FERTIGATION AND MULCHING STUDIES IN YARD LONG BEAN

(*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)

By

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THESIS

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DECLARATION

I, Mahsuma Puthuppalli (2012-12-104) hereby declare that this thesis entitled **"Fertigation and mulching studies in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

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17/09/2014

CERTIFICATE

Certified that this thesis entitled **"Fertigation and mulching studies in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)"** is a bonafide record of research work done independently by **Ms. Mahsuma Puthuppalli** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, associateship, fellowship to her.

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INTRODUCTION

1. INTRODUCTION

When water becomes scarce, demand management becomes the key to the overall strategy for managing water (Molden *et al.*, 2001). Since agriculture is the major competitive use of diverted water in India (GOI, 1999), demand management in agriculture would be central to reducing the aggregate demand for water to match with the available future supplies, thereby reducing the extent of water stress, that the country is likely to face (Kumar, 2003a and Kumar, 2003b). Improving productivity of water use in agriculture is an important part of the overall framework of managing agricultural demand for water (Barker *et al.*, 2003; Frederick, 1993). Efficient irrigation technologies help establish greater control over water delivery to the crop root and reduce the non beneficial evaporation and deep percolation losses from the field.

Yard long bean [*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt] is one of the most important vegetable crops of Kerala. Being highly remunerative, area under its cultivation is fast expanding under irrigated conditions. The crop has a high protein content of about 25% in the grain (dry weight basis) (Bresani, 1985), and serves as a cheap source of protein, vitamins and minerals. In addition, the crop improves the cropping systems and soil fertility by reducing soil erosion, suppressing the weeds and fixing atmospheric nitrogen, which contributes to increased yields of nitrogen demanding crops grown with or after it (Tarawali *et al.*, 2002). However, despite such importance, average cowpea yield is low and the major constraints contributing to the low cowpea yields include biotic stresses (insect pests, nematodes, diseases and weeds), abiotic stresses (low soil fertility and drought), poor agronomic practices, poor seed quality, cultivation of low yielding and non-improved cultivars, and limited breeding work. Adoption of recent agro-techniques can also help to fulfill the requirement.

Micro irrigation system was found to result in 30 to 70% water saving (INCID, 1994) in various orchard crops and vegetables along with 10 to 60% increase in yield as compared to conventional methods of irrigation. It is prudent to make efficient use of water and bring more area under irrigation through available water resources. This can be achieved by introducing advanced methods of irrigation and improved water management practices (Zaman *et al.*, 2001). Drip irrigation in combination with mulch is one of the best water management methods, which can improve the water use efficiency significantly. Drip irrigation, with its ability to provide small and frequent water application directly in the vicinity of the plant root zone has attracted interest because of decreased water requirement and possible increase in production (Darwish *et al.*, 2003). About 20–60% higher yields were obtained with drip irrigation in some studies (Sivanappan *et al.*, 1974), while in other studies yield was reported to be slightly lower or equal to that of conventional irrigation (Doss and Evans, 1980) along with reduction in irrigation requirement of 30–60%.

India stands 27^{th} in terms of degree of adoption of water saving and yield enhancing micro-irrigation devices. Sivanappan and Lamm (1999) reported that the area under drip irrigation was meager to the extent of 7000 ha in 1994. The most recent data on the extent of use of micro irrigation devices is the data compiled by International Commission on Irrigation and Drainage (ICID), reported that India has a total of 9.1851 lakh ha of cropped area under drip and sprinkler irrigation, of which 2.6 lakh ha is under drips (Kumar *et al.*, 2006).

Mulching is another water management practice for increasing water use efficiency. Any material spread on the surface of soil to protect it from solar radiation, evaporation or weeds is called mulch. Different types of materials like straw, stubbles, grass, wood, plastic film etc. are used as mulches. Surface mulches have been used to improve soil water retention, reduce soil temperature and wind velocity at the soil surface (Kay, 1998). Surface mulches can also improve water penetration by impeding runoff and protecting the soil from raindrop splash and reducing soil crusting (Munshower, 1994). Beneficial response of plants to mulch includes earlier production (Call and Courter, 1989), greater total yield (Jensen, 1990) and reduced insect and disease problems (Greenough *et al.*, 1990).

Recent advances in agro-technology make it possible to apply fertilizer materials through the irrigation systems, a practice referred to as fertigation (Greeff, 1975). This practice has several advantages including: 1) savings in cost of fertilizer application and labour; 2) fertilizer elements are already in solution form and become available to plant roots more quickly than dry materials placed on soil surface; and 3) the high flexibility in irrigation timing makes it easier to schedule fertilization. The fertilizer can be applied frequently and periodically in small amounts with each irrigation to ensure adequate supply of water and nutrients in the root zone. Therefore, as a result of the shift from the surface irrigation to drip method, fertigation becomes most common, in the irrigated agriculture. The use of soluble and compatible fertilizers, good quality irrigation water, and need based application are the prerequisites of the successful fertigation system (Biswas, 2010). The availability of nutrients under fertigation is very high, and hence the efficiency is more. Liquid fertilizers as well as water soluble fertilizers are used in drip fertigation with an increased fertilizer use efficiency of 80 to 90 per cent besides minimizing pollution of ground water through nitrate-nitrogen leaching to a considerable extent

Considering the above facts, the present study entitled "Fertigation and mulching studies in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)" was undertaken with the following objectives:

- To standardize the fertigation requirement of yard long bean and
- To assess the relative efficacy of fertigation and mulching over the conventional methods.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Water and nutrients are the major inputs contributing to higher productivity in irrigated agriculture. In intensive agriculture, both fertilizer and irrigation management have contributed immensely in increasing the yield and quality of crops. Micro-irrigation systems along with mulching are the most modern systems of water management where the water use efficiency is very high. Fertigation provides flexibility in fertilizer application, which enables the specific nutritional requirement of the crop to be met at different stages of its growth. In comparison with the conventional methods, it appears that fertigation gives higher crop yields with substantial saving in fertilizers.

Several studies have indicated the possibility of increasing the yield of many vegetables by adopting suitable irrigation and nutrient management. Very little information is available on the water and nutritional requirements of cowpea through fertigation. Hence the works conducted in India and abroad on cowpea and other vegetables on water and nutrient management and soil moisture conservation techniques are reviewed in this chapter.

2.1 INFLUENCE OF METHOD, DEPTH AND FREQUENCY OF IRRIGATION ON VEGETABLES

Water Use Efficiency (WUE) would be of particular interest in situations where growth is affected as a result of limited water availability. Muthuvel and Krishnamoorthy (1978) found that among the multiple factors contributing to plant growth and yield, water is the most important and limiting one. Many studies have reported linear response in plant growth to increase in water application rate (Shmueli and Goldberg, 1972).

According to Pai and Hucker (1979), for good growth of vegetables the soil moisture should be maintained at or above 75 per cent of availability in the active root zone. Plant growth and development in terms of size, number and quality of fruits, were very much influenced by soil moisture content (Yadav and Singh, 1991).

Experiment conducted at the Agricultural Research Station, Mannuthy showed that the treatment which received frequent irrigation showed higher values of consumptive use throughout the crop growth period in cucurbits (Radha, 1985). Similarly Veeraputhiran (1996) observed an increase in yield attributing characters in oriental pickling melon with the increase in frequency of irrigation and it was maximum at IW/CPE ratio of 1.2.

Prabhakaran (2003) studied the moisture extraction pattern of soybean crop in field experiments conducted at Coimbatore. He found that most of the moisture under all irrigation levels (IW/CPE 0.5, 0.7 and 0.9) was extracted from the surface 0-30 cm depth. Top 15 cm layer contributed the highest when minimum number of irrigation was given (IW/CPE 0.5). Moisture extraction from lower profile (30-45 cm) was higher in less irrigation water applied treatment (IW/CPE 0.5) to a tune of 25.5 and 22.6 per cent respectively during summer and kharif seasons. The relative contribution of moisture in the upper layer for extraction was higher with composted coir pith application.

Kassem (2008) conducted a study to investigate the effect of irrigation frequency on irrigation water depth, wetted area width and depth in potato root distribution, soil moisture distribution, water loss by deep percolation, potato tuber yield and water use efficiency. Treatments consisted of seven different drip irrigation frequencies such as irrigating every half day, irrigating every day, irrigating every 2 days, irrigating every 3 days, irrigating every 4 days, irrigating every 6 days and irrigating every 8 days. The results indicated that irrigation water depth was increased with decreasing irrigation frequency from irrigating every half day to irrigating every 8 days, depending on the growth stage of potato and climatic conditions. Also, wetted area width and depth, water loss by deep percolation were increased with decreasing irrigation frequency.

Seed yield of cowpea was found to be particularly sensitive to water deficit, where the highest seed yield (1.12 Mg/feddan) was observed with full irrigation, while the lowest (0.67 Mg/feddan) occurred when the water application was equal to 60% of soil moisture content at field capacity (Aboamera, 2010). Bisht *et al.* (2012) reported that in potato, the maximum emergence (92%), plant height (71.2 cm) and the number of stems (4.2) were recorded under irrigation given on alternate day basis while, the number of leaves per hill was maximum at the irrigation given on daily basis and decreased with the decrease in irrigation schedules on daily basis.

2.2 SCHEDULING OF IRRIGATION USING PAN EVAPORATION

The positive relationship between water loss from an evaporimeter and the potential evapotranspiration makes this approach more attractive for irrigation scheduling, as the evaporation is easy to monitor and the necessary equipment is very simple and easy to maintain (Doorenbos and Pruitt, 1977). Vamadevan (1980) indicated that evaporation values measured from a standard USWB class A open pan evaporimeter are extensively used for scheduling of irrigation.

Studies in watermelon by Srinivas *et al.* (1989) with four levels of evaporation (25, 50, 75 and 100 %) replenishment under drip and furrow irrigation indicated that replenishment of 25 per cent evaporation loss under drip, and 50 to 70 per cent evaporation loss under furrow irrigation, were optimum for higher yield.

Locascio and Smajstrla (1989) reported that scheduling water application was also critical, as excessive irrigation reduced yield, while inadequate irrigation caused water stress and reduced production. They found that the highest yield of extra large fruit was obtained with 0.50 Ep and the highest total marketable yield was obtained with 0.75 Ep. The quantity of water to be applied by pan evaporation to obtain maximum tomato production varied with soil type, season and rainfall. In these studies, maximum yields were consistently produced with water quantities between 0.5 and 1.0 Ep in dry years. In a season with 3.4 cm rainfall per week, no response to irrigation was obtained.

Musard and Yard (1990) found that vitreous flesh disorder in melons was due to too much of water during fruit ripening and they also suggested that irrigation must be reduced to 40-50 per cent of evaporation during the last week before harvest. According to Batra and Kalloo (1991) in carrot cv. Gurgaon selection, grown at IW/CPE ratio of 0.4, 0.8 and 1.2; the soil moisture content was significantly higher at the IW/CPE ratio of 1.2 water consumption increased with irrigation rate.

In irrigation cum fertilizer trial at Thailand, Yingjawal and Markmoon (1993) found that increasing the irrigation rate from 100 to 200 per cent potential evapo-transpiration increased the total yield of cucumber by 13 per cent. Further, study on Indian Institute of Horticulture Research, Bangalore revealed that irrigation scheduled to replenish 120 per cent of pan evaporation recorded 25 per cent more early harvestable yield (Prabhakar and Naik, 1993) in cucumber.

Veeraputhiran (1996) observed an increase in yield in oriental pickling melon with the increased frequency of irrigation and it was maximum at IW/CPE ratio of 1.2. The peak consumptive use was reached between 36-50 days after sowing for the irrigation intervals of IW/CPE ratio 1.2.

In a study on the effect of irrigation on fruit weight and total yield, in oriental pickling melon, Leekyaeongbho *et al.* (1999) observed that plants irrigated up to 20 days after flowering (88.8 mm) produced highest yield (11.4 t/ha) of good quality fruits. Similar study in oriental pickling melon revealed that growth, yield and net income increased with increase in level of daily drip irrigation from 50 -125 per cent Ep and reached the maximum at 125 per cent Ep (Gebrimedhin, 2001).

Prabhakaran (2003) studied the influence of irrigation on water use in soybean in field experiments conducted at the research farm of Tamil Nadu Agricultural University, Coimbatore. He has reported that when soybean was irrigated at narrower irrigation frequency as dictated by IW/CPE ratio of 0.9, soil moisture content was higher by 17.2 and 19.2 per cent, respectively during summer and kharif in the surface 0-30 cm layer. It was also higher in the lower layer of 30-45 cm by 19.7 and 21.5 per cent, respectively during summer and kharif season. Application of composted coirpith at the rate of 12.5 t ha-1 increased the soil moisture by five per cent in summer and eight per cent in kharif against control. Rekha *et al.* (2005) found that the highest fruit yield and water use efficiency were noted when bhindi crop was drip irrigated at 1.0 Ep and fertilized with 120 Kg N ha^{-1}.

Bahadur *et al.* (2006) studied the effect of fertigation on growth and yield of tomato in an irrigation experiment conducted at the Indian Institute of Vegetable Research, Varanasi. Results indicated that for maximum number of fruits per plant, fruit weight and fruit yield, drip irrigation should be scheduled in tomato at 100 per cent Ep. Similar studies conducted by Sharda *et al.* (2006) in onion also revealed that highest plant height; number of leaves and yield of onion were obtained when irrigation was scheduled at 1.0 per cent Ep.

2.3 DRIP IRRIGATION

Drip irrigation is a multi disciplinary agricultural practice and has enormous potentials and possibilities (Goldberg, 1971). The better performance under drip was attributed to maintenance of favorable soil water status in the root zone, which in turn helped the plants to utilize moisture as well as nutrients more efficiently from the limited wetted area (Phene and Beale, 1976). In 1860 an Israeli engineer Simcha Blass developed the first drip irrigation system using micro tubes extending from a plastic line (Anwar and Kumar, 1980).

The increased yield under drip irrigation system might have resulted due to better water utilization (Manfrinato, 1974), higher uptake of nutrients (Bafna *et al.*, 1993) and excellent soil–water–air relationship with higher oxygen concentration in the root zone (Gornat *et al.*, 1973).

Micro irrigation systems make efficient use of the available water resources, as frequent application of water to the plant root zone minimizes loss through seepage. There is considerable saving of water in these systems (up to 40-50%) depending upon the climate, as soil surface wetting is restricted to root zone both in respect of spread and depth. The evaporation is also reduced (Bruce *et al.*, 1980).

Singh *et al.* (2001) conducted studies on the emerging scenario of micro irrigation in India and reported that drip system permitted the use of fertilizers, pesticides and other soluble chemicals along the irrigation water. It has a potential for use as a major component in adoption of precision farming. Several types of drippers or emitters are manufactured such as laminar flow, turbulent flow and orifice type. Pressure compensating drippers enables irrigation of undulated and sloping lands with uniform flow rate from the drippers. Pressure compensating drippers are self flushing and operate in the range of 0.7 to 3.0 kg/cm^2 (Natan, 2005).

Micro irrigation is the slow application of water on, or below the soil by surface drip, subsurface drip and bubbler and micro sprinkler systems. Water is applied as discrete or continuous drips, tiny streams, or miniature spray through emitters or applicators placed along a water delivery line adjacent to the plant row (James *et al.*, 2007).

Schwanki and Hanson (2007) defined drip irrigation as an irrigation method that transfer the water under a definite pressure, after filtering, through pipe network into the soil surrounding the root system of plants in drops slowly and uniformly. The emitters are to drip the water from the pipeline to the root zone of the crops evenly and steadily, so as to guarantee the water demand for the crop growth. The quality of the emitter has an important effect on the reliability, life span of the drip irrigation system and irrigation quality.

2.3.1 Effect of drip irrigation on growth, yield and quality of vegetables

Drip irrigation relies on the concepts of irrigating only the root zone of a crop and maintaining moisture content of the root zone at nearly optimum level. Irrigating only a portion of the land surface limits evaporation, reduces weed growth and minimizes interruption to cultural operations. Maintaining nearly optimum moisture content in the root zone usually involves frequent applications of small amount of water which improve the water-use efficiency (WUE) with higher yield and quality of crop.

Batchelor *et al.* (1996) reported that micro-irrigation techniques can be used to improve irrigation efficiency in vegetable gardens by reducing soil evaporation and drainage loss and by creating and maintaining soil moisture conditions that are favorable to crop growth. Among different micro irrigation techniques evaluated, subsurface irrigation found to be particularly effective in improving yields, crop quality and water use efficiency as well as being cheap, simple and easy to use, compared to low-head drip irrigation, pitcher irrigation and subsurface irrigation.

Studies conducted with KAU micro sprinkler revealed that a large increase in yield of bitter gourd (4.31 t ha^{-1}) was possible with micro sprinkler irrigation as compared to drip irrigation (2.98 t ha^{-1}) (Kerala Agricultural University, 1996). Field experiments conducted to study the response of micro irrigation on various vegetables showed that maximum water use efficiency of 2.11 t $ha\text{-}cm^{-1}$ was achieved for tomato irrigated through drip micro-tube followed by drip emitter (1.89 t $ha\text{-}cm^{-1}$) and minimum for surface methods of irrigation (0.89 t $ha\text{-}cm^{-1}$).

Tiwari *et al.* (1998) reported that 100% irrigation requirement met through drip irrigation along with black plastic mulch gave the highest yield (14.51 t/ha) in okra with 72% increase in yield as compared to furrow irrigation.

According to Bell *et al.* (1998) surface drip irrigation and associated mandatory minimum tillage practices significantly reduced the incidence of lettuce crop drop caused by *Sclerotinia minor* and the severity of corcky root on lettuce compared with furrow irrigation and conventional tillage. The suppression of lettuce drop under drip irrigation is attributed to differential moisture and temperature effects rather than to change in the soil microflora or their inhibitory effects on *S. minor*.

Sivanappan (1998) has compared the data on application efficiencies of drip and surface irrigation methods at various stages such as conveyance efficiency, field application efficiency and soil moisture evaporation. The result showed that drip irrigation had the maximum efficiency of 80-90 per cent compared to surface irrigation because of very high level of conveyance and application efficiency, coupled with low evaporation.

Mustafa (1999) found that the highest yield was obtained by drip irrigation as compared to furrow irrigation under the same condition for two varieties of okra. Similar study by Raina *et al.* (1999) at Solan found that drip irrigation enhanced tomato fruit yield by 40 per cent when compared to the surface irrigation

Drip irrigation generally achieved better crop yield and balanced soil moisture in the active root zone with few losses (Yildirim and Korukcu, 2000) and the irrigation efficiency ranged from 80 to 91% when the crop was grown in fields using a drip system (Al-Jamal *et al.*, 2001).

Savings of water achieved for green chilli over surface irrigation was maximum (40.4%) in drip microtube followed by drip emitter (40.0%) and minimum in micro sprinkler irrigation (16.0%) (Manjunatha *et al.*, 2001b).

A comparative study of drip and sprinkler irrigation on garlic by Sankar *et al.* (2001) indicated that drip irrigation at 100 per cent PE led to the production of 147.8 q ha^{-1} bulbs and 44 per cent water saving over conventional method. Sprinkler irrigation at 100 per cent PE gave 128.2 q ha^{-1} yield and 41 per cent water saving.

Manjunatha *et al.* (2001a) studied the effect of micro sprinkler and surface irrigation methods on potato and reported a net increase of 9.2 per cent in plant height 22.6 per cent in average number of secondary branches, 18.7 per cent in average number of leaves and 19.4 per cent in mean leaf area with micro sprinkler irrigation as compared to furrow irrigation.

The irrigation level at I_2 (Irrigation at 10 mm CPE with 20 mm water through micro-sprinklers) registered significantly superior pod yield of cowpea over the other two levels (Irrigation at 20 mm CPE with 40 mm water through surface method and 20 mm by pot watering) (Geetha and Varughese, 2001). In irrigation trial conducted at the research farm of College of Agriculture, Raipur during 1999-2000, to compare the benefit of drip irrigation over flood irrigation in tomato, an increased growth and yield parameters were observed under drip irrigation compared to flood irrigation (Agrawal *et al.*, 2004).

Singh *et al.* (2005) found from their experiments, that the potato yield was 588.0 quintals/ha under drip irrigation method compared to 507.8 quintals/ha under furrow mode and 561.6 quintals/ha under sprinkler irrigation

Sprinkler irrigation systems with low irrigation frequencies of three days increased pod yield (ranged from 602 to 651 g m^{-2}) and water use efficiency (WUE) of peanut due to decreasing water loss (Plaut and Ben-Hur, 2005). In a study conducted at Kerala Agricultural University, by Rekha *et al.* (2005) found that furrow irrigated bhindi showed 54% and 57% lower yield than drip irrigated plants @ 1.0 Potential Evaporation value (E_{pari}) and fertigated with 120 kg N ha^{-1}.

Bahadur *et al.* (2006) reported from the field experiments conducted at Indian Institute of Vegetable Research, Varanasi that drip irrigation at 100 per cent Ep resulted in maximum number of fruits, fruit weight, total fruit yield and marketable fruit yield of tomato compared to other levels of Ep and surface irrigation. Drip irrigation scheduled at 100 and 80 per cent ET_0 saved 45.8 and 46.5 per cent water, respectively over surface irrigation.

Field experiment conducted at Punjab Agriculture University by Sharda *et al.* (2006) revealed the benefit of drip irrigation over surface irrigation in onion. Drip irrigation at 1.3 Ep resulted in the highest plant height, number of leaves and yields in onion. Singh *et al.* (2006) reported that when green peas were drip irrigated with 0.5 Epan, pod yield was highest (154.3 q/ha) and increased by 36.5% and 59.4% over check basin method of irrigation when the crop was sown in paired or single rows, respectively.

Rolbiecki (2007) studied the effect of drip and micro sprinkler irrigations on the growth and yield of cucumber on sandy soil in central Polland. He observed up to 85 per cent increase in fruit yield under drip and micro sprinkler irrigations compared to flood irrigation. In brinjal, higher yields (42.33t/ha in first crop and 37.90 t/ha in second crop) were recorded under drip irrigation @ 75% of Ep with fertigation of 75% of recommended N and K (Vijayakumar *et al.*, 2010).

Susila *et al.* (2012) reported that with drip irrigation plant height of yard long bean were higher than those without drip irrigation. Similarly, Tagar *et al.* (2012) observed that the drip irrigation method saved 56.4% water and gave 22% more yield in tomato as compared to that of furrow irrigation.

Pandey *et al.* (2013) revealed that the method of drip irrigation had significantly increased yield (10.50 kg / m^2) and net income (60.30 Rs/m^2) of chilli as compared to flood irrigation. The crop yield improved by 60.30% in chilli when the crop was irrigated through drip. Maximum water saving, minimized weeds, diseases and total time of irrigation were found in drip irrigation.

In a study, Shaker *et al.* (2013) found that in Phaseolus bean the highest yield obtained was 522 kg/feddan for drip irrigation system using 400 m^3/feddan/month compared to the surface irrigation method with 800 m^3/feddan/month gave an yield of 492 kg/feddan, while the lowest yield of 136 kg/feddan was obtained from drip irrigation system with 800 m^3/feddan/month.

Nakaande (2013) reported that drip irrigation at 60% Ep resulted in significantly higher plant height while plant spread, number of non wrapping leaves and wrapping leaves were highest at 80 % Ep in cabbage. In a fertigation trail in oriental pickling melon, Ningaraju (2013) revealed that drip irrigation with 100 % Ep increased the length of vine, number of leaves per vine, number of branches per vine, number of fruits per plant, leaf area index, weight of fruits, volume of fruits, and fruit yield.

2.3.2 Effect of drip irrigation on soil moisture characteristics and water use efficiency

Hedge and Srinivas (1990) reported higher WUE with drip irrigation (48.6 Kg ha-cm^{-1}) compared to basin irrigation (43.10 Kg ha-cm^{-1}) in banana crop. This was due to higher total dry matter, bunch weight and higher total nutrient uptake.

Raina *et al.* (1999) at Solan found that in tomato crop WUE under drip irrigation alone, drip irrigation plus polythene mulch and surface irrigation were 0.34, 0.48, 0.16 t ha cm^{-1} respectively. Besides drip irrigation saved 54 per cent irrigation water.

In an experiment to study the response of cowpea variety Malika to nitrogen and potassium under varying levels of irrigation, the maximum yield of green pods was obtained when the crop was irrigated through micro sprinklers at 20 mm CPE with a depth of 10 mm water. Moisture depletion was higher from the top 0-5 cm layer of the soil when the crop was irrigated at 10 mm CPE with a depth of 20 mm water through micro sprinkler. At 15-30 cm and 30-45 cm depth, surface method recorded the highest moisture depletion (Geetha, 1999).

In potato, the higher water use efficiency of 2.26 t ha-cm^{-1} was achieved for potato irrigated through drip emitters followed by drip microtube (1.74 t ha-cm^{-1}), micro sprinkler (1.20 t ha-cm^{-1}) and furrow methods of irrigation (0.96 t ha-cm^{-1}) (Manjunatha *et al.*, 2001b).

Gebrimedhin (2001) reported that drip irrigation in oriental pickling melon at sandy loam soils of Agricultural Research Station, Mannuthy at 50 Ep led to 158.68 kg ha cm^{-1} of CWUE (cumulative water use efficiency) whereas conventional irrigation i.e., basin irrigation once in three days produced 62.69 kg ha cm^{-1}. Similarly Manickasundaram *et al.* (2002) found that the water use efficiency was 20 to 60% higher in drip irrigation treatments compared to that of surface irrigation.

Rajput and Patel (2002) studied the response of okra to drip irrigation and reported that the cyclic regulation and continuous wetting of soil associated with drip irrigation maintained optimum moisture in the crop root zone which in turn facilitated greater rates of water and nutrient absorption. Rekha *et al.* (2005) conducted investigation on trickle and furrow irrigation in bhindi at the Directorate of Oil Seeds Research, Hyderabad. They found that highest fruit yield and water use efficiency were noted when bhindi crop was drip irrigated at 1.0 Ep and fertilized with 120 kg N ha^{-1}.

The highest water use efficiency value was recorded at the lowest water level (315 mm) with black plastic mulch, whereas the lowest WUE (9.08 kg/m3) was obtained at 565 mm without mulch treatment, which indicated that the plastic mulch distinctly improved the water use efficiency of tomato (Berihun, 2011).

An experiment conducted for the comparative study of drip and furrow irrigation methods at the farmer's field in Umar Kot, revealed that higher water use efficiency of about 4.87 was obtained in drip irrigation method; whereas lower water use efficiency of about 1.66 was obtained in furrow irrigation method (Tagar *et al.*, 2012).

Studies of Ningaraju (2013) found that field water use efficiency decreased significantly with increase in irrigation levels, in oriental pickling melon. Drip irrigation with 50 % Ep along with 200% RDF recorded significantly higher field water use efficiency and the lowest by pot irrigation.

According to Yaghi *et al.* (2013) the highest WUE (0.262 t $ha^{-1}mm^{-1}$) was obtained for the Drip + Transparent Mulch treatment because this treatment consumed about 64% and 16% less water than the Surface Irrigation and Drip irrigation treatments respectively, and produced comparatively higher yield.

2.4 EFFECT OF DIFFERENT LEVELS OF FERTILIZER ON GROWTH AND YIELD OF VEGETABLES

Fertilizer is one of the most important inputs contributing to crop production because it increases productivity and improves quality. Papadopoulos (1992) conducted an experiment to study the effect of different levels of Phosphorus (0, 20, 40, 60 mg/l) in growth and yield of potato cultivar 'Spunta'. The result showed that the application of 40 mg/P resulted in no accumulation of P in deep layers of soil profile. This level of P was recommended for obtaining high yields of good quality tubers. Studies of Hartz *et al.* (1993) revealed that fruit yield and mean fruit size of pepper peaked at 252 kg N/ha but additional N application retarded crop productivity.

In a study on the effect of phenophased irrigation on cowpea variety Malika under graded doses of nitrogen and phosphorus, the maximum yield of green pods and haulm were noticed at a NP ratio of 30:45 kg ha^{-1}. The uptake of major nutrients viz., N, P and K by the crop, net income, B:C ratio and protein content of pods were significantly increased by irrigation at 75 per cent of field capacity throughout the cropping period and at the NP ratio of 30:45 kg ha^{-1} (Jyothi, 1995).

The utilization of N can be increased by balanced application of N, P and K and lighter and more frequent irrigation (Bijay-Singh *et al.,* 1995). The nitrogen and potassium levels at 20 kg ha^{-1} enhanced pod yield of cowpea variety Malika. High level of potassium was found to influence the moisture depletion pattern (Geetha, 1999).

An experiment on vegetable cowpea [*Vigna unguiculata* var. *sesquipedalis*] with three methods of irrigation and three levels each of nitrogen and potassium (0, 20 and 40 kg/ha) was conducted in the sandy clay loam soils of Trivandrum, Kerala. The study revealed that higher level of nitrogen above 20 kg ha^{-1} tended to reduce the pod yield. Potassium at 20 kg ha^{-1} gave the maximum yield indicating the possibility of higher requirement of K for vegetable cowpea due to staggered pattern of harvesting (Geetha and Varughese, 2001).

Field studies were conducted at Bangalore, India, by Sajjan *et al.* (2002) to evaluate the effect of sowing date, spacing and nitrogen rates (100, 125 and 150 kg/ha) on the yield attributes and seed yield of okra cv. Arka Anamika. Sowing on 15 July coupled with 60x30 cm spacing and 150 kg N/ha recorded the highest yield attributes *viz.,* branches per plant, fruits per plant, 100-seed weight, length and girth of fruits, processed seed recovery and processed yield (1139.7 kg/ha) in the kharif season.

Ranjan and Chaudhary (2006) conducted field experiment at Bihar, during 2001 kharif season, to determine the response of okra to the application of organic and inorganic fertilizers. The highest nutrient uptake and net return in okra was recorded from the treatment supplied with 25% of the recommended rate of nutrients through farm yard manure. It was closely followed by the combination of inorganic fertilizers in the same proportion. Application of 18 kg nitrogen per hectare was more beneficial in terms of net returns compared to the full rate of inorganic fertilizers.

A trial was conducted in vegetable cowpea variety TUX 944 with three levels of phosphorus (50, 60 and 70 Kg/ha), three levels of potassium (50, 60 and 70 Kg/ha) and constant dose of nitrogen (20 Kg/ha). Results showed that application of 70 kg phosphorus and potassium increased the pod yield per plot (4.80 and 3.58 kg), crude protein content (25.44 and25.13 per cent) and dry matter production per plant (21.65 and 19.41 g). The yield difference among the treatments could be due to the yield attributing characters viz., number of pods per plant, pod weight and average pod weight and length (Anuja *et al.*, 2006).

Singh *et al.* (2007) conducted field experiment in Meerut, Uttar Pradesh to determine the effect of N (50, 100 and 150 kg/ha) and Cu (500, 1000 and 2000 ppm) on the growth and yield of okra Cv. Pusa Sawani. The maximum plant height, stem diameter, leaf length, leaf width, fresh pod weight and green pod yield, including the earliest number of days to emergence was obtained with 100 kg N/ha and 1000 ppm Cu.

An experiment was conducted during summer by Meena *et al.* (2008) in Lucknow, Uttar Pradesh; in randomized block design to access the suitable dose (40, 80 and 120 kg) of nitrogen with and without bio fertilizer (*Azotobacter*) in okra cv. Arka Anamika. The results showed that 120 kg/ha of nitrogen along with *Azotobacter* application gave significantly highest yield in okra crop.

The impact of phosphate fertilizer as a pest management tactic in four cowpea varieties was studied by Asiwe (2009). The results indicated that damage by *Aphis craccivora*, *Megalurothrips sjostedti* and *Maruca vitrata* were significantly lower at 30 and 45 kg P_2O_5 ha^{-1} and consequently higher grain yields were obtained.

Integrated Nutrient Management study in cowpea was conducted by Subbarayappa *et al.* (2009) in Southern Dry Zone of Karnataka. The results indicated that application of 100 per cent RDF+FYM significantly increased the uptake of major nutrients, N, P and K (39.5, 20.36, 41.90 kg ha^{-1} respectively), the pod length (15.85), seed yield (1586 kg ha^{-1}), stover yield (5124 kg ha^{-1}), harvest index (0.23) and net returns (Rs. 22,372 ha^{-1}) followed by 75 per cent RDF+FYM.

According to Akande *et al.* (2010) application of 2.5 tones organic-based fertilizer and 60kg N as NPK 20-10-10 most favoured Okra growth and yield. Similarly Hasan *et al.* (2010) reported that the application of 25 kgN2/ha gave the highest plant height (96.25 cm) and green matter yield, dry and organic matter, and crude protein yield of cowpea forage.

A pot experiment was carried out, to study the phosphrous-sulphur interaction at Udaipur on a sandy loam soil medium in P and deficient in S with cluster bean (Yadav, 2011). Result showed that the application of 40 kg P_2O_5 ha^{-1} increased the number of nodules by 10.2 and 31.9% and the weight of nodules/ha plant by 25.9 and 14.4 % over control and 20 kg P_2O_5 ha. He reported an increase in protein content of fruits at a rate of 53.29% over control.

