treatment I_3 i.e drip irrigation at 60 per cent ET_c (79.64 and 82.04), followed by I_2 i.e. irrigation at 80 per cent ET_c (72.85 and 76.00) and I_1 i.e. irrigation at 100 per cent ET_c (66.06 and 69.95) respectively. Similarly, water saving was observed by Ahmed *et al* (2014) in hot pepper.

Table 11: Comparison of water applied in different treatments

Irrigation treatments (I)	Total depth of irrigation water applied (cm)	Conventional irrigation (cm)	Percentage of saving water over conventional irrigation
Water saving during 2017-18			
I_1 (100% ET_c)	24.29	71.58	66.06
I_2 (80% ET_c)	19.43	71.58	72.85
I_3 (60% ET_c)	14.57	71.58	79.64
Water saving during 2018-19			
I_1 (100% ET_c)	21.35	71.06	69.95
I_2 (80% ET_c)	17.05	71.06	76.00
I_3 (60% ET_c)	12.76	71.06	82.04
Mean data			
I_1 (100% ET_c)	22.82	71.32	68.00
I_2 (80% ET_c)	18.24	71.32	74.43
I_3 (60% ET_c)	13.66	71.32	80.85

ET_c: Evapotranspiration of the crop

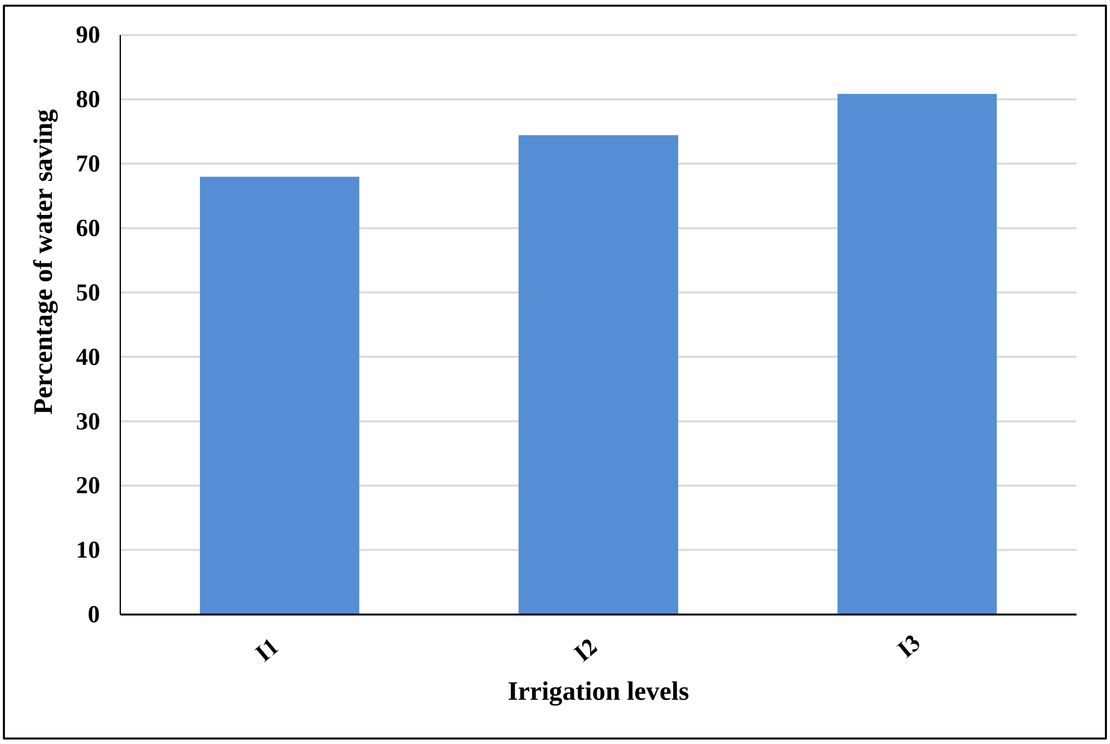


Fig. 9: Comparison of water applied in different treatments

I_1: 100% ET_c **I_2:** 80% ET_c **I_3:** 60% ET_c **ET_c:** Evapotranspiration of the crop

4.10 Water use efficiency

Different levels of irrigation, mulch and fertilizer levels significantly influenced the water use efficiency and is exhibited in Table 12 and Fig. 10. Pooled results uncovered that water use proficiency in I_1 (1.0 ET_c) treatment was significantly lower when contrasted with I_2 (0.8 ET_c) and I_3 (0.6 ET_c). Result showed that increase in the levels of irrigation leads to corresponding decrease in water use efficiency, respectively. During 2017-18 and 2018-19, increase in water use effectiveness was 29.16 and 30.33 per cent in I_3 (0.6 ET_c) over I_1 (1.0 ET_c) treatment in corresponding years. The decrease in efficiency of water usage with increase in irrigation levels may be because of persistent loss of soil water.

Table 12: Water use efficiency (q/ha-cm) as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	**Water use efficiency (q/ha-cm)**		
	2017-18	**2018-19**	**Pooled**
Control	2.39	2.36	2.37
Irrigation (I)			
I_1 (100% ET_c)	8.21	9.35	8.78
I_2 (80% ET_c)	9.84	11.30	10.57
I_3 (60% ET_c)	11.59	13.42	12.51
CD (p= 0.05)	0.69	0.98	0.72
Mulch (M)			
M_1 (Mulch)	10.60	12.23	11.42
M_0 (No mulch)	9.15	10.49	9.82
CD (p=0.05)	0.57	0.80	0.59
Fertigation (F)			
F_1 (100% RDF)	10.36	11.85	11.11
F_2 (80% RDF)	9.94	11.54	10.74
F_3 (60% RDF)	9.34	10.69	10.02
CD (p=0.05)	0.44	0.78	0.54
Interaction			
I × M	NS	NS	NS
I × F	NS	NS	NS
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop **RDF:** Recommended dose of fertilizers
Control: Conventional method **NS:** Non significant

