STANDARDIZATION OF IRRIGATION AND FERTIGATION TECHNIQUES IN JASMINE (*Jasminum grandiflorum*) var CO. 2

Thesis submitted in part fulfillment of the requirements for the degree of ***Doctor of Philosophy (Horticulture) in Floriculture and Medicinal Crops*** *to the Tamil Nadu Agricultural University, Coimbatore.*

By
K.S.VIJAY SELVARAJ. M.Sc.,(Hort.)
I.D. No. 04-822-003

DEPARTMENT OF FLORICULTURE AND LANDSCAPING
HORTICULTURAL COLLEGE AND RESEARCH INSTITUTE
TAMILNADU AGRICULTURAL UNIVERSITY
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(K.S.Vijay Selvaraj)

ABSTRACT

STANDARDIZATION OF IRRIGATION AND FERTIGATION TECHNIQUES IN JASMINE (*Jasminum grandiflorum*) var CO. 2

By

K.S. Vijay Selvaraj, M.Sc., (Hort.)

Degree : Doctor of Philosophy (Horticulture) in Floriculture and Medicinal Crops

Chairman : Dr. M.JAWAHARLAL, Ph.D.,
Professor and Head,
Department of Floriculture and Landscaping,
Tamil Nadu Agricultural University,
Coimbatore- 641 003

2007

Field experiments were conducted at the Department of Floriculture and Landscaping, TNAU, Coimbatore to evaluate the performance of drip fertigation on growth, yield and water use in jasmine. Subsequently greenhouse experiments were conducted at The Hebrew University of Jerusalem, Israel to assess water use efficiency and to identify aquaporin genes in jasmine. The field experiments were conducted during November, 2005 to August, 2006 at TNAU, India in split plot design with irrigation regimes in main plots *viz.*, W_1- Drip irrigation with 5 litres of water per day (LPD),

W_2- Drip irrigation with 10 LPD, W_3- Drip irrigation with 15 LPD and fertilizer level in sub plots *viz*., F_1-50 percent of recommended dose of fertilizers (RDF), F_2- 75 per cent RDF, F_3- 100% RDF and sub plots with black polyethylene mulch as M_1 and without mulch as M_0 with three replications.

The drip irrigation was scheduled at 5 LPD, 10 LPD and 15 LPD. The nutrients for the treatment schedule were 50, 75 and 100 % recommended dose of fertilizers. Entire nitrogen application was spread over a period of 45 to 120 days after pruning with its maximum share during the peak vegetative phase. Sixty percent of phosphorous was applied as basal in the beginning and the rest was applied through fertigation. The application of potassium nutrient was scheduled right from 75 to 130 DAP (coinciding with flowering phase).

The soil moisture content was estimated upto a depth of 30-40 cm at a distance upto 40 cm between lateral and 30 cm along the lateral at 10 cm interval at 24 and 48 hrs after drip irrigation. Soil nutrient dynamics were estimated by analyzing nitrate nitrogen, available phosphorous and potassium.

The plant height was more under the irrigation of 10 litres of water per day with 75 percent RDF with mulch and it was followed by 15 LPD, 100 % RDF with mulch. The number of primary branches was higher under the drip irrigation with 10 litres of water per day and it was on par with drip irrigation with 15 litres of water per day. The 75 per cent RDF recorded higher number of primary branches, which was on par with 100 per cent RDF.

Same trend was observed in the number of secondary branches also, the number was highest under the drip irrigation with 10 litres of water per day and it was on par with drip irrigation with 15 litres of water per day. The 75 per cent RDF recorded the highest number of primary branches, which was on par with 100 per cent RDF.

Days to first flowering of *Jasminum grandiflorum* were significantly influenced by irrigation regimes, fertilizer levels and with mulch.

The growth of the root in terms of number and length of primary and secondary roots increased during all the growth stages with drip irrigation at 10 litres of water per day and this was on par with 15 litres of water per day treatment with 100 per cent RDF.

All the parameters which determine the flower quality like 100 flower buds weight, length of flower stalk, diameter of the flower and concrete content were significantly influenced by different irrigation and fertilizer regimes. 10 litres of water per day with 100 and 75 % RDF proved superior with respect to above parameters followed by 15 litres of water per day with 100 % of RDF under mulched condition.

Application of 100 per cent RDF through drip irrigation of 15 LPD under mulch recorded highest total flower yield (14.43 t ha^{-1}). Among the irrigation regimes, drip irrigation of 10 litres of water per day resulted in highest WUE. The WUE was very less in surface irrigation (2.3 kg ha^{-1} mm^{-1}) as compared to all levels of drip irrigation. The WUE decreased with increased level of drip irrigation.

The horizontal and vertical movement of N, P and K were greatly enhanced under drip fertigation system and the available nutrient concentration was higher.