Singh *et al.* (2011) also observed significantly higher stover yield, grain yield and increased nodulation (2115 kg ha^{-1}, 1353 kg ha^{-1}, 54 respectively) in cowpea plants supplied with 60 kg P ha^{-1} than with 0 (1411 kg ha^{-1}, 1017 kg ha^{-1}, 43), 20 (1482 kg ha^{-1}, 1067 kg ha^{-1}, 50) and 40 kg P_2O_5 ha^{-1} (1571 kg ha^{-1}, 951 kg ha^{-1}, 53).

Farahvash and Mirshekari (2011) conducted a study to determine the application of biofertilizers, instead of chemical fertilizers for optimal nutrition of cowpea. Results showed that application of 52.5 kg/ha urea and Yashil + Nitragine with 52.5 kg/ha urea increased the grain yield, number of grains per pod, number of grains per plant, number of pods per plant, 1000 grain weight, biomass yield, harvest index, grain yield per unit area, number of leaves, plant height and pod length.

A field experiment was conducted by Chavan *et al.* (2012) at Junagadh to study the effect of potassium and zinc on quality and nutrient uptake in cowpea. Twelve treatments comprising four levels of potassium and three levels of zinc were tried. The results of the study indicated that significantly higher grain (1587 and 1553 kg/ha) and stover (2047 and 2010 kg/ha) yields were recorded with application of 60 kg K_2O/ha and 40 kg Zn/ha, respectively. Application of 60 kg/ha potassium recorded higher protein content of grain as well as uptake of nitrogen, phosphorus, potash and zinc by grain and stover in cowpea.

Yadav and Choudhary (2012) noticed that in cowpea, the application of 100% RDF significantly increased the seed yield, net returns and total uptake of nitrogen, phosphorus and potassium over preceding levels of fertility (control, 50 and 75% RDF), whereas, protein content in seed, nitrogen, phosphorus and potassium content in seed and straw and potassium content in straw increased significantly upto 75% RDF and remained on par with 100% RDF.

Jat *et al.* (2013) conducted an experiment during kharif season of 2008 to study the effect of different phosphorus and sulfur levels on profitability, nutrient content and uptake in cowpea. The results showed that application of phosphorus upto 40 kg P_2O_5/ha recorded significantly higher seed (858 kg/ha) and straw (1209 kg/ha) yields, protein content in seed, nitrogen, phosphorus and sulfur content in seed and straw and total uptake compared to control and 20 kg P_2O_5/ha. Similarly Amba *et al.* (2013) also reported that application of phosphorus at 26.4 kg P/ha significantly produced higher number of nodules in cowpea.

According to Gad and Kandil (2013) molybdenum increased the efficiency of nitrogen fertilization, reduce the recommended dose by about 25% and resulted in superior yield by 39.8 % relative to the control (100% N alone).

Henry and Chinedu (2014) studied the effect of different rates of phosphorus fertilization in cowpea. The results showed that an increased P fertilization led to increased grain yield up to 30 kg Phosphorus ha^{-1}; however beyond this, yield decline was observed.

2.5 FERTIGATION

Since irrigation and fertilizer applications were regarded as very critical inputs, enterprising farmers and scientists in the past have attempted to let fertilizers be distributed through irrigation; a concept termed as fertigation with yield advantages (Goldberg and Shmueli, 1969). Efficient use of fertilizer and water is highly critical to sustained agricultural production. Fertilizers applied under traditional methods are generally not utilized efficiently by the crop. In fertigation, nutrients are applied through emitters directly into the zone of maximum root activity and consequently fertilizer-use efficiency can be improved over conventional method of fertilizer application.

Subsequently, this approach of supplying fertilizers through drip or sprinklers particularly for horticultural crops was developed by scientists in several countries (Bester *et al.*, 1977). Though the initial cost of establishing a micro-irrigation system could be high, benefits in saving water, labour, non-interference with cultural practices and distinct possibility of saving fertilizers when given through these systems are very important.

The major advantage of fertigation with drip irrigation is saving of water, labour, better timing, uniform distribution, less damage to crop and soil and ultimately higher yield. Also this method offers an opportunity for precise application of water soluble fertilizers and other nutrients to the soil at appropriate times with desired concentration (Kumar *et al.*, 1992). Generally crop response to fertilizer application through drip irrigation has been excellent and frequent nutrient applications have improved the fertilizer-use efficiency (Malik *et al.*, 1994).

For efficient and uniform distribution of plant nutrients, the irrigation system must fulfill certain requirements like, (i) it must be designed correctly to operate efficiently and (ii) should ensure complete solubility of the fertilizer without leaving any residue and (iii) should supply solution at constant rate and pressure from the main flow line (Nache, 1996).

Loccascio (2000) reported that drip irrigation systems were generally costly and required good management. Water application rate was reduced and the nutrient use efficiencies were increased with fertigation system. Loss of nutrients from the root zone was reduced in the fertigation system. Nutrients such as N and K were commonly applied through drip system, while P was more difficult to apply and to obtain proper distribution in soil. Because of the tendency of P to form insoluble precipitate with Ca and Mg commonly found in irrigation water, the use of traditional P fertilizer in drip irrigation is not very common (Hebbar *et al.*, 2004).

Fertilizers supplied under traditional methods of irrigation were not effectively used by the crop. Through fertigation, water and fertilizer are efficiently used by the plant. Studies conducted in various commercial, horticultural and high value crops, revealed that adoption of this technology improved the yield and quality of crops. It is also highly beneficial to the farming community in reducing the cost of production. Further it helps in sustaining the soil health for better productivity and reducing environmental hazards (Manickasundaram, 2005).

2.5.1 Effect of fertigation on growth, yield and quality of vegetables

Studies on effects of drip irrigation and different rates of N, P and K fertilizers on fruit yield and quality of cultivar Mountain Pride tomato revealed that application of 1000 lb of 10: 10: 10 NPK fertilizers before planting, in combination with drip irrigation produced yields equal to those with higher rates of fertilizers applied partly before planting and partly through irrigation stream (Mullins *et al.*, 1992).

Highest tuber yield (15.03 t/ha) was obtained by soil application of 50 per cent of recommended nitrogen with furrow irrigation and the remaining 50 per cent N through drip irrigation at four weekly split applications. The water use efficiency was highest when drip irrigation was provided daily in potatoes (Keshvaiah and Kumaraswamy, 1993).

Carballo *et al.* (1994) studied the effect of drip irrigation with various rates and timings of N and K application on fruit quality of bell pepper. They found that higher fertilizer rates (266-309 kg/ha of N and K, respectively) increased the yield of class I fruits in the first harvest and reduced the total discards. The low fertilizer rates (70-81 kg/ha of N and K) increased the yields of class I fruits in the first harvest and mid or late season fertigation produced more of second harvest yields and less discards than the first harvest.

Chaudhari *et al.* (1995) conducted field experiment to investigate the response of okra cultivars Parbhani Kranti and Selection 2 to 100 kg N, 50 kg P_2O_5 and 50 kg K_2O in various combinations. The plant height, number of leaves and number of internodes per plant were significantly influenced by application of 100kgN/ha as compared to control. The variety Parbhani Kranti was found to be more vigorous than selection 2.

Studies by Prabhakar and Hebbar (1996) indicated that highest fruit yield of 45.7 t/ha was obtained for tomato with the application of recommended dose of fertilizers comprising polyfeed (19:19:19), MAP (12:60:0) and urea through fertigation. The yield was nearly 22-27 per cent higher, compared to the yield obtained in crop which was provided with normal fertilizers through soil application.

Soumkuwar *et al.* (1997) reported that application of 75 kg N/ha increased the vegetable growth, number and weight of fruit per plant and yield per ha in okra varieties Parbhani Kranthi, Selection 2 and Punjab-7. Among these varieties tested Parbhani Kranthi recorded higher yield (77.70 q/ha) with low incidence of yellow vein mosaic virus and shoot borer.

A fertigation experiment was conducted by Neelam and Rajput (1998) at IARI, New Delhi in onion with four fertilizer levels of 100, 80, 60, and 40 per cent. The yields of onion realized under different treatments of fertigation were compared with that achieved by conventional methods. Fertigation resulted in 60 per cent saving of fertilizer for achieving same level of production compared to conventional method of fertilizer application.

Deolankar and Berad (1999) found that in chickpea, 75 per cent of recommended fertilizer dose (18.75: 37.5: 18.75 Kg N: P_2O_5: K_2O ha^{-1}) was sufficient if applied as liquid fertilizer through drip to sustain better growth and crop yield. Raman *et al.* (2000) reported the effect of fertigation on growth and yield of gherkins (*Cucumber* sp.) where the treatments consisted of four fertigation with different soluble fertilizer combinations at two levels (100 and 75% NPK) compared with recommended dose of solid fertilizers applied through band application in soil. Application of 75 per cent of recommended dose of NPK with soluble fertilizers through drip irrigation system gave higher yields, resulting in 25 per cent saving of fertilizers, than band application.

The fertigation study on potato cv. Kufri Chadramukhi in Ludhiana revealed that leaf area index, per cent groundcover and dry matter accumulation were higher in trickle irrigated crop than the furrow irrigated conventionally fertilized crop. The trickle fertigated crop also gave maximum fresh tuber yield of 36.29 t ha^{-1} as compared to 21.5 t ha^{-1} produced by furrow irrigated crop (Chawla and Nardà, 2000).

Anila *et al.* (2001) conducted field experiment in sandy loam soil to investigate the water and nutrient use efficiency of sprouting broccoli grown on sandy loam soil using fertigation. Yield obtained showed that substantial saving in the fertilizer applied to the extent of 20-40 per cent could be accomplished through fertigation.

Veeranna *et al.* (2001) conducted field experiment to investigate the effects of broadcast application and fertigation of normal and water soluble fertilizer at three rates through drip irrigation and furrow irrigation methods on yield, water and fertilizer use efficiency in chilli (*Capsicum annuum*). Fertigation with 80 per cent water soluble fertilizer was effective in producing about 31 and 24.7 per cent higher yield over soil application of normal fertilizer at 100 per cent recommended level in furrow and drip irrigation methods respectively, with 20 percent saving of fertilizers and 36 per cent saving of irrigation water.

Study conducted on tomato cv. BRH-1 at IIHR, Hessarghatta revealed that mean fruit yield of 134.1 t ha^{-1}, fruit weight of 61.20 g and average fruit yield of 3.6 kg $plant^{-1}$ were obtained when 50% of NK fertigation (100:100:100 kg NPK ha^{-1}) was adopted under black LDPE sheet mulch. Under full NK fertigation i.e., 200:100:200 kg NPK ha^{-1} a fruit yield of 121.3 t ha^{-1} was obtained with an average 60.10g weight of fruits and 3.6 kg $plant^{-1}$ under the same mulch condition (Prabhakar *et al.*, 2001).

Studied on effect of source and levels of fertigation on capsicum hybrid 'Green Gold' under greenhouse during winter revealed that, water soluble fertilizers at higher level (120% RDF) resulted in maximum productivity (13.72 kg/m^2) of excellent quality fruits having shelf-life of 11.36 days (Manohar, 2002).

Darwish *et al.* (2003) studied the impact of N fertigation in potato and reported that fertigation with continuous N feeding through drip system based on actual N demand and available N in the soil resulted in 55 per cent N recovery; and for spring potato crop in this treatment, 44.8 per cent N need was met from the soil N and 21.8per cent from the irrigation water. Higher N input increased not only the N derived from fertilizer, but also the residual soil N.

A field experiment was conducted at the University of Agricultural Sciences, Bangalore to study the effect of fertigation with sources and levels of fertilizer and methods of fertilizer application on growth, yield and fertilizer-use efficiency of hybrid tomato in red sandy loam soil. The investigations revealed that fertigation with water-soluble fertilizers recorded significantly higher total dry matter, LAI (181.9 g and 3.69, respectively) fruit yield (79.2 $Mgha^{-1}$), fruits per plant (56.9) and fertilizer-use efficiency (226.48 kg yield kg−1 NPK) compared to drip and furrow irrigated controls (Hebbar *et al.*, 2004).

Shinde *et al.* (2006) fertigated Cabbage cv. Early Drum Head plants with 50, 75, 100, 125 and 150% of the recommended NPK rates in a field experiment conducted in Maharashtra, India. They observed that among the treatments, fertigation with 150% of the recommended rates of NPK fertilizer resulted in the highest cabbage yield (32.26 t/ha), average spread of plants (40.7 cm) and water use efficiency (949 kg/ha cm), whereas fertigation with 125% of the recommended rates of NPK fertilizer resulted in the highest average weight of head (1.197 kg).

Soujala *et al.* (2006) revealed that fertigation in pickling cucumber with lower total amount of nitrogen (110 kg/ha) resulted in the lowest yield. The highest nitrogen supply (170 kg/ha) gave the highest yield and use of all nutrients in fertigation had no effect on the yield, in comparison with giving only N and K and finally states that 120-140 kg/ha of nitrogen was enough for producing a good yield

Aruna *et al.* (2007) in an experiment conducted in tomato at the Horticulture College and Research Institute, Periakulam reported that increased plant height, early flowering, increased number of fruits per plant, fruit weight and fruit yield were observed when fertigated plots were mulched with black polythene. Paddy straw and sugarcane trash were inferior to black polythene mulch.

Fertigation studies conducted by Bhakre and Fatkal (2008) in onion with 100 per cent recommended dose of fertilizers applied through drip irrigation resulted in 106 per cent increase in water use efficiency, 40 per cent saving of irrigation water and 53 percent increase of fertilizer use efficiency over 100 percent recommended dose of fertilizers applied through surface incorporation under conventional surface application of water.

Shedeed *et al.* (2009) observed significant increase in growth parameters (plant height, LAI, fruit dry weight, total dry weight), yield components (number of fruits /plant, mean fruit weight, fruit yield/plat) and total fruit yield in tomato with the application of 100% RDF through fertigation over furrow and drip irrigation and soil application of fertilizers.

The effect of different fertilization (i.e. broadcast application and fertigation) and irrigation practices (tank sprinkler and drip irrigation) on yield, quality (nitrate content), nitrogen uptake of white cabbage (*Brassica oleracea* var. *capitata* L.) and the potential for N losses was assessed on sandy-loam soil. It was found that the highst yield (93 t ha−1), plant N uptake (246 kg ha−1), and fertilizer use efficiency (42%) were obtained under treatment with broadcast fertilization with farmer's practice of irrigation (tank sprinkler). The surplus N after harvest was 41 kg N ha^{-1}, indicating the lowest potential for N losses (Sturm *et al.*, 2010).

A bio-fertigation trial was conducted at Egypt to study the relative efficacy of bio-fertigation of liquid formulation of N-fixer (*Azospirillum* sp. and *Azotobacter* sp.)

and P-solubilizer (*Basillus megatherium*) and humic substances and inorganic fertilizers injected through drip irrigation system on soil properties and growth and yield of cowpea. Application of 50% recommended dose of NPK with bio fertigation and humic substances improved nutrient content in soil, plant growth, nodule parameters, seed quality and fertilizer use efficiency (Abdelhamid *et al*., 2011).

Basavarajappa *et al.* (2011) reported that drip irrigation system with 100 per cent RDF was more profitable as compared to furrow irrigation due to the increase in yield of brinjal. The highest yield obtained in furrow irrigation with 100 per cent RDF (21.00 t/ha) was less than the yield obtained in 60 per cent ET and 50 per cent RDF level under drip irrigation which has given 32 t/ha, and also stated that there was 51.4 per cent saving of water over furrow irrigation and 50 per cent saving of fertilizers.

Ruby *et al.* (2012) reported that highest fruit weight (38.50g), fruit length (10.55 cm), and average fruit weight per vine (6.31 kg) of pointed gourd were recorded by 100 per cent fertigation with mulch. This was statistically at par with 80per cent fertigation with mulch. Likewise highest yield of 15.78 tonnes per hectare was recorded by 100 per cent fertigation with mulch.

Fanish and Muthukrishnan (2013) reported that the increase in yield under 100% RDF with P and K as WSF might be due to the fact that fertigation with more readily available form of fertilizer obviously resulted in higher availability of all the three (NPK) major nutrients in the soil solution which led to higher uptake and better translocation of assimilates from source to sink thus in turn increased the yield

Chattoo *et al.* (2013) conducted an experiment for two successive year's *viz.* Rabi of 2008 and 2009 to study the performance of radish var. Japanese White Long under drip irrigation and fertigation system. The treatments consisted of four levels of irrigation viz., 100, 75 and 50% ET through drip and 100% surface irrigation; and four levels of fertilizer application viz. 100, 75 and 50% recommended NPK through fertigation and 100% recommended NPK through traditional method. Result showed that the treatment combination of 75% ET through drip+75% recommended NPK through fertigation was found to be significantly superior over all other treatments recording 68.9% yield enhancement over conventional method with 46.2 q/ha-cm water use efficiency and 4.78 q/ha-kg N and 7.17 q/ha-kg P and K fertilizer use efficiency respectively over conventional method.

2.5.2 Nutrient dynamics under drip fertigation

The mobility of nutrients in the soil depends on the quantity and kinds of fertilizer applied, moisture content of the soil and other reacting ions present in soil solution. The availability of nutrients at root zone of the crops influence the uptake and yield of the crop. Leaching, volatilization and fixation of nutrients in the soil are some of the factors that affect the availability of soil nutrients.

Soliman and Doss (1992) observed that application of liquid fertilizers resulted in higher yields as compared to solid fertilizers in two cultivars of tomato. Similarly Bafna *et al.* (1993) reported that a significantly higher total N uptake by different parts of tomato plant was recorded under drip irrigation over conventional irrigation.

Alva and Mozzafari (1995) reported that fertigation treatments maintained high concentration of NO3-N at shallow depth than deeper layer. Phosphorus is less mobile in the soil and tends to dripper accumulate near the point of application i.e. under the dripper, with little being leached downward or moved laterally. Zeng *et al.* (2000) also reported that potassium (K) distribution in the soil profile is characterized by decreasing soil K content with depth. K content increased significantly throughout the 0-15 cm soil profile even though movement of surface applied K in the soil profile was slow.

Castellanos *et al.* (2001) found that in garlic grown under fertigation removed 25 kg more phosphorus (89 kg P_2O_5 ha^{-1}) than furrow irrigated (64 kg P_2O_5 ha^{-1}) crop, under Mexican condition. They also observed that higher yield of the crop under fertigation, increased the phosphorus demand by the plant by almost 50 per cent.

Verma and Batra (2001) observed that the nitrogen uptake increased with increase in intensity of irrigation and level of nitrogen supply. The highest fruit yield could be ensured with moderate intensity of irrigation. According to Hebbar *et al.* (2004) fertigation with WSF resulted in lesser leaching of NO3-N and K to deeper layers of soil, higher available P in deeper layer. The higher nitrogen concentration was observed in the layer of 15-30 cm depth and at the distance of 20 cm from the emitter. The highest available phosphorus in soil was confined to 0-15 cm of soil layer but the potassium availability was higher in the top layers.

As reported by Alva (2009), fertigation is expected to increase the nutrient uptake efficiency, thereby minimizing leaching losses compared to the application of fertiliser in dry granular form broadcast over a large soil area at less frequent intervals.

The nitrogen availability steadily increased with increased depth upto 30 cm after which declined in all the distances. The highest available phosphorus in soil was confined to 0-15 cm of soil layer under all fertigation levels and it decreased with increase in distance and soil depth. Soil K content was significantly higher in the surface soil than in the sub-soils, due to the fact that majority of applied K was held in the surface soil and the downward movement was slow (Fanish and Muthukrishnan, 2013)

2.6 MULCHING

2.6.1 Effect of mulching on growth, yield and quality of vegetables

Beneficial response of plants to mulch includes earlier production (Call and Courter, 1989), greater total yield (Jensen, 1990) and reduced insect and disease problems (Greenough *et al.*, 1990). The advantages of mulching in vegetable crop production have been well documented by Clough and Locascio (1990). Various mulching materials are being utilized and these include weed or grass clippings, paddy straw, bark, sawdust, plastic, etc. Mulches effectively minimize water loss as vapour, soil erosion, weed problem and nutrient loss.

Salman *et al.* (1991) observed that vegetative growth (plant height, number of leaves and leaf area) increased irrespective of mulch colour that is, black or transparent in case of cucumber; but in black polythene in case of watermelon. Field trials conducted at Regional Agricultural Research Station, Pilicode revealed that practice of daily irrigation along with paddy straw mulching gave more yield in cucumber than other treatments (Kerala Agricultural University, 1991).

Tomato cvs. Sunny and Pine-Rite grown under trickle irrigation produced an average 84 t ha^{-1} of fruits under black polythene mulching, whereas the fruit yield was only 43 t ha^{-1} under non mulching with trickle irrigation (Abdul-Baki *et al.*, 1992).

Khalak and Kumaraswamy (1992) in an experiment conducted at Bangalore with potato cv. Kufri Jyothi revealed that dry matter accumulation and tuber yields were the highest with plastic mulch followed by rice straw mulch. Quadir (1992) conducted an experiment on watermelon using straw, black polythene mulches and unmulched control. Marketable fruit yield per plant was the highest with black polythene mulch.

According to Wien *et al.* (1993) tomato (*Lycopersicon esculentum* Mill.) plants grown on polyethylene (PE) mulch in New York State frequently had more branches, increased mineral nutrient uptake, root length and yield than plants which were not mulched. They opined that the increased aboveground growth observed would be the consequence of enhanced root growth and nutrient uptake by the plant under mulched condition.

Mulching decreased the fluctuations in temperature in the first 20- 30 cm depth in soils and promoted root development, reduced vegetative competition in the rooting zone, reduced fertilizer leaching and soil compaction, and the vegetable produces were cleaner since no soil was splashed onto the plants or fruits (Ham *et al.*, 1993).

Siwek *et al.* (1994) studied the effect of white or black polythene mulching on changes in microclimate and on the growth and yield of sweet pepper grown in plastic tunnels. The black polythene mulch resulted in 10.3 per cent increase and the white polythene resulted in only 6.1 per cent increase in the yield over the bare tunnel soil. Fruits were larger with either mulches than with no mulch.

Srinivas and Hedge (1994) reported that the evapo-transpiration under polythene mulch decreased by 8 per cent and 14 per cent compared with that under straw mulch and no mulch. Water use efficiency was highest under polythene mulch, and resulted in higher yield due to reduced evapo-transpiration.

Investigations on the effect of drip irrigation and mulching on capsicum conducted at four locations in Korean Republic by Yoon *et al.* (1995) revealed that mulching increased soil water content as well as crop yield compared with control where no mulch was applied.

According to Veeraputhiran (1996) the highest fruit yield ha^{-1} in oriental pickling melon was obtained from paddy waste mulching, but comparable with that of coir pith mulching. It produced 27 and 17 per cent more yield respectively compared to unmulched control. Munguia *et al.* (1998) reported an increase in plant growth and fruit yield of muskmelon due to increased concentration of total dissolved salts under mulching treatment with black polyethylene.

Sunilkumar (1998) conducted studies on effect of mulch cum drip irrigation system in sandy loam soils in okra and found that mean plant height was higher under mulched situation than unmulched, in both furrow and drip irrigation system irrespective of levels of irrigation.

Almasoum (1998) reported that tomato plants grown on bare soil or black polythene mulch were taller than that grown on red and clear plastic mulches. But red mulched plant gave 95.8, 86.7 and 57.8 per cent more yield compared to that under bare soil, black and clear mulches respectively. Shinde *et al.* (1999) observed that sugarcane trash mulching for the chilli variety Agnirekha gave maximum plant height (91.5 cm), more number of branches (17.5) and maximum yield of green chilli (12.2 t ha^{-1}) compared to mulching using black transparent plastic mulch.

Thakur *et al.* (2000) reported that with the use of different mulches in *Capsicum annuum* (L.) under the water deficit of 75 per cent, the lantana mulch gave the highest fruit yield of 73.36 quintals per hectare over unmulched plots (36.90 q/ha). In similar studies Uppal *et al.* (2001) observed that mulched tubers of potato contained about 46 per cent less reducing sugars compared to normal crop.

Sunilkumar and Jaikumaran (2002) reported that methods of irrigation did not affect number of fruiting branches when the crop was mulched. At the same level of irrigation drip cum mulch and furrow cum mulch enhanced fruiting branches by 99 per cent and 91 per cent respectively over that produced by the control i.e. furrow irrigation at 0.06 MPa. When the crop was mulched, it produced 51 per cent more number of flowers and higher levels of fruits were set (88.1%) under the same level of drip irrigation than the control crop.

Islam *et al.* (2002) studied the effect of mulching on the growth and yield of cabbage cv. Atlas-70. The treatments included mulching with six types of mulches viz., ash, straw, sawdust, water hyacinth, black polythene and rice husk and a control with no mulch. They observed that mulching significantly induced the growth and yield of cabbage. The highest gross yield (71.85 kg/plot) was obtained from the black polythene mulch followed by water hyacinth mulch (65.99 kg/plot).

Nagalakshmi *et al.* (2002) obtained the maximum number of fruits per plant (97.67), length of fresh fruit (6.93 cm), circumference of fruit (3.57 cm) and yield in chilli (8.6 t ha^{-1}) with the application of black LLDPE mulch, compared to organic mulch and no mulch.

A field experiment was carried out at the vegetable research farm of University of Arid Agriculture, Rawalpindi, to evaluate the performance of tomato under organic and inorganic mulches. The results revealed that maximum plant height (93 cm) and maximum number of leaves (160) was produced in plot mulched with 4 inch wheat straw, whereas, maximum leaf area $plant^{-1}$ (65 cm^2) was produced with transparent polythene mulch (150 μm guage) (Khan *et al.*, 2005).

Natarajan *et al.* (2005) studied the effect of integrated nutrient management and mulching on yield and economics of tomato hybrids under polyhouse and found that soil + FYM + coirpith medium when protected by black polythene mulch produced the highest fruit yield and recorded the best BC ratio.

Singh (2005) studied the effect of different types of mulches on the growth and yield of tomato in the north Indian plains. Polythene mulches were superior to organic mulches in improving growth and yield of tomato. Early flowering, greater number of fruits per plant and larger fruits were also observed with black and clear polythene mulches, and resulted in 57.5 and 40.7 per cent higher fruit yield respectively over unmulched conditions.

Awasthi *et al.* (2005) studied the growth and yield of brinjal under different types of mulching in arid condition. Treatment which received black and clear polythene mulches produced more number of fruits per plant and significantly higher yield over control. In black polythene mulched plots average fruit yield was 832 g per plant and the corresponding yield under clear polythene and unmulched control were in the order of 596 and 135 g respectively. Under different organic mulches the yield per plant varied from 270-400 g.

Gandhi and Bains (2006) observed that mulches modified the microclimate by modifying soil temperature, soil moisture and evaporation and the modified microclimate affected the yield contributing characters of tomato. Crop under straw mulch produced higher number of branches (8.7), fruit weight (28.08 g) and total yield (496.3 q ha-1) as compared to no mulch.

Moreno *et al.* (2009) observed that black polyethylene as mulch is the most extended material for vegetable growing; however, photodegradable and biodegradable films have appeared as an alternative to conventional mulches due to the risk of the progressive contamination of soils. Biodegradable mulch disappeared visually from the soil about three months after the crop was finished. Photodegradable mulch deteriorated prematurely and polyethylene film was practically intact at the end of the cropping season. In similar studies Berihun (2011) observed that the highest marketable and total fruit yield of tomato (48.02 and 55.32 tons/ha) in the first and (65.44 and 70.85 tons/ha) second year, respectively were obtained by using black plastic mulch.

Studies of Henry and Chinedu (2014) revealed that cowpea plants in mulched plots were 39–80% and 20–62% higher in grain yield and dry matter accumulation, respectively, compared to the un-mulched plots.

2.6.2 Effect of mulching on weed control

Gupta and Acharya, (1994) observed that black polythene suppressed weed growth whereas transparent polythene encouraged excessive weed growth. An integrated weed management study conducted by Dwivedi *et al.* (199) in pointed gourd reported that black polythene mulch kept the plots totally weed free throughout the cropping season and produced the highest fruit yield and gross income per hectare. Saw dust was found to be a wonderful soil improver as it conserved soil moisture, decreased run-off, increased infiltration and percolation, decreased evaporation, etc. under clear mulch (Waterer, 2000).

Gebrimedhin (2001) reported 100 per cent weed control by black polythene mulching and 47 per cent weed control by paddy waste mulching in an experiment conducted in oriental pickling melon. Similarly Awodoyin and Ogunyemi (2005) have reported that the weed control efficiency of different types of mulch in cayenne pepper production ranged from 27% to 97%.

Choudhary *et al.* (2002) observed that among the different mulches, black polythene mulch had maximum weed control efficiency (72.9 per cent) followed by paddy straw mulch (32 per cent). Maximum weeds were found under no mulching followed by transparent polythene mulching.

Singh (2005) studied the effect of polythene and organic mulching in tomato and found that black polythene controlled weed growth completely, while clear polythene, rice straw and sugarcane trash mulches checked weed growth by 70.2, 79.1 and 84.2 per cent respectively, over control.

Black plastic was more effective in controlling weeds and warming the soil in order to cultivate earlier produce in comparison to other mulch colors and other methods of weed control (Katherine *et al.*, 2006). Verma *et al.* (2007) reported 81 per cent weed control under drip irrigation combined with polythene mulching, whereas in the unmulched plot weeding was done 15 times during growing season.

Patel *et al.* (2009) reported that lesser weed germination by restricting the penetration of solar radiation under black polythene mulch resulted in higher weed control efficiency. Transparent polythene mulch induced the germination of grasses therefore weed control efficiency was comparatively lower.

Dzomcku *et al.* (2009) reported that plastic mulch controlled weeds adequately, while straw much reduced weed growth satisfactory and enhanced tomato and hot pepper crop production in the Guinea Savannah Zone. Chakraborti and George (2010) cited that polythene mulching recorded total dry weight of 0.9 g/sqm at 30 days after planting and there was no weed emergence at later stages. Similarly Berihun (2011) reported that mulching reduced the incidence of weed from 38 to 50 per cent.

The black PE mulch covering of full ridge and half furrow successfully controlled the different kinds of weeds in tomato crop, and the density of the weeds was much less in this treatment compared to that of the other mulching treatments (Hätami *et al.*, 2012).

Patil *et al.* (2014) conducted field experiment to formulate an economic weed management strategy in vegetable cowpea. The results based on two years pooled data revealed that, the weed control treatments of mulching with black polythene and pendimethalin @ 1 kg/ha+one hand weeding 30 DAS, provided effective control of weeds and significantly increased pod yield of vegetable cowpea over weedy check

2.6.3 Effect of mulching on rooting and nutrient uptake

Polythene mulching accelerated early root growth in tomato by enhancing root zone temperature. This stimulated the above ground growth as expressed through branching, flowering, early and total fruit yields and nutrient concentration in the tops (Knavel and Mohr, 1967).

Harn et al (1993) found that mid day soil temperature was the highest beneath the mulches with high short wave absorbance (black plastic). These microclimate changes strongly affected the soil moisture in the root zone and hence root growth increased.

Wein *et al.* (1993) reported that tomato plants grown under polythene mulching produced more branches and yield than the plant that were not mulched. Clear polythene mulch stimulated root extension shortly after transplanting. Mulching increased branching, flowering and increased the concentration of major nutrients in the above ground parts.

Gebremedhin (2001) reported that in oriental pickling melon, root depth was more in mulched plot than in control and that the depth of roots increased progressively from 50 to 100 per cent Ep with drip irrigation. Chaudary *et al.* (2002) observed that total nitrogen content in plants were significantly higher (4.34%) under green plastic mulching, while the P and K content in plants were found significantly higher (0.35 and 3.73%) under black plastic mulching.

2.7 ECONOMIC FEASIBILITY OF MULCHING, DRIP AND FERTIGATION TECHNOLOGIES FOR VEGETABLES

Rajagopalan *et al.* (1989) in an experiment conducted in watermelon and cucumber grown in summer rice fallow at the Regional Agricultural Research Station, Pilicode revealed that irrigation at IW/CPE ratio 0.5 had the maximum BC ratio for both the crops. Jadhav *et al.* (1990) observed that the benefit cost ratio for tomato cv. Pusa Ruby was 5.15 with drip irrigation and 2.96 with furrow irrigation.

Water management and fertilizer studies conducted at the College of Agriculture, Velleyani showed that scheduling irrigation (5 cm depth) when the CPE values reached 25 mm was the most economic management practice for cucumber raised in summer rice fallows (Kerala Agricultural University, 1991).

Salvi *et al.* (1995) reported that the highest fruit yield (15.03 t ha^{-1}), net monetary return (Rs. 46.77 ha^{-1}) and BC ratio (2.75) were obtained when irrigation was scheduled at 25 mm CPE in combination with 150 Kg N ha^{-1} on lateritic soil of Konkan in bell pepper.