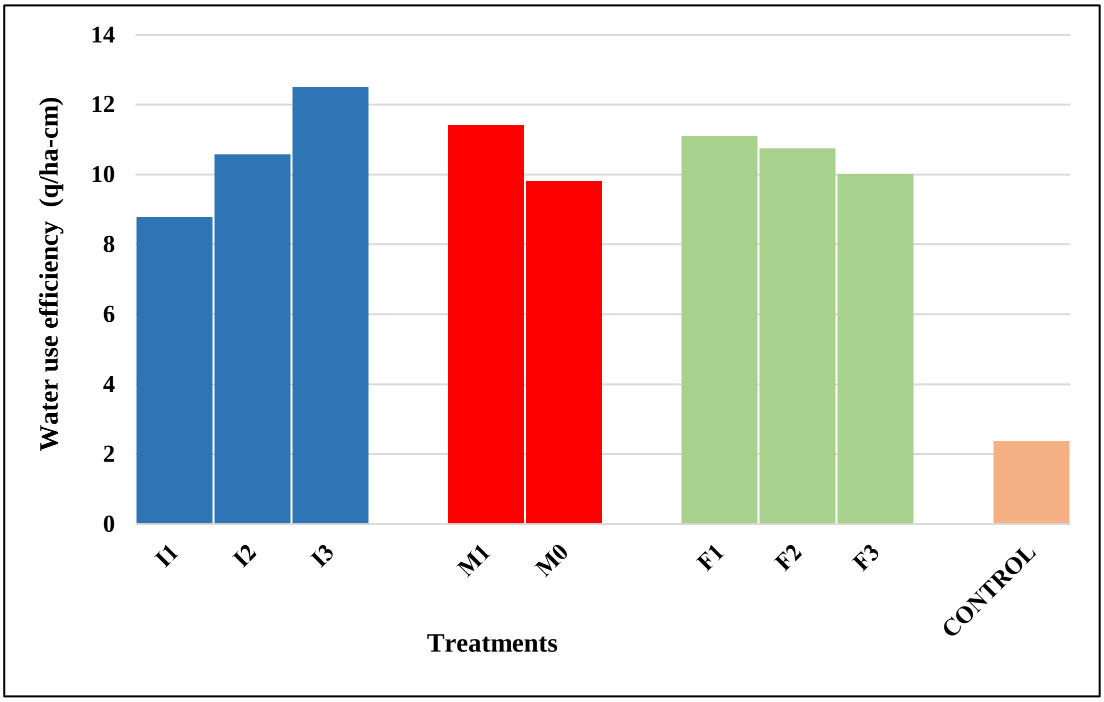


Fig. 10: Water use efficiency (q/ha-cm) as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

I_1: 100% ET_c **I_2:** 80% ET_c. **I_3:** 60% ET_c **M_1:** Silver black mulch **M_0:** No mulch
F_1: 100% RDF **F_2:** 80% RDF **F_3:** 60% RDF **Control:** Conventional method
ET_c: Evapotranspiration of the crop **RDF:** Recommended dose of fertilizers

These outcomes are as per studies directed by Kirnak *et al* (2005) and Simsek and Comlekcioglu (2011) in muskmelon. Lowest water use efficiency (WUE) was observed in I_1 (1.0 ET_c), however, maximum yield was obtained from this treatment. These results confirms the sensitivity of muskmelon to irrigation deficiency (Fabeiro *et al* 2002).

Results demonstrated that mulching further increased the water use efficiency. Water use productivity was recorded to be 14.0 per cent higher under silver black polythene mulch (M_1) when compared with no mulch (M_0) conditions. The results are in line with the findings of Spizewski *et al* (2010) and Kirnak and Demirtas (2006) in cucumber. Reduced evaporation from soil surface under mulch resulting in decreased evapotranspiration of the crop might be the reason for increased WUE (Monteiro *et al* 2008).

Pooled analysis depicted increase in WUE with increase in dose of fertilizers. During 2017-18, treatment in which 100 per cent RDF was given (F_1) (10.36 q/ha-cm) recorded maximum WUE, followed by 80 per cent RDF (F_2) (9.94 q/ha-cm) and 60 per cent RDF (F_3) (9.34 q/ha-cm). Similarly during 2018-19, maximum WUE was observed with 100 per cent RDF (F_1) (11.85 q/ha-cm), followed by 80 per cent RDF (F_2) (11.54 q/ha-cm) and significantly lower efficiency with 60 per cent RDF (F_3) (10.69 q/ha-cm). Treatment F_1 and F_2 were found to be statistically at par with each other.

Water use efficiency under control was 2.39 and 2.36 during both the years. The efficiency of water usage was much lower in conventional method in comparison with different treatments. Increase in WUE i.e. about 2-3 times with trickle water system in comparison with control was reported by Leskover *et al* (2001) in muskmelon.

The above results indicate that increasing the depth of irrigation through drip system in muskmelon increased the total yield, but water use efficiency was found to decrease. Thus, in circumstances where water is in shortage, yield potential as I_1 and I_2 can be achieved by lowering the amount of irrigation water alongside utilization of silver black polythene mulch.

D) Quality characteristics

4.11 Ascorbic acid

Ascorbic acid is the natural occurring compound with antioxidant properties important for humans. Table 13 depicts the impact on vitamin C content on growing muskmelon under drip irrigation, fertigation and mulch conditions. Significant variation in vitamin C content due to irrigation levels was observed. Remarkable increase in the content of vitamin C was observed when depth of the irrigation water was increased. In pooled analysis, ascorbic acid content recorded under I_1 (1.0 ET_c), I_2 (0.8 ET_c) and I_3 (0.6 ET_c) was 22.09, 21.01 and 20.28 mg/100g respectively with significant differences among them. During 2017-18, significantly highest ascorbic acid was recorded under I_1 (1.0 ET_c) (21.03 mg/100g) and was followed by I_2 (0.8 ET_c) (19.97 mg/100g) and I_3 (0.6 ET_c) (19.41 mg/100g). Similar trends with significant variation regarding ascorbic acid content with different irrigation levels was observed during 2018-19. These results are in accordance with the findings of Vijitha and Mahendran (2010) in tomato illustrating significant decrease in vitamin C content with deficit irrigation. They reported that such reduction in content might be attributed to reduction in synthesis of D- glucose (precursor of vitamin C) under the period of stress.