Flowers under normal packing and storage under 5^0C showed more freshness and longer vase life (4.2 days) when compared to room temperature storage (2 days).

Since jasmine is an isohydric plant, the sudden increase or decrease in water potential inside the xylem vessels did not affect the physiology. Hence the optimal level of water inside the plant through the application of 10 litres of water per day should be maintained for the potential growth and development.

Though the additional expenditure towards drip fertigation system and is higher, the net income is highly profitable. Drip irrigation of 15 LPD with 100 per cent RDF under mulch registered the highest additional net income of Rs.2,59,866/- and BCR of 3.70:1. Which was closely followed by drip irrigation of 10 LPD with 100 per cent RDF under mulch registering an additional net income of Rs. 2,57,886/- and BCR of 3.69:1 over surface irrigation including water saving benefits which accounted additional area coverage and additional gross income.

The MBCR values for 15 and 10 LPD with 100 per cent RDF under mulch gave almost similar value indicating the comparable nature in the production of MBCR.

From the above results it could be concluded that adoption of drip fertigation *Jasminum grandiflorum* is a viable proposition for the farmers to get greater income benefits from additional investments with less amount of water. Drip fertigation of 10 litres of water per day with 75 per cent recommended dose of fertilizer under mulch would be an ideal practice to achieve greater yield, income and water saving benefits as compared to surface irrigation.

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CHAPTER I

INTRODUCTION

Efficient use of available irrigation water is essential for increasing agricultural productivity for the alarming Indian population. With the present potential of 114 million hectare meters (MHM) of water, only 97 mha is under irrigation in India, among the total cultivated area of 145 mha. Tamil Nadu is one of the water starving states in India, which receives mean annual rainfall of 946 mm over the total geographical area of 13.0 million ha, accounting for about 12.3 MHM per year, but the utilizable run off is about 2.486 MHM

The present area of net irrigation is about 2.8 to 3.0 mha and gross area is about 3.4 to 3.6 mha. The available surface and ground water is estimated as 2.34 and 2.63 MHM respectively (Sivanappan, 1998). About 90 per cent of surface water and more than 70 per cent of the ground water have been harnessed.

Efficient management of water resources is essential to meet the increasing competition for water between agricultural and non-agricultural sectors and the present day share of 80 per cent of water used for agriculture is anticipated to be reduced by 70 per cent in the coming decade. This necessitates scientific management of available water resources, particularly in the agricultural sector. Sustainability of any system requires optimal utilization of resources such as water, fertilizer and soil. Apart from the economic considerations, the adverse effect of injudicious use of water and fertilizers on the environment can have far reached implications. There is a need to develop agro technologies, which will help in sustaining the precious resources and maximize the crop production, without any detrimental impact on the environment.

Water availability for irrigation is going to be a major constraint for agriculture in the near future. Efficient management of available water resources is hence necessary for expanding the area under irrigation. Bringing more area under irrigation would depend largely upon efficient use of water. In this context, micro irrigation has a very significant role to achieve not only higher productivity and water use efficiency but also to have sustainability with economic use and productivity.

Fertilizer management is the most important agro-technique, which controls development, yield and quality of a crop. Fertilizer use efficiency is only 50 per cent in conventional practice of soil application. Location specific fertilizer management practices are essential for increasing fertilizer use efficiency for optimizing the fertilizer input and maximizing the productivity.

Every attempt is therefore necessary, in achieving this objective of higher water and fertilizer use efficiency. Under these circumstances, drip fertigation, which is known to be hi-tech and efficient way of applying fertilizers through irrigation system as a carrier and distributor of crop nutrients, holds bright promise. Fertigation has been found to be effective in saving labour and energy. Fertigation increases both water and nutrient use efficiency. It supplies nutrients directly to the root zone in available forms and hence it regulates the nutrient balance and prevents loss of nutrients. It offers flexibility in fertilizer application to match crop’s nutritional requirement at different growth stages.

Introduction of simultaneous micro irrigation and fertigation opened up new possibilities for controlling water and nutrient supplies to crops and maintaining the desired concentration and distribution in the soil. By introducing fertigation, it is possible to increase the yield potential by three times with the same quantity of water, by saving about 45 to 50 per cent of irrigation water and increasing the productivity by about 40 per cent. When fertilizer is applied through drip irrigation, it was observed that the yield has been increased and about 30 per cent of the fertilizer could be saved (Sivanappan, 1998).