Rani and Pushpakumari (1996) found that six equal split application of nutrients in gave a net profit of Rs. 9,3232 ha^{-1} whereas two equal split doses gave only Rs. 14710 ha^{-1}.

The tomato cv. Co.3 grown under plastic mulching recorded a gross return of Rs. 50,940 compared to Rs. 39,688 in non-mulched control and plastic mulching resulted an increase of Rs. 5,602 in net seasonal income over control (Lourduraj *et al.*, 1996).

The research conducted at Solan on pea cv. Lincoln revealed that the seasonal income under drip only and drip plus plastic mulch was 60.8 and 91.6 per cent higher respectively as compared to conventional method of irrigation. The benefit cost ratio worked out for drip alone and drip plus mulch and conventional irrigation respectively were 2.06, 2.11 and 1.98 (Raina *et al.*, 1998). Sunilkumar (1998) in an irrigation study in bhindi at Agricultural Research Station, Mannuthy reported that maximum BC ratio of 1.58 was derived when the crop was mulched and irrigated at soil moisture tension of 0.08 MPa.

Tiwari *et al.* (1998) studied the economic feasibility of drip irrigation in combination with different types of mulches for an okra crop. The study indicated that the net seasonal income, benefit cost ratio and the yield per unit depth of water used, were found to be the highest for drip irrigation with black plastic mulch, drip irrigation alone and drip irrigation with black plastic mulch respectively.

Shinde and Firake (1998) opined that the drip was the most economical for chillies. The benefit cost ratio of 2.84:1 and net extra income of Rs. 42,164 per hectare were obtained for the system over control. According to Sharmasarkar *et al.* (2001) in USA, return from sugarbeet crop was \$ 2080 and \$ 2310 ha^{-1} for furrow and drip irrigation practices respectively. They also observed that sugar beet production under drip irrigation would be the most profitable for larger area with payback period ranging from 7 to 10 years.

Manjunatha *et al.* (2001c) reported that income generated from brinjal cultivation was maximum for micro sprinkler irrigation followed by drip microtube, drip emitter and surface method in the descending order. The highest income achieved through micro sprinkler irrigation was due to the production of more yield compared to other treatments.

Gebremedhin (2001) has observed that drip irrigation at 125 per cent Ep was the most efficient in registering increased growth, higher fruit yield, higher net income and net profit per rupee invested and this was closely followed by drip irrigation at 100 and 75 percent Ep in oriental pickling melon. The above schedules when combined with black polythene mulch were superior to paddy waste mulch and unmulched control.

Natarajan *et al.* (2005) reported that highest fruit yield and BC ratio for tomato grown in polyhouse when water soluble fertilizer was applied at 250 Kg NPK ha^{-1} through drip and mulched with black polythene. Net seasonal income from green pea was Rs. 73,514 per hectare for drip, and this was 40.1 per cent more as compared to basin method of irrigation (Rs. 29,640) (Singh *et al.*, 2006).

Studies by Aruna *et al.* (2007) revealed that mulching with black polythene and fertigation with recommended NPK recorded highest fruit yield and net return in tomato in a study conducted at Horticulture College and Research Station, Periyakulam.

Duraisamy and Manickasundaram (2008) reported that application of raw coconut coir pith @ 12.5 t ha-1 and adoption of the irrigation schedule of 0.45 IW/CPE ratio recorded the highest BC ratio of 1.42 in perennial red gram BSR 1. Similarly Dirja *et al.* (2008) reported an increase of net profit at a rate of 12.59% in salad cucumber and 12.34% in tomato under drip irrigation compared to furrow irrigation.

Spehia *et al.* (2010) evaluated the effect of drip irrigation and water use efficiency on yield of okra under black polythene mulch. The results revealed that the seasonal income under drip irrigation alone and drip irrigation + polythene mulch was 32.6 and 53.5 per cent higher as compared to conventional method of irrigation. The highest B:C ratio of 2.69 was obtained for drip irrigation + polythene mulch followed by drip irrigation alone (2.33).

In brinjal, the highest benefit cost ratio of 4.99 was obtained in the treatment receiving 100 per cent crop ET with 100 per cent RDF and the least (3.72) in furrow irrigation with 50 per cent recommended dose of fertilizer (Bhogi *et al.*, 2011).

Kanwar *et al.* (2013) reported that fertigation with 80 % RDF (120:80:80 kg NPK ha^{-1}) under polythene mulching in sweet pepper resulted in the maximum net income (Rs. 265070/-) and B:C ratio (1.2:1) followed by 100 % RDF (150:100:100 kg NPK ha^{-1}) through fertigation with black polythene mulching and 120 % RDF (180:120:120 kg NPK ha^{-1}) through fertigation with black polythene mulching.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation on "Fertigation and mulching studies in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)" was carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during January - May 2014. The details of the materials used and techniques adopted during the course of investigations are described in this chapter.

3.1 SITE, SOIL AND CLIMATE

The experimental site is located at 10^0 32' N latitude, 76^0 13' E longitude at an altitude of 22.25 m above mean sea level. The area experiences typical warm humid climate and receives an average rainfall of 2663 mm per year. The mean meteorological data from January 2014 to May 2014 were collected from the meteorological observatory of College of Horticulture, Vellanikkara (Appendix II).

3.2 EXPERIMENTAL MATERIAL

3.2.1 Crop and variety

The Yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt) variety Vellayani Jyothika released by Kerala Agricultural University was used for the study. It's a selection from Sreekaryam local. It's a high yielding variety (19.33t/ha) with long light green pods. The seeds of this high yielding variety was collected from the Department of Olericulture, College of Agriculture, Vellayani and stored under ambient conditions.

3.3 EXPERIMENTAL METHOD

3.3.1 Design and Layout

The experiment was laid out in strip plot design having 17 treatments consisting of two levels of irrigation and four levels of fertilizer application with or without mulching.

The technical programme of the study is as follows:-

Design	-	Strip plot
Spacing	-	2.0 m X 0.5 m (on trellis)
Number of plants / treatment	-	20
Replications	-	2
3.3.2 Treatments	**-**	**Detailed below**

Mulching

M_1- with mulching (LDPE, W/B, 30 μ)

M_2- without mulching

Irrigation -2 levels

I_1- 80% pan evaporation (Ep)

I_2- 60% pan evaporation (Ep)

Fertilizer- 4 levels

F_1 - 75% POP (Mono Ammonium Phosphate, Urea & Muriate of Potash)

F_2- 100% POP (Mono Ammonium Phosphate, Urea & Muriate of Potash)

F_3- 125% POP (Mono Ammonium Phosphate, Urea & Muriate of Potash)

F_4 -100% POP with water soluble fertilizers (19:19:19)

Control

Conventional channel irrigation, once in 3 days, without mulching at POP level of fertilizer application. (It was not included in the strip plot analysis.)

Table 3.1 Details of treatment combinations

Sl No.	Name of treatments	Particulars of treatment
T_1	$I_1M_1F_1$	80% pan evaporation, 75% recommended dose of fertilizer, with mulching
T_2	$I_1M_1F_2$	80% pan evaporation, 100% recommended dose of fertilizer, with mulching
T_3	$I_1M_1F_3$	80% pan evaporation, 125% recommended dose of fertilizer, with mulching
T_4	$I_1M_1F_4$	80% pan evaporation, 100% recommended dose with water soluble fertilizer, with mulching

T_5	$I_1M_2F_1$	80% pan evaporation, 75% recommended dose of fertilizer, without mulching
T_6	$I_1M_2F_2$	80% pan evaporation, 100% recommended dose of fertilizer, without mulching
T_7	$I_1M_2F_3$	80% pan evaporation, 125% recommended dose of fertilizer, without mulching
T_8	$I_1M_2F_4$	80% pan evaporation, 100% recommended dose with water soluble fertilizer, without mulching
T_9	$I_2 M_1F_1$	60% pan evaporation, 75% recommended dose of fertilizer, with mulching
T_{10}	$I_2 M_1F_2$	60% pan evaporation, 100% recommended dose of fertilizer, with mulching
T_{11}	$I_2 M_1F_3$	60% pan evaporation, 125% recommended dose of fertilizer, with mulching
T_{12}	$I_2 M_1F_4$	60% pan evaporation, 100% recommended dose with water soluble fertilizer, with mulching
T_{13}	$I_2 M_2F_1$	60% pan evaporation, 75% recommended dose of fertilizer, without mulching
T_{14}	$I_2 M_2F_2$	60% pan evaporation, 100% recommended dose of fertilizer, without mulching

T_{15}	$I_2 M_2F_3$	60% pan evaporation, 125% recommended dose of fertilizer, without mulching
T_{16}	$I_2 M_2F_4$	60% pan evaporation, 100% recommended dose with water soluble fertilizer, without mulching
T_{17}	Control	Channel irrigation, once in 3 days, without mulching at POP level of fertilizer (100 per cent RDF) application

Recommended dose of fertilizer (RDF) as per Package of Practices (POP) of Kerala Agricultural University is 20: 30: 10 kg ha^{-1} of N: P_2O_5: K_2O.

3.3.3 Cultural practices

3.3.3.1 Land preparation

The experimental area was ploughed using tractor to bring the soil to a fine tilth and the plot was laid out as per the plan (Fig. 3.1). Channels were opened at a depth of 15 cm and at a width of 60 cm. Basal doses of manures and lime were applied. After thorough mixing with top soil, beds were prepared at specified spacing. For control, channels were taken instead of beds.

3.3.3.2 Installation of drip system and fertigation unit

The drip irrigation system was installed in the experimental plot after bed preparation. The drip unit consisted of main line, laterals, valves and filters. Eight water tanks were kept on platforms of 2 m height above the ground. The main line was PVC with 60mm diameter from which laterals made of LDPE having 12 mm internal diameter were connected. Inline drippers were put on the beds at 0.5 m apart. Each dripper was adjusted at the flow rate of 2 liters of water per hour.

The tanks were filled with water by connecting to the pumping line. Wire mesh filter was provided in the pumping line to prevent impurities entering in to the drip system. Separate valves were used to regulate water flow to each bed.

3.3.3.3 Mulching

Beds receiving mulching treatments were covered with 30 μ white-black LDPE sheets. Holes of 10 cm diameter were made at 0.5m distance on the sheets.

3.3.3.4 Manures and fertilizer application

Farm yard manure at the rate of 20 t/ha and lime at the rate of 250 kg/ha was applied during land preparation. Entire dose of fertilizers were applied along with irrigation water through drip, at 3 days interval from 3rd day of sowing onwards (Appendix III). Fertilizers were applied in the form of Urea, Mono Ammonium Phosphate (MAP) and Muriate of Potash (MOP). In control plots, full dose of phosphorus and half nitrogen and potassium were applied as basal. Remaining nitrogen and potassium were applied 45 days after sowing.

3.3.3.5 Sowing

Two seeds were sown at a distance of 0.5 cm from each other at the recommended spacing of 0.5 m.

3.3.3.6 Irrigation

From the first day of sowing itself drip system was used. Daily irrigation was scheduled based on pan evaporation value of the previous day and the rate was fixed as per the experiment (80 and 60 per cent Ep). Control plots were irrigated once in three days.

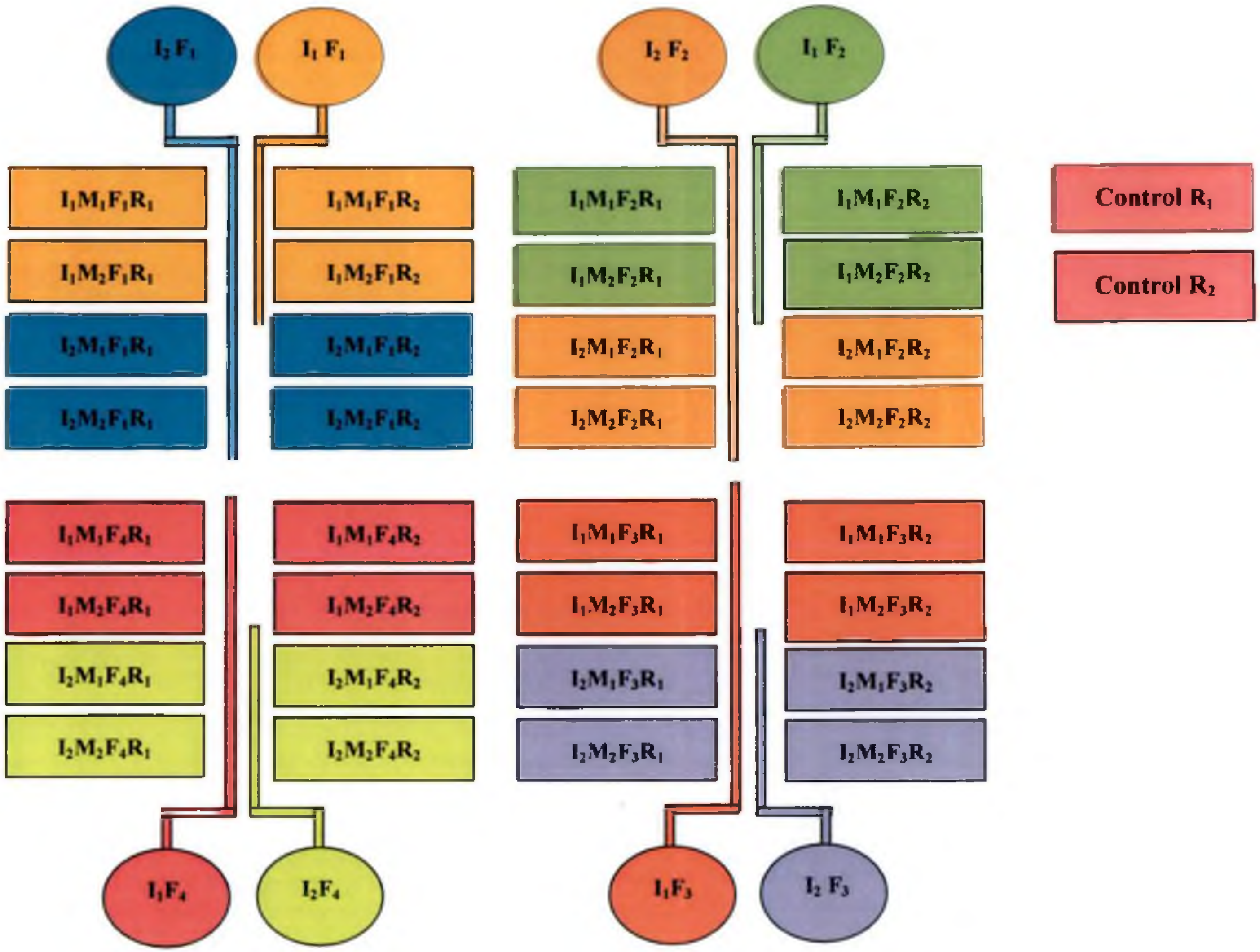


Fig. 3.1 Layout of the experimental plot

3.3.3.7 Aftercare

Hand weeding was done at 20, 40, 60 and 75 DAS. The crop was trailed on trellis.

3.3.3.8 Harvesting

Pods were harvested periodically at vegetable maturity stage.

3.3.4 Biometric observations

For understanding the influence of fertigation and mulching on growth and yield of the crop, three plants per plot were selected randomly for taking biometric observations and the average was worked out for further analysis.

3.3.4.1 Growth parameters

3.3.4.1.1 Days to germination

The number of days taken for germination was noted and expressed in numbers.

3.3.4.1.2 Vine length (cm)

The length of vines was measured from the base to the tip of the plant at 45^{th}, 60^{th} and 75^{th} days after sowing and average was worked out.

3.3.4.1.3 Days to first flower appearance

The number of days from the date of sowing to the date of opening of first flower was counted.

3.3.4.1.4 Days to first fruit set

Number of days taken for first fruit set was recorded in all observational plants.

3.3.4.1.5 Days to first harvest

Number of days taken from sowing to the harvest of first formed fruits in all the observational plants was recorded.

3.3.4.1.6 Days from flowering to harvest

Number of days taken from flowering to harvest of the fruit was counted in all treatments.

3.3.4.1.7 Number of pods per plant

The total number of pods produced per plant at the time of each harvest was recorded and the average was worked out.

3.3.4.1.8 Duration of the crop

The number of days from sowing to the date of last marketable fruit harvest was counted.

3.3.4.1.9 Number of harvests

The total number of harvests from the first to the last harvest was noted.

3.3.4.1.10 Yield per plant (kg)

Weight of fruits harvested periodically from each plant was recorded separately and the total was worked out and expressed in kilogram.

3.3.4.1.11 Pod weight (g)

Weight of pods per plant at each harvest was recorded and the average pod weight was worked out.

3.3.4.1.12 Pod length (cm)

Length of pods from the stem end to the blossom end was measured and the average was recorded in centimeter.

3.3.4.1.13 Colour of pods

Colour of pods in each treatment was observed.

3.3.4.1.14 Number of seeds per pod

Number of seeds contained in each pod was counted and the average was recorded.

3.3.4.1.15 Protein (%)

Protein content of the pods was estimated using Lowry's method (Lowry *et al.*, 1951).

3.3.4.1.16 Fresh and dry weight of weeds (kg/ha)

Weeds were collected from each bed and fresh weight of the weeds was taken immediately after collection. They were oven dried to concurrent weight and the dry weight of weeds was recorded.

3.3.4.1.17 Root length (cm)

The length of root was measured in observational plants after final harvest and average was worked out.

3.4 SOIL ANALYSIS

Soil samples were collected from the plots before planting, 45 days after planting and after final harvest. Soil samples were analysed for pH, electrical conductivity, organic carbon and soil nutrient status (Available NPK).

3.4.1 Organic carbon (%)

Chromic acid wet digestion method (Walkley and Black,1934) was used to quantify the amount of organic carbon present in the soil samples taken from the plots before planting, 45 days after planting and after final harvest.

3.4.2 Available Nitrogen (kg ha^{-1})

The available nitrogen content of soil was determined by alkaline permanganate method (Subbiah and Asija, 1956) before planting, 45 days after planting and after final harvest.

3.4.3 Available Phosphorus (kg ha^{-1})

The available phosphorus content of soil was determined by Bray and Kurtz method (Bray and Kurtz, 1947) at 45, 60 and 75 DAS.

3.4.4 Available Potassium (kg ha^{-1})

The available potassium content of soil was determined by neutral normal ammonium acetate extract using flame photometer (Jackson, 1958) before planting, 45 days after planting and after final harvest.

3.4.5 Soil pH

Soil pH was measured using pH meter (Jackson, 1958).

3.4.6 Electrical conductivity (EC) (dSm^{-1})

Electrical Conductivity of the soil samples were measured using EC Bridge (Jackson, 1958).

3.5 ECONOMICS OF PRODUCTION

The economics of production was worked out on the basis of input costs, labour charges and the return. Cost of the drip irrigation system used for the experiment was taken as $1/5^{th}$ of the total cost of the materials as it is assumed that a unit drip irrigation system can be used at least for five consecutive crops. Similarly, the cost of mulching material was taken as $1/3^{rd}$ of the total cost of LDPE sheet, as it is assumed that the same material can be used for at least three consecutive crops. Total cost and return was worked out for the experiment. Benefit cost ratio was worked out as per the formula given below

BCR = Gross return / Cost of cultivation

3.6 STATISTICAL ANALYSIS

Data pertaining to different characters were tabulated and subjected to statistical analysis as per the statistical design of strip plot and Post-hoc analysis (DMRT) performed wherever necessary. Comparison of effect of different treatments with control was also performed statistically.

RESULTS

4. RESULTS

The observations recorded on the crop during the conduct of the experiment on 'Fertigation and mulching studies in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)' were statistically analyzed and the results are furnished in this chapter (Plates 1-3).

4.1 GROWTH PARAMETERS

4.1.1 Days to germination

The number of days to germination did not differ among the treatments. In all the treatments germination was on the third day after sowing (DAS).

4.1.2 Vine length (cm)

The data on average length of vines at 45, 60 and 75 DAS are presented in Table 4.1.

Levels of irrigation significantly influenced the vine length at 45, 60 and 75 DAS. The maximum vine length (257.53 cm, 419.17 cm and 485.68 cm respectively) was observed at the irrigation level I_1 (80 per cent pan evaporation) and was significantly superior to the irrigation level I_2 (60 per cent pan evaporation) at 45, 60 and 75 DAS.

Mulching had no effect on vine length at 45 DAS but it significantly influenced the vine length at 60 and 75 DAS. The maximum vine length of 513.81 cm (at 75 DAS) was recorded in mulched plots whereas it was only 431.79 cm in un-mulched treatments at 75 DAS.

Fertilizer levels significantly influenced the vine length at 45, 60 and 75 DAS. Highest vine length at 45, 60 and 75 DAS was observed with F_3 (296.83 cm, 433.45 cm and 510.83 cm respectively).

The interaction effects of irrigation (I) with mulching (M) and irrigation with fertilizer (F) were non-significant with regards the length of vine at 45, 60 and 75 DAS (Table 4.1a and 4.1b).

The increase in vine length was significant with increase in fertilizer in mulched plots at 45 DAS and the maximum (315.40 cm) was with F_3 level of fertilizer. With regards to vine length the fertilizer levels F_1, F_2 and F_4 were on par (Table 4.1c). The interaction effects between mulching and fertilizer level was non-significant at 60 and 75 DAS.

The interaction of IMF had significant effects on vine length at 45, 60 and 75 DAS. The treatment $I_1M_1F_3$ recorded the highest vine length (330.8 cm, 491.7 cm and 553.5 cm at 45, 60 and 75 DAS).

4.1.3 Root length (cm)

The data on average root length at final harvest are presented in Table 4.1.

The levels of irrigation and mulching had no significant effect on root length. Fertilizer levels significantly influenced the root length of cowpea at final harvest. The treatment F_4 (100 % recommended dose with water soluble fertilizer) recorded the highest root length (30.81 cm) and F_1, F_2 and F_3 were on par.

The interaction effects of irrigation with mulching and fertilizer were not significant. Similarly the root length was not significantly influenced by the interaction between mulching and fertilizer (Table 4.1a, 4.1b and 4.1c).

The interaction effects of irrigation, mulching and fertilizer were significant with respect to root length at final harvest. The treatment $I_2M_2F_4$ recorded the highest value (32.5 cm) which was on par with the treatments $I_1M_1F_4$ and $I_1M_2F_4$.

4.1.4 Days to first flowering

The data on days taken to first flowering of cowpea as influenced by irrigation, fertilizer and mulching are given in Table 4.2.

The separate and interaction effects of irrigation, mulching and fertilizer levels on days taken for first flower appearance were not significant. It took 42 days for first flower appearance in F_1, F_2 and F_3 and 43 days in F_4.

4.1.5 Days for first fruit set

The data on days taken to first fruit set of cowpea as influenced by irrigation, fertilizer and mulching are given in Table 4.2.

The effect of irrigation, mulching and fertilizer levels on days taken for first fruit set was not significant. Their interaction was also not significant. The days taken to fist fruit set remained constant at F_1, F_2 and F_3 (42 days) and in F_4 it has taken 43 days for fruit set.

4.1.6 Days for first harvest

The data on days taken to first harvest of cowpea as influenced by irrigation, fertilizer and mulching are given in Table 4.2.

The direct and interaction effects of irrigation, mulching and fertilizer levels on days taken for first harvest of cowpea pods were not significant. It took 54 days for first harvest in all the treatments.

4.1.7 Days from flowering to harvest

The data on days from flowering to harvest of cowpea as influenced by irrigation, fertilizer and mulching are given in Table 4.2.

Table 4.1. Effect of irrigation, mulching and fertilizer on vine length and root length of cowpea

Treatments	Vine length at 45 DAS (cm)	Vine length at 60 DAS (cm)	Vine length at 75 DAS (cm)	Root length (cm)
Irrigation				
I_1	257.53[a]	419.17[a]	485.68[a]	26.47[a]
I_2	231.58[b]	389.77[b]	459.92[b]	26.28[a]
Mulching				
M_1	262.66[a]	441.76[a]	513.81[a]	26.22[a]
M_2	226.44[a]	367.18[b]	431.79[b]	26.53[a]
Fertilizer				
F_1	204.43[c]	379.35[c]	449.58[b]	25.13[b]
F_2	241.19[b]	412.08[b]	468.31[b]	24.13[b]
F_3	296.83[a]	433.45[a]	510.83[a]	25.44[b]
F_4	235.76[b]	392.00[c]	462.49[b]	30.81[a]

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.1(a). Interaction effect of irrigation and mulching on vine length and root length of cowpea

Treatments	Vine length at 45 DAS (cm)	Vine length at 60 DAS (cm)	Vine length at 75 DAS (cm)	Root length (cm)
$I_1 M_1$	275.75[a]	458.78[a]	535.23[a]	27.00[a]
$I_1 M_2$	239.31[a]	379.56[a]	436.14[a]	25.94[a]
$I_2 M_1$	249.58[a]	424.75[a]	492.40[a]	25.44[a]
$I_2 M_2$	213.58[a]	354.78[a]	427.44[a]	27.13[a]

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.1(b). Interaction effect of irrigation and fertilizer on vine length and root length of cowpea

Treatments	Vine length at 45 DAS (cm)	Vine length at 60 DAS (cm)	Vine length at 75 DAS (cm)	Root length (cm)
$I_1 F_1$	221.13^{a}	392.40^{a}	462.73^{a}	24.13^{a}
$I_1 F_2$	247.80^{a}	426.40^{a}	476.58^{a}	24.63^{a}
$I_1 F_3$	309.33^{a}	452.48^{a}	531.83^{a}	26.00^{a}
$I_1 F_4$	251.87^{a}	405.40^{a}	471.60^{a}	31.13^{a}
$I_2 F_1$	187.75^{a}	366.30^{a}	436.43^{a}	26.13^{a}
$I_2 F_2$	234.58^{a}	397.75^{a}	460.05^{a}	23.63^{a}
$I_2 F_3$	284.33^{a}	414.43^{a}	489.83^{a}	24.88^{a}
$I_2 F_4$	219.65^{a}	380.60^{a}	453.38^{a}	30.50^{a}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.1(c). Interaction effect of mulching and fertilizer on vine length and root length of cowpea

Treatments	Vine length at 45 DAS (cm)	Vine length at 60 DAS (cm)	Vine length at 75 DAS (cm)	Root length (cm)
$M_1 F_1$	205.73^{c}	411.65^{a}	490.65^{a}	24.13^{a}
$M_1 F_2$	265.30^{b}	450.83^{a}	521.65^{a}	24.38^{a}
$M_1 F_3$	315.40^{a}	472.90^{a}	539.80^{a}	26.63^{a}
$M_1 F_4$	264.23^{b}	431.70^{a}	503.15^{a}	29.75^{a}
$M_2 F_1$	203.15^{c}	347.05^{a}	408.50^{a}	26.13^{a}
$M_2 F_2$	217.08^{c}	373.33^{a}	414.98^{a}	23.88^{a}
$M_2 F_3$	278.25^{b}	394.00^{a}	481.85^{a}	24.25^{a}
$M_2 F_4$	207.73^{c}	354.33^{a}	421.83^{a}	31.88^{a}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.1(d). Interaction effect of irrigation, mulching and fertilizer on vine length and root length of cowpea

Treatments	Vine length at 45 DAS (cm)	Vine length at 60 DAS (cm)	Vine length at 75 DAS (cm)	Root length (cm)
$I_1M_1F_1$	221.45^{efg}	435.65^{bc}	516.30^{abc}	24.25^{cde}
$I_1M_1F_2$	268.95^{bcd}	470.30^{ab}	540.00^{a}	23.75^{cde}
$I_1M_1F_3$	330.80^{a}	491.65^{a}	553.30^{a}	29.00^{ab}
$I_1M_1F_4$	281.80^{bc}	437.50^{bc}	531.30^{ab}	31.00^{a}
$I_1M_2F_1$	220.80^{efg}	349.15^{fg}	409.15^{f}	24.00^{cde}
$I_1M_2F_2$	226.65^{ef}	382.50^{ef}	413.15^{f}	25.50^{bcd}
$I_1M_2F_3$	287.85^{bc}	413.30^{cde}	510.35^{abc}	23.00^{de}
$I_1M_2F_4$	221.95^{efg}	373.30^{efg}	411.90^{f}	31.25^{a}
$I_2M_1F_1$	190.00^{gh}	387.65^{def}	465.00^{cdef}	24.00^{cde}
$I_2M_1F_2$	261.65^{cd}	431.35^{bc}	503.30^{bcd}	25.00^{bcde}
$I_2M_1F_3$	300.00^{ab}	454.15^{abc}	526.30^{ab}	24.25^{cde}
$I_2M_1F_4$	246.65^{de}	425.85^{bcd}	475.00^{cdef}	28.50^{abc}
$I_2M_2F_1$	185.50^{h}	344.95^{fgh}	407.85^{f}	28.25^{abc}
$I_2M_2F_2$	207.50^{fgh}	364.15^{fg}	416.80^{f}	22.25^{de}
$I_2M_2F_3$	268.65^{bcd}	374.70^{efg}	453.35^{def}	25.50^{bcd}
$I_2M_2F_4$	192.65^{fgh}	335.35^{gh}	431.75^{e}	32.50^{a}
Control	192.50	303.95	350.85	20.50
Treatments v/s control	S	S	S	S

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Plate 1 General view of experimental plot

Plate 2 Plants at 30 days after sowing

Plate 3 Plants at bearing stage

The effect of irrigation, mulching and fertilizer levels on days from flowering to harvest of cowpea pods was not significant. Their interaction also was not significant. It took 11 days for flowering to harvest in all the treatments.

4.2 YIELD AND YIELD ATTRIBUTES

4.2.1 Number of pods per plant

The data on total number of pods per plant as influenced by irrigation, mulching and fertilizer are presented in Table 4.4.

Levels of irrigation significantly influenced the number of pods per plant. Maximum number of pods per plant (42.49) was observed at the irrigation level I_1 and was significantly superior to the irrigation level I_2.

Mulching also had significant effect on number of pods per plant. Significantly higher number of pods per plant (50.79) was observed in mulched (M_1) treatments compared to the un-mulched treatments.

Fertilizer levels significantly influenced the number of pods per plant. With increase in fertilizer levels, the number of pods per plant also increased and the maximum number (47.39) was observed in F_3. The lowest number of pods per plant (34.56) was reported in F_1 (75 per cent RDF).

The interaction effect between irrigation and mulching was not significant with respect to the number of pods per plant. Irrigation and fertilizer interacted significantly with respect to the number of pods per plant. The treatment I_1 F_3 recorded highest (48.96), followed by I_2 F_3 (45.29).

Mulching and fertilizer showed significant positive interaction for the number of pods per plant. Treatment M_1 F_3 recorded the highest number of pods per plant (62.72) followed by the treatment M_1 F_2. The lowest number of pods per plant (27.84) was recorded in the treatment M_2 F_1.