Pooled data analysis supported the fact that ascorbic acid content increases under the mulch treatment (M_1) (21.60 mg/100g). Silver black polythene mulch (M_1) recorded higher content of vitamin C viz. 20.51 and 22.69 mg/100g) during 2017-18 and 2018-19 respectively. Increase in ascorbic acid under mulch application was found to be 4.35 per cent higher over the bare soil. The discoveries were in concurrence with the discoveries of Ashrafuzzaman *et al* (2011) in which mulch application resulted in increased content of vitamin C.

A perusal of data presented in Table 13 revealed that different levels of fertilizer application were found to affect vitamin C content significantly. Overall mean analysis depicted significantly highest content of ascorbic acid in F_1 (100 per cent RDF) (22.44 mg/100g). Treatment F_3 (60 per cent RDF) (19.79 mg/100g) recorded significantly lowest

Table 13: Ascorbic acid content (mg/100g) as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	Ascorbic acid (mg/100g)		
	2017-18	**2018-19**	**Pooled**
Control	19.58	20.44	20.01
Irrigation (I)			
I_1 (100% ET_c)	21.03	23.15	22.09
I_2 (80% ET_c)	19.97	22.04	21.01
I_3 (60% ET_c)	19.41	21.15	20.28
CD (p= 0.05)	0.38	0.45	0.35
Mulch (M)			
M_1 (Mulch)	20.51	22.69	21.60
M_0 (No mulch)	19.77	21.54	20.66
CD (p=0.05)	0.31	0.36	0.28
Fertigation (F)			
F_1 (100% RDF)	21.36	23.51	22.44
F_2 (80% RDF)	20.32	21.99	21.16
F_3 (60% RDF)	18.74	20.85	19.79
CD (p=0.05)	0.55	0.54	0.46
Interaction			
I × M	NS	NS	NS
I × F	NS	NS	NS
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop
RDF: Recommended dose of fertilizers
Control: Conventional method
NS: Non significant

content of ascorbic acid. During 2017-18 and 2018-19, significantly highest content of vitamin C was obtained with F_1 (100 per cent RDF) (21.36 and 23.51 mg/100g), followed by F_2 (80 per cent RDF) (20.32 and 21.99 mg/100g) and lowest in F_3 (60 per cent RDF) (18.74 and 20.85 mg/100g) respectively. High N uptake resulting in improved activity of enzymes for amino acids amalgamation might be the reason for increased content of vitamin C under increased dose of fertilizer. These outcomes are in concurrence with the discoveries of Chavan *et al* (1997) and Bidari (2000) in chilli.

Average content of ascorbic acid content under conventional method during 2017-18 and 2018-19 was 19.58 and 20.44 mg/100g respectively. Among the various possible interactions, none of them were found to be significant in terms of ascorbic acid content.

4.12 Total soluble solids

TSS is one of the most important quality parameter which directly influences the flavour of muskmelon. Table 14 depicts the significant differences observed in respect of TSS under various levels of irrigation, mulch and fertilizer. Pooled mean data showed significantly maximum TSS in treatment I_2 i.e. irrigation at 80 per cent ET_c (11.83 °Brix) followed by I_1 i.e. irrigation at 100 per cent ET_c (11.42 °Brix) and lowest in I_3 i.e. irrigation at 60 per cent ET_c (10.98 °Brix). During 2017-18, significant differences were observed among different levels of drip irrigation for TSS. Treatment I_2 i.e. irrigation at 80 per cent ET_c level recorded the highest TSS (11.72 °Brix), followed by I_1 i.e. irrigation at 100 per cent ET_c level (11.27 °Brix). Significantly lower TSS value was observed under treatment I_3 i.e irrigation at 60 per cent ET_c level (10.88 °Brix). Similar trend was followed during 2018-19. These results are in line with Yildirim *et al* (2009) in muskmelon.

Application of plastic mulch (M_1) also resulted in significantly higher value of TSS i.e. 11.58 and 11.83 °Brix during 2017-18 and 2018-19 respectively. The percentage increase in TSS under mulch conditions over no mulch treatment was 4.93. Higher value of TSS have been reported in muskmelon under transparent mulch (Mohamedien *et al* 1992).

Mean data statistical analysis revealed remarkable increase in TSS content with increase in dose of fertilizer from 60 to 100 per cent of RDF. Significantly higher TSS value was recorded in F_1 (100 per cent RDF) (11.68 °Brix) and was followed by F_2 (80 per cent RDF) (11.46 °Brix) and F_3 (60 per cent RDF) (11.10 °Brix). During 2017-18 and 2018-19, TSS value was found to be significantly higher under F_1 (100 per cent RDF) (11.55 and 11.81°Brix) followed by F_2 (80 per cent RDF) (11.36 and 11.56 °Brix) and significantly lower in F_3 (60 per cent RDF) (10.96 and 11.24 °Brix) respectively. Treatment F_1 and F_2 were found to be statistically at par. Aguyoh *et al* (2010) in watermelon and Brahma *et al* (2010b) in capsicum also reported the similar results. Increase in TSS value with increased dose of fertilizer might be attributed to better uptake of nitrogen and phosphorus, which play role in starch formation which gets converted into sugars during ripening process, thereby, enhancing the sweetness (Aguyoh *et al* 2010).

Conventional method resulted in TSS of 11.20 and 11.00 °Brix during 2017-18 and 2018-19, which was lower from the treatment when drip irrigation and fertigation was given at 80 per cent of ET_c and RDF respectively. Application of mulch also resulted in higher TSS over the control.