Floriculture has proved as one of the fast growing industries in our country. Among the traditional flowers jasmine (*Jasminum grandiflorum)* is one of the oldest fragrant flowers cultivated. The flower is used for various purposes such as making garlands, decoration and religious offering etc. It is also used for the production of jasmine concrete which is used in cosmetic and perfumery industries. TamilNadu is the leading producer of jasmine in the country with an annual production of 18,684 t from the cultivated area of 2,205 ha. The flowers produced in the state are exported to the neighboring countries *viz*., Sri Lanka, Singapore, Malaysia and Middle East countries. However, in the recent past, area and productivity of jasmine in the country has been dwindling , owing to many reasons, scarcity of water being the foremost.

Keeping the above points in view, field studies were carried out in *Jasminum grandiflorum* var. CO. 2 with the following objectives.

i) To find optimum irrigation and nutrient requirements through drip fertigation.

ii) To asses the effect of drip fertigation and mulch on growth and flower yield.

iii) To compare water and fertilizer use efficiency under drip fertigation with surface irrigation.

iv) To study the soil moisture and nutrient dynamics under varied drip fertigation levels.

v) To study the transpirational and water balance related behaviour.

vi) To work the cost economics of drip fertigation with surface irrigation.

CHAPTER II

REVIEW OF LITERATURE

1. Irrigation

1.1 Flood irrigation

Surface irrigation is the most widespread irrigation technology, covering more than 90 per cent of the area under irrigation world wide. Generally, it is regarded as a wasteful technology as only 30 to 70 per cent of the total water remains in the active root zone. Fertigation is not a common practice in surface irrigation. The application of fertilizers through surface irrigation may be wasteful and a significant amount of fertilizer, notable N, may be lost in tail water and in deep percolation.

Flooding and irrigation with small furrows were the age old and traditional systems in our country, which bear very low irrigation efficiencies, especially the distribution uniformity (Howell *et al.,* 1981). The conventional methods of irrigation has got poor irrigation efficiency as low as 25-30 per cent (Rajput, 1988). The drawbacks of the flooding type of irrigation system in jasmine crop included non-uniform application of water, impounding in certain pockets, loss of water due to percolation and leaching of nutrients due to excess water application (Mishra *et al.,* 1997). Bofna *et al.* 1993 reported that the water source through bore well or open well was becoming dry during the summer season as a result of which the farmers were quiting the further extension of cultivating Jasmine and other flower crops.

1.2. Drip irrigation

Drip irrigation provides water most efficiently at the right rate and practically near the root zone of the crop. In this system, only a fraction of the soil surface is wetted, which ranges from 15 to 60 per cent. The creation of inexpensive, weather-resistant plastic after World War II paved the way for drip irrigation. Through a network of perforated plastic tubing installed on or below the soil surface, drip systems deliver water under low pressure almost directly to the roots of plants through small holes or emitters. When well maintained and combined with soil-moisture monitoring or other ways of assessing crops' water requirements, drip irrigation can achieve application efficiencies as high as 95 per cent (Vickers, in press). Losses through evaporation, deep percolation and surface runoff are negligible. Farmers can also apply fertilizers in measured quantities through drip system, simultaneously reducing chemical use and the potential for land and water pollution.

Israeli engineers have developed drip systems for commercial applications. By the mid-1970s, farmers in a half-dozen countries, Australia, Israel, Mexico, New Zealand, and South Africa, were using drip methods on a portion of their cropland (Pawar *et al.*, 1993). Starting from a small base of approximately 56,000 hectares worldwide in the mid-1970s, drip and other micro-irrigation systems spread rapidly to 1.6 million hectares by 1991, the latest year for which a global survey has been completed (Bucks, 1995). Bucks (1998) estimated that the global area under micro irrigation has likely expanded by 75 per cent since 1991, which would place the current total at approximately 2.8 million hectares. This impressive growth is attributable to the higher crop yields and water use efficiencies obtained with drip irrigation and the wider dissemination of these field results.

In countries as diverse as India, Israel, Jordan, Spain, and the United States, studies have consistently shown drip irrigation to reduce water use by 30 to 70 per cent and to raise crop yields by 20 to 90 per cent (Sivanappan,1994, 1995; World Bank, 1993). In India, research from a variety of institutions have consistently shown drip to cut water use by 30 to 60 per cent and to raise yields by 5 to 50 per cent compared with conventional surface irrigation methods (Indian National Committee, 1994; Sivanappan, 1998).

As recently as 1985, India had only 1,000 hectares under drip irrigation (Indian National Committee, 1994), but in 1998, the estimated area under drip has expanded to 2,25,000 hectares (Sivanappan, 1998). Drip irrigation combination of water savings and yield increases, typically produces atleast a doubling of water productivity, yield per unit water, and makes it a leading technology in the global challenge of boosting crop production in the face of serious water constraints (Pawar *et al.*, 1993).