Table 4.2 Effect of irrigation, mulching and fertilizer on number of days for flowering, fruiting, number of harvests and duration of cowpea

Treatments	Days for first flowering	Days to first fruit set	Days for first harvest	Days from flowering to harvest	Number of harvests	Duration of the crop (days)
Irrigation						
I_1	42.56[a]	42.56[a]	54.25[a]	11.69[a]	13.94[a]	99.31[a]
I_2	42.75[a]	42.75[a]	54.25[a]	11.50[a]	13.69[a]	97.56[a]
Mulching						
M_1	42.38[a]	42.38[a]	54.13[a]	11.75[a]	14.25[a]	98.56[a]
M_2	42.94[a]	42.94[a]	54.38[a]	11.44[a]	13.38[a]	98.31[a]
Fertilizer						
F_1	42.38[a]	42.38[a]	54.00[a]	11.63[a]	13.50[a]	98.00[a]
F_2	42.63[a]	42.63[a]	54.75[a]	12.13[a]	14.13[a]	98.63[a]
F_3	42.50[a]	42.50[a]	54.00[a]	11.50[a]	14.38[a]	100.38[a]
F_4	43.13[a]	43.13[a]	54.25[a]	11.13[a]	13.25[a]	96.75[a]

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.2(a) Interaction effect of irrigation and mulching on number of days for flowering, fruiting, number of harvests and duration of cowpea

Treatments	Days for first flowering	Days first fruit set	Days for first harvest	Days from flowering to harvest	Number of harvests	Duration of the crop (days)
$I_1 M_1$	42.25[a]	42.25[a]	54.25[a]	12.00[a]	14.88[a]	99.50[a]
$I_1 M_2$	42.88[a]	42.88[a]	54.25[a]	11.38[a]	13.00[a]	99.13[a]
$I_2 M_1$	42.50[a]	42.50[a]	54.00[a]	11.50[a]	13.63[a]	97.63[a]
$I_2 M_2$	43.00[a]	43.00[a]	54.50[a]	11.50[a]	13.75[a]	97.50[a]

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.2(b) Interaction effect of irrigation and fertilizer on number of days for flowering, fruiting, number of harvests and duration of cowpea

Treatments	Days for first flowering	Days first fruit set	Days for first harvest	Days from flowering to harvest	Number of harvests	Duration of the crop (days)
$I_1 F_1$	42.50^{a}	42.50^{a}	54.0^{a}	11.50^{a}	14.25^{a}	102.00^{a}
$I_1 F_2$	42.75^{a}	42.75^{a}	55.0^{a}	12.25^{a}	15.00^{a}	100.00^{ab}
$I_1 F_3$	42.25^{a}	42.25^{a}	54.0^{a}	11.75^{a}	14.00^{a}	100.00^{ab}
$I_1 F_4$	42.75^{a}	42.75^{a}	54.0^{a}	11.25^{a}	12.50^{a}	95.25^{bc}
$I_2 F_1$	42.25^{a}	42.25^{a}	54.0^{a}	11.75^{a}	12.75^{a}	94.00^{c}
$I_2 F_2$	42.50^{a}	42.50^{a}	54.5^{a}	12.00^{a}	13.25^{a}	97.25^{abc}
$I_2 F_3$	42.75^{a}	42.75^{a}	54.0^{a}	11.25^{a}	14.75^{a}	100.75^{a}
$I_2 F_4$	43.50^{a}	43.50^{a}	54.5^{a}	11.00^{a}	14.00^{a}	98.25^{abc}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.2(c) Interaction effect of mulching and fertilizer on number of days for flowering, fruiting, number of harvests and duration of cowpea

Treatments	Days for first flowering	Days first fruit set	Days for first harvest	Days from flowering to harvest	Number of harvests	Duration of the crop (days)
$M_1 F_1$	42.00^{a}	42.00^{a}	54.0^{a}	12.00^{a}	15.00^{a}	98.00^{a}
$M_1 F_2$	42.00^{a}	42.00^{a}	54.5^{a}	12.50^{a}	15.00^{a}	99.25^{a}
$M_1 F_3$	42.25^{a}	42.25^{a}	54.0^{a}	11.75^{a}	15.25^{a}	100.75^{a}
$M_1 F_4$	43.25^{a}	43.25^{a}	54.0^{a}	10.75^{a}	11.75^{b}	96.25^{a}
$M_2 F_1$	42.75^{a}	42.75^{a}	54.0^{a}	11.25^{a}	12.00^{b}	98.00^{a}
$M_2 F_2$	43.25^{a}	43.25^{a}	55.0^{a}	11.75^{a}	13.25^{ab}	98.00^{a}
$M_2 F_3$	42.75^{a}	42.75^{a}	54.0^{a}	11.25^{a}	13.50^{ab}	100.00^{a}
$M_2 F_4$	43.00^{a}	43.00^{a}	54.5^{a}	11.50^{a}	14.75^{a}	97.25^{a}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.2(d) Interaction effect of irrigation, mulching and fertilizer on number of days for flowering, fruiting, number of harvests and duration of cowpea

Treatments	Days for first flowering	Days first fruit set	Days for first harvest	Days from flowering to harvest	Number of harvests	Duration of the crop (days)
$I_1M_1F_1$	42.0^a	42.0^a	54^a	12.0^a	16.5^a	102.0^a
$I_1M_1F_2$	42.0^a	42.0^a	55^a	13.0^a	16.0^a	102.0^a
$I_1M_1F_3$	42.0^a	42.0^a	54^a	12.0^a	15.5^a	100.0^a
$I_1M_1F_4$	43.0^a	43.0^a	54^a	11.0^a	11.5^a	94.0^a
$I_1M_2F_1$	43.0^a	43.0^a	54^a	11.0^a	12.0^a	102.0^a
$I_1M_2F_2$	43.5^a	43.5^a	55^a	11.5^a	14.0^a	98.0^a
$I_1M_2F_3$	42.5^a	42.5^a	54^a	11.5^a	12.5^a	100.0^a
$I_1M_2F_4$	42.5^a	42.5^a	54^a	11.5^a	13.5^a	96.5^a
$I_2M_1F_1$	42.0^a	42.0^a	54^a	12.0^a	13.5^a	94.0^a
$I_2M_1F_2$	42.0^a	42.0^a	54^a	12.0^a	14.0^a	96.5^a
$I_2M_1F_3$	42.5^a	42.5^a	54^a	11.5^a	15.0^a	101.5^a
$I_2M_1F_4$	43.5^a	43.5^a	54^a	10.5^a	12.0^a	98.5^a
$I_2M_2F_1$	42.5^a	42.5^a	54^a	11.5^a	12.0^a	94.0^a
$I_2M_2F_2$	43.0^a	43.0^a	55^a	12.0^a	12.5^a	98.0^a
$I_2M_2F_3$	43.0^a	43.0^a	54^a	11.0^a	14.5^a	100.0^a
$I_2M_2F_4$	43.5^a	43.5^a	55^a	11.5^a	16.0^a	98.0^a
Control	43.5	43.5	55	11.50	16.0	100.0
Treatments v/s control	NS	NS	NS	NS	NS	NS

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

The interaction effects of irrigation, mulching and fertilizer when taken together had significant effect on the number of pods per plant. The treatment $I_1M_1F_3$ recorded the highest number (63.68) followed by the treatments $I_2M_1F_3$.

4.2.2 Pod weight (g)

The data on pod weight as influenced by irrigation, mulching and fertilizer are presented in Table 4.3.

The levels of irrigation did not significantly influence the pod weight. Mulching had significant influence on the pod weight. Mulched treatments recorded significantly higher pod weight (27.17 g) than un-mulched treatments (25.04 g).

Fertilizer levels also significantly influenced the pod weight. With increase in fertilizer levels, the pod weight also increased. It was 29.4 g for F_3, 26.78 g for F_2, 25.21 g for F_4 and 23.30g for F_1.

The interaction effects of irrigation with both mulching and fertilizer levels were not significant with respect to pod weight. Mulching and fertilizer showed significant positive interaction on pod weight. The treatment M_1F_3 recorded the highest value (30.05 g). This was followed by M_1F_2 (28.05 g) and the lowest (21.9 g) was recorded in treatment M_2F_1.

Irrigation, mulching and fertilizer significantly influenced the pod weight. The highest pod weight (30.95 g) was recorded in the treatment $I_1M_1F_3$ followed by the treatment $I_2M_1F_3$. The lowest pod weight (21.2 g) was recorded in the treatment $I_2M_2F_1$.

4.2.3 Pod length (cm)

The data on pod length are presented in Table 4.3.

Pod length was not significantly influenced by levels of irrigation. Mulching significantly influenced the pod length. Mulched treatments recorded significantly higher pod length (56.13 cm) than the un-mulched treatments.

Fertilizer levels also significantly influenced the pod length. The highest pod length (57.68 cm) was observed in F_3 which was on par with F_2. The lowest pod length (52.28 cm) was observed in the treatment F_1.

The interaction effects between irrigation and mulching and fertilizer levels were non-significant. The interaction of mulching and fertilizer significantly influenced the pod length. Treatment $M_1 F_3$ recorded the highest value for pod length (58.47 cm). The lowest pod length (50.08 cm) was recorded in the treatment $M_2 F_1$.

The interaction of irrigation, mulching and fertilizer had significant influence on pod length. The highest pod length (58.6 cm) was recorded in the treatment $I_1M_1F_3$ which was on par with $I_2M_1F_3$. The lowest pod length (49.55 cm) was recorded in the treatment $I_2M_2F_1$ which was on par with the treatments $I_1M_2F_1$.

4.2.4 Number of seeds per pod

The data on number of seeds per pod are presented in Table 4.3.

Levels of irrigation and mulching had no significant influence on the number of seeds per pod. Fertilizer levels significantly influenced the number of seeds per pod. With increase in fertilizer levels, significantly higher number of seeds per pod was observed. The highest number of seeds per pod (19.63) was recorded in F_3 and the lowest (16.23) in F_1.

Table 4.3. Effect of irrigation, mulching and fertilizer on pod characters of cowpea

Treatments	Pod length (cm)	Pod weight (g)	Number of seeds per pod
Irrigation			
I_1	55.53^a	26.78^a	18.44^a
I_2	54.72^a	25.56^a	17.88^a
Mulching			
M_1	56.31^a	27.29^a	18.69^a
M_2	53.94^b	25.04^b	17.63^a
Fertilizer			
F_1	52.28^c	23.01^d	16.25^d
F_2	56.73^a	26.78^b	18.88^b
F_3	57.68^a	29.65^a	19.63^a
F_4	53.83^b	25.21^c	17.88^c

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.3(a). Interaction effect of irrigation and mulching on pod characters of cowpea

Treatments	Pod length (cm)	Pod weight (g)	Number of seeds per pod
$I_1 M_1$	56.69^a	27.99^a	19.13^a
$I_1 M_2$	54.38^a	25.57^a	17.75^a
$I_2 M_1$	55.94^a	26.60^a	18.25^a
$I_2 M_2$	53.50^a	24.51^a	17.50^a

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.3(b). Interaction effect of irrigation and fertilizer on pod characters of cowpea

Treatments	Pod length (cm)	Pod weight (g)	Number of seeds per pod
$I_1 F_1$	52.63[a]	23.63[a]	16.75[a]
$I_1 F_2$	57.03[a]	27.68[a]	19.25[a]
$I_1 F_3$	57.75[a]	29.85[a]	19.75[a]
$I_1 F_4$	54.73[a]	25.95[a]	18.00[a]
$I_2 F_1$	51.93[a]	22.43[a]	15.75[a]
$I_2 F_2$	56.43[a]	25.88[a]	18.50[a]
$I_2 F_3$	57.60[a]	29.45[a]	19.50[a]
$I_2 F_4$	52.93[a]	24.48[a]	17.75[a]

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.3(c). Interaction effect of mulching and fertilizer on pod characters of cowpea

Treatments	Pod length (cm)	Pod weight (g)	Number of seeds per pod
$M_1 F_1$	54.48[c]	24.15[e]	16.75[a]
$M_1 F_2$	56.95[b]	28.05[b]	19.25[a]
$M_1 F_3$	58.48[a]	30.55[a]	20.25[a]
$M_1 F_4$	55.35[bc]	26.43[d]	18.50[a]
$M_2 F_1$	50.08[e]	21.90[g]	15.75[a]
$M_2 F_2$	56.50[b]	25.50[c]	18.50[a]
$M_2 F_3$	56.65[b]	26.80[c]	18.70[a]
$M_2 F_4$	52.30[d]	24.00[f]	17.25[a]

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.3(d). Interaction effect of irrigation, mulching and fertilizer on pod characters of cowpea

Treatments	Pod length (cm)	Pod weight (g)	Number of seeds per pod
$I_1M_1F_1$	54.65^{g}	24.65^{g}	17.5^{ef}
$I_1M_1F_2$	57.50^{b}	28.90^{bc}	19.5^{bc}
$I_1M_1F_3$	58.60^{a}	30.95^{a}	20.5^{a}
$I_1M_1F_4$	56.00^{f}	27.45^{d}	19.0^{cd}
$I_1M_2F_1$	50.60^{j}	22.60^{h}	16.0^{g}
$I_1M_2F_2$	56.55^{e}	26.45^{e}	19.0^{cd}
$I_1M_2F_3$	56.90^{c}	28.75^{c}	19.0^{bcd}
$I_1M_2F_4$	53.45^{i}	24.45^{g}	17.0^{f}
$I_2M_1F_1$	54.30^{h}	23.65^{h}	16.0^{g}
$I_2M_1F_2$	56.40^{e}	27.20^{d}	19.0^{cd}
$I_2M_1F_3$	58.35^{a}	30.15^{b}	20.0^{ab}
$I_2M_1F_4$	54.70^{g}	25.40^{f}	18.0^{de}
$I_2M_2F_1$	49.55^{j}	21.20^{i}	15.5^{g}
$I_2M_2F_2$	56.45^{e}	24.55^{g}	18.0^{de}
$I_2M_2F_3$	56.85^{c}	28.75^{c}	19.0^{bcd}
$I_2M_2F_4$	51.15^{j}	23.55^{h}	17.5^{ef}
Control	46.50	21.20	14.5
Treatments v/s control	S	S	S

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.4. Effect of irrigation, mulching and fertilizer on yield, number of pods and protein content of cowpea

Treatments	Yield/plant (kg)	Number of pod/plant	Yield (t ha^{-1})	Protein (%)
Irrigation				
I_1	0.65^a	42.49^a	6.5^a	1.23^a
I_2	0.61^b	37.92^b	6.1^b	1.28^a
Mulching				
M_1	0.81^a	50.79^a	8.1^a	1.24^a
M_2	0.45^b	29.62^b	4.5^b	1.27^a
Fertilizer				
F_1	0.50^d	34.56^d	5.0^d	1.25^a
F_2	0.67^b	41.58^b	6.7^b	1.21^a
F_3	0.73^a	47.13^a	7.3^a	1.21^a
F_4	0.63^c	37.54^c	6.3^c	1.35^a

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.4(a). Interaction effect of irrigation and mulching on yield, number of pods and protein content of cowpea

Treatments	Yield/plant (kg)	Number of pods/plant	Yield (t ha^{-1})	Protein (%)
$I_1 M_1$	0.82^a	53.51^a	8.2^a	1.24^a
$I_1 M_2$	0.48^a	31.46^a	4.8^a	1.23^a
$I_2 M_1$	0.80^a	48.05^a	8.0^a	1.24^a
$I_2 M_2$	0.42^a	27.79^a	4.2^a	1.31^a

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.4(b). Interaction effect of irrigation and fertilizer on yield, number of pods and protein content of cowpea

Treatments	Yield/plant (kg)	Number of pods/plant	Yield (t ha^{-1})	Protein (%)
$I_1 F_1$	0.53^f	36.78^f	5.3^e	1.20^a
$I_1 F_2$	0.69^c	42.48^c	6.9^b	1.18^a
$I_1 F_3$	0.75^a	48.96^a	7.5^a	1.17^a
$I_1 F_4$	0.65^d	41.72^d	6.5^c	1.34^a
$I_2 F_1$	0.48^g	32.34^h	4.8^f	1.25^a
$I_2 F_2$	0.65^d	40.68^e	6.5^c	1.25^a
$I_2 F_3$	0.70^b	45.29^b	7.0^a	1.25^a
$I_2 F_4$	0.61^e	33.36^g	6.1^d	1.36^a

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.4(c). Interaction effect of mulching and fertilizer on yield, number of pods and protein content of cowpea

Treatments	Yield/plant (kg)	Number of pods/plant	Yield (t ha^{-1})	Protein (%)
$M_1 F_1$	0.62^d	41.30^d	6.2^d	1.24^a
$M_1 F_2$	0.87^b	52.40^b	8.7^b	1.17^a
$M_1 F_3$	0.93^a	62.72^a	9.3^a	1.18^a
$M_1 F_4$	0.83^c	46.72^c	8.3^c	1.37^a
$M_2 F_1$	0.39^h	27.84^g	3.9^h	1.25^a
$M_2 F_2$	0.46^f	30.76^f	4.6^f	1.26^a
$M_2 F_3$	0.49^e	31.07^e	4.9^e	1.25^a
$M_2 F_4$	0.43^g	28.36^f	4.3^g	1.33^a

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.4(d). Interaction effect of irrigation, mulching and fertilizer on yield, number of pods and protein content of cowpea

Treatments	Yield/plant (kg)	Number of pods/plant	Yield (t ha^{-1})	Protein (%)
$I_1M_1F_1$	0.63^{d}	42.76^{d}	6.3^{d}	1.28^{a}
$I_1M_1F_2$	0.90^{ab}	54.00^{ab}	9.0^{ab}	1.13^{a}
$I_1M_1F_3$	0.93^{a}	63.68^{a}	9.3^{a}	1.16^{a}
$I_1M_1F_4$	0.83^{bc}	53.60^{bc}	8.3^{bc}	1.38^{a}
$I_1M_2F_1$	0.43^{f}	29.84^{ef}	4.3^{f}	1.21^{a}
$I_1M_2F_2$	0.47^{ef}	30.96^{ef}	4.7^{ef}	1.24^{a}
$I_1M_2F_3$	0.57^{e}	34.24^{a}	5.7^{e}	1.18^{a}
$I_1M_2F_4$	0.46^{f}	30.80^{fg}	4.6^{f}	1.30^{a}
$I_2M_1F_1$	0.60^{e}	39.80^{cd}	6.0^{e}	1.19^{a}
$I_2M_1F_2$	0.84^{b}	50.80^{ab}	8.4^{b}	1.22^{a}
$I_2M_1F_3$	0.92^{a}	61.76^{ab}	9.2^{a}	1.20^{a}
$I_2M_1F_4$	0.82^{cd}	39.84^{c}	8.2^{cd}	1.36^{a}
$I_2M_2F_1$	0.35^{g}	24.88^{fg}	3.5^{fg}	1.30^{a}
$I_2M_2F_2$	0.45^{f}	30.56^{ef}	4.5^{f}	1.28^{a}
$I_2M_2F_3$	0.48^{e}	28.82^{e}	4.8^{e}	1.31^{a}
$I_2M_2F_4$	0.39^{fg}	26.88^{g}	3.9^{gh}	1.37^{a}
Control	0.27	18.28	2.7	1.27
Treatments v/s control	S	S	S	S

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

The interactions between irrigation and mulching and fertilizer levels were non-significant. Similarly interaction of mulching and fertilizer also had no significant effect on number of seeds per pod.

Combination of IMF significantly affected the number of seeds per pod. The treatment $I_1M_1F_3$ recorded the highest number (20.5) followed by $I_2M_1F_3$.

4.2.5 Yield per plant (kg)

The data on yield per plant as influenced by irrigation, mulching and fertilizer are presented in Table 4.4.

Levels of irrigation significantly influenced the yield per plant. Maximum yield per plant (0.65 kg) was observed at the irrigation level I_1 and was significantly superior to the level I_2.

Mulching also significantly influenced the yield per plant. The mulched treatments recorded significantly higher yield per plant (0.81 kg) than the un-mulched treatments.

Fertilizer levels also significantly influenced the yield per plant. Significantly more yield per plant (0.73 kg) was observed in F_3. The lowest yield per plant (0.50 kg) was observed in F_1.

The interaction between irrigation and mulching was not significant for yield per plant (Table 4.4a).

The interaction between irrigation and fertilizer level was significant with respect to the yield per plant. In all irrigation levels the yield per plant increased with increasing fertilizer levels. Under both higher and lower irrigation levels, I_1F_3 recorded the highest yield per plant (0.75 kg) followed by I_2F_3. The lowest yield per plant (0.48 kg) was observed in I_2F_1.

The yield per plant was significantly influenced by the interaction between mulching and fertilizer. The mulched treatments showed significantly higher yield per plant than the un-mulched treatments. The yield per plant increased with increase in fertilizer levels irrespective of mulching. The highest yield per plant (0.93 kg) was observed in the treatment M_1F_3 and it was significantly superior to all other treatments.

The three way interaction of irrigation, mulching and fertilizer was significant with respect to yield per plant. The highest yield per plant was observed in the treatment $I_1M_1F_3$ (0.93 kg) which on par with the treatment $I_2M_1F_3$.

4.2.6 Yield per hectare (t)

The data on yield per hectare as influenced by irrigation, mulching and fertilizer are presented in Table 4.4.

Levels of irrigation significantly influenced the yield per hectare. Maximum yield per hectare (6.5 t) was observed at the irrigation level I_1 and it was significantly superior to the level I_2. Mulching significantly influenced the yield per hectare. The mulched treatments recorded significantly higher yield per hectare (8.1 t) than the un-mulched treatments.

Fertilizer levels also significantly influenced yield per hectare. With increase in fertilizer levels significantly more yields per hectare (7.3 t) was observed with F_3. The lowest yield per hectare (5.0 t) was observed in F_1. The interaction between irrigation and mulching was not significant with regard to yield per hectare.

The interaction between irrigation and fertilizer level was significant with regard to yield per hectare. In all irrigation levels yield per hectare increased with increasing fertilizer levels. The highest yield per hectare (7.5 t) was recorded in I_1 F_3 and which was on par with I_2 F_3. The lowest yield per hectare (4.8 t) was observed in I_2 F_1.

Interaction of mulching and fertilizer had significant influence on yield per hectare. In all mulching treatments there was significantly higher yield per hectare compared to un-mulched treatments. In all mulching and un-mulching treatments yield per hectare increased with increase in fertilizer levels. The highest yield per hectare (9.3 t) was observed in M_1 F_3 and it was significantly superior to all other treatments (Table 4.4c).

The interaction of irrigation, mulching and fertilizer had significant effect on yield per hectare. The treatment $I_1M_1F_3$ recorded highest yield per hectare (9.3t) which on par with the treatment $I_2M_1F_3$.

4.2.7 Number of harvests

The data on number of harvests of cowpea as influenced by irrigation, fertilizer and mulching are given in Table 4.2.

The *per se* effect of irrigation, mulching and fertilizer levels on the number of harvests of cowpea was not significant. Their interaction was also not significant.

4.2.8 Duration of the crop

The data on duration of the crop as influenced by irrigation, fertilizer and mulching are given in Table 4.2.

The *per se* effect of irrigation, mulching and fertilizer levels on duration of the crop was not significant. The interaction effects between irrigation and mulching and between mulching and fertilizer were not significant with respect to duration of the crop.

Interaction effect of irrigation with fertilizer was significant. The crop duration was 94 days in I_2F_1 while that of I_1F_1 was 102 days and this was on par with I_2F_3. The levels of irrigation, mulching and fertilizer when considered together had no significant effect on the duration of the crop.

Table 4.5. Effect of irrigation, mulching and fertilizer on weed growth of cowpea

Treatments	Fresh weight of weeds (kg/ha)				Dry weight of weeds (kg/ha)			
	20 DAS	40 DAS	60 DAS	75 DAS	20 DAS	40 DAS	60 DAS	75 DAS
Irrigation								
I_1	188.1^{a}	530.5^{a}	135.5^{a}	227.9^{a}	46.4^{a}	106.1^{a}	26.3^{a}	49.9^{a}
I_2	130.1^{a}	368.8^{a}	138.7^{a}	121.1^{a}	26.3^{a}	65.6^{a}	35.8^{a}	27.3^{a}
Mulching								
M_1	39.5^{b}	49.8^{b}	15.3^{b}	25.2^{b}	7.1^{b}	8.7^{b}	4.0^{b}	5.4^{b}
M_2	278.7^{a}	849.4^{a}	258.9^{a}	323.8^{a}	65.7^{a}	159.9^{a}	58.1^{a}	71.9^{a}
Fertilizer								
F_1	121.4^{b}	535.9^{ab}	57.9^{c}	143.2^{a}	26.8^{b}	107.1^{ab}	15.3^{c}	31.5^{a}
F_2	189.5^{ab}	325.2^{b}	146.7^{b}	192.2^{a}	38.3^{ab}	64.7^{b}	34.1^{b}	43.1^{a}
F_3	214.1^{a}	649.9^{a}	231.6^{a}	218.9^{a}	42.8^{a}	129.9^{a}	44.3^{a}	46.9^{a}
F_4	111.4^{b}	287.4^{b}	112.4^{b}	143.6^{a}	23.9^{b}	46.9^{b}	30.1^{b}	32.9^{a}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.5(a). Interaction effect of irrigation and mulching on weed growth of cowpea

Treatments	Fresh weight of weeds (kg/ha)				Dry weight of weeds (kg/ha)			
	20 DAS	40 D AS	60 DAS	75 DAS	20 DAS	40 DAS	60 DAS	75 DAS
$I_1 M_1$	41.3^{a}	45.1^{c}	13.7^{a}	34.9^{a}	7.4^{a}	9.0^{a}	3.7^{a}	7.5^{a}
$I_1 M_2$	334.8^{a}	1015.8^{a}	257.5^{a}	420.9^{a}	85.5^{a}	197.2^{a}	48.9^{a}	92.5^{a}
$I_2 M_1$	37.7^{a}	54.5^{c}	16.9^{a}	15.5^{a}	6.8^{a}	8.4^{a}	4.3^{a}	3.4^{a}
$I_2 M_2$	222.6^{a}	682.9^{b}	260.4^{a}	226.6^{a}	45.8^{a}	122.8^{a}	67.3^{a}	51.3^{a}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.5(b). Interaction effect of irrigation and fertilizer on weed growth of cowpea

Treatments	Fresh weight of weeds (kg/ha)				Dry weight of weeds (kg/ha)			
	20 DAS	40 DAS	60 DAS	75 DAS	20 DAS	40 DAS	60 DAS	75 DAS
$I_1 F_1$	141.9^a	601.7^a	52.75^a	171.8^a	30.5^a	114.5^a	13.2^a	38.7^a
$I_1 F_2$	156.3^a	361.1^a	148.2^a	247.5^a	43.7^a	77.95^a	30.2^a	54.7^a
$I_1 F_3$	298.9^a	832.1^a	235.8^a	326.8^a	81.5^a	164.3^a	36.8^a	68.0^a
$I_1 F_4$	150.1^a	326.9^a	105.5^a	165.6^a	30.1^a	55.65^a	25.0^a	38.4^a
$I_2 F_1$	100.9^a	470.1^a	63.00^a	114.5^a	23.0^a	71.90^a	17.5^a	24.3^a
$I_2 F_2$	222.8^a	289.4^a	145.1^a	136.9^a	32.9^a	51.35^a	37.9^a	31.4^a
$I_2 F_3$	129.1^a	467.9^a	227.3^a	111.1^a	31.6^a	100.8^a	51.9^a	25.9^a
$I_2 F_4$	67.75^a	247.8^a	119.2^a	121.6^a	17.7^a	38.25^a	35.9^a	27.7^a

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.5(c). Interaction effect of mulching and fertilizer on weed growth of cowpea

Treatments	Fresh weight of weeds (kg/ha)				Dry weight of weeds (kg/ha)			
	20 DAS	40 DAS	60 DAS	75 DAS	20 DAS	40 DAS	60 DAS	75 DAS
$M_1 F_1$	54.25^c	76.5^d	13.2^e	7.1^a	8.95^c	10.9^d	3.13^d	1.6^a
$M_1 F_2$	33.75	45.9^d	6.75^e	40.5^a	6.65^c	8.75^d	2.42^d	8.1^a
$M_1 F_3$	42.50^c	19.8^d	20.7^e	28.0^a	7.70^c	3.85^d	3.63^d	6.25^a
$M_1 F_4$	27.40^c	57.2^d	20.65^e	25.0^a	4.90^c	11.25^d	6.75^d	5.65^a
$M_2 F_1$	188.5^b	995.3^{ab}	102.7^d	279.2^a	44.6^b	175.6^{ab}	27.5^c	61.5^a
$M_2 F_2$	345.3^b	604.6^{bc}	286.6^b	343.9^a	69.85^{ab}	120.6^b	65.6^b	77.9^a
$M_2 F_3$	385.6^a	1280.2^a	442.4^a	409.9^a	105.3^a	261.1^a	85.0^a	87.6^a
$M_2 F_4$	195.4^b	517.5^c	204.1^c	262.1^a	42.8^b	82.7^c	54.2^b	60.4^a

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Table 4.5(d). Interaction effect of irrigation, mulching and fertilizer on weed growth of cowpea

Treatments	Fresh weight of weeds (kg/ha)				Dry weight of weeds (kg/ha)			
	20 DAS	40 DAS	60 DAS	75 DAS	20 DAS	40 DAS	60 DAS	75 DAS
$I_1M_1F_1$	60.2[def]	53.4[de]	9.7[e]	5.4[d]	10.2[def]	9.8[de]	1.9[fg]	1.1[d]
$I_1M_1F_2$	35.0[ef]	22.7[de]	2.2[e]	46.3[cd]	7.9[def]	4.8[e]	0.4[g]	9.4[d]
$I_1M_1F_3$	36.3[ef]	29.2[de]	19.9[e]	54.4[cd]	5.7[ef]	5.4[e]	4.7[fg]	12.2[cd]
$I_1M_1F_4$	33.8[ef]	75.2[de]	22.9[e]	33.4[cd]	5.73[ef]	16.1[de]	7.8[fg]	7.2[d]
$I_1M_2F_1$	223.1[cd]	1150.0[b]	95.9[de]	338.1[abc]	50.9[bcdef]	219.2[ab]	24.5[ef]	76.4[ab]
$I_1M_2F_2$	277.5[bc]	699.5[bc]	294.3[b]	448.6[abc]	79.5[b]	151.1[bc]	60.0[bc]	100.0[ab]
$I_1M_2F_3$	561.7[a]	1635.0[a]	451.7[a]	599.2[a]	157.3[a]	323.1[a]	101.1[a]	123.9[a]
$I_1M_2F_4$	276.4[bc]	578.6[cd]	188.1[bcd]	297.8[bcd]	54.5[bcd]	95.3[bcde]	42.3[cde]	69.6[abc]
$I_2M_1F_1$	48.4[def]	99.6[de]	16.6[e]	8.8[d]	7.7[def]	11.8[de]	4.4[fg]	2.0[d]
$I_2M_1F_2$	32.5[ef]	68.9[de]	11.3[e]	34.8[cd]	5.4[ef]	12.7[de]	4.4[fg]	6.9[d]
$I_2M_1F_3$	48.8[def]	10.4[e]	21.5[e]	1.7[d]	9.8[def]	2.3[e]	2.6[fg]	0.4[d]
$I_2M_1F_4$	21.1[f]	39.2[de]	18.4[e]	16.7[d]	4.2[f]	6.5[de]	5.7[fg]	4.2[d]
$I_2M_2F_1$	153.4[cdef]	840.6[bc]	109.5[cde]	220.3[bcd]	38.4[bcdef]	131.9[bcde]	30.6[de]	46.6[bcd]
$I_2M_2F_2$	413.1[ab]	509.8[cde]	278.9[b]	239.2[bcd]	60.3[bc]	90.0[bcde]	71.3[b]	55.9[bcd]
$I_2M_2F_3$	209.5[cde]	925.3[bc]	433.1[a]	220.6[bcd]	53.4[bcde]	199.2[abc]	68.9[b]	51.4[bcd]
$I_2M_2F_4$	114.5[cdef]	456.4[cde]	220.0[bc]	226.4[bcd]	31.1[cdef]	70.0[cde]	66.1[b]	51.2[bcd]
Control	87.8	570.9	196.9	248.4	18.9	142.5	51.1	56.1
Treatments v/s control	NS	NS	S	NS	NS	NS	S	NS

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

4.3 QUALITY OF PODS

4.3.1 Protein content of fresh pods (%)

The data on protein content of pods are presented in Table 4.4.

Protein content was not influenced by levels of irrigation, mulching and fertilizer. Their interaction was also not significant. The protein content of cowpea pods ranged from 1.1 to1.3 per cent (fresh weight basis).

4.4 WEED GROWTH

4.4.1 Fresh weight and dry weight of weeds (kg/ha)

The data on fresh weight and dry weight of weeds on 20, 40, 60 and 75 DAS as influenced by irrigation, mulching and fertilizer are presented in Table 4.5.

Levels of irrigation had no significant influence on fresh weight and dry weight of weeds at 20, 40, 60 and 75 DAS.

Mulching had significant effect on fresh weight and dry weight of weeds at 20, 40, 60 and 75 DAS (Plate 4). The treatments with mulching recorded the lowest fresh and dry weight of weeds.

Levels of fertilizer significantly influenced the fresh weight and dry weight of weeds at first, second and third weeding. The highest levels of fertilizer (F_3) recorded highest fresh weight (214.1 kg, 649.9 kg and 231.6 kg respectively) and dry weight (42.8 kg, 129.9 kg and 44.3 kg respectively) of weeds at first, second and third weeding. Levels of fertilizer had no significant effect on fresh weight and dry weight of weeds at fourth weeding.

The interactions of irrigation with mulching and irrigation with fertilizer were not significant on the fresh weight and dry weight of weeds.

Fresh weight and dry weight of weeds at first, second and third weeding was significantly influenced by the interaction of mulching and fertilizer. In all fertilizer levels, higher weed growth was observed in un-mulched treatments and was significantly superior to mulched treatments (Table 4.5c). Weed growth in mulched treatments did not vary significantly.

The interaction of irrigation, mulching and fertilizer was significant on the fresh weight and dry weight of weeds. The treatment $I_1M_2F_3$ recorded the highest weed growth in terms of fresh and dry weight at 20, 40, 60 and 75 DAS.

4.5 SOIL

Soil parameters viz., soil pH, electrical conductivity (EC), organic carbon and soil nutrient status were recorded before planting, 45 DAS and at final harvest and are presented in Tables 4.6 and 4.7.

4.5.1 pH

Soil pH observed before planting, 45 DAS and at final harvest is shown in Table 4.6.

Soil pH before planting was 5.2. Soil pH at 45 DAS and at final harvest was not influenced by levels of irrigation and mulching. Fertilizer levels significantly influenced the soil pH at 45 DAS and at final harvest. F_1 recorded higher value for pH (6.4 and 5.9) at 45 DAS and at final harvest.