Table 14: Total soluble solids (°Brix) as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	Total soluble solids (°Brix)		
	2017-18	2018-19	Pooled
Control	11.20	11.00	11.10
Irrigation (I)			
I_1 (100% ET_c)	11.27	11.57	11.42
I_2 (80% ET_c)	11.72	11.94	11.83
I_3 (60% ET_c)	10.88	11.08	10.98
CD (p= 0.05)	0.29	0.21	0.22
Mulch (M)			
M_1 (Mulch)	11.58	11.83	11.71
M_0 (No mulch)	10.99	11.24	11.12
CD (p=0.05)	0.23	0.17	0.18
Fertigation (F)			
F_1 (100% RDF)	11.55	11.81	11.68
F_2 (80% RDF)	11.36	11.56	11.46
F_3 (60% RDF)	10.96	11.24	11.10
CD (p=0.05)	0.25	0.25	0.23
Interaction			
I × M	NS	NS	0.30
I × F	NS	NS	NS
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop
RDF: Recommended dose of fertilizers
Control: Conventional method
NS: Non significant

During 2017-18 and 2018-19, none of the interaction was found to be significant. However, in pooled analysis (Table 15), significant interaction was found between various irrigation levels and mulch, stating that both the factors influence each other and affects the TSS value. Treatment combination of drip irrigation at 80 per cent ET_c level along with mulch application (I_2M_1) reported significantly highest TSS value (12.06 °Brix). Lowest TSS (10.53 °Brix) was recorded when irrigation was given at 60 per cent ET_c under bare soil conditions (I_3M_0).

Table 15: Total soluble solids (°Brix) as affected by interaction between irrigation (I) and mulch (M) in muskmelon

Irrigation (I)	Pooled data		
	Total soluble solids (TSS)		
	Mulch (M)		
	M_0 (No mulch)	M_1 (Mulch)	MEAN
I_1 (100% ET_c)	11.36	11.63	11.49
I_2 (80% ET_c)	11.60	12.06	11.83
I_3 (60% ET_c)	10.53	11.44	10.99
MEAN	11.16	11.71	
CD (p=0.05)	0.30		

ET_c: Evapotranspiration of the crop

4.13 Dry matter content

Critical examination of data presented in Table 16 depicts that irrigation has significant effect on dry matter content. Significant differences between I_1, I_2 and I_3 treatment influencing the dry matter content was depicted in pooled mean data. During 2017-18, significantly highest dry matter content was observed in treatment where irrigation was applied at 100 per cent ET_c (I_1) (8.29 g/100g), followed by irrigation at 80 per cent ET_c (I_2) (7.04 g/100g) and lowest in treatment where irrigation was given at 60 per cent ET_c (I_3) (6.58 g/100g). Similarly, during 2018-19, significant higher content of dry matter was observed in I_1 treatment viz. irrigation at 100 per cent ET_c (10.13 g/100g), followed by I_2 viz. irrigation at 80 per cent ET_c (8.51 g/100g) with significant lower content in I_3 viz. irrigation at 60 per cent ET_c (8.04 g/100g). Increase in dry matter content under increased depth of irrigation might be due to better availability of moisture, which in turn improves the plant growth in terms of plant height, number of branches, leaf area, thus leading to higher production of biomass. The results are in line with the findings of Rouphael *et al* (2008) in watermelon.

Significantly more content of dry matter was recorded when silver black polythene mulch (M_1) was used. Pooled mean data revealed significant increment in dry matter content under mulch application (M_1) (8.40 g/100g). During 2017-18 and 2018-19, mulch resulted in significantly higher dry matter content (7.51 and 9.29 g/100 g) over bare soil conditions (7.10 and 8.49 g/100g) respectively. Better vegetative growth due to improved microclimate under mulch conditions might be responsible for increasing the dry matter content.

Mean data analysis depicted that among various fertilizer levels, 100 per cent RDF (F_1) recorded significantly highest (8.74 g/100g) dry matter content, followed by 80 per cent

RDF (F_2) (8.06 g/100g) and lowest in 60 per cent RDF (7.51 g/100g). During 2017-18 and 2018-19, significantly higher content of dry matter was recorded with 100 per cent RDF (F_1) with mean values of 8.00 and 9.47 g/100g in the corresponding years. Treatment with 100 per cent RDF (F_1) was followed by 80 per cent RDF (F_2) and significantly lower content of dry matter observed under 60 per cent RDF (F_3). Dry matter content observed with 60 per cent RDF during 2017-18 and 2018-19 was 6.61 and 8.40 g/100g respectively. Better accessibility and uptake of nutrients may be doled out as the explanation for notable increment in dry matter in 100 per cent RDF treatment. The results are in accordance with Castellanos *et al* (2011) in watermelon.

Table 16: Dry matter content (g/100g) as affected by irrigation (I), fertigation (F) and mulching (M) in muskmelon

Treatments	Dry matter content (g/100g)		
	2017-18	**2018-19**	**Pooled**
Control	7.25	7.05	7.15
Irrigation (I)			
I_1 (100% ET_c)	8.29	10.13	9.21
I_2 (80% ET_c)	7.04	8.51	7.78
I_3 (60% ET_c)	6.58	8.04	7.31
CD (p= 0.05)	0.15	0.19	0.12
Mulch (M)			
M_1 (Mulch)	7.51	9.29	8.40
M_0 (No mulch)	7.10	8.49	7.80
CD (p=0.05)	0.12	0.16	0.18
Fertigation (F)			
F_1 (100% RDF)	8.00	9.47	8.74
F_2 (80% RDF)	7.31	8.81	8.06
F_3 (60% RDF)	6.61	8.40	7.51
CD (p=0.05)	0.33	0.28	0.24
Interaction			
I × M	0.21	NS	NS
I × F	NS	0.48	0.41
M × F	NS	NS	NS
I × M × F	NS	NS	NS

ET_c: Evapotranspiration of the crop **RDF:** Recommended dose of fertilizers
Control: Conventional method **NS:** Non significant

Dry matter recorded under conventional method was 7.25 and 7.05 g/100g during 2017-18 and 2018-19 respectively and was lower than treatments of irrigation and fertigation given with drip method. Mulch application also resulted in increment in dry matter content.

Under the various interactions between irrigation, mulch and fertigation, interaction was found to be significant for irrigation and mulch during 2017-18 (Table 17) and irrigation and fertilizer during 2018-19 and pooled data mean (Table 18). During 2017-18, irrigation at 100 per cent ET_c in combination with mulch application (I_1M_1) resulted in maximum content of dry matter (8.61 g/100g) and was followed by combination of irrigation at 100 per cent ET_c with no mulch application (I_1M_0) (7.98 g/100g). Significantly lower value of dry matter was recorded with irrigation at 60 per cent ET_c under bare soil conditions (I_3M_0) (6.47 g/100g).