Soil pH was not affected by the interactions between either irrigation and fertilizer or mulching and fertilizer at 45 DAS. But the interactions were significant at final harvest. In interaction between irrigation and fertilizer higher pH (6.5) was recorded in I_1 F_1 followed by I_1 F_4. Similarly combination of mulching and fertilizer also significantly influenced the pH after planting. Higher pH (6.0) was observed in M_2 F_1 which on par with M_1 F_1 (Table 4. 6c).

Interaction of irrigation, mulching and fertilizer was significant at final harvest with respect to soil pH. Treatments $I_1M_1F_1$ and $I_1M_2F_1$ recorded higher pH (6.5) followed by the treatment $I_1M_1F_1$.

4.5.2 EC (dSm^{-1})

Electrical conductivity of soil was observed before planting, 45 DAS and at final harvest is shown in Table 4.6.

EC of soil before panting was 0.06 dSm^{-1}. Levels of irrigation and mulching had no effect on EC of soil 45 DAS and at final harvest. Fertilizer level significantly influenced the EC of soil at 45 DAS and at final harvest. F_1 recorded the lowest value for EC of soil (0.19 dSm^{-1} and 0.06 dSm^{-1}) at 45 DAS and at final harvest.

Interaction of irrigation and mulching had no significant influence on EC at 45 DAS but effect was noticed at final harvest. Interaction of I_2M_2 recorded the lowest EC (0.06 dSm^{-1}) followed by I_2 M_1 (0.11 dSm^{-1}) at final harvest.

Interactions of irrigation and fertilizer were significant at 45 DAS and at final harvest. EC was lowest in I_2F_1 (0.19 dSm^{-1} and 0.06 dSm^{-1}) at 45 DAS and at final harvest followed by I_1F_1. Similarly the interaction effect of mulching and fertilizer was significant at 45 DAS and at final harvest. Treatment M_1F_1 recorded the lowest EC (0.14 dSm^{-1} and 0.06 dSm^{-1}) at 45 DAS and at final harvest.

The three way interaction was significant with respect to EC of soil at 45 DAS and at final harvest. Treatment $I_1M_2F_1$ recorded the lowest EC (0.13 dSm^{-1} and 0.06 dSm^{-1}) at 45 DAS and at final harvest and was on par with the treatment $I_2M_2F_1$.

4.5.3 Organic carbon (%)

Soil organic carbon observed before planting, 45 DAS and at final harvest is shown in Table 4.6.

The initial organic carbon content in the soil was 1.29 per cent. Soil organic carbon content at 45 DAS and at final harvest was not affected by levels of irrigation and mulching. Fertilizer level significantly influenced the soil organic carbon content at 45 DAS and at final harvest. F_3 recorded higher value for organic carbon content of soil (1.94 per cent and 1.47 per cent) at 45 DAS and at final harvest.

Interaction of irrigation and mulching had no effect on soil organic carbon before planting, 45 DAS and at final harvest.

Interaction effect between irrigation and fertilizer was significant at 45 DAS and at final harvest. Highest organic carbon content was reported in $I_1 F_3$ (1.98 per cent and 1.58 per cent) at 45 DAS and at final harvest. Similarly mulching and fertilizer interaction effect was significant at 45AS and after harvest. Treatment $M_1 F_3$ recorded highest organic carbon content (1.98 per cent and 1.49 per cent) at 45 DAS and at final harvest.

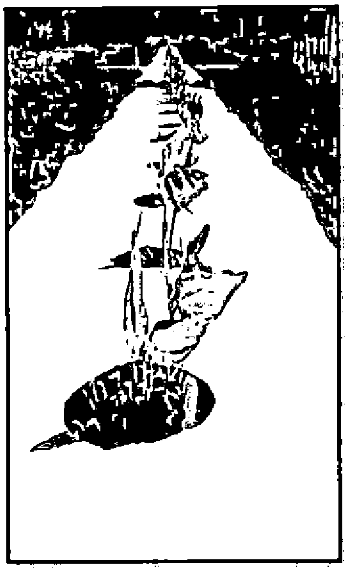
The interaction between irrigation, mulching and fertilizer was significant with respect to soil organic carbon content at 45 DAS and at final harvest. Treatment $I_2M_1F_3$ recorded highest organic carbon content (1.99 per cent) at 45 DAS and the treatment $I_1M_1F_3$ recorded the highest value (1.58 per cent) at final harvest.

4.5.4 Available nitrogen in soil (kg ha^{-1})

The data related to available nitrogen in soil is presented in Table 4.7.

The available nitrogen content before planting was 242.9 kg ha^{-1}. The available nitrogen content was not influenced by levels of irrigation and mulching. Fertilizer levels significantly influenced the available nitrogen in soil. The highest available nitrogen was observed in F_3 (397.2 kg ha^{-1} and 288.9 kg ha^{-1}) at 45 DAS and at final harvest.

Drip without mulch



Drip with mulch

Channel irrigation

Plate 4 Weed growth

4.6 Effect of irrigation, mulching and fertilizer on pH, EC and organic carbon content of soil at 45 DAS and at final harvest

Treatments	45 DAS			At final harvest		
	pH	EC (dSm^{-1})	Organic carbon (%)	pH	EC (dSm^{-1})	Organic carbon (%)
Irrigation						
I_1	6.1^a	0.46^a	1.73^a	5.7^a	0.14^a	1.38^a
I_2	5.9^a	0.39^a	1.72^a	5.1^a	0.09^a	1.30^a
Mulching						
M_1	5.9^a	0.51^a	1.71^a	5.4^a	0.16^a	1.35^a
M_2	5.9^a	0.32^a	1.75^a	5.4^a	0.06^a	1.32^a
Fertilizer						
F_1	6.4^a	0.19^d	1.48^d	5.9^a	0.06^d	1.19^d
F_2	5.9^c	0.33^c	1.83^b	5.2^b	0.07^c	1.38^b
F_3	5.6^c	0.57^b	1.94^a	5.1^c	0.11^b	1.47^a
F_4	6.0^b	0.62^a	1.66^c	5.2^b	0.21^a	1.31^c

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

4.6(a) Interaction effect of irrigation and mulching on pH, EC and organic carbon content of soil at 45 DAS and at final harvest

Treatments	45 DAS			At final harvest		
	pH	EC (dSm^{-1})	Organic carbon (%)	pH	EC (dSm^{-1})	Organic carbon (%)
$I_1 M_1$	5.9^a	0.55^a	1.69^a	5.8^a	0.21^a	1.36^a
$I_1 M_2$	6.1^a	0.36^a	1.77^a	5.7^a	0.07^c	1.39^a
$I_2 M_1$	5.9^a	0.52^a	1.74^a	5.1^a	0.11^b	1.34^a
$I_2 M_2$	5.8^a	0.28^a	1.72^a	5.2^a	0.06^d	1.26^a

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

4.6(b) Interaction effect of irrigation and fertilizer on pH, EC and organic carbon content of soil at 45 DAS and at final harvest

Treatments	45 DAS			At final harvest		
	pH	EC (dSm^{-1})	Organic carbon (%)	pH	EC (dSm^{-1})	Organic carbon (%)
$I_1 F_1$	6.6^{a}	0.20^{e}	1.46^{e}	6.5^{a}	0.06^{c}	1.16^{e}
$I_1 F_2$	5.9^{a}	0.38^{d}	1.83^{b}	5.3^{c}	0.07^{d}	1.42^{ab}
$I_1 F_3$	5.7^{a}	0.59^{b}	1.98^{a}	5.3^{c}	0.12^{b}	1.58^{a}
$I_1 F_4$	6.1^{a}	0.67^{a}	1.65^{c}	5.8^{b}	0.31^{a}	1.35^{bc}
$I_2 F_1$	6.2^{a}	0.19^{f}	1.51^{d}	5.4^{c}	0.06^{e}	1.21^{d}
$I_2 F_2$	5.9^{a}	0.29^{e}	1.84^{ab}	5.1^{d}	0.07^{d}	1.34^{bc}
$I_2 F_3$	5.6^{a}	0.55^{c}	1.90^{a}	4.9^{e}	0.10^{c}	1.37^{b}
$I_2 F_4$	5.9^{a}	0.58^{c}	1.67^{bc}	5.2^{d}	0.11^{c}	1.28^{c}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

4.6(c) Interaction effect of mulching and fertilizer on pH, EC and organic carbon content of soil at 45 DAS and at final harvest

Treatments	45 DAS			At final harvest		
	pH	EC (dSm^{-1})	Organic carbon (%)	pH	EC (dSm^{-1})	Organic carbon (%)
$M_1 F_1$	6.5^{a}	0.24^{e}	1.37^{f}	5.9^{a}	0.07^{d}	1.20^{d}
$M_1 F_2$	5.9^{a}	0.39^{d}	1.89^{b}	5.2^{bc}	0.09^{c}	1.39^{c}
$M_1 F_3$	5.6^{a}	0.73^{b}	1.98^{a}	5.1^{c}	0.16^{b}	1.49^{a}
$M_1 F_4$	6.0^{a}	0.79^{a}	1.61^{e}	5.6^{ab}	0.34^{a}	1.33^{cd}
$M_2 F_1$	6.3^{a}	0.14^{f}	1.59^{e}	6.0^{a}	0.06^{d}	1.18^{e}
$M_2 F_2$	5.9^{a}	0.28^{e}	1.78^{c}	5.2^{bc}	0.06^{d}	1.38^{c}
$M_2 F_3$	5.6^{a}	0.41^{c}	1.89^{b}	5.1^{c}	0.06^{d}	1.46^{b}
$M_2 F_4$	6.0^{a}	0.45^{c}	1.71^{d}	5.4^{b}	0.09^{c}	1.29^{d}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

4.6(d) Interaction effect of irrigation, mulching and fertilizer on pH, EC and organic carbon content of soil at 45 DAS and at final harvest

Treatments	45 DAS			At final harvest		
	pH	EC (dSm^{-1})	Organic carbon (%)	pH	EC (dSm^{-1})	Organic carbon (%)
$I_1M_1F_1$	6.5^{a}	0.26^{ef}	1.37^{j}	6.5^{a}	0.06^{i}	1.08^{d}
$I_1M_1F_2$	5.8^{a}	0.47^{c}	1.85^{d}	5.3^{cd}	0.08^{g}	1.42^{bc}
$I_1M_1F_3$	5.6^{a}	0.69^{b}	1.97^{bc}	5.3^{cd}	0.17^{b}	1.58^{a}
$I_1M_1F_4$	6.0^{a}	0.79^{a}	1.56^{i}	6.0^{b}	0.52^{a}	1.36^{c}
$I_1M_2F_1$	6.6^{a}	0.13^{g}	1.55^{i}	6.5^{a}	0.06^{i}	1.24^{cd}
$I_1M_2F_2$	6.0^{a}	0.28^{ef}	1.81^{e}	5.3^{cd}	0.06^{i}	1.42^{bc}
$I_1M_2F_3$	5.7^{a}	0.49^{c}	1.98^{ab}	5.2^{cde}	0.06^{i}	1.57^{b}
$I_1M_2F_4$	6.2^{a}	0.54^{c}	1.74^{fg}	5.6^{bc}	0.10^{e}	1.33^{c}
$I_2M_1F_1$	6.4^{a}	0.22^{f}	1.37^{j}	5.3^{cd}	0.07^{h}	1.31^{c}
$I_2M_1F_2$	5.9^{a}	0.30^{de}	1.92^{c}	5.0^{de}	0.09^{f}	1.35^{c}
$I_2M_1F_3$	5.6^{a}	0.77^{a}	1.99^{a}	4.8^{e}	0.15^{c}	1.40^{bc}
$I_2M_1F_4$	6.0^{a}	0.79^{a}	1.66^{gh}	5.2^{cde}	0.14^{d}	1.31^{c}
$I_2M_2F_1$	5.9^{a}	0.15^{g}	1.64^{h}	5.4^{cd}	0.05^{j}	1.11^{d}
$I_2M_2F_2$	5.8^{a}	0.28^{ef}	1.75^{f}	5.1^{de}	0.05^{j}	1.33^{c}
$I_2M_2F_3$	5.5^{a}	0.32^{de}	1.81^{e}	5.0^{de}	0.06^{i}	1.34^{c}
$I_2M_2F_4$	5.8^{a}	0.36^{d}	1.68^{gh}	5.2^{cde}	0.07^{h}	1.25^{cd}
Control	6.6	0.16	1.35	6.3	0.10	1.47
Treatments v/s control	S	S	S	S	S	S

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

Combination of irrigation and mulching had no effect on available nitrogen content of soil at 45 DAS and at final harvest. The interaction between irrigation and fertilizer level was significant with respect to available nitrogen content of soil at 45DAS and at final harvest. Among the treatment combinations I_1F_3 recorded highly significant available nitrogen (401.4 kg ha^{-1} and 322.0 kg ha^{-1}) at 45 DAS and at final harvest.

Mulching and fertilizer interaction effect was also significant with respect to available nitrogen. The highest nitrogen content was observed in M_1 F_3 (420.9 kg ha^{-1} and 306.1 kg ha^{-1}) at 45 DAS and at final harvest.

The interaction between irrigation, mulching and fertilizer was significant at 45 DAS and at final harvest. The treatments $I_2M_1F_3$ (448.0 kg ha^{-1}) and $I_1M_1F_3$ (350.9 kg ha^{-1}) recorded highest nitrogen at 45 DAS and at final harvest respectively.

4.5.5 Available phosphorus in soil (kg ha^{-1})

The data related to available phosphorus in soil is presented in Table 4.7.

The available phosphorus before planting was 40.5 kg ha^{-1}. The available phosphorus at 45 DAS and at final harvest was not influenced by levels of irrigation and mulching.

Fertilizer levels significantly influenced the available phosphorus content in soil. The highest available phosphorus was observed in F_3 (50.9 kg ha^{-1} and 43.0 kg ha^{-1}) and the lowest was observed in F_1 (41.0 kg ha^{-1} and 35.4 kg ha^{-1}) at 45 DAS and at final harvest.

Interaction between irrigation and mulching influenced the available phosphorus content at 45 DAS and at final harvest. Under both mulched and unmulched conditions, the highest phosphorus content was observed in I_1. Among the combinations $I_1 M_1$ recorded the highest value (47.3 kg ha^{-1} and 43.5 kg ha^{-1}) at 45 DAS and at final harvest followed by $I_1 M_2$.

Significant interaction effect was noted between irrigation and fertilizer levels with respect to available phosphorus content of soil at 45 DAS and at final harvest. Among the treatment combinations I_1F_3 recorded significantly high available phosphorus (52.3 kg $ha^{-1}$and 47.3 kg ha^{-1}) at 45 DAS and at final harvest.

The interaction effect of mulching and fertilizer was also significant with respect to available phosphorus. The highest phosphorus content was observed in M_1 F_3 (51.1 kg ha^{-1} and 43.0 kg ha^{-1}) at 45 DAS and at final harvest.

The three way interaction of irrigation, mulching and fertilizer was significant at 45 DAS and at final harvest with respect to available phosphorus content. The treatment $I_1M_1F_3$ recorded the highest phosphorus content (52.5 kg ha^{-1} and 48.5 kg ha^{-1}) at 45 DAS and at final harvest.

4.5.6 Available potassium in soil (kg ha^{-1})

The data related to available potassium in soil is presented in Table 4.7.

The available potassium content of soil before planting was 203.3 kg ha^{-1}. Levels of irrigation and mulching did not influence the available potassium content at 45 DAS and at final harvest. Fertilizer levels significantly influenced the available potassium in soil. The highest available potassium was observed in F_3 (321.2 kg ha^{-1} and 147.5 kg ha^{-1}) at 45 DAS and at final harvest followed by F_2.

Combinations of irrigation and mulching influenced the available potassium content of soil at 45 DAS and at final harvest. Among the combinations I_1M_1 recorded the highest value (314.3 kg ha^{-1} and 142.3 kg ha^{-1}) at 45 DAS and at final harvest.

The interaction between irrigation and fertilizer levels was significant with respect to available potassium content of soil at 45 DAS and at final harvest. Among the treatment combinations I_1F_3 recorded the highest available potassium (324.4 kg ha^{-1} and 157.3 kg ha^{-1}) at 45 DAS and at final harvest.

The available potassium content was also influenced by the interaction of mulching and fertilizer. The highest potassium content was observed in M_1F_3 (339.9 kg ha^{-1} and 155.5 kg ha^{-1}) at 45 DAS and at final harvest.

The interaction effects of irrigation, mulching and fertilizer were significant at 45 DAS and at final harvest with respect to available potassium content. The treatment $I_1M_1F_3$ recorded the highest potassium content (388.8 kg ha^{-1} and 173.7 kg ha^{-1}) followed by $I_2M_1F_2$ (308.8 kg ha^{-1}) at 45 DAS and at final harvest.

4.6 Economics of production

The data pertaining to the economics of production of cowpea crop under different treatments in terms of total cost, gross return and B:C ratio as influenced by irrigation, mulching and fertilizer is presented in Table 4.8.

There was significant difference among treatments. The highest B:C ratio (1.83) was recorded in the treatments $I_1M_1F_3$ and $I_2M_1F_3$. This was closely followed by $I_1M_1F_2$ (1.81). The lowest B:C ratio was recorded in the treatment $I_2M_2F_1$ (0.61) which was on par with the treatment $I_2M_2F_4$.

4.7 Effect of irrigation, mulching and fertilizer on available N, P and K in soil at 45 DAS and at final harvest

Treatments	45 DAS			At final harvest		
	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
Irrigation						
I_1	335.3^{a}	47.4^{a}	291.8^{a}	263.7^{a}	42.7^{a}	133.3^{a}
I_2	332.0^{a}	45.0^{a}	262.3^{a}	242.7^{a}	37.1^{a}	118.6^{a}
Mulching						
M_1	336.7^{a}	45.7^{a}	290.7^{a}	259.2^{a}	40.1^{a}	130.7^{a}
M_2	330.6^{a}	46.8^{a}	263.5^{a}	247.1^{a}	39.6^{a}	121.2^{a}
Fertilizer						
F_1	276.7^{c}	41.0^{c}	234.8^{c}	221.2^{bc}	35.4^{d}	100.3^{c}
F_2	344.4^{b}	46.5^{ab}	290.7^{b}	253.4^{ab}	40.0^{c}	126.1^{bc}
F_3	397.2^{a}	50.9^{a}	321.2^{a}	288.9^{a}	43.0^{a}	147.5^{a}
F_4	316.4^{c}	46.3^{b}	261.6^{bc}	249.2^{b}	41.2^{b}	130.0^{b}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

4.7(a) Interaction effect of irrigation and mulching on available N, P and K in soil at 45 DAS and at final harvest

Treatments	45 DAS			At final harvest		
	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
$I_1 M_1$	330.4^{a}	47.3^{a}	314.3^{a}	267.9^{a}	43.5^{a}	142.3^{a}
$I_1 M_2$	340.2^{a}	47.5^{a}	269.0^{b}	259.6^{a}	41.9^{b}	124.4^{b}
$I_2 M_1$	343.0^{a}	44.1^{c}	266.8^{c}	250.6^{a}	36.7^{d}	119.2^{c}
$I_2 M_2$	321.1^{a}	45.9^{b}	257.9^{d}	234.7^{a}	37.4^{c}	118.0^{d}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

4.7(b) Interaction effect of irrigation and fertilizer on available N, P and K in soil at 45 DAS and at final harvest

Treatments	45 DAS			At final harvest		
	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
$I_1 F_1$	272.5^{d}	41.8^{e}	261.2^{e}	216.6^{f}	36.3^{e}	102.3^{e}
$I_1 F_2$	352.8^{b}	49.1^{bc}	285.8^{d}	256.7^{b}	43.5^{c}	135.3^{bc}
$I_1 F_3$	401.4^{a}	52.3^{a}	324.4^{a}	322.0^{a}	47.3^{a}	157.3^{a}
$I_1 F_4$	280.9^{d}	46.4^{c}	296.0^{c}	259.5^{ab}	43.7^{b}	138.6^{b}
$I_2 F_1$	314.6^{c}	40.3^{f}	208.5^{g}	225.9^{e}	34.5^{f}	98.30^{f}
$I_2 F_2$	336.0^{b}	43.9^{d}	295.5^{c}	250.2^{c}	36.4^{e}	117.0^{d}
$I_2 F_3$	392.9^{a}	49.6^{b}	318.1^{b}	255.7^{b}	38.7^{d}	137.9^{b}
$I_2 F_4$	318.3^{bc}	46.1^{c}	227.3^{f}	238.9^{d}	38.8^{d}	121.4^{c}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

4.7(c) Interaction effect of mulching and fertilizer on available N, P and K in soil at 45 DAS and at final harvest

Treatments	45 DAS			At final harvest		
	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
$M_1 F_1$	255.7^{f}	40.6^{g}	251.9^{g}	223.1^{e}	35.6^{f}	103.7^{f}
$M_1 F_2$	369.6^{bc}	45.9^{d}	310.8^{b}	258.6^{c}	40.8^{d}	133.8^{c}
$M_1 F_3$	420.9^{a}	51.1^{a}	339.9^{a}	306.1^{a}	43.5^{a}	155.5^{a}
$M_1 F_4$	300.6^{de}	45.1^{e}	260.3^{f}	249.2^{d}	40.7^{d}	129.9^{d}
$M_2 F_1$	297.7^{e}	41.5^{f}	217.8^{h}	219.4^{f}	35.2^{g}	96.85^{g}
$M_2 F_2$	319.2^{cd}	47.1^{c}	270.6^{d}	248.3^{d}	39.2^{e}	118.5^{e}
$M_2 F_3$	373.4^{b}	50.8^{b}	302.6^{c}	271.6^{b}	42.5^{b}	139.6^{b}
$M_2 F_4$	332.3^{c}	47.4^{c}	263.0^{e}	249.2^{d}	41.8^{c}	130.0^{d}

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

4.7(d) Interaction effect of irrigation, mulching and fertilizer on available N, P and K in soil at 45 DAS and at final harvest

Treatments	45 DAS			At final harvest		
	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})	Available N (kg ha^{-1})	Available P (kg ha^{-1})	Available K (kg ha^{-1})
$I_1M_1F_1$	255.7^{i}	41.6^{k}	299.5^{e}	201.6^{d}	36.8^{h}	105.5^{j}
$I_1M_1F_2$	380.8^{cd}	49.3^{c}	312.8^{b}	265.1^{bc}	45.0^{c}	150.2^{b}
$I_1M_1F_3$	393.9^{bc}	52.5^{a}	338.8^{a}	350.9^{a}	48.5^{a}	173.7^{a}
$I_1M_1F_4$	291.2^{h}	45.6^{g}	307.4^{d}	253.9^{c}	43.8^{d}	139.6^{d}
$I_1M_2F_1$	289.3^{h}	42.0^{j}	222.8^{j}	231.5^{cd}	35.8^{j}	97.10^{l}
$I_1M_2F_2$	324.8^{fg}	48.9^{d}	258.8^{h}	248.3^{c}	42.0^{e}	120.3^{h}
$I_1M_2F_3$	408.8^{b}	52.0^{b}	309.9^{c}	293.1^{b}	46.1^{b}	140.8^{c}
$I_1M_2F_4$	337.9^{ef}	47.2^{f}	284.6^{f}	265.1^{bc}	43.6^{d}	137.5^{f}
$I_2M_1F_1$	255.7^{i}	39.5^{l}	204.2^{m}	244.5^{c}	34.3^{k}	101.9^{k}
$I_2M_1F_2$	358.4^{de}	42.5^{i}	308.8^{c}	252.0^{c}	36.5^{i}	117.3^{i}
$I_2M_1F_3$	448.0^{a}	49.6^{c}	340.9^{a}	261.3^{bc}	38.5^{g}	137.3^{f}
$I_2M_1F_4$	309.9^{fgh}	44.6^{h}	213.2^{l}	244.5^{c}	37.6^{h}	120.2^{h}
$I_2M_2F_1$	306.1^{gh}	41.0^{n}	212.7^{k}	207.2^{d}	34.6^{k}	94.60^{m}
$I_2M_2F_2$	313.6^{fgh}	45.3^{g}	282.3^{g}	248.3^{c}	36.3^{i}	116.6^{i}
$I_2M_2F_3$	337.9^{ef}	49.5^{c}	295.2^{e}	250.1^{c}	38.8^{g}	138.4^{e}
$I_2M_2F_4$	326.7^{fg}	47.6^{e}	241.3^{i}	233.3^{cd}	39.9^{f}	122.5^{g}
Control	252.0	42.2	164.0	274.4	32.4	97.16
Treatments v/s control	S	S	S	S	S	S

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

4.8 Interaction effect of irrigation, mulching and fertilizer on Benefit Cost ratio

Treatments	Total cost of production per hectare (Rs.)	Gross income per hectare (Rs.)	B:C ratio
$I_1M_1F_1$	197574	252000	1.28^{e}
$I_1M_1F_2$	200138	360000	1.81^{ab}
$I_1M_1F_3$	202794	372000	1.83^{a}
$I_1M_1F_4$	204169	332000	1.63^{c}
$I_1M_2F_1$	190634	172000	0.90^{fg}
$I_1M_2F_2$	193198	188000	0.97^{efg}
$I_1M_2F_3$	195854	192000	0.98^{efg}
$I_1M_2F_4$	197229	184000	0.93^{fg}
$I_2M_1F_1$	195989	240000	1.20^{e}
$I_2M_1F_2$	198493	336000	1.69^{b}
$I_2M_1F_3$	201149	368000	1.83^{a}
$I_2M_1F_4$	202524	328000	1.62^{cd}
$I_2M_2F_1$	188971	116000	0.61^{g}
$I_2M_2F_2$	191553	180000	0.94^{efg}
$I_2M_2F_3$	194209	228000	1.17^{ef}
$I_2M_2F_4$	195584	124000	0.63^{g}
Control	104366	108000	1.03
Treatments v/s control			S

Figures with same alphabets as superscript do not differ significantly at 5 % level in DMRT

DISCUSSION

5. DISCUSSION

Drip irrigation is the concept where water is applied at low rate, frequently near the root zone of the plant. This system can easily be used for fertigation through which the applied fertilizer is placed in the active root zone, and crop nutrient requirement can be met accurately. Combinations of drip irrigation and polythene mulches have recently been used as an advanced technology to manage water efficiently and to produce high quality vegetables.

Yard long bean is grown widely in tropics and subtropics for fresh long pods. It is considered as a crop less prone to drought with high yield potential. It is also important because it fixes atmospheric nitrogen which is available for subsequent crop uptake thereby reducing the cost of nitrogen fertilization in a cropping system.

The results obtained in the study entitled "Fertigation and mulching studies in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)" carried out in the variety Vellayani Jyothika, are discussed in this chapter. The study was conducted to standardize the fertigation requirement of yard long bean and also to assess the relative efficacy of fertigation and mulching over the conventional methods.

5.1 GROWTH PARAMETERS

The result of the study indicated that levels of irrigation had significant influence on the vine length at 45, 60 and 75 DAS. It was observed that the plants irrigated with 80 per cent Ep recorded significantly higher vine length (257.53 cm, 419.17 cm and 485.68 respectively) than those receiving 60 per cent pan evaporation proving that vine length was positively influenced by higher levels of irrigation (Fig. 5.1). Similar results were reported by Gebrimedhin (2001), Ningaraju (2013) and Nakaande (2013).

Days taken for first flower appearance, first fruit set and first harvest of cowpea were not influenced by levels of irrigation and mulching. This is in agreement with the findings of Anoop (2009) in OP melon. The number of days taken for first flowering was 42 to 43 and this variation was negligible considering the levels of irrigation. Since all the irrigation levels contributed sufficient soil moisture ideal for crop growth, days to flower and fruit production did not vary between them.

It is observed that mulching had significant effect on vine length except at 45 DAS (Fig. 5.2). The result of the study indicated that the maximum vine length of 513.81 cm (at 75 DAS) was recorded in treatments mulched with white-black polythene sheet, whereas it was only 431.79 cm in un-mulched treatments at 75 DAS. The better physical conditions, weed free situations and higher soil moisture status under full polythene mulching provided the ideal conditions, supporting better growth. These results are in close conformity to the findings of Salman *et al.* (1991), Khan *et al.* (2005) and Anoop (2009).

Likewise, vine length and root length showed significant difference with different levels of fertilizer (Fig. 5.3 and Fig. 5.4). The study revealed that the highest level of fertilizer resulted in the highest vine length at 45, 60 and 75 DAS as observed in F_3 (296.83 cm, 433.45 cm and 510.83 cm respectively). Similarly the root length was observed to be maximum (30.81 cm) in the treatment F_4 (100 % recommended dose with water soluble fertilizer) and the treatments F_1, F_2 and F_3 were on par. The highest vine length with 120 per cent RDF (F_3) through fertigation might be due to the optimum availability of nutrients and moisture which facilitated the production of better root biomass, resulting better nutrient uptake from the soil (Chawla and Narda, 2000). Similar findings were reported by Ruby *et al.* (2012) and Fanish and Muthukrishnan (2013).

It is observed from the study that the interaction of irrigation with mulching and irrigation with fertilizer were non-significant with regard to vine length, root length,

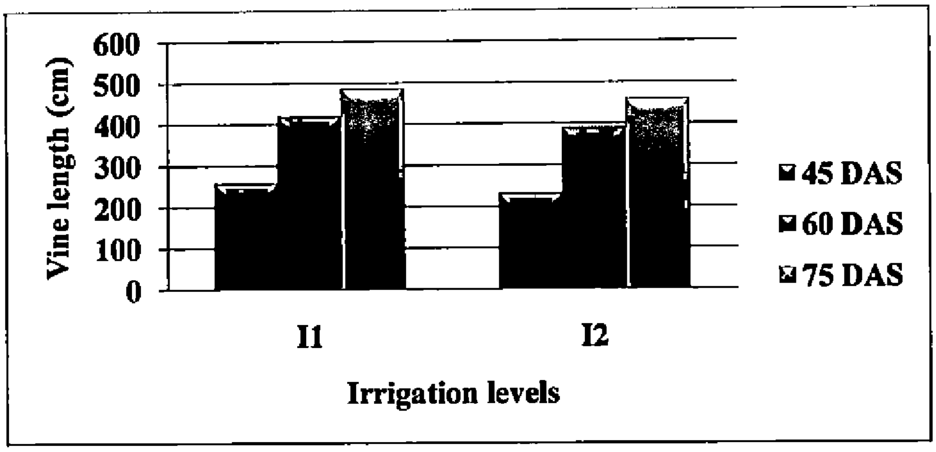


Fig. 5.1 Effect of irrigation on vine length

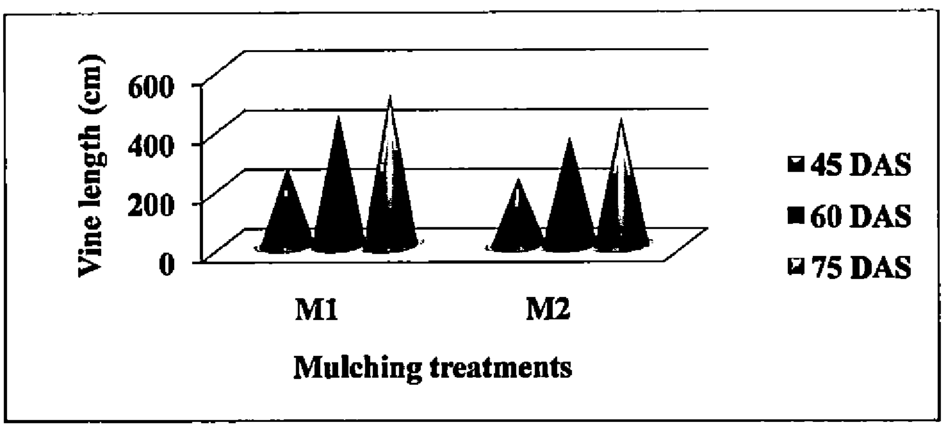


Fig. 5.2 Effect of mulching on vine length

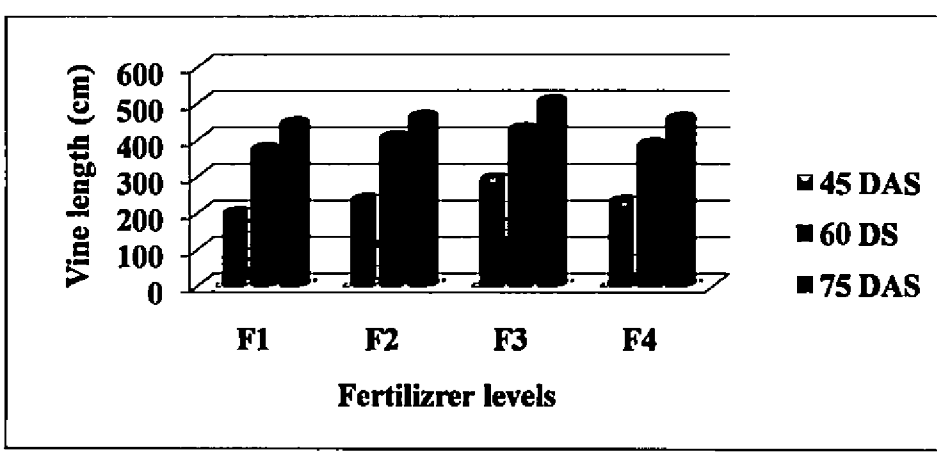


Fig. 5.3 Effect of fertilizer on vine length

days taken for first flower appearance, first fruit set and first harvest; while the interaction between fertilizer and mulching was significant with respect to vine length. The study revealed that the increase in vine length was significant with increase in fertilizer in mulched plots at 45 DAS and the maximum (315.40 cm) was with F_3 level of fertilizer. With regard to vine length, the fertilizer levels F_1, F_2 and F_4 were on par. The interaction effects between mulching and fertilizer level were non-significant at 60 and 75 DAS.

It is observed that the interaction between mulching and fertilizer had no influence on root length, days taken for first flower appearance, first fruit set and first harvest. When irrigation, mulching and fertilizer were considered together, there was no significant effect on days taken for first flower appearance, first fruit set and first harvest, whereas vine and root length were significant. It took 42 days for the first flower appearance and first fruit set in F_1, F_2 and F_3 and 43 days in F_4. Similarly all the treatments took 54 days for first harvest. The highest vine length was recorded in the treatment $I_1M_1F_3$ and the highest root length was observed in the treatment with 60 per cent Ep and water soluble fertilizer at 100 per cent RDF without mulching ($I_2M_2F_4$). Reduced irrigation and increased evaporation due to the absence of mulch might have contributed to the increased root length in the treatment $I_2M_2F_3$ compared to other treatments.

5.2 YIELD AND YIELD ATTRIBUTES

Yield (yield per plant and yield per hectare) and the number of pods per plant were found to be significantly higher in the treatments supplied with irrigation at the level of 80 per cent of Ep than the treatments supplied with 60 per cent Ep indicating the high water requirement of yard long bean (Fig. 5.10 and Fig. 5.11). The highest level of irrigation (80 per cent Ep) recorded significantly higher number of pods per plant (42.49), yield per plant (0.65 kg) and yield per hectare (6.5 t) as compared to lower level of irrigation (60 per cent Ep). Among the two irrigation levels, the

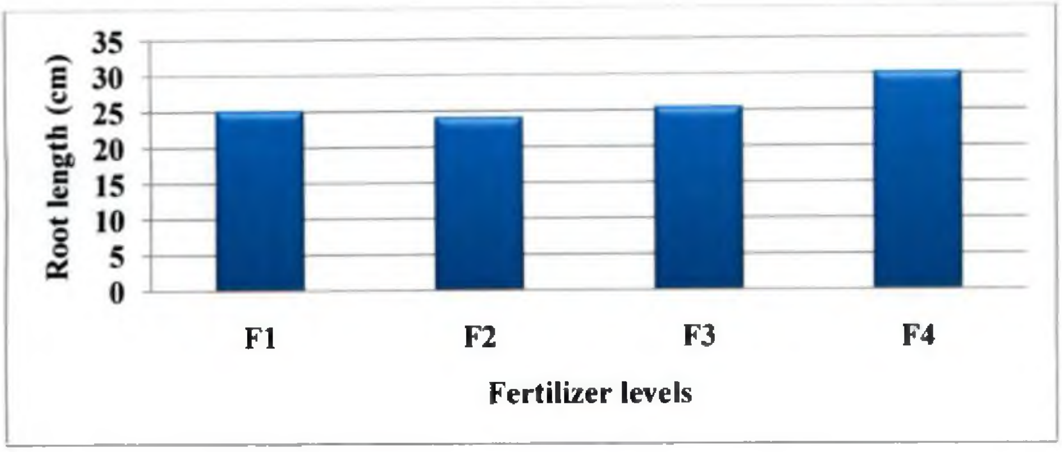


Fig. 5.4 Effect of fertilizer on root length

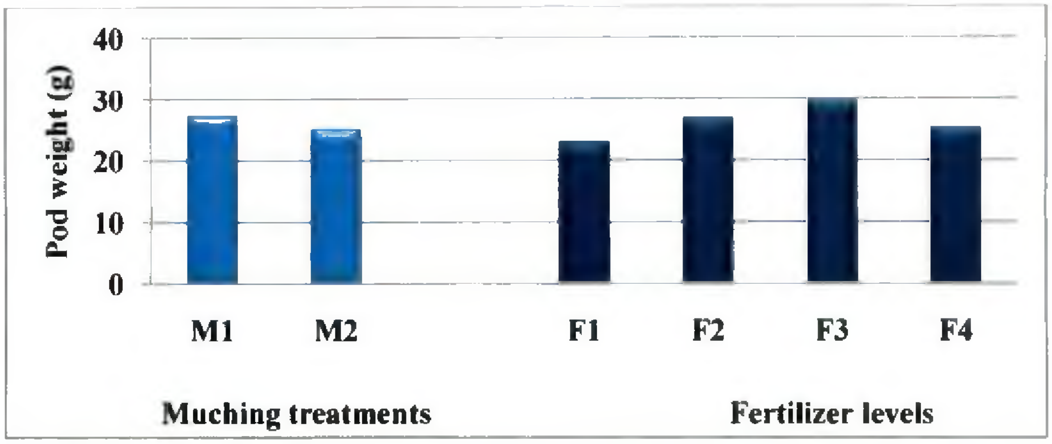


Fig. 5.5 Effect of mulching and fertilizer levels on pod weight

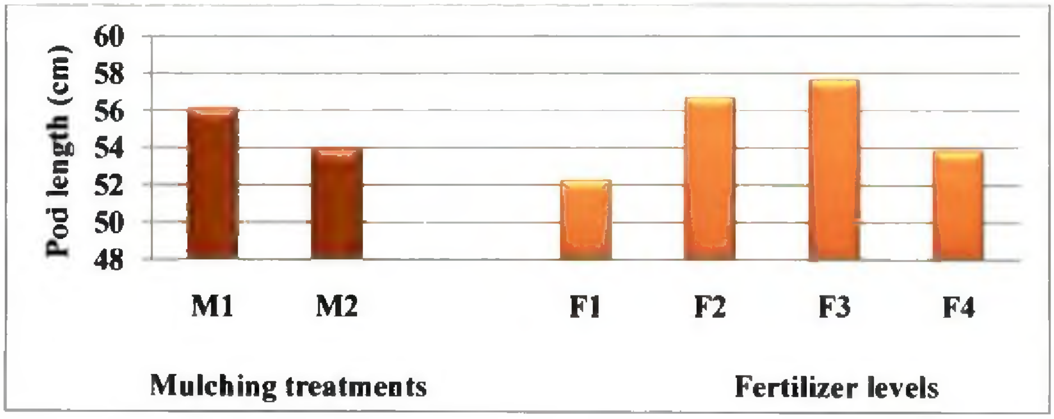


Fig. 5.6 Effect of mulching and fertilizer levels on pod length

days taken for first flower appearance, first fruit set and first harvest; while the interaction between fertilizer and mulching was significant with respect to vine length. The study revealed that the increase in vine length was significant with increase in fertilizer in mulched plots at 45 DAS and the maximum (315.40 cm) was with F_3 level of fertilizer. With regard to vine length, the fertilizer levels F_1, F_2 and F_4 were on par. The interaction effects between mulching and fertilizer level were non-significant at 60 and 75 DAS.

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The important yield attributes *viz.*, number of pods per plant, pod weight, pod length, yield per plant and yield per hectare were significantly influenced in mulched treatments compared to un-mulched treatments (Fig. 5.5 and Fig. 5.6). This might be due to higher vegetative growth, higher production of assimilates and better partitioning of assimilates. This finding is in agreement with that of Clough and Locascio (1990) in chilli, Wien *et al.* (1993) in tomato, Awasthi *et al.* (2005) in brinjal and Henry and Chinedu (2014) in cowpea.

The fertilizer levels in the study also showed significant effect on yield and yield attributes like number of pods per plant, number of seeds per pod (Fig. 5.7), pod weight and pod length. With the increase in fertilizer levels the yield and yield attributes also increased and the maximum was observed in F_3 (125 per cent RDF). The increased availability of nutrients with increased levels of fertilizer application and higher uptake of applied nutrients by the plants might have resulted in increased yield.

Irrigation combined with mulching and fertilizer levels were non-significant with respect to the number of pods per plant, pod weight, pod length and number of seeds per pod. The interaction between irrigation and mulching was not significant with respect to yield and number of pods per plant, while the combination of irrigation and fertilizer levels was significant (Fig. 5.12 and Fig. 5.13). The probable

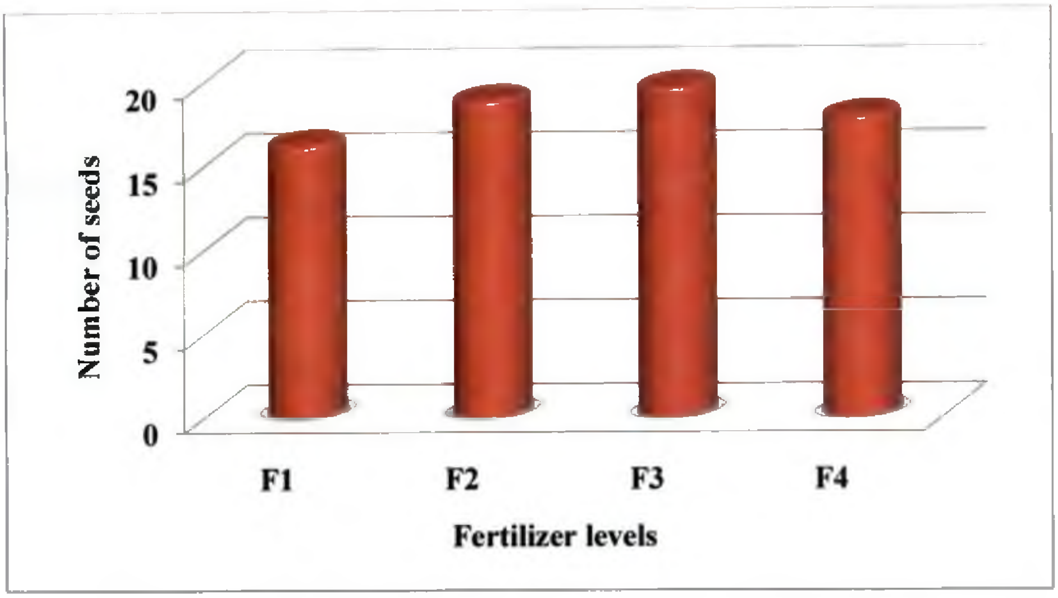

Fig. 5.7 Effect of fertilizer levels on number of seeds per pod

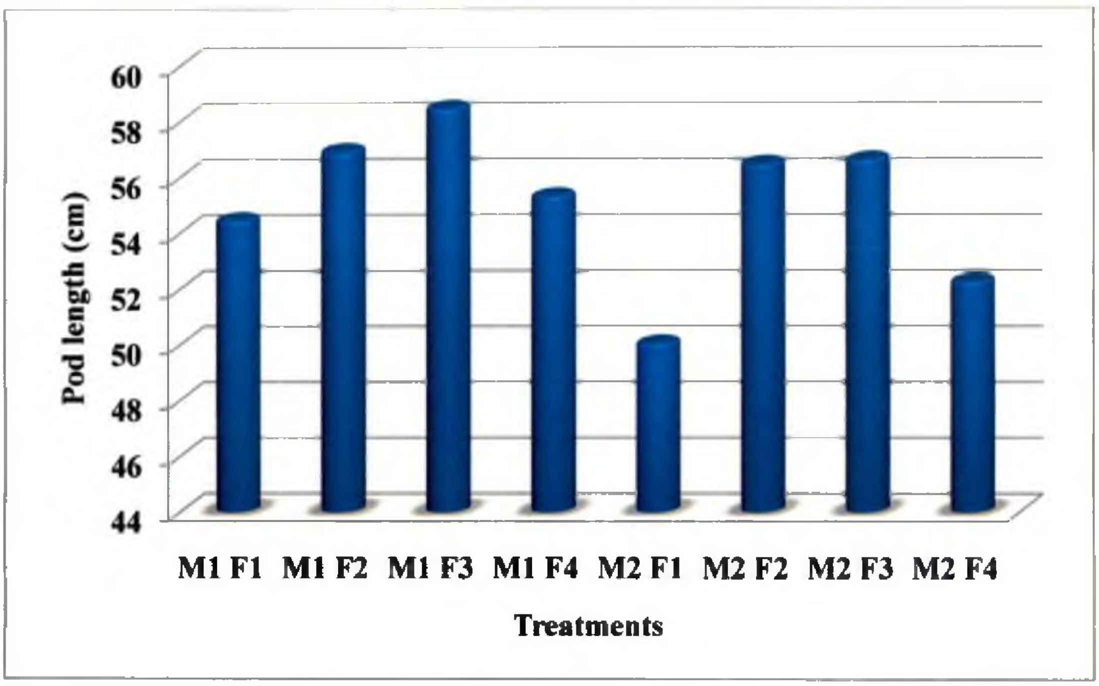

Fig. 5.8 Interaction effect of mulching and fertilizer levels on pod length

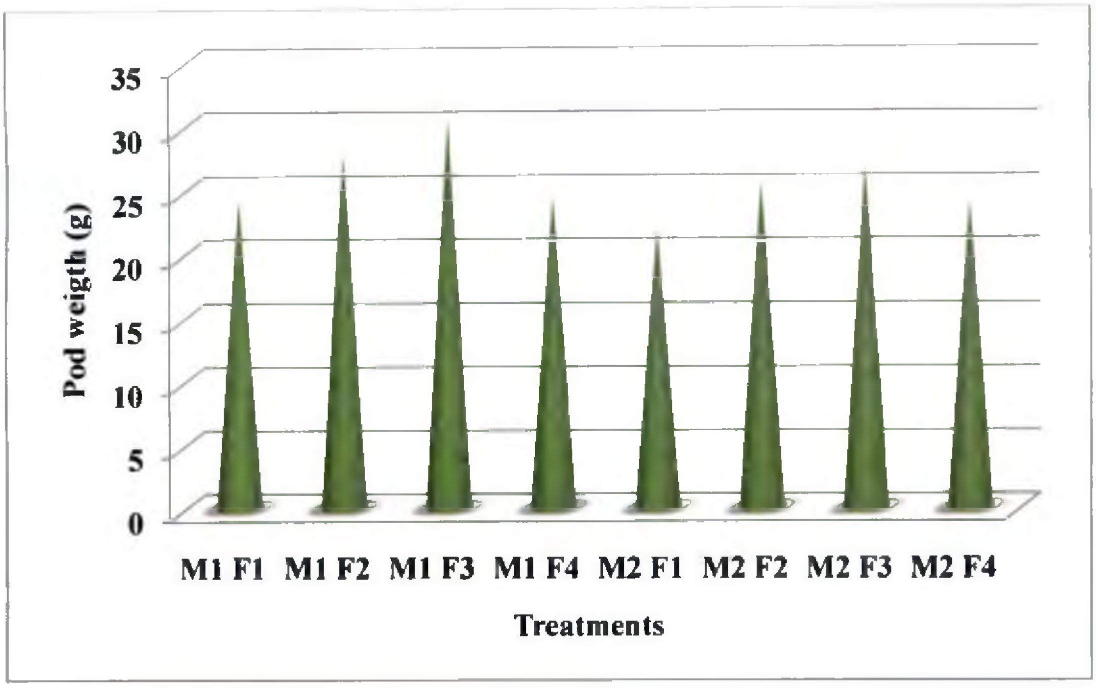

Fig. 5.9 Interaction effect of mulching and fertilizer levels on pod weight

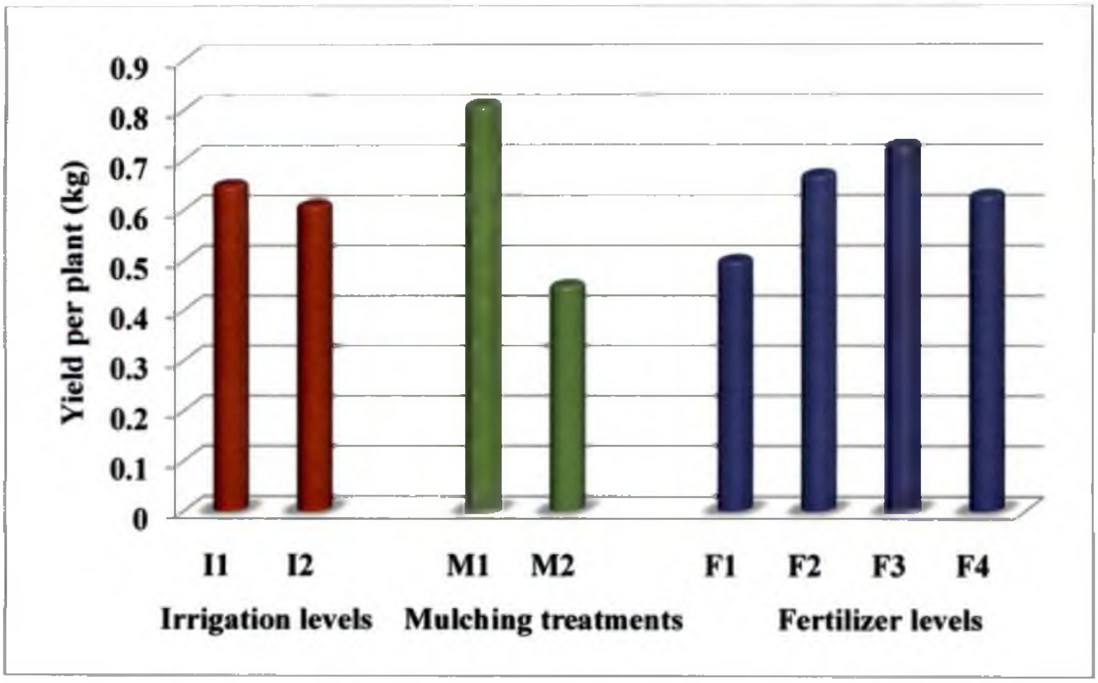

Fig. 5.10 Effect of irrigation, mulching and fertilizer levels on yield per plant

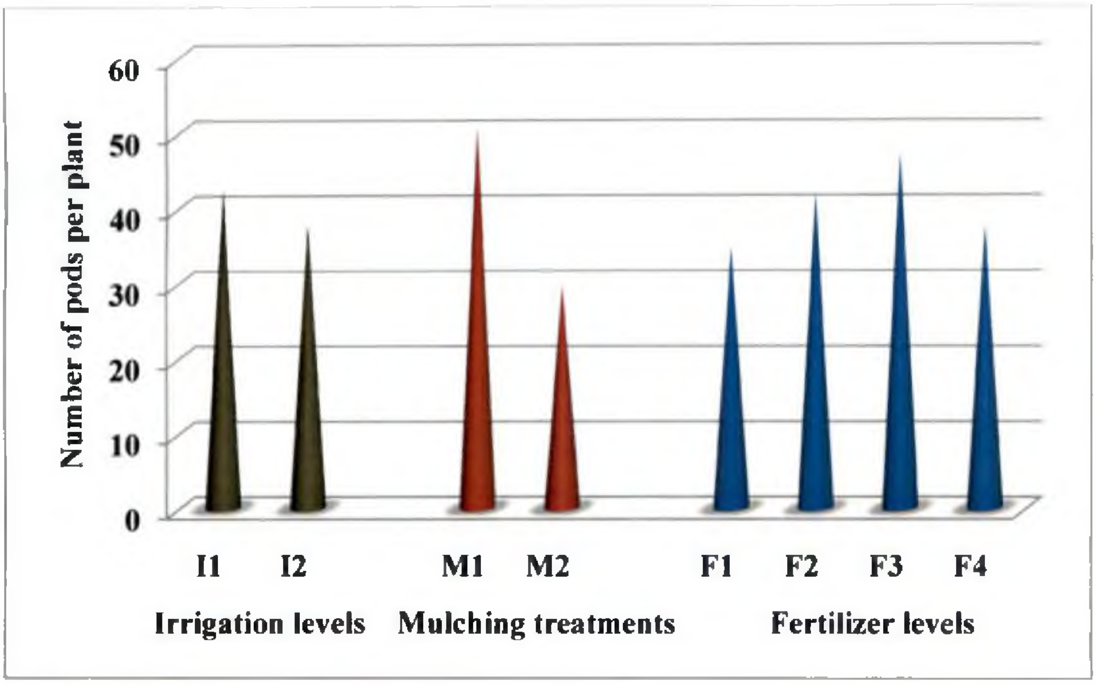

Fig. 5.11 Effect of irrigation, mulching and fertilizer levels on number of pods per plant

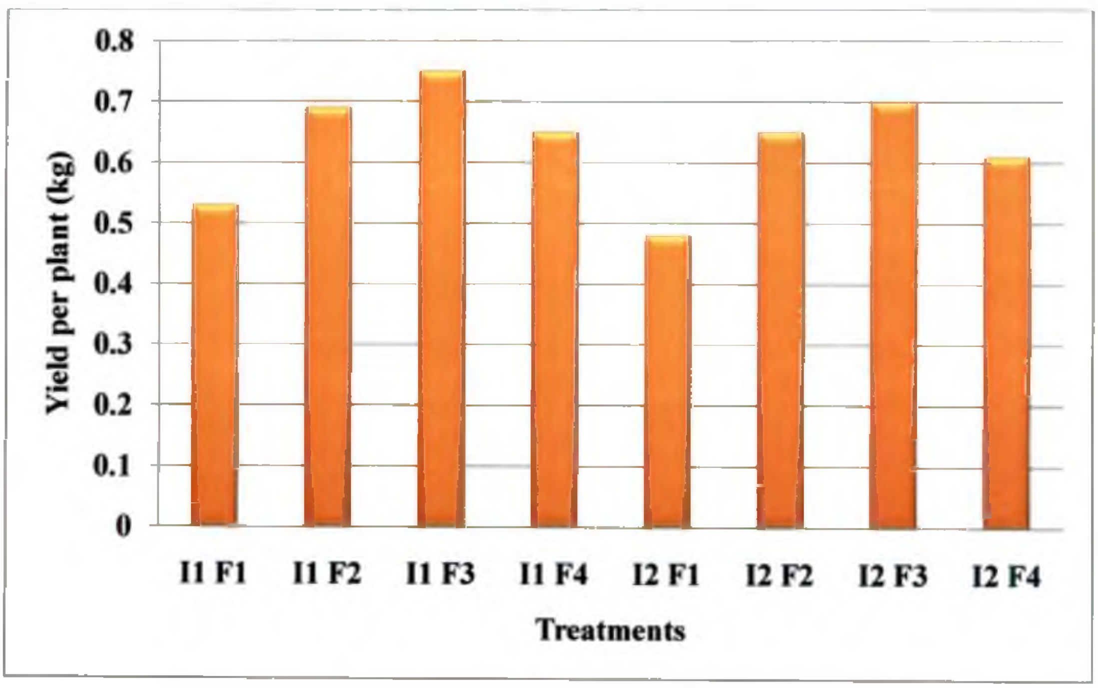

Fig. 5.12 Interaction effect of irrigation and fertilizer levels on yield per plant

reason might be the enhanced source capacity and sink strength due to continuous nutrient availability with favorable moisture regime, which in turn might have influenced yield attributing characters.

Mulching and fertilizer showed significant positive interaction on the number of pods per plant, pod weight, pod length, yield per plant and yield per hectare (Fig. 5.8 and Fig. 5.9). The treatment M_1F_3 recorded the highest value for number of pods per plant (62.72), pod weight (30.05 g), pod length (58.47 cm), yield per plant (0.93 kg) and yield per hectare (9.3 t) while number of seeds per pod was not significant (Fig 5.14 and Fig. 5.15). Similar results were reported by Gandhi and Bains (2006) in tomato. Increased yield could be largely attributed to the improvement in soil environment around roots due to application of mulch, which resulted in increased plant growth and yield. These results are in conformity with those of Ruby *et al.* (2012) in pointed gourd and Gebrimedhin (2001) in oriental pickling melon who reported increased yield due to mulching and higher fertilizer application.

The interaction effects of irrigation, mulching and fertilizer when taken together had significant effect on number of pods per plant, pod weight, pod length, number of seeds per pod and yield per plant. The appropriate and sufficient fertilizer application through fertigation made it possible to match the crop nutrient requirement at various growth stages, with minimum leaching beyond the root zone, resulting in improved growth and yield characteristics. The plants supplied with higher levels of irrigation (I_1) with mulching (M_1) produced higher yield compared to plants receiving lower levels of irrigation without mulching. The highest yield and pod length was observed in the treatment $I_1M_1F_3$ which was on par with the treatment $I_2M_1F_3$. Similar results were reported by Aruna *et al.* (2007) in tomato, Sturm *et al.*, (2010) in Cabbage and Chattoo *et al.* (2013) in radish.

The lowest yield and yield attributing characters were reported in the control treatment with conventional channel irrigation once in three days with 100 per cent

RDF. There was a decrease of 29 per cent yield in control over the best treatment ($I_1M_1F_3$). The fact that under flood irrigation most of the applied water was lost through evaporation and leaching due to fast rate of application whereas under drip irrigation water was supplied drop by drop with slow flow rate which restricted the water losses and allowed the plants to absorb available soil moisture from the root zone increasing the productivity. This is in agreement with the findings of Singh *et al.* (2001), Ningaraju (2013), Gebrimedhin (2001) and Nakaande (2013) who observed higher productivity for the treatments under drip irrigation with plastic mulching performed better growth over control.

The decreased yield in control as well as in other treatments, compared to the potential yield of 15 t/ha of yard long bean variety Vellayani Jyothika, might be due to the unfavourable climatic condition prevailed during flowering stage of the crop (Appendix II). The optimum temperature for flowering in yard long bean is 21-33^0 C, above which flower abscission occurs (Pandey, 1991). During the entire cropping period, especially during flowering the temperature, to which the crop was exposed, was above 37^0 C. The present recommendation (KAU, 2011) of 20:30:10 kg/ha N: P_2O_5: K_2O for yard long bean seems to be highly insufficient as the crop duration is more than 100 days and the yield potential is more than 15 t/ha. Yard long bean is a crop which highly responds to fertilizer application (Maharana and Das, 1973) as experienced with 9.3 t/ha yield with the highest dose of fertilizer. More yield would have been resulted, if a higher dose of fertilizer have been applied.

5.3 QUALITY OF FRUITS

The study revealed that the levels of irrigation, mulching and fertilizer had no significant influence on the protein content of pods. Their interaction was also not significant with respect to protein content of pods. The protein content of pods varied from 1.1 to 1.3 per cent and the difference was not significant. Similar observations have been reported by Hasan *et al.* (2010) in cowpea.

5.4 WEED GROWTH

The results on weed growth in terms of dry matter produced indicated that weed population was significantly reduced by polythene mulching (Fig. 5.16). Similarly fertilizer levels had significant influence on fresh weight and dry weight of weeds at 20, 40, 60 and 75 DAS whereas levels of irrigation did not affect the weed growth significantly. The treatments with polythene mulching recorded the lowest fresh and dry weight of weeds.

Absolute absence of sunlight under the polythene mulch completely checked the growth of weeds under it. Similar findings were reported by Dwivedi *et al.* (1999), Chaudhary *et al.* (2002) and Berihun (2011). Under mulching weeds emerged only near the plants where holes were made on polythene, whereas under unmulched condition weeds emerged in all the areas. It might be due to the unavailability of solar radiation which restricted the germination and emergence of weed seeds as polythene mulch completely restricted the penetration of light in to the soil.

Increased weed growth was observed with increase in fertilizer levels. The application of 125 per cent RDF through fertigation had recorded significantly higher weed growth at 20, 40 and 60 DAS. This might be due to the availability of more nutrients for better growth of the weeds. Whereas 100 per cent RDF recorded lower weed growth in first and second weeding with a good yield compared to 75 per cent RDF.

There was no significant interaction effect either between irrigation levels and mulching or between irrigation levels and fertilizer levels on weed growth. However the combination of MF was significant with regard to fresh and dry weight of weeds at first, second and third weeding. The study indicated that in all fertilizer levels, lowest weed growth was observed in mulched treatments.