Table 17: Dry matter content (g/100g) as affected by interaction between irrigation (I) and mulch (M) in muskmelon

Irrigation (I)	2017-18		
	Dry matter content		
	Mulch (M)		
	M_0 (No mulch)	M_1 (Mulch)	Mean
I_1 (100 % ET_c)	7.98	8.61	8.29
I_2 (80 % ET_c)	6.84	7.25	7.05
I_3 (60 % ET_c)	6.47	6.69	6.58
MEAN	7.10	7.52	
CD (p=0.05)	0.21		

ET_c: Evapotranspiration of the crop

Table 18: Dry matter content (g/100g) as affected by interaction between irrigation (I) and fertigation (F) levels in muskmelon

Irrigation (I)	Dry matter content							
	Fertigation (F)							
	2018-19				Pooled data			
	F_1 (100% RDF)	F_2 (80% RDF)	F_3 (60% RDF)	Mean	F_1 (100% RDF)	F_2 (80% RDF)	F_3 (60% RDF)	Mean
I_1 (100 % ET_c)	12.12	11.02	10.75	11.30	10.29	9.06	8.28	9.21
I_2 (80 % ET_c)	8.83	8.57	8.12	8.51	8.26	7.78	7.29	7.78
I_3 (60 % ET_c)	8.30	8.00	7.84	8.05	7.66	7.34	6.95	7.32
MEAN	9.75	9.20	8.90		8.74	8.06	7.51	
CD (p=0.05)	0.48				0.41			

ET_c: Evapotranspiration of the crop **RDF:** Recommended dose of fertilizers

Pooled mean data depicted significantly higher content of dry matter under irrigation at 100 per cent ET_c along with 100 per cent RDF (I_1F_1) (10.29 g/100g) and was followed by treatment combination of irrigation at 100 per cent ET_c with 80 per cent RDF (I_1F_2) (9.06 g/100g). Lowest content was recorded when irrigation was given at 60 per cent ET_c level in combination with 60 per cent RDF (I_3F_3) (6.95 g/100g). During 2018-19, significantly high dry matter content was observed in treatment combination of 100 per cent ET_c and 100 per cent RDF (I_1F_1) (12.12 g/100g) and was followed by application of irrigation at 100 per cent ET_c along with 80 per cent RDF (I_1F_2) (11.02 g/100 g). Significantly lower content was observed when irrigation was given at 60 per cent ET_c level in combination with 60 per cent RDF (I_3F_3) (7.84 g/100g).

E) Economic analysis

Economic evaluation of a technology before adopting is of utmost importance. To access the economic viability of drip irrigation system in comparison with conventional method, fixed cost, operating cost and interest were taken into consideration (Table 19). Net returns for drip irrigation (with and without mulch) and conventional method of irrigation is calculated and presented in Table 19. Net returns were found to be highest in drip irrigation along with mulch usage (Rs 130023/ha), followed by drip method of irrigation without mulch application (Rs 124362/ha). Conventional method of cultivation resulted in lowest returns (Rs 107580/ha). The results are in line with the findings of Saini and Singh (2006). They reported 3.6 times higher net returns under drip when compared with conventional irrigation in different vegetable crop sequences (Cauliflower- Hybrid chilli). (Singh *et al* 2011) also reported gross income of about Rs 2,83,905 per ha and Rs 2,30,475 per ha from drip and conventional method of irrigation in bell pepper.

Table 19: Comparative economic analysis of drip irrigation system (with and without mulch) and conventional method for 1 hectare

Sr. No.	Description	Drip with mulch	Drip without mulch	Conventional
1	Main, sub main, pump, fertilizer tank etc”			
	a) Fixed cost (Rs)	61898	61898	
	b) Accessories (10% of a)	6189.8	6189.8	
	c) Total cost (a+b)	68087.8	68087.8	
	d) Life in years	20	20	
	e) Depreciation on capital by taking two crops per year (c/40)	1702	1702.19	
	f) Interest @8% per crop by taking two crops per year (c*0.08/4)	1362	1361.75	
	g) Total (e+f)	3064	3063.95	
2.	Lateral and installation			
	a) Cost of laterals with inbuild emitters @10.45 per metre for 1 ha	22000	22000	
	b) Cost of installation	2200	2200	
	c) Total cost	24200	24200	
	d) Life in year	10	10	
	e) Depreciation on capital by taking two crops per year	1210	1210	
	f) Interest @8% per crop by taking two crops per year (d*0.08/4)	484	484	
	g) Total (e+f)	1694	1694	
3	Mulch	17500		
4	Cultivation cost of muskmelon (Rs)	55289	55289	61789
5	Total cost of cultivation (Rs)	77547	60047	61789
6	Produce (q/ha)	207.57	184.41	169.37
7	Selling price (Rs/q)	1000	1000	1000
8	Gross income (Rs)	207570	184410	169370
9	Net income (Rs)	130023	124362	107580

CHAPTER V

SUMMARY

Muskmelon (*Cucumis melo* L.) is an important commercial cucurbit cultivated in tropical and sub-tropical regions of the world. Around the globe, muskmelon ranks third after watermelon and cucumber (Nunez-Palenius *et al* 2008). The production of the crop highly depends upon the agronomic practices followed during the cultivation. Among these, irrigation and nutrients management is of utmost importance because of greater impact on muskmelon production and quality (Fabiero *et al* 2002 and Long *et al* 2006). In order to improve water use efficiency (WUE), nutrient use efficiency (NUE), yield and quality in muskmelon, drip fertigation and mulching can play important role. Drip irrigation saves water to the degree of 50 to 60 per cent, decreases the inter-cultivation cost by 30 to 40 per cent, increase the yield by 15 to 20 per cent and enhances the harvest quality (Kumar 2013, Kulecho and Weatherhead 2005, Narayanamoorhty1997; 2003, Qureshi *et al* 2001 and Verma *et al* 2004). Fertigation results in high fertilizer use efficiency, uniform distribution of nutrients into the soil and decreased volatilization of nitrogen from soil surface (Papadopoulos 1985). Beneficial effects of using mulch includes reduced leaching of nutrients, lower soil evaporation, suppression of unwanted plants, increasing/decreasing the temperature of soil surface, conserving the soil moisture and higher uniform yield (Lamont 2005, Kumar and Lal 2012, Ban *et al* 2009). Thus, by keeping in view the above benefits of drip irrigation, mulch and fertigation, there is need to standardize optimum moisture regime and NPK fertilizer levels to obtain good crop establishment, growth and quality fruit production along with high yield.