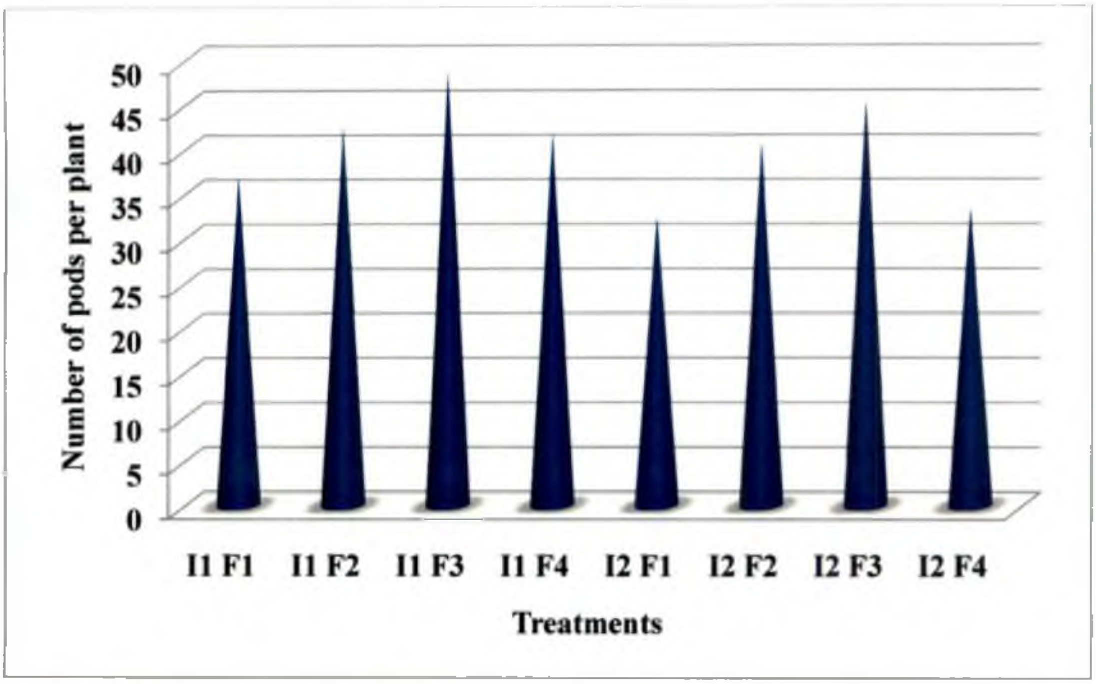

Fig. 5.13 Interaction effect of irrigation and fertilizer levels on number of pods per plant

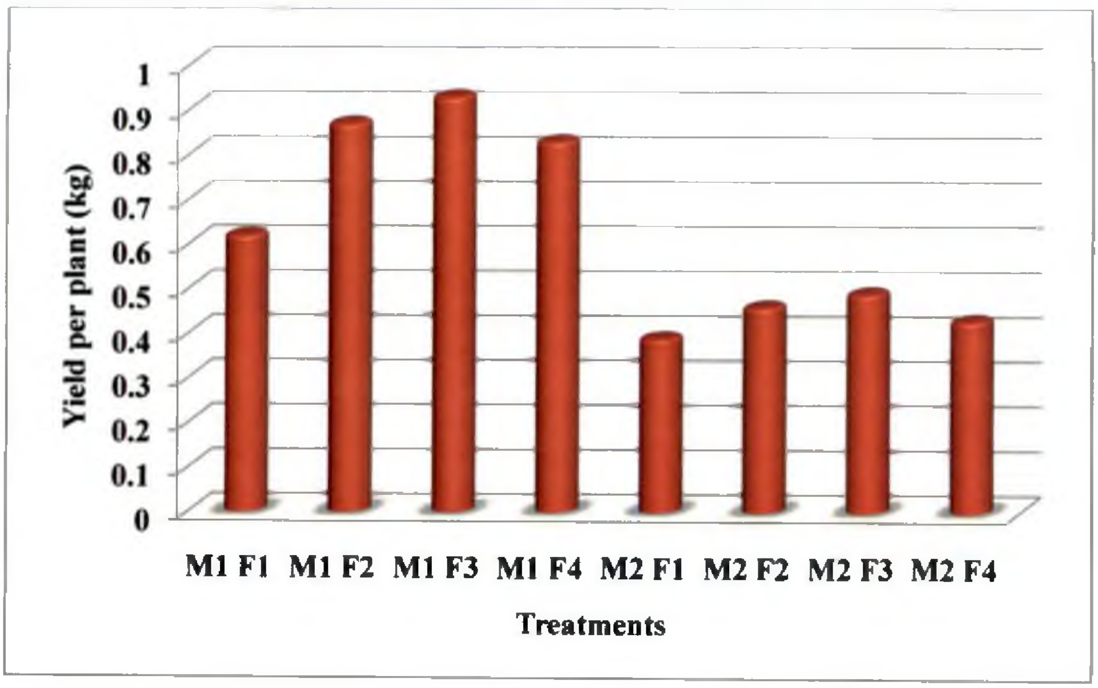

Fig. 5.14 Interaction effect of mulching and fertilizer levels on yield per plant

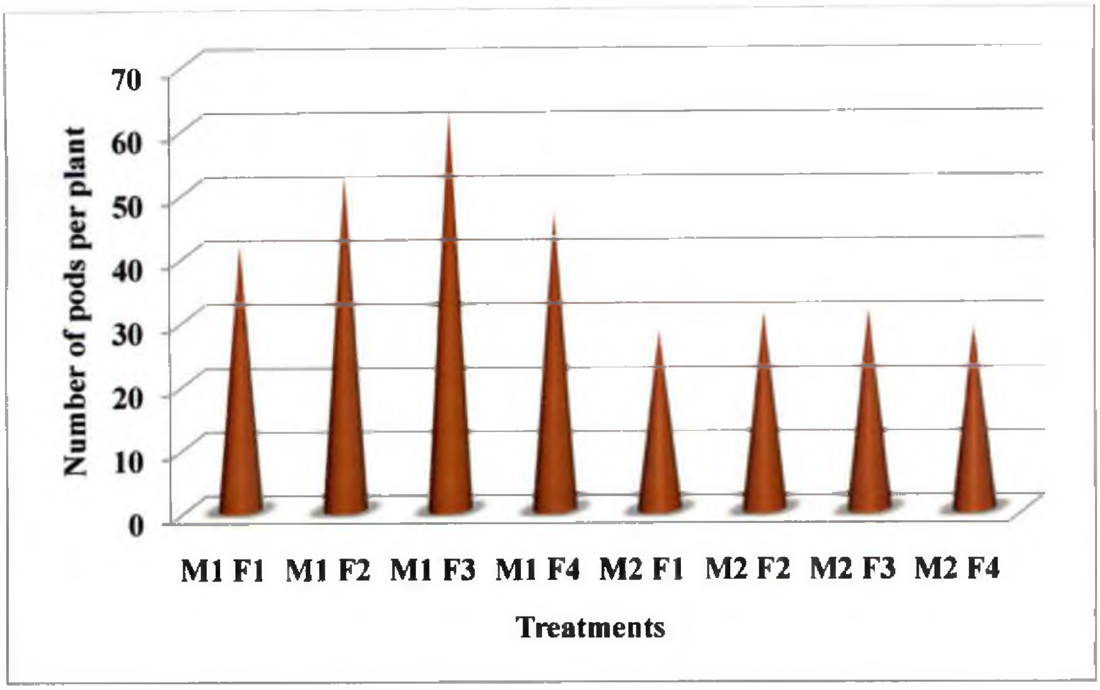

Fig. 5.15 Interaction effect of mulching and fertilizer levels on number of pods per plant

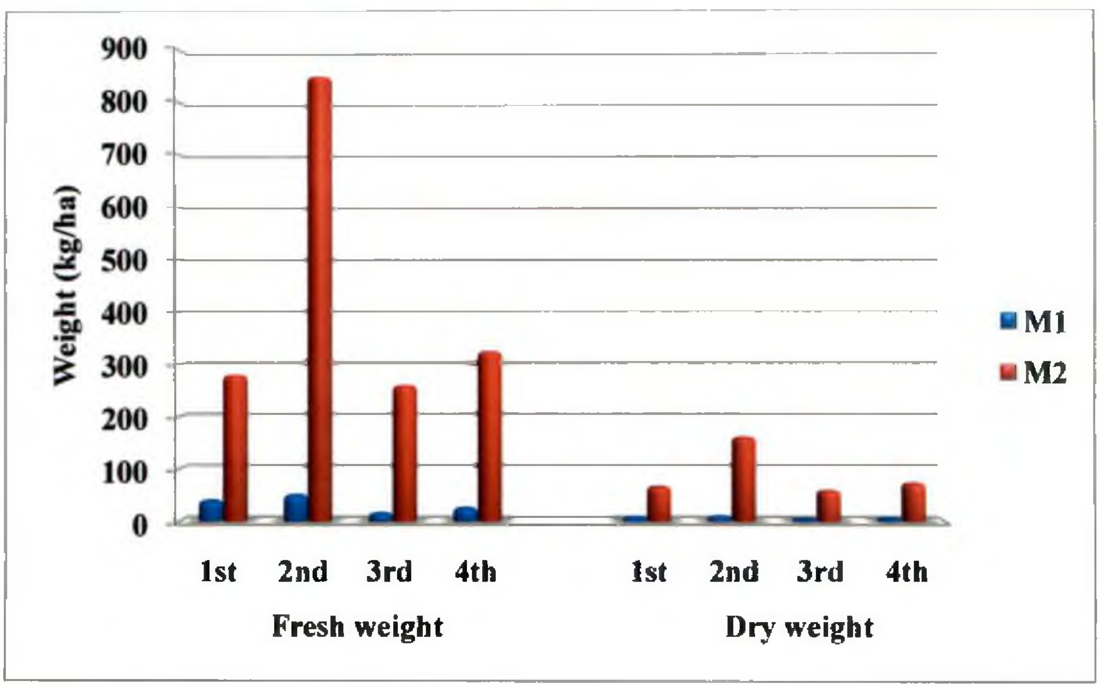

Fig. 5.16 Effect of mulching on fresh and dry weight of weeds

When the interaction of all the three factors; irrigation, mulching and fertilizer was considered together there was significant difference with regards to fresh and dry weight of weeds. The treatment $I_1M_2F_3$ recorded the highest weight of weeds in terms of fresh and dry weight at 20, 40, 60 and 75 DAS. Lowest weed growth was observed in mulched treatments irrespective of irrigation and fertilizer levels. Drip irrigation was effective in controlling the weed growth. Under control treatment (channel irrigation) which received full wetting of beds recorded a higher weed growth than all treatments receiving drip irrigation (Plate 4). Since, water is applied at specific points in drip irrigation; weed growth was much reduced in the inter-dripped areas due to limited wetting zone compared to channel irrigation.

5.5 SOIL

5.5.1 Chemical properties of soil

There was no considerable change in soil pH and EC by levels of irrigation and mulching. The treatments receiving lower levels of fertilizer (F_1) recorded the highest value for pH and lowest value for EC of soil (Fig. 5.17 and Fig. 5.18). The highest EC was recorded in F_4 (100 per cent RDF with water soluble fertilizer). Wien *et al.* (1993) reported that increase in the nitrogen rate gradually raised the EC of the soil especially when soluble fertilizers were used as the nitrogen source. He has also reported that large amount of nitrogen markedly decreased soil pH value while higher the rate of phosphorus and potassium did not affect the soil pH value but significantly accelerated the EC to rise in a slow rate. Similar results were also reported by Bryla *et al.* (2010).

While considering the interactions, soil pH was not affected by the interactions between either irrigation and fertilizer or mulching and fertilizer at 45 DAS. But the interactions were significant at final harvest. Irrespective of fertilizer, highest pH was recorded in irrigation level I_1 (Fig. 5.19). Highest pH was recorded in the lowest level of fertilizer rates irrespective of type of fertilizer. Considering the interaction between irrigation and fertilizer, higher pH (6.5) was recorded in $I_1 F_1$. But EC was influenced by the interaction of irrigation and fertilizer at 45 DAS and at final harvest (Fig. 5.20). The lowest EC was recorded in I_2F_1 (60 per cent Ep with 75 per cent RDF).

Considering the EC of the soil, interaction of irrigation and mulching had no significant influence on EC at 45 DAS but the effect was significant at final harvesting. Interaction of I_2M_2 recorded lowest EC (0.06 dSm^{-1}) followed by I_1M_2 (0.07 dSm^{-1})) at final harvest

Similarly combination of mulching and fertilizer also significantly influenced the pH at final harvest and EC of the soil at 45 DAS and at final harvest (Fig5.21 and Fig. 5.22). The treatments $M_2 F_1$ recorded higher pH and lowest EC which was on par with $M_1 F_1$.

Interaction of IMF was significant at 45 DAS and at final harvest with respect to EC, while pH was significant only at final harvest. Treatments $I_1M_1F_1$ and $I_1M_2F_1$ recorded higher pH whereas the lowest EC was recorded in the treatment $I_1M_2F_1$ followed by the treatment $I_2M_2F_1$ at 45 DAS and at final harvest.

5.5.2 Organic carbon

Soil organic carbon content was not influenced by the levels of irrigation and mulching at 45 DAS and at final harvesting. Fertilizer level significantly influenced the soil organic carbon content at 45 DAS and at final harvesting. F_3 (75 per cent RDF) level of fertilizer recorded higher value for organic carbon content of soil (1.94 and 1.47 per cent) at 45 DAS and at final harvesting. Result showed that organic carbon content increased with the increase in fertilizer levels and thus might be due to increased release of organic leachates from the roots as well as more addition of dried leaves from the crop receiving higher application rate of fertilizers to the soil.

Combination of irrigation and fertilizer was found to be significant with respect to organic carbon at 45 DAS and at final harvest. Highest organic carbon content (1.98 per cent) was reported from plots supplied with 80 per cent irrigation with 125 per cent RDF (I_1 F_3) at 45 DAS and at final harvest. Similar results were observed in interaction of mulching and fertilizer levels. Treatments receiving 125 per cent RDF with mulching (M_1 F_3) resulted in higher organic carbon content in soil.

There was an increase in organic carbon content at 45 DAS from initial 1.29 per cent to a maximum of 1.99 per cent in the treatment $I_2M_1F_3$; while decrease in organic carbon content was observed at final harvest due to increased uptake and utilization for dry mater production. Treatment $I_2M_1F_3$ recorded the highest organic carbon content (1.99 per cent) at 45 DAS and the treatment $I_1M_1F_3$ recorded the highest value (1.58 per cent) at final harvest.

5.5.3 Available nitrogen in soil (kg ha^{-1})

The available nitrogen content was not influenced by levels of irrigation and mulching. Fertilizer levels significantly influenced the available nitrogen in soil. The nitrogen content of soil increased with increase in fertilizer level up to F_3 (Fig. 5.23). The highest available nitrogen (397.1 kg/ha) was observed in F_3 (125 per cent RDF) at 45 DAS. The increased nitrogen content at 45 DAS compared to the initial nitrogen content (242.9 kg/ha) might be due to the continuous supply of nitrogenous fertilizer through drip in all fertilizer levels. It was clearly observed that there was depletion of available nitrogen content in soil at final harvest which might be due to the uptake and utilization by the plants which resulted in increased dry matter production in terms of yield. But the depletion decreased with increase in fertility levels up to F_3.

When the interaction of factors like irrigation, mulching and fertilizer was considered together, there was significant influence when fertilizer was combined with both irrigation and mulching, while interaction of irrigation with mulching had

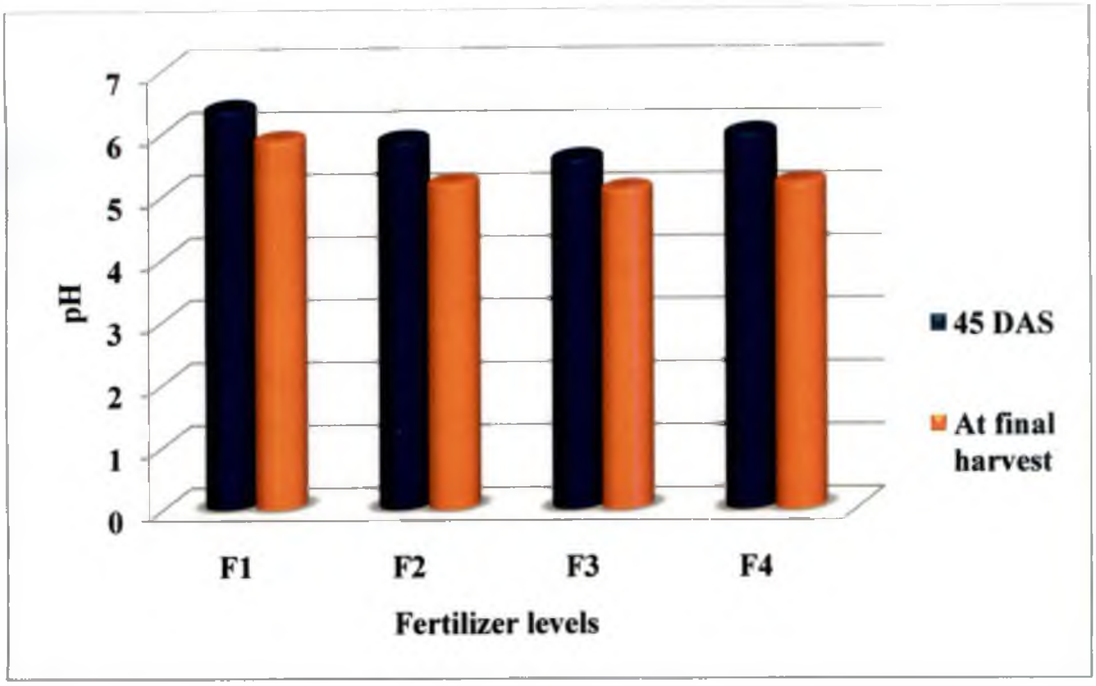

Fig. 5.17 Effect of fertilizer levels on soil pH

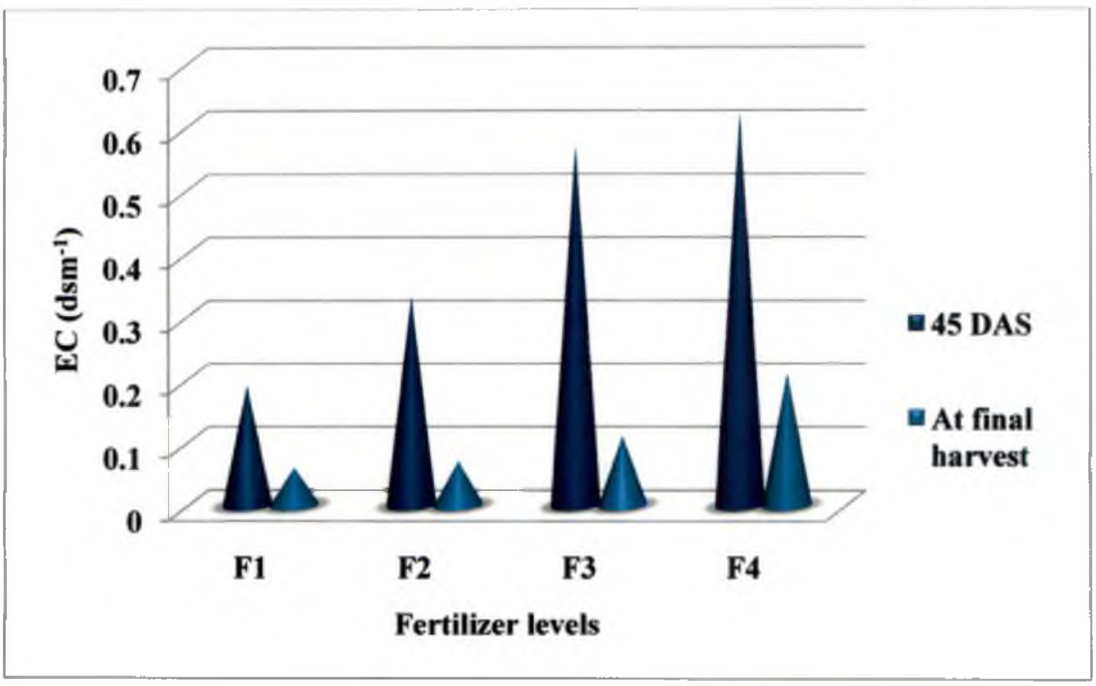

Fig. 5.18 Effect of fertilizer levels on EC of soil

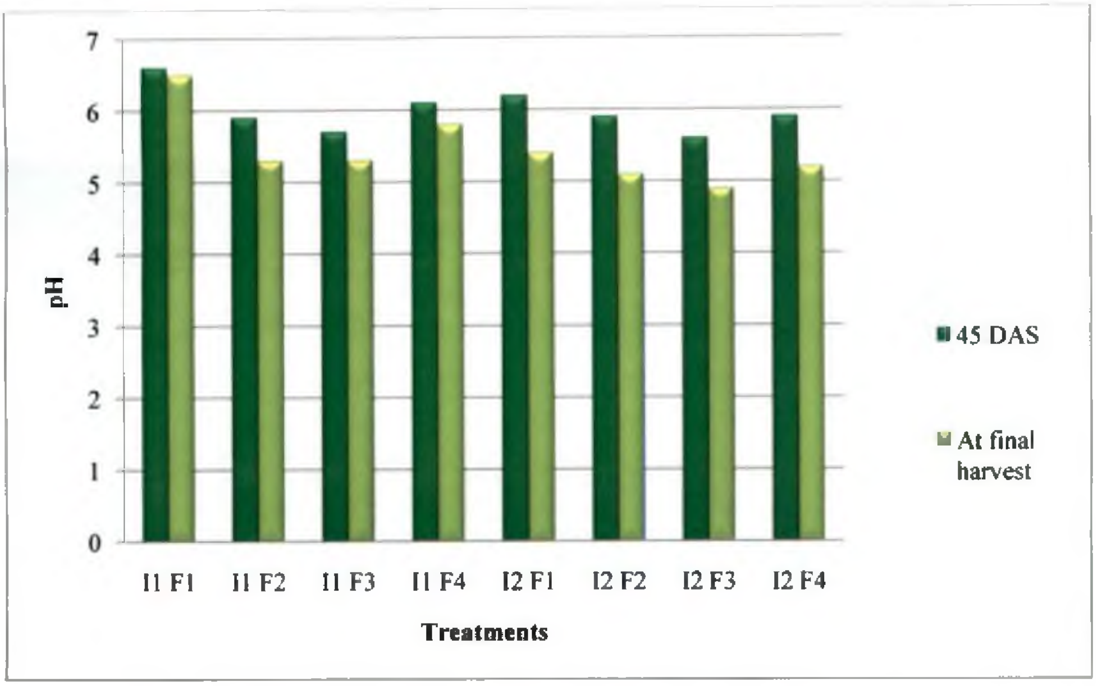

Fig. 5.19 Interaction effect of irrigation and fertilizer levels on soil pH

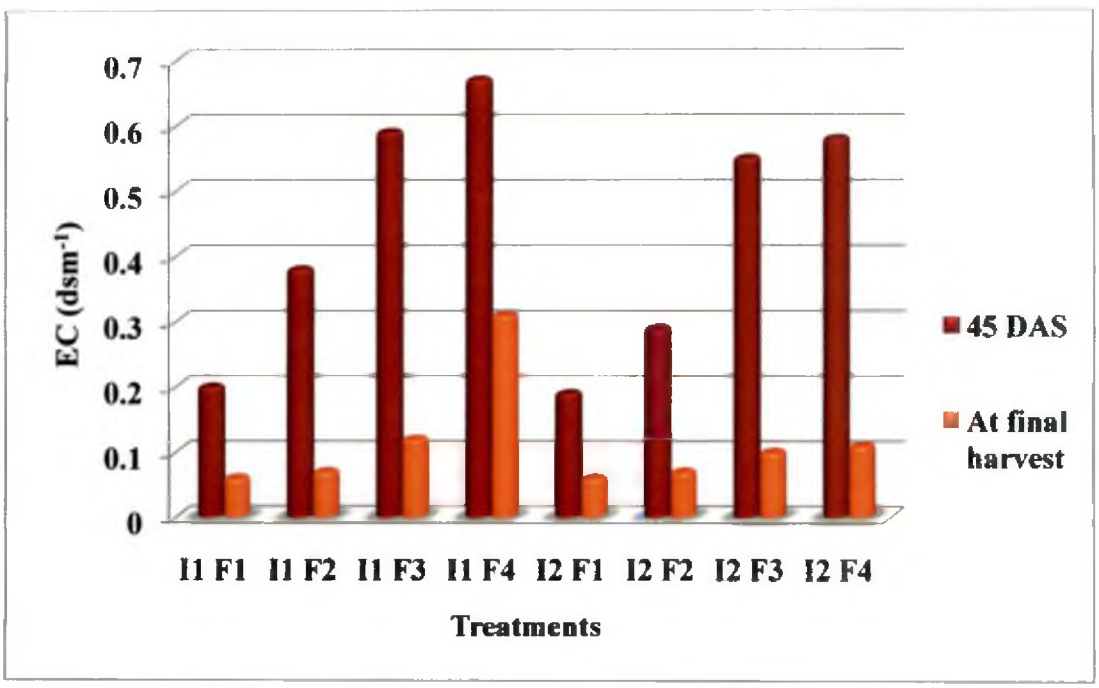

Fig. 5.20 Interaction effect of irrigation and fertilizer levels on EC of soil

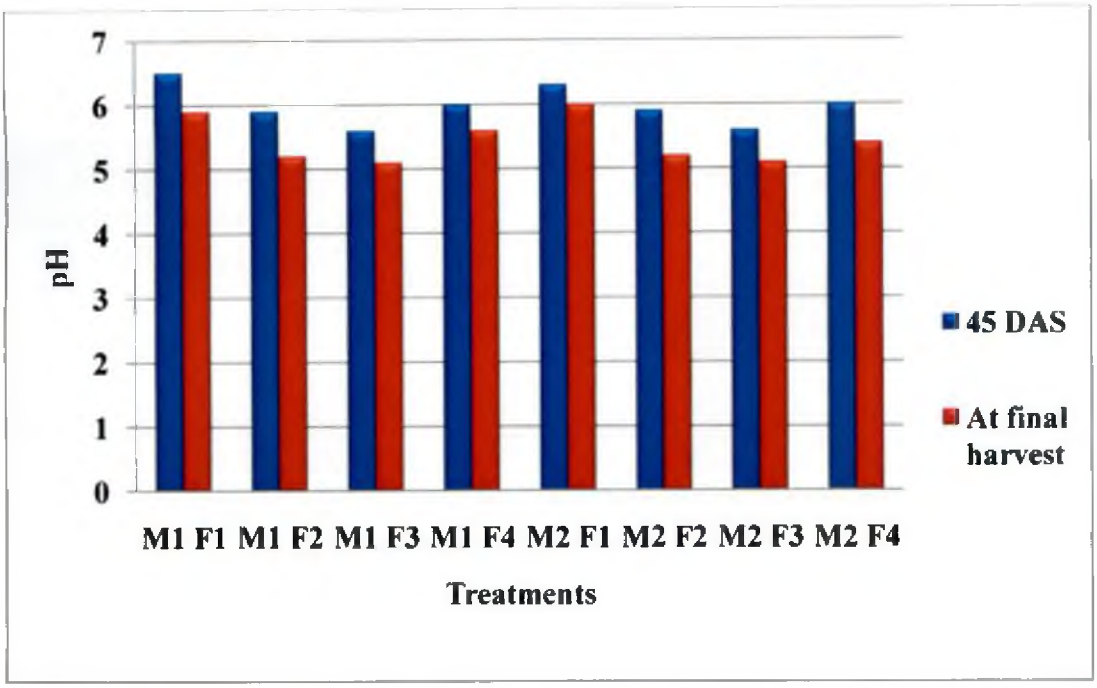

Fig. 5.21 Interaction effect of mulching and fertilizer levels on soil pH

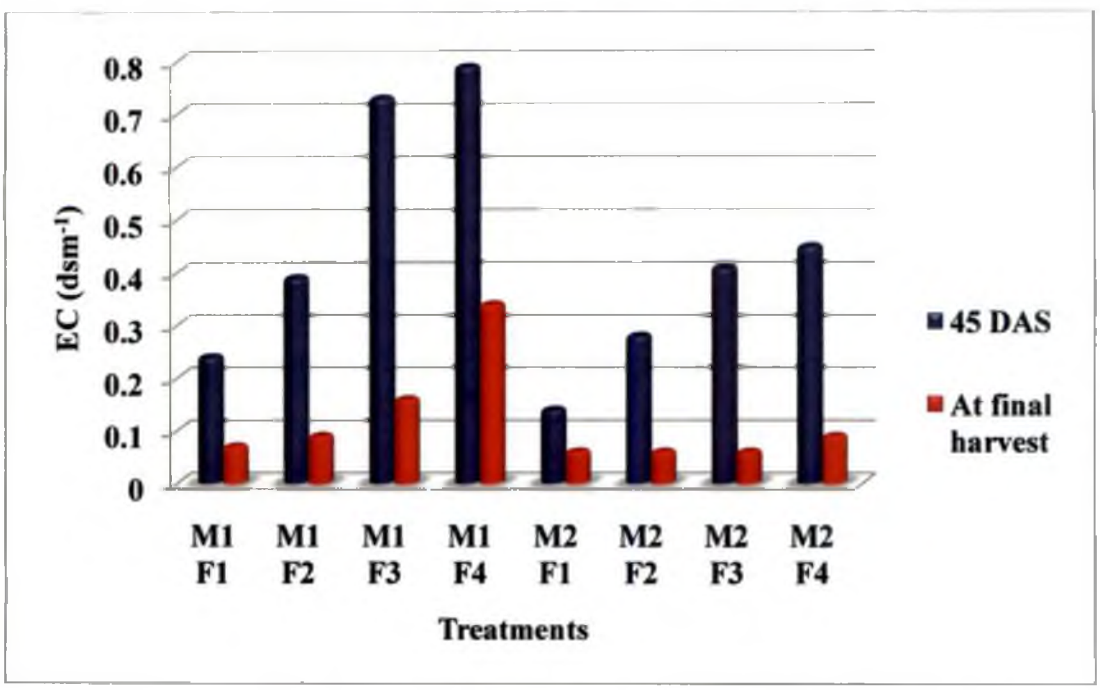

Fig. 5.22 Interaction effect of mulching and fertilizer levels on EC of soil

no effect on available nitrogen content of soil at 45 DAS and at final harvest. It was observed from the result that irrespective of mulching and irrigation, fertilizer level 3 showed the highest available nitrogen in the soil. Among the treatment combinations, I_1F_3 and M_1 F_3 recorded highest available nitrogen content at 45 DAS and at final harvest. When the interactions of all the three factors were taken together, the treatments $I_2M_1F_3$ and $I_1M_1F_3$ recorded high nitrogen at 45 DAS and at final harvest. Higher N levels through drip have contributed more to available nitrogen in soil.

5.5.4 Available phosphorus in soil (kg ha^{-1})

As in the case of available nitrogen, available phosphorus content in soil was also greatly influenced by fertigation with mulching. The amount of available phosphorus content of the soil increased from initial 40.5 kg/ha to a maximum of 52.5 kg/ha at 45 DAS. It was due to application of phosphatic fertilizers through irrigation water up to 30 DAS. The phosphorus content decreased to a minimum of 34.33 kg/ha at final harvest due to the absorption of phosphorus by the plants.

There was no significant effect in available phosphorus with different levels of irrigation because phosphorus mobility with water moving in the soil is negligible and that crop uptake did not vary very much at the younger stages between irrigation levels.

In proportion to the increase in the levels of fertilizer application through drip, the available phosphorus content of soil also increased (Fig. 5.23). The highest available phosphorus was observed in F_3 and the lowest in F_1 both at 45 DAS and at final harvest. Ningaraju (2013) and Anoop (2009) also reported increase in phosphorus content with increase in fertilizer levels in oriental pickling melon.

The interactions of the treatments were also significant with respect to available phosphorus content of soil. Irrespective of fertilizer and mulching, irrigation level 1 (80 per cent Ep) recorded the highest phosphorus content. Among the combinations I_1M_1 and I_1F_3 recorded the highest value at 45 DAS and at final harvest. Similarly irrespective of irrigation and fertilizer, mulched treatments recorded higher values. The highest phosphorus content was observed in I_1 M_1 and M_1 F_3 at 45 DAS and at final harvest.

The three way interaction of irrigation, mulching and fertilizer was significant at 45 DAS and at final harvest with respect to available phosphorus content. The treatment $I_1M_1F_3$ recorded the highest phosphorus content both at 45 DAS and at final harvest.

5.5.45 Available potassium in soil (kg ha^{-1})

Levels of irrigation and mulching did not influence the available potassium while the levels of fertilizer significantly influenced the available potassium content at 45 DAS and at final harvest indicating the influence of higher levels of applied potassium on available K_2O in soil. The available potassium increased linearly with increase in fertilizer levels from 75 to 125 per cent, due to higher rate of application of fertilizers through drip (Fig. 5.23). A decline in available K_2O in soil was observed from 45 DAS to harvest in all treatments. This decrease in available potassium content in the soil upto harvest was in direct proportion to the dry matter produced by the plants in terms of yield.

The available potassium content as influenced by the combination of the treatments also showed similar tendency like phosphorus. The treatment combinations I_1 M_1, I_1F_3 and M_1 F_3 recorded the highest values at 45 DAS and at final harvest.

The interaction effects of irrigation, mulching and fertilizer were significant at 45 DAS and at final harvest with respect to available potassium content. The treatment $I_1M_1F_3$ recorded the highest potassium content (338.8) followed by $I_1M_1F_2$ (312.8) at 45 DAS and the treatment $I_1M_1F_3$ recorded the highest (173.7) potassium

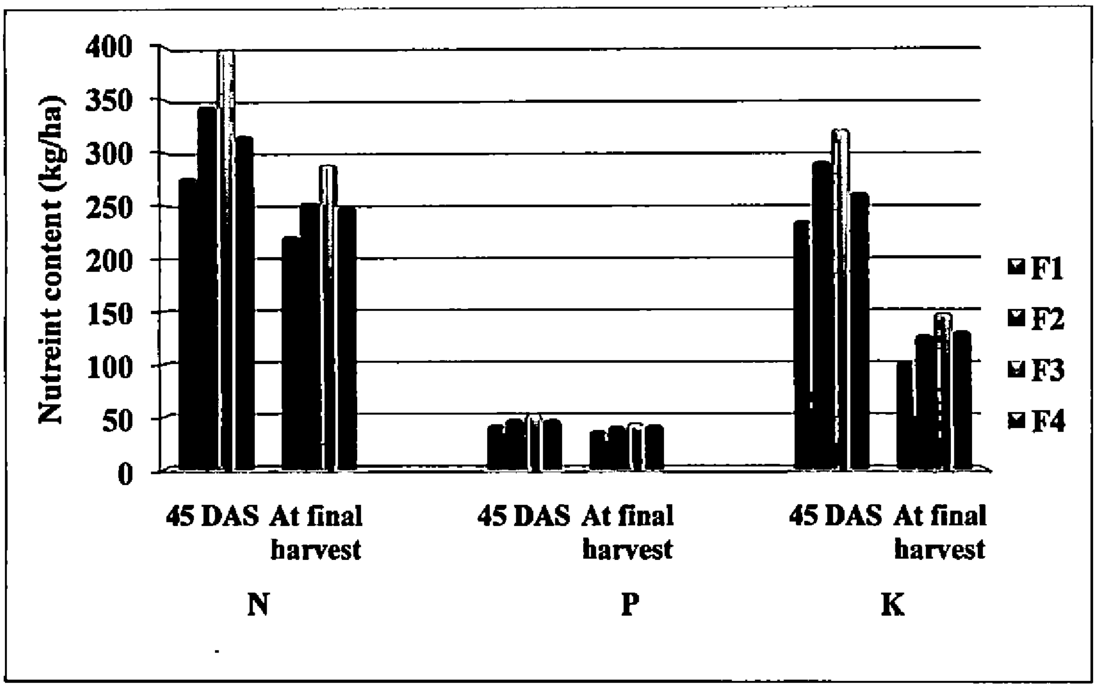

Fig. 5.23 Effect fertilizer levels on available nitrogen, phosphorus and potassium content of soil

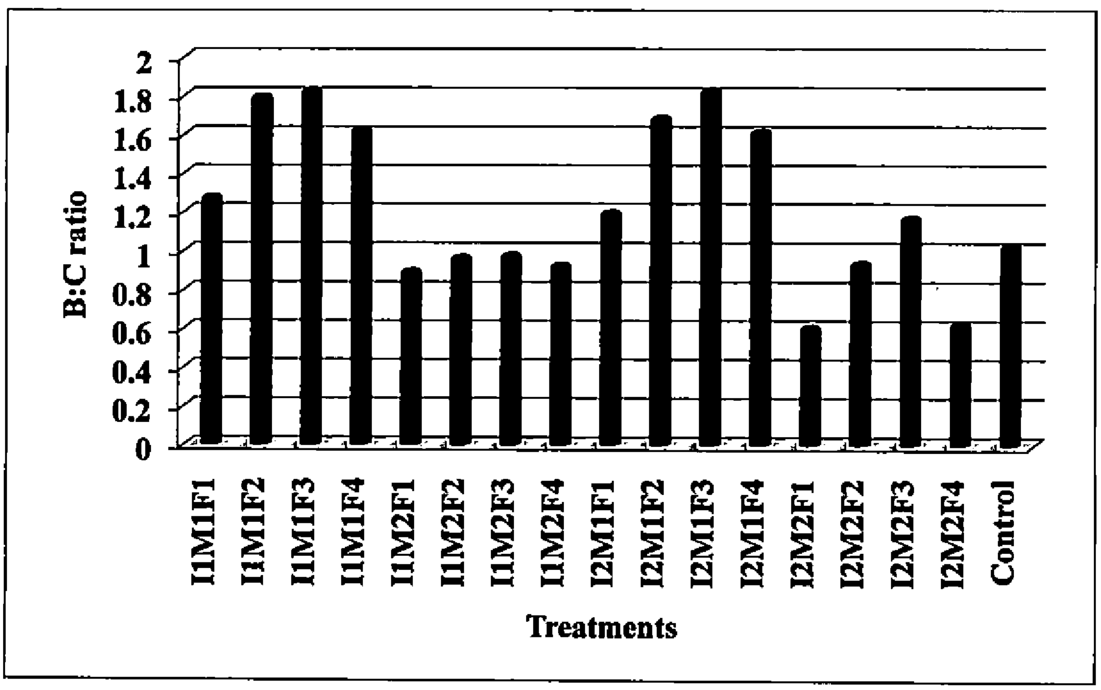

Fig. 5.24 Effect of irrigation, mulching and fertilizer levels on B:C ratio

content at final harvest. These results were in conformity with the findings of Rajees (2013) and Ningaraju (2013).

4.6 Economics of production

There was significant difference among the treatments with respect to B:C ratio (Fig. 5.24). The highest B:C ratio (1.83) was recorded in the treatments $I_1M_1F_3$ and $I_2M_1F_3$. The results showed that, even though cost of production for the treatment $I_2M_1F_3$ was lower than the treatment $I_1M_1F_3$ they resulted in the same B:C ratio. It might be due to the difference in yield and the gross return obtained for those treatments. Raina *et al.* (1999) reported that the seasonal income under drip only and drip plus plastic mulch in pea cv. Lincoln was 60.8 and 91.6 per cent higher respectively as compared to conventional method of irrigation. The benefit cost ratio worked out for drip alone and drip plus mulch and conventional irrigation respectively were 2.06, 2.11 and 1.98 in pea. Singh *et al.* (2006) reported that in green pea, the net income by drip irrigation method was 40.1 per cent more as compared to basin method of irrigation and further increase in yield could be possible where water is scarce by increasing the area under cultivation with the saved amount of water.

Irrespective of irrigation and mulching, the plants which received F_3 levels of fertilizers showed higher B:C ratio, which might be due to the availability of higher nutrients for the crop which resulted in better growth and higher yield. The lowest B:C ratio was recorded in the treatment $I_2M_2F_1$ (0.61) which was on par with $I_2M_2F_4$. Poor yield and higher cost of cultivation for the treatment $I_2M_2F_4$ resulted in the lowest B:C ratio (0.63). Duraisamy and Manickasundaram (2008) reported the highest B:C ratio of 1.42 by the adoption of the irrigation schedule of 0.45 IW/CPE ratio in perennial red gram BSR 1.

Among the different fertilizer levels, fertilizer level 3 (F_3) recorded the highest B:C ratio irrespective of irrigation and mulching. The lowest B:C ratio was observed in F_4 (100 per cent RDF with water soluble fertilizer), due the poor yield in the treatment. The higher total cost of production might also contribute to lower B:C ratio. Both in F_2 and F_4 the fertilizer level was same (100 per cent) but the source of nutrient was different. This resulted in increased cost of production for the treatment receiving F_4 level of fertilizer compared to F_2 level of fertilizer due to high cost of water soluble fertilizer (19:19:19) compared to Urea and Muriate of Potash (MOP). Also the *per se* content of each nutrient present in the water soluble fertilizer (WSF) being less, demanded higher quantity and resulted in higher total cost, compared to Urea and MOP. This was in close conformity with the findings of Kanwar *et al.* (2013) in sweet pepper, Rajees (2013) in OP melon, Spehia *et al.* (2010) in okra and Aruna *et al.* (2007) in tomato.

The major drawback of the drip irrigation system is its high initial investment; however, cost can be recovered in a short span, if proper water and nutrient management and design principles are followed. The deisred economic benefits of drip fertigation are possible in the crop only when proper drip fertigation strategeis for nutreint application (4 R- Right source, Right rate, Right time and Right place) are adopted.

Conclusion

The above findings revealed that interactions between levels of irrigation, mulching and fertilizer when considered together, had marked effect on vine length, all yield attributes, weed growth and all soil properties. The highest vine length, yield and yield attributes and soil nutrients were recorded in the treatment $I_1M_1F_3$ (80 per cent Ep, with mulching, 125 per cent RDF), which was on par with the treatment $I_2M_1F_3$ (60 per cent Ep, with mulching, 125 per cent RDF) indicating that when mulching was provided irrigation at 60 per cent Ep and 80 per cent Ep were equal in performance. Without mulching there was yield reduction at lower level of irrigation (60 per cent Ep). When fertilizer levels alone were considered, higher levels of fertilizer (125 per cent RDF) resulted in higher yield than 75 and 100 per cent RDF. There was an increase of 3.4 times in yield in the best treatment $I_1M_1F_3$ over conventional channel irrigation at 3 days interval with 100 per cent RDF.

Future line of work

Fertilizer recommendation specific for yard long bean should be standardized. The effect of higher doses (than in the present study) of fertilizer with mulching in yard long bean is to be studied. Effect of mulching and fertilizer levels during seasons other than summer need to be evaluated. Role of mulching on root nodulation and microbial growth is to be studied.

SUMMARY

6. SUMMARY

The investigations on "Fertigation and mulching studies in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)" were carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during January – May 2014. The study was conducted in the yard long bean variety Vellayani Jyothika to standardize the fertigation requirement and to assess the relative efficacy of fertigation and mulching over the conventional methods in yard long bean.

The experiment was laid out in strip plot design with two replications. There was a total of 17 treatments consisting of combinations of two irrigation levels (60 and 80 per cent Ep through drip irrigation) and four fertilizer levels (75, 100 and 125 per cent recommended dose of fertilizer (RDF) and 100 per cent RDF with water soluble fertilizer) with and without mulching and a control treatment (channel irrigation once in three days with 100 per cent RDF).

During the course of experiment, plant growth, yield and quality of the produce under different treatments were critically observed. The salient findings and conclusions drawn out from the study are summarized below.

1) Levels of irrigation (I) significantly influenced the vine length at 45, 60 and 75 DAS. The maximum vine length (257.53 cm, 419.17 cm and 485.68 respectively) was recorded at 80 per cent Ep and it was significantly superior to 60 per cent Ep. Fertilizer levels (F) also significantly influenced the vine length; the highest vine length (296.83 cm, 433.45 cm and 510.83 cm) was recorded with 125 per cent RDF at 45, 60 and 75 DAS.
2) Mulching (M) had no effect on vine length at 45 DAS but it significantly influenced the vine length at 60 and 75 DAS. The maximum vine length of 513.81 cm (at 75 DAS) was recorded in mulched plots whereas it was only 431.79 cm in un-mulched plots at 75 DAS.

3) Days to first flowering, first fruit set, first harvest and days from flowering to harvest were not influenced due to either *per se* effect or interaction of different levels of irrigation, fertilizer and mulching. In general, days taken to first flowering and fruit set were 42 days and days to first harvest was 54.
4) Root length was not affected by levels of irrigation and mulching but it was significantly influenced by the levels of fertilizer. The highest root length (30.81 cm) was observed with water soluble fertilizer at 100 per cent RDF.
5) Interaction effects of irrigation with mulching and irrigation with fertilizer were non-significant with regard to the length of vine at 45, 60 and 75 DAS, whereas the interaction effect of mulching with fertilizer was significant at 45 DAS. The treatment which received 125 per cent RDF through drip with mulching recorded the highest vine length (315.4 cm).
6) The vine and root length was significantly influenced by the interaction of irrigation, mulching and fertilizer. The highest vine length was recorded by the treatment $I_1M_1F_3$ with 80 per cent Ep and 125 per cent RDF given through drip with mulching. The highest root length (32.5 cm) was observed at 60 per cent irrigation with 100 per cent RDF (water soluble fertilizer) without mulching.
7) Number of pods per plant and yield per plant were significantly influenced by the irrigation levels. Maximum number of pods per plant (42.49) and yield per plant (0.65 kg) was recorded at 80 per cent Ep given through drip (I_1). Mulching also had significant effect on the number of pods per plant and yield per plant. The mulched treatments (M_1) recorded significantly higher number of pods per plant (50.79) and yield per plant (0.81 kg) than the un-mulched treatments. Among the fertilizer levels 125 per cent RDF (F_3) resulted in the highest number of pods per plant (47.13), yield per plant (0.73 kg) and yield per hectare (7.3 t) and was superior to all other treatments.
8) The interaction between irrigation and mulching was not significant with respect to number of pods per plant and yield per plant. The combination of IF

and MF significantly affected the number of pods and yield per plant. The highest number of pods per plant (48.96) and yield per plant (0.75 kg) was recorded in the treatment with 80 per cent Ep with 125 per cent RDF (I_1F_3). Similarly among the MF combinations, mulched treatment with 125 per cent RDF gave the highest number of pods per plant (62.72) and yield per plant (0.93 kg).

9) Number of pods and yield per plant were significantly influenced by the interaction of irrigation, mulching and fertilizer. The highest yield (0.93 kg) and number of pods per plant (63.68) were recorded in the mulched treatment with 80 per cent Ep along with 125 per cent RDF ($I_1M_1F_3$).

10) Length and weight of pods was not influenced by the levels of irrigation. Mulching influenced the length and weight of pods significantly. The highest length (56.31 cm) and weight (27.29 g) of pods was recorded in mulched treatments. Similarly levels of fertilizer also significantly influenced the length and weight of pods. Maximum length (57.68 cm) and weight (29.65 g) of pods was observed at 125 per cent RDF through drip irrigation and it was significantly superior to all other treatments.

11) Levels of irrigation and mulching had no significant influence on the number of seeds per pod. Fertilizer levels significantly influenced the number of seeds per pod. The highest number of seeds per pod (19.63) was observed with 125 per cent RDF. The combinations of IF, IM and MF were not significant with respect to number of seeds per pod.

12) Interaction effect of mulching and fertilizer was significant with respect to length and weight of pods. The highest length and weight (58.48 cm and 30.55 g respectively) was recorded at 125 per cent RDF with mulching (M_1F_3). The combination of IF and IM were not significant with respect to length and weight of pods.

13) The pod characters like length, weight and number of seeds per pod were significantly influenced by the interaction of irrigation, mulching and fertilizer. Among the treatment combinations the highest length, weight and number of seeds per pod (58.6 cm, 30.95 g and 20.5) were recorded in the mulched treatment receiving irrigation at 80 per cent Ep through drip along with 125 per cent RDF ($I_1M_1F_3$).

14) The *per se* effect of irrigation, mulching and fertilizer was not significant with respect to the number of harvests, duration of the crop and protein content of cowpea pods. Their interaction was also not significant.

15) Levels of irrigation had no significant influence on fresh and dry weight of weeds at 20, 40, 60 and 75 DAS. Mulching had significant effect on fresh weight and dry weight of weeds at 20, 40, 60 and 75 DAS. The treatments with mulching recorded the lowest fresh and dry weight of weeds.

16) Levels of fertilizer significantly influenced the fresh and dry weight of weeds at first, second and third weeding. The highest level of fertilizer (F_3) recorded the highest fresh weight (214.1 kg, 649.9 kg and 231.6 kg respectively) and dry weight (42.8 kg, 129.9 kg and 44.3 kg respectively) of weeds at first, second and third weeding. Levels of irrigation had no significant effect on fresh and dry weight of weeds at fourth weeding.

17) The combinations of IM and IF were not significant with respect to fresh and dry weight of weeds. Interaction of mulching and fertilizer had significant effect on fresh and dry weight of weeds at first, second and third weeding. Under all fertilizer levels, higher weed growth was observed in un-mulched plots.

18) Fresh and dry weight of weeds was significantly influenced by the interaction of irrigation, mulching and fertilizer. The unmulched plots irrigated with 80 per cent Ep and with 125 per cent RDF recorded the highest weed growth in terms of fresh and dry weight at 20, 40, 60 and 75 DAS.

19) Irrigation levels and mulching had no significant effect on soil pH and EC at 45 DAS and at final harvest. Fertilizer levels significantly influenced the soil pH and EC at 45 DAS and at final harvest. The highest soil pH (6.4 and 5.9) and the lowest EC (0.19 and 0.06 dSm^{-1}) at 45 DAS and at final harvest were recorded at 75 per cent RDF (F_1).

20) Soil pH was affected by the interactions of IF and MF at final harvest. The highest soil pH was recorded at 80 per cent Ep with 75 per cent RDF (I_1F_1) followed by I_1F_4 and the un-mulched treatments with 75 per cent RDF (M_2F_1).

21) Interaction of irrigation, mulching and fertilizer was significant at final harvest with respect to soil pH. Among the treatment combinations, the highest pH (6.5) was recorded for 80 per cent Ep with 75 per cent RDF with mulching ($I_1M_1F_1$) and was on par with the treatments with same irrigation and fertilizer without mulching ($I_1M_2F_1$).

22) Interaction of irrigation and mulching had no significant influence on EC at 45 DAS but the combination of 60 per cent Ep without mulching recorded the lowest EC (0.06 dSm^{-1}) at final harvest.

23) Soil EC was influenced by the combinations of IF and MF at 45 DAS and at final harvest. Among the combinations, 60 per cent Ep along with 75 per cent RDF and the treatment with 75 per cent RDF without mulching recorded the lowest electrical conductivity. The interaction of IMF was significant with respect to EC of soil at 45 DAS and at final harvest. The treatment with 80 per cent Ep along with 75 per cent RDF without mulching recorded the lowest EC (0.13 and 0.06 dSm^{-1}) at 45 DAS and at final harvest.

24) Levels of irrigation and mulching had no significant effect on organic carbon (OC), available nitrogen (N), available phosphorus (P) and available potassium (K) content of soil at 45 DAS and at final harvest. Fertilizer levels significantly influenced the OC and available NPK of the soil. Treatments with 125 per cent RDF recorded the highest value for OC and available NPK (1.94 per cent,

397.2, 50.9 and 321.2 kg/ha respectively) at 45 DAS and (1.47 per cent, 288.9, 43.0 and 147.5 kg/ha respectively) at final harvest.

25) Interaction of irrigation and mulching had no effect on soil organic carbon and available nitrogen whereas available phosphorus and potassium content was significant at 45 DAS and at final harvest. The highest available P and K were recorded at 80 per cent Ep with mulching. Combinations of IF and MF were significant with respect to OC and available NPK at 45 DAS and at final harvest. The highest values were observed in the combinations of mulching with 125 per cent RDF (M_1 F_3), and 80 per cent Ep with 125 per cent RDF (I_1 F_3) for all the soil parameters at 45 DAS and at final harvest.

26) The interaction between irrigation, mulching and fertilizer was significant with respect to soil organic carbon, available nitrogen, phosphorus and potassium content at 45 DAS and at final harvest. In general, the treatments receiving 80 per cent Ep along with 125 per cent RDF with mulching ($I_1M_1F_3$) recorded the highest organic carbon, available nitrogen, phosphorus and potassium content of soil at 45 DAS and at final harvest.

27) Benefit cost ratio was significantly influenced by the levels of irrigation, fertilizer and mulching. The highest B:C ratio (1.83) was recorded in the mulched treatments $I_1M_1F_3$ (80 per cent Ep and 125 per cent RDF) and $I_2M_1F_3$ (60 per cent Ep and 125 per cent RDF).

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*Originals not seen

APPENDICES

APPENDIX I

a) Cost of drip system per hectare

Sl no.	Materials	Quantity	Unit cost (Rs.)	Total cost (Rs.)
1	EPC drip 12mm lateral pipe	944	6.2	5838.2
2	EPC drip grommet connector and straight connector	2272	2.8	6346.0
3	EPC drip 12mm x 50 inline lateral pipe	3790 m	9.1	34402.8
4	EPC drip lateral pipe end	756	2.9	2186.9
5	Drip plastic filter	1	1250	1246.9
6	Insulated GI wire	186	3.6	667.9
7	PVC pipe 32 mm x 10.0 kg/sm^2 ISI	2614	40.2	104820.0
	PVC pipe Tee 32 mm	338	16.2	5461.9
9	PVC pipe Tee 50 mm	16	39.3	627.2
10	PVC pipe bend	1210	14.7	17742.53
11	PVC pipe reducing Tee 40 x 32mm	148	46.4	6850.0
12	PVC pipe reducer 50 x 32 mm	16	15.9	253.8
13	PVC pipe FTA	185	14.7	2712.7
14	PVC pipe 50 mm x 6 kg/cm^2	718	41.4	29650.9
15	PVC pipe Teflon tape + shellac	282+754	12.5	4451.3
16	PVC pipe solvent cement 250 ml	16	62	989.5
17	PVC pipe ball valve 40 mm	167	118.5	19740.0
18	PVC pipe flush valve 40 mm	300	80	23940.0
19	PVC pipe ball tank connector	148	41	6052.8
20	Tanks	148	500	73815.0
21	Transportation and installation charge			95637.0
	Total			**4,43,433.20**

One fifth of the cost (Rs. 88,686.65) of the drip system per hectare is taken for calculating the B:C ratio, assuming that the system will serve for five seasons.

b) Cost of inputs per hectare

Sl no.	Inputs	Quantity	Unit cost (Rs.)	Total cost (Rs.)
1	Seed	4 kg	1440/kg	5600
2	FYM	20 t	880/t	17600
3	Lime	250 kg	15.5/kg	3875
4	Urea		10/kg	
	F_1	23 kg		230
	F_2	30.5 kg		305
	F_3	38 kg		380
	F_4	13 kg		130
	Control	30.5 kg		380
5	MAP		200/kg	
	F_1	37 kg		7400
	F_2	49 kg		9800
	F_3	61.5 kg		12300
	F_4	32.8 kg		6560
	Control	49 kg		9800
6	MOP		20/kg	
	F_1	12.5 kg		250
	F_2	17 kg		340
	F_3	21 kg		420
	Control	17 kg		340
7	19:19:19		148/kg	
	F_4	52.6 kg		7785
8	PP chemicals			2500
9	Coir for trellis	200 bundles	20/bundle	4000
10	Polythene sheet	6000 m^2	6/m^2	36000

One third of the cost (Rs. 12000) of the polythene sheet per hectare is taken for calculating the B:C ratio, assuming that the mulch will last for three seasons.

c) Cost of cultivation

Sl no.	Particulars	Quantity	Unit cost (Rs.)	Total cost (Rs.)
1	Ploughing by tractor	3 h	400/h	1200
2	Field preparation and taking beds	50 men	380	19000
3	Application and incorporation of FYM and lime	15 men 9 women	380 280	5700 2520
4	Sowing of seeds	9 women	280	2520
5	Spreading mulching sheets	10 men	380	3800
6	Spraying PP chemicals	4 men	380	1520
7	Fertilizer application in control plots	6 women	280	1680
8	Making trellis	27 men	380	10260
9	Harvesting	21 women	280	5880

d) Cost of weeding per hectare

Sl no.	Treatment	Quantity	Unit cost (Rs.)	Total cost (Rs.)
1	Drip with mulch	17 women	280	4760
2	Drip without mulch	49 women	280	13720
3	Control	82 women	280	22960

e) Cost for irrigation and electricity

Sl no.	Treatments	Quantity	Unit cost (Rs.)	Total cost (Rs.)
1	I_1 (Drip irrigation at 80 per cent Ep)			
	Labour cost	15 men	380	5700
	Electricity cost	173 units	2.9	502
	Total			6202
2	I_2 (Drip irrigation at 60 per cent Ep)			
	Labour cost	11 men	380	4180
	Electricity cost	130 units	2.9	377
	Total			4557
3	Control (Channel irrigation once in three days)			
	Labour cost	8 men	380	3040
	Electricity cost	40 units	2.9	116
	Total			3156

APPENDIX II

a) Weekly weather data

Date	Temperature (^0C)		Relative humidity (%)	Wind speed (km/h)	Mean sunshine hours (h)	Rainfall (mm)	Rainy days	Evaporation (mm)	Mean evaporation (mm)
	Maximum	Minimum							
15/1/14-21/1/14	33.2	23.7	050	5.8	8.8	000.0	0	37.6	5.4
22/1/14-28/1/14	32.5	23.3	051	8.8	9.3	000.0	0	44.5	6.4
29/1/14-04/2/14	33.7	22.3	047	7.8	9.9	000.0	0	43.3	6.2
05/2/14-11/2/14	35.1	21.0	037	3.9	9.8	000.0	0	38.2	5.5
12/2/14-18/2/14	33.6	22.6	070	2.4	7.4	000.0	0	25.4	3.6
19/2/14-25/2/14	35.0	24.3	054	5.3	7.5	000.0	0	37.7	5.4
26/2/14-04/3/14	35.2	24.6	060	3.9	8.7	000.0	0	37.4	5.3

05/3/14-11/3/14	35.1	25.1	054	4.9	7.2	000.0	0	41.6	5.9
12/3/14-18/3/14	37.4	22.7	042	5.2	9.7	000.0	0	53.9	7.7
19/3/14-25/3/14	37.3	24.7	065	2.7	8.5	000.0	0	38.2	5.5
26/3/14-01/4/14	38.1	24.3	056	2.9	8.9	000.0	0	44.1	6.3
02/4/14-08/4/14	36.3	25.9	071	2.6	7.1	000.7	0	33.7	4.8
09/4/14-15/4/14	34.5	24.3	074	2.1	5.1	040.0	2	28.2	4.1
16/4/14-22/4/14	35.2	25.8	073	2.4	8.4	003.5	1	31.5	4.5
23/4/14-29/4/14	35.2	26.5	075	2.1	4.9	014.6	1	27.4	3.9
30/4/14-06/5/14	35.0	25.0	072	3.2	5.6	086.4	1	29.0	4.1

b) Daily evaporation data

Date	Evaporation (mm)	Rainfall (mm)
21-01-14	7.1	00.0
22-01-14	7.3	00.0
23-01-14	5.6	00.0
24-01-14	4.1	00.0
25-01-14	7.1	00.0
26-01-14	6.2	00.0
27-01-14	6.6	00.0
28-01-14	7.0	00.0
29-01-14	6.0	00.0
30-01-14	5.0	00.0
31-01-14	5.7	00.0
01-02-14	6.0	00.0
02-02-14	6.6	00.0
03-02-14	7.1	00.0
04-02-14	6.3	00.0
05-02-14	4.0	00.0
06-02-14	5.5	00.0
07-02-14	6.1	00.0
08-02-14	6.0	00.0
09-02-14	5.9	00.0
10-02-14	5.5	00.0
11-02-14	5.2	00.0
12-02-14	3.4	00.0
13-02-14	1.5	00.0
14-02-14	3.5	00.0
15-02-14	4.1	00.0
16-02-14	3.8	00.0
17-02-14	4.1	00.0
18-02-14	5.0	00.0
19-02-14	3.9	00.0
20-02-14	5.4	00.0
21-02-14	5.2	00.0
22-02-14	5.1	00.0

23-02-14	4.9	00.0
24-02-14	5.4	00.0
25-02-14	7.8	00.0
26-02-14	7.2	00.0
27-02-14	6.4	00.0
28-02-14	5.4	00.0
01-03-14	4.7	00.0
02-03-14	4.8	00.0
03-03-14	4.9	00.0
04-03-14	4.0	00.0
05-03-14	5.2	00.0
06-03-14	5.5	00.0
07-03-14	5.7	00.0
08-03-14	6.4	00.0
09-03-14	6.5	00.0
10-03-14	4.0	00.0
11-03-14	6.1	00.0
12-03-14	7.4	00.0
13-03-14	7.2	00.0
14-03-14	7.9	00.0
15-03-14	8.2	00.0
16-03-14	7.0	00.0
17-03-14	8.5	00.0
18-03-14	7.6	00.0
19-03-14	7.4	00.0
20-03-14	5.7	00.0
21-03-14	5.8	00.0
22-03-14	6.0	00.0
23-03-14	5.0	00.0
24-03-14	3.8	00.0
25-03-14	5.2	00.0
26-03-14	6.7	00.0
27-03-14	8.9	00.0
28-03-14	6.7	00.0
29-03-14	6.9	00.0
30-03-14	5.2	00.0

31-03-14	5.6	00.0
01-04-14	5.2	00.0
02-04-14	4.4	00.0
03-04-14	5.2	00.0
04-04-14	5.1	00.0
05-04-14	5.1	00.0
06-04-14	5.2	00.0
07-04-14	5.0	00.0
08-04-14	4.4	0.70
09-04-14	4.5	00.0
10-04-14	2.6	00.0
11-04-14	5.1	29.0
12-04-14	3.5	00.0
13-04-14	5.6	11.0
14-04-14	4.5	00.0
15-04-14	2.3	00.0
16-04-14	3.9	00.0
17-04-14	3.9	00.0
18-04-14	4.9	00.0
19-04-14	3.9	3.50
20-04-14	4.9	3.30
21-04-14	4.3	00.0
22-04-14	5.1	00.0
23-04-14	3.4	00.0
24-04-14	4.9	00.0
25-04-14	4.4	00.0
26-04-14	3.0	00.0
27-04-14	4.0	00.0
28-04-14	4.4	14.6
29-04-14	3.3	00.0
30-04-14	3.4	00.0
01-05-16	3.5	00.0
02-05-16	3.4	00.0

APPENDIX III

Schedule of fertilizer application

Date	Levels of fertilizer											
	F_1 (75 per cent RDF)			F_2 (100 per cent RDF)			F_3 (125 per cent RDF)			F_4 (100 per cent RDF)		
	MAP (kg/ha)	Urea (kg/ha)	MOP (kg/ha)	MAP (kg/ha)	Urea (kg/ha)	MOP (kg/ha)	MAP (kg/ha)	Urea (kg/ha)	MOP (kg/ha)	MAP (kg/ha)	Urea (kg/ha)	19:19:19 (kg/ha)
23-01-14	0.75	0	0.15	1.00	0	0.19	1.26	0	0.257	0.67	0	0.53
26-01-14	1.51	0	0.19	2.01	0	0.25	2.51	0	0.31	1.34	0	0.65
29-01-14	2.26	0	0.22	3.02	0	0.29	3.77	0	0.37	2.01	0	0.78
01-02-14	2.26	0	0.22	3.02	0	0.29	3.77	0	0.37	2.01	0	0.78
04-02-14	2.26	0	0.22	3.02	0	0.29	3.77	0	0.37	2.01	0	0.78
07-02-14	2.26	0	0.22	3.02	0	0.29	3.77	0	0.37	2.01	0	0.78
10-02-14	2.26	0	0.22	3.02	0	0.29	3.77	0	0.37	2.01	0	0.78
13-02-14	2.26	0	0.22	3.02	0	0.29	3.77	0	0.37	2.01	0	0.78
16-02-14	5.27	0	0.37	7.04	0	0.48	8.79	0	0.60	4.69	0	1.28
19-02-14	5.27	0	0.37	7.04	0	0.48	8.79	0	0.60	4.69	0	1.28
22-02-14	5.27	0	0.37	7.04	0	0.48	8.79	0	0.60	4.69	0	1.28
25-02-14	5.27	0	0.37	7.04	0	0.48	8.79	0	0.60	4.69	0	1.28
28-02-14	0	0.79	0.37	0	1.05	0.48	0	1.31	0.60	0	0.45	1.28
03-03-14	0	0.79	0.37	0	1.05	0.48	0	1.31	0.60	0	0.45	1.28
06-03-14	0	0.79	0.37	0	1.05	0.48	0	1.31	0.60	0	0.45	1.28

Date	Levels of fertilizer											
	F_1 (75 per cent RDF)			F_2 (100 per cent RDF)			F_3 (125 per cent RDF)			F_4 (100 per cent RDF)		
	MAP (kg/ha)	Urea (kg/ha)	MOP (kg/ha)	MAP (kg/ha)	Urea (kg/ha)	MOP (kg/ha)	MAP (kg/ha)	Urea (kg/ha)	MOP (kg/ha)	MAP (kg/ha)	Urea (kg/ha)	19:19:19 (kg/ha)
09-03-14	0	0.79	0.37	0	1.05	0.48	0	1.31	0.60	0	0.45	1.28
12-03-14	0	1.23	0.80	0	1.64	1.05	0	2.04	1.31	0	0.71	2.78
15-03-14	0	1.23	0.80	0	1.64	1.05	0	2.04	1.31	0	0.71	2.78
18-03-14	0	1.23	0.80	0	1.64	1.05	0	2.04	1.31	0	0.71	2.78
21-03-14	0	1.23	0.80	0	1.64	1.05	0	2.04	1.31	0	0.71	2.78
24-03-14	0	1.23	0.80	0	1.64	1.05	0	2.04	1.31	0	0.71	2.78
27-03-14	0	1.23	0.80	0	1.64	1.05	0	2.04	1.31	0	0.71	2.78
30-03-14	0	1.23	0.80	0	1.64	1.05	0	2.04	1.31	0	0.71	2.78
02-04-14	0	1.23	0.80	0	1.64	1.05	0	2.04	1.31	0	0.71	2.78
05-04-14	0	1.68	0.69	0	2.22	0.91	0	2.79	1.14	0	0.97	2.40
08-04-14	0	1.68	0.69	0	2.22	0.91	0	2.79	1.14	0	0.97	2.40
11-04-14	0	1.68	0.69	0	2.22	0.91	0	2.79	1.14	0	0.97	2.40
14-04-14	0	1.68	0.69	0	2.22	0.91	0	2.79	1.14	0	0.97	2.40
17-04-14	0	1.68	0.69	0	2.22	0.91	0	2.79	1.14	0	0.97	2.40
20-04-14	0	1.68	0.69	0	2.22	0.91	0	2.79	1.14	0	0.97	2.40

FERTIGATION AND MULCHING STUDIES IN YARD LONG BEAN

(*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)

By

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ABSTRACT OF THE THESIS

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ABSTRACT

The investigations on 'Fertigation and mulching studies in yard long bean (*Vigna unguiculata* var. *sesquipedalis* (L.) Verdcourt)' were carried out in the Department of Olericulture, College of Horticulture, Vellanikkara during January – May 2014. The study was conducted in the yard long bean variety Vellayani Jyothika to standardize the fertigation requirement and to assess the relative efficacy of fertigation and mulching over the conventional method.

The experiment was laid out in strip plot design with two replications. There was a total of 17 treatments consisting of combinations of two irrigation levels (60 and 80 per cent pan evaporation (Ep) through drip irrigation) and four fertilizer levels (75, 100 and 125 per cent recommended dose of fertilizer (RDF) and 100 per cent RDF with water soluble fertilizer) with and without mulching and a control treatment (channel irrigation once in three days with 100 per cent RDF).

The study revealed that irrigation, mulching and fertilizer levels had significant effect on vine length. Scheduling of irrigation at 80 per cent Ep resulted in significantly higher vine length. At higher levels of irrigation (80 per cent Ep) yield and number of pods per plant were higher whereas, length and weight of pods, and number of seeds per pod were not influenced by the levels of irrigation. Mulching significantly influenced yield and yield attributing characters like number of pods per plant, and length and weight of pods but had no influence on number of seeds per pod and protein content of pods. Plants receiving 125 per cent RDF resulted in significantly higher yield and yield attributing characters like number of pods per plant, number of seeds per pod, length and weight of pods compared to 75 and 100 per cent RDF.

Per se and interaction effects of irrigation, mulching and fertilizer were not significant with respect to days to first flowering, first fruit set, first harvest, days

from flowering to harvest, number of harvests, duration of the crop and protein content.

Weed growth in terms of fresh and dry weight was not influenced by levels of irrigation while mulched plots recorded significantly lower weed growth than the unmulched plots. Among the fertilizer levels, 125 per cent RDF resulted in higher weed growth. Organic carbon content, available nitrogen, available phosphorus and available potassium on 45 DAS and at final harvest were the highest in treatments receiving 125 per cent RDF whereas, the highest pH and the lowest EC were recorded in 75 per cent RDF.

Interactions between levels of irrigation, mulching and fertilizer when considered together, had significant effect on vine length, all yield attributes, weed growth and all soil parameters. The vine length, yield, yield attributes like length and weight of pods and soil nutrients were the highest when irrigation was given at 80 per cent Ep along with mulching and 125 per cent RDF ($I_1M_1F_3$). This was statistically on par with the treatment $I_2M_1F_3$ in which irrigation was limited to 60 per cent Ep. An increase of 3.4 times was there in yield in the treatments $I_1M_1F_3$ and $I_2M_1F_3$ over conventional channel irrigation at 3 days interval with 100 per cent RDF (control).

The highest BC ratio of 1.83 was obtained for the treatments $I_1M_1F_3$ and $I_2M_1F_3$ (60 and 80 per cent Ep with mulching, 125 per cent RDF). Irrigation at 60 or 80 per cent Ep along with 125 per cent RDF and mulching with white on black polythene was found to be the best treatments.