The present investigation entitled ‘Response of muskmelon (*Cucumis melo* L.) to drip irrigation and fertigation under mulch conditions’ was carried out at Vegetable Research Farm and Biochemical Laboratory, Department of Vegetable Science, Punjab Agricultural University, Ludhiana for two consecutive years 2017-18 and 2018-19. Physio-chemical analysis of soil was done by collecting a composite sample from three different locations from a depth of 0-15 cm. Hybrid ‘MH-27’ was used as plant material. The experiment was laid in split plot design with irrigation and mulch treatments in main plot and fertigation in sub plot. Irrigation treatment included three different levels of drip irrigation I_1: Drip irrigation at 100 per cent evapotranspiration of the crop (ET_c), I_2: Drip irrigation at 80 per cent ET_c and I_3: Drip irrigation at 60 per cent ET_c. Mulch treatment included application of silver black polythene mulch (M_1) and no mulch condition (M_0). Under the fertigation treatments, F_1: 100 per cent Recommended dose of fertilizer (RDF), F_2 (80 per cent RDF) and F_3 (60 per cent RDF) levels were included. In addition to this, conventional method of cultivation was included as control.

There were nineteen treatment combinations with three replications making total plot number to fifty seven. The results of the experiment are presented below:

- The data recorded on vine length at 30 days after transplanting (DAT) showed significant differences with different levels of irrigation, fertigation and mulch application. Significantly higher length of the main branch was observed in treatment I_1 (1.0 ET_c) (98.7 cm), F_1 (100 per cent RDF) (95.9 cm) and under mulch (M_0) (96.6 cm) treatment. I_1 (1.0 ET_c) and I_2 (0.8 ET_c) and F_1 (100 per cent RDF) and F_2 (80 per cent RDF) were found to be significantly at par. None of the interaction was found to be significant.
- Vine length recorded 60 DAT was maximum in I_1 (1.0 ET_c) (196.9 cm), followed by I_2 (0.8 ET_c) (188.7 cm) and significantly lower in I_3 (0.6 ET_c) (176.9 cm) during 2017-18. However, during 2018-19, I_1 (1.0 ET_c) (201.6 cm) and I_2 (0.8 ET_c) (194.5 cm) were found to be statistically at par with each other. Mulch (M_1) application significantly increased the length of the main vine i.e. 195.3 cm. During 2017-18, 100 per cent RDF (F_1) (191.9 cm) resulted in maximum vine length and was followed by 80 per cent RDF (F_2) (188.4 cm). Treatment with 100 per cent RDF (F_1) and 80 per cent RDF (F_2) were statistically at par. No significant differences among the different fertilizer treatments were observed during 2018-19.
- Number of primary branches were recorded to be maximum under I_1 (1.0 ET_c) (3.1) and F_1 (100 per cent RDF) (3.1) treatment which was at par with I_2 (0.8 ET_c) (2.8) and F_2 (80 per cent RDF) (2.9) respectively. Lowest number was observed under treatment I_3 (0.6 ET_c) (2.5) and F_3 (60 per cent RDF) (2.6). Due to alteration in soil conditions with the use of mulch, number of branches were found to be more.
- Number of fruits per vine directly influences the crop yield. No significant differences between different irrigation and mulch treatments were observed. Among the fertigation treatments, no significant difference was observed during 2017-18. However, during 2018-19, 100 per cent RDF (F_1) (3.91) recorded maximum number of fruits and was followed by treatment with 80 per cent RDF (F_2) (3.84). F_1 and F_2 treatments were statistically at par.
- Average weight of the fruit was found to be significantly high with I_1 (1.0 ET_c) (902 g) treatment, followed by I_2 (0.8 ET_c) (883 g) and significantly lower in I_3 (0.6 ET_c) (805 g). Treatment I_1 (1.0 ET_c) and I_2 (0.8 ET_c) were found to be statistically at par. Due to better crop establishment and favourable microclimatic conditions, average fruit weight was found to be more under mulch application (M_1) (917 g) when compared with no mulch treatment (M_0) (810 g). 100 per cent RDF (F_1) (890 g) treatment recorded significantly higher fruit weight over 80 per cent RDF (F_2) (872 g) and 60 per cent RDF (F_3) (828 g).

F_1 and F_2 were found to be statistically at par with each other. All the interactions were found to be non-significant, stating independent behaviour of each factor.

- Significant differences in fruit diameter with different levels of irrigation were observed. I_1 (1.0 ET_c) (18.1 cm) recorded maximum diameter followed by I_2 (0.8 ET_c) (17.8 cm) and significantly more from I_3 (0.6 ET_c) (16.8 cm). I_1 (1.0 ET_c) and I_2 (0.8 ET_c) were statistically at par with each other. Application of mulch (M_0) (18.0 cm) resulted in significant increase in diameter of the fruit. 100 per cent RDF (F_1) (18.1 cm) resulted in maximum fruit diameter and was followed by 80 per cent RDF (F_2) (17.8 cm). F_1 and F_2 were found to be statistically at par.
- Significant effect of various irrigation, fertigation and mulch treatments on total yield was observed. Among the irrigation levels, drip irrigation at 100 per cent ET_c (I_1) (199.6 q/ha) recorded maximum yield, which was at par with treatment, where drip irrigation at 80 per cent ET_c level (I_2) (191.8 q/ha) was applied. Drip irrigation at 60 per cent ET_c levels (I_3) (170.0 q/ha) resulted in significantly lower yield. Among different fertilizer levels, 100 per cent RDF (F_1) recorded maximum yield (196.7 q/ha), followed by 80 per cent RDF (F_2) (189.5 q/ha) and significantly lower yield in 60 per cent RDF (F_3) (176.1 q/ha). F_1 and F_2 were found to be at par statistically. Application of silver black polythene mulch (M_1) produced higher yield i.e. 200.6 q/ha. None of the interaction were found to be significant. Mean yield recorded under control was 169.3 q/ha, which was lower when compared with drip fertigation and mulch treatments. Lesser availability of nutrients and moisture to the plants for growth and development due to various losses under conventional method might be the reason for lower yield.
- A remarkable impact on marketable yield of the crop was observed under various treatments. I_1 (1.0 ET_c) recorded the maximum yield (186.8 q/ha), followed by I_2 (0.8 ET_c) (175.8 q/ha) and significantly lower yield in I_3 (0.6 ET_c) (152.4 q/ha). I_1 (1.0 ET_c) and I_2 (0.8 ET_c) were statistically at par with each other. Significantly higher marketable yield under mulch conditions (M_1) (186.8 q/ha) was observed. Among the various fertilizer levels, significantly high marketable yield was recorded under 100 per cent RDF (F_1) (179.4 q/ha) and was followed by 80 per cent RDF (F_2) (173.8 q/ha). Treatment F_1 and F_2 were found to be statistically at par.
- Saving of irrigation water under drip method of irrigation was observed in comparison with the conventional method of irrigation. Depth of water applied under conventional method of irrigation was 71.32 cm. Among different irrigation levels, maximum percentage of water saving over control was observed in treatment I_3 (0.6 ET_c) (80.85 per cent) and lowest in treatment I_1 (1.0 ET_c) (68.00 per cent).

- Data regarding water use efficiency (WUE) depicted that increase in level of irrigation leads to corresponding decrease in WUE. Results uncovered that WUE in I_1 (1.0 % ET_c) (8.78 q/ha-cm) was lower when compared with treatment I_3 (0.6 ET_c) (12.51 q/ha-cm). Highest water use efficiency was recorded under treatment I_3. The increase in water use efficiency was 29.81 percent in I_3 (0.6 ET_c) over I_1 (1.0 ET_c) treatment. Application of mulch (M_1) (11.42 q/ha-cm) was found to increase WUE significantly over no mulch conditions (M_0) (9.82 q/ha-cm). Among various fertilizer levels, significantly higher WUE was recorded in F_1 (100 per cent RDF) (11.11 q/ha-cm), trailed by F_2 (80 per cent RDF) and lower in F_3 (60 per cent RDF) (10.02 q/ha-cm). F_1 and F_2 were found to be statistically at par with each other. Water use efficiency under control was 2.37 and was much lower in comparison with different treatments.
- Significant variation in vitamin C content due to mulch application, irrigation and fertigation levels was observed. Significantly higher content of vitamin C among the irrigation levels was recorded in I_1 (1.0 ET_c) (22.09 mg/100g), followed by I_2 (0.8 ET_c) (21.01 mg/100g) and lowest in I_3 (0.6 ET_c) (20.28 mg/100g). Reduction in vitamin C content under the period of stress might be attributed to reduction in synthesis of D-glucose (precursor of vitamin C). Mulch application (M_1) (21.60 mg/100g) significantly improved the vitamin C content in comparison with no mulch (M_0) (20.66 mg/100g) treatment. 100 per cent RDF (F_1) (22.44 mg/100g) resulted in significant increase in vitamin C content and was followed by 80 per cent RDF (21.16 mg/100g). None of the interactions were found to be significant.
- Total soluble solids (TSS) is an important quality parameter which gets affected with the moisture content. Optimum content of moisture results in improving TSS content, thereby enhancing the fruit quality. TSS was found to be highest when irrigation was applied at 80 per cent ET_c (I_2) (11.83 °Brix). Application of polythene mulch (M_1) (11.71 °Brix) significantly increased the TSS content over no mulch treatment (M_0) (11.12 °Brix). Among the fertilizer treatments, maximum value of TSS was found in 100 per cent RDF (F_1) (11.68 °Brix) and was followed by treatment with 80 per cent RDF (F_2). Treatment F_1 and F_2 were found to be statistically at par with each other.

  Among the interactions, interaction between irrigation and mulch was found to influence the TSS value. Combination of treatment with drip irrigation at 80 per cent ET_c level along with mulch application (I_2M_1) reported significantly highest TSS (12.06 °Brix). Lowest TSS (10.53 °Brix) was recorded when irrigation was given at 60 per cent ET_c under bare soil conditions (I_3M_0).

- Significant differences in dry matter content with application of different irrigation levels were observed. Highest content of dry matter was recorded in I_1 (1.0 ET_c) (9.21 g/100g) and was followed by treatment I_2 (0.8 ET_c) (7.78 g/100g). Significantly more content of dry matter was recorded when silver black polythene mulch (M_1) (8.40 g/100g) was used. Significant increase in dry matter content was observed when 100 per cent RDF (F_1) (8.74 g/100g) was applied. 60 per cent RDF (F_3) (7.51 g/100g) resulted in significantly lower dry matter content.

  Interaction between irrigation and mulch and irrigation and fertilizer was found to be significant. During 2017-18, irrigation at 100 per cent ET_c in combination with mulch application resulted in maximum content of dry matter (I_1M_1) (8.61 g/100g). During 2018-19 and pooled analysis, drip irrigation at 100 per cent ET_c along with fertilizer application at 100 per cent RDF (I_1F_1) resulted in significantly higher dry matter content viz. (12.12 g/100g) and (10.29 g/100g) respectively.

- Drip irrigation along with mulch application resulted in maximum net returns (Rs 130023/ha) and was followed by drip method of irrigation without mulch application (Rs 124362/ha). Conventional method of cultivation resulted in lowest returns (Rs 107580/ha).

Conclusion

From the present investigation, it may be concluded that drip fertigation at 80 per cent ET_c level and 80 per cent RDF along with mulch application is beneficial to improve productivity and quality of muskmelon with saving of 80.85 water and 20 per cent fertilizer over the conventional method.

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ANNEXURE-I

Weekly meteorological observations during 2017-18

Weeks	Maximum Temperature (^oC)	Minimum Temperature (^oC)	Maximum Relative Humidity (%)	Minimum Relative Humidity (%)	Actual Sunshine Hours	Wind Velocity (m/s)	Rainfall (mm)
Feb19- Feb 25	25.6	12.0	86.3	49.2	7.2	1.0	0.5
Feb 26- Mar 4	25.8	13.1	88.7	50.9	6.5	0.8	0.0
Mar 5- Mar 11	27.3	12.2	87.8	41.7	10.4	0.9	0.0
Mar 12- Mar 18	29.9	14.1	85.0	29.6	10.0	0.8	0.0
Mar 19- Mar 25	29.9	14.1	85.0	29.6	10.0	0.8	0.0
Mar 26- Apr 1	33.1	16.5	74.1	29.6	10.2	1.3	0.0
Apr 2- Apr 8	34.8	20.3	68.9	32.6	5.9	1.4	0.0
Apr 9- Apr 15	33.1	18.0	72.9	31.9	7.4	1.3	1.4
Apr 16- Apr 22	35.4	19.5	58.0	23.9	9.8	1.8	0.0
Apr 23- Apr 29	39.6	21.5	45.0	18.7	11.0	1.3	0.0
Apr 30- May 6	36.5	24.3	56.3	34.9	7.8	2.4	2.2
May 7- May 13	38.3	23.2	54.7	23.0	9.0	1.8	0.5
May 14- May 20	38.4	23.4	50.6	22.9	6.2	1.4	0.0
May 21- May 27	42.1	23.7	33.0	8.6	10.1	1.1	0.0
May 28- June 3	40.9	27.9	45.1	24.3	7.7	2.8	0.0
June 4- June 10	39.6	27.8	59.5	35.3	7.6	2.4	2.5

ANNEXURE-II

Weekly meteorological observations during 2018-19

Weeks	Maximum Temperature (^oC)	Minimum Temperature (^oC)	Maximum Relative Humidity (%)	Minimum Relative Humidity (%)	Actual Sunshine Hours	Wind Velocity (m/s)	Rainfall (mm)
Feb 20- Feb 26	21.1	10.2	89.9	56.1	7.0	1.2	1.5
Feb 27- Mar 5	20.0	9.6	89.1	55.9	6.9	0.8	0.9
Mar 6- Mar 12	23.1	9.9	87.4	47.4	8.3	0.8	0.2
Mar 13- Mar 19	25.2	11.3	90.6	43.9	6.9	0.8	0.0
Mar 20- Mar 26	26.9	12.8	87.3	43.4	5.4	0.9	0.0
Mar 27- Apr 2	31.7	15.1	86.9	35.7	10.1	0.7	0.0
Apr 3- Apr 9	34.5	18.8	81.6	35.9	9.2	0.8	0.0
Apr 10- Apr 16	34.5	19.9	69.9	30.1	6.0	1.6	1.1
Apr 17- Apr 23	32.8	18.5	76.7	34.6	10.4	0.9	4.3
Apr 24- Apr 30	39.3	22.3	51.6	19.1	10.2	1.3	0.5
May 1- May 6	37.7	20.5	44.9	13.6	10.0	1.1	0.6
May 7- May 13	38.7	22.3	48.4	19.9	9.2	1.3	0.5
May 14- May 20	35.2	22.3	66.7	31.6	8.2	1.3	1.7
May 21- May 27	37.9	22.1	54.6	23.3	10.5	1.5	0.1
May 28- June 3	43.7	26.4	45.8	19.8	11.1	1.5	0.3

ANNEXURE-III

Weekly soil temperature (°C) during 2017-18

Weeks	Morning (Minimum)		Evening (Maximum)	
	Silver black mulch	No mulch	Silver black mulch	No mulch
Feb19- Feb 25	18.2	16.5	29.8	32.1
Feb 26- Mar 4	18.0	17.5	30.4	32.8
Mar 5- Mar 11	19.4	16.8	30.0	33.1
Mar 12- Mar 18	21.8	18.8	32.6	35.1
Mar 19- Mar 25	21.7	19.1	31.0	34.5
Mar 26- Apr 1	21.1	19.6	31.3	34.7
Apr 2- Apr 8	24.6	21.7	35.1	38.8
Apr 9- Apr 15	26.7	24.1	35.9	39.7
Apr 16- Apr 22	24.7	21.0	35.3	38.5
Apr 23- Apr 29	26.7	23.3	37.4	41.4
Apr 30- May 6	30.4	28.1	40.3	44.1
May 7- May 13	31.7	30.2	33.3	36.4
May 14- May 20	31.0	29.5	36.1	39.6
May 21- May 27	31.0	30.1	36.7	39.8
May 28- June 3	36.9	35.6	34.7	40.0
June 4- June 10	35.1	33.1	46.4	49.5

ANNEXURE-IV

Weekly soil temperature (°C) during 2018-19

Weeks	Morning (Minimum)		Evening (Maximum)	
	Silver black mulch	No mulch	Silver black mulch	No mulch
Feb 20- Feb 26	18.0	17.5	28.4	30.8
Feb 27- Mar 5	19.4	18.8	30.0	32.1
Mar 6- Mar 12	22.8	20.8	31.9	35.1
Mar 13- Mar 19	20.7	19.1	29.0	33.5
Mar 20- Mar 26	17.8	15.9	29.3	33.7
Mar 27- Apr 2	20.4	18.6	36.1	38.8
Apr 3- Apr 9	25.1	22.6	37.0	39.7
Apr 10- Apr 16	25.8	23.7	34.3	37.5
Apr 17- Apr 23	23.0	21.4	38.4	40.4
Apr 24- Apr 30	25.9	24.7	42.9	44.1
May 1- May 6	26.8	24.7	31.5	37.4
May 7- May 13	28.4	26.2	34.3	39.6
May 14- May 20	29.0	25.2	38.9	40.8
May 21- May 27	28.2	26.6	36.6	39.0
May 28- June 3	32.1	30.4	48.5	51.5

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