In the late eighties, drip irrigation gained popularity with its inherent advantages like saving water and use in problematic soil. Various research institutes conducted experiments on drip irrigation and made people aware of its benefits. Some manufacturers also conducted their own studies first by importing the materials before venturing into commercial production of drip systems. The farming community ususally believes only after personally observing the benefits. Today, more than 60,700 hectares are brought under drip irrigation convering more than 30 crops. Farmers from various places communicated their experiences of drip irrigation on various crops like sugarcane, cotton, grapes, banana, pomegranate, vegetables, tea, ber, flowers, etc. The increase in yield as compared to conventional irrigation methods is from 20 to 100 %, whereas saving in water ranges from 40% to 70%.

The results achieved by drip irrigation in a developing country like India can show many third world countries optimum utilization of resources for increased agricultural production.

Howell *et al.* (1981) reviewed various research reports on crop response to drip irrigation with other methods of water application and found yields were better in all the cases, even though the amount of water applied was less with drip irrigation. Drip irrigation is one of the latest innovative methods of irrigation, which enables slow and precise application of water and nutrients to precise locations, avoiding soil erosion and wastage of water by deep percolation (Herman, 1982).

Earlier, drip irrigation was considered an emerging technology with its application limited to some special crops. Now a days it is used on a wide variety of crops, which were initially considered unprofitable for management under drip irrigation. Drip irrigation can be used easily for growing horticultural crops with considerable savings in irrigation water. The increase in the yield of vegetable crops to the tune of 40 per cent was reported under drip irrigation (Patil, 1982; Sivanappan *et al.,* 1987). With drip irrigation systems, water and nutrients can be applied directly to the crop at the root level, having positive effects on yield and water savings and increasing the irrigation performance (Phene and Howell, 1984).

Drip irrigation can be used easily for growing vegetable crops with considerable saving in irrigation water (Bengal *et al.,* 1987). Sivanappan *et al*. (1987) recommended drip irrigation in place of conventional furrow irrigation due to economy in water utilization to the extent of 84.7 per cent without any yield loss. Nakayama and Bucks (1991) stated that drip irrigation was considered as emerging technology with its application limited to some special crops. Now a days, it is used on a wide variety of crops which were initially considered unprofitable for management under drip irrigation. The drip irrigation method provides the best possible conditions of total soil water potential for a given quality of irrigation water (Shalhevet, 1991).

In gladiolus, the irrigation water applied had effects on all characters of flowering and flower quality except corm weight (Rushi Bustag *et al.*, 2005) and it was determined that every mm of water increased flower percentage of gladiolus by 0.3%.

Drip irrigation had the greatest potential where water was either very expensive or scarce or the soils were sandy, rocky or the terrain was undulating and difficult to level. Poor quality water could also be used without reducing yields (Constantz, 1989; Nightingale *et al.*, 1991). Drip irrigation can be used in row crops such as sugarcane, vegetables, mulberry, cotton, cassava, etc., in water scarcity areas. There can be considerable saving of irrigation water by adopting drip method since water can be applied almost precisely and directly in the root zone with out wetting the entire surface area (Bafna *et al.*, 1993).

Paired row method of planting in drip irrigation was reported for tomato and potato, for reducing the cost of laterals and also to economize irrigation water without any reduction in the recommended plant population. Micro irrigation can be used to improve the irrigation efficiency of vegetable gardens by reducing evaporation and drainage losses by creating and maintaining soil moisture conditions that are favourable to crop growth. Micro irrigation that was evaluated includes low-head drip irrigation, pitcher irrigation and subsurface irrigation using clay pipes. Good results were obtained with subsurface irrigation when irrigation was carried out with poor quality water (Batchler *et al.,* 1996). Ponnuswamy (1996) reported that drip irrigation with 100 per cent of irrigation water recorded higher tuber yield (42.2 t ha^{-1}) in cassava and net return due to continuous moisture availability and with higher nutrient absorption. Drip irrigation could also be used for widely spaced row crops like Jasmine of high return wherever water scarcity was a main problem. Though the initial cost would be more, the pay back period for many commercial crops like loose flowers, sugarcane, turmeric, banana, vegetables, etc, was within two years (Selvaraj, 1997a). At Bhavanisagar, results were encouraging with drip irrigation to close spaced crops like turmeric. The fresh rhizome yield of turmeric was enhanced upto 76.3 per cent with water saving of 53.1 per cent besides 25 per cent saving in nitrogen fertilizer when applied through drip system daily at 40 per cent of surface irrigation level (Selvaraj *et al.*, 1997).

Bushes under drip irrigation produced higher yields compared to those with microjet system in blue berry (Holzapfel *et al.*, 2004)

Results of the experiments on micro irrigation at Bhavanisagar revealed that drip irrigation to tapioca once in 2 days at 50 per cent of surface irrigation level enabled 39.8 per cent water saving and 33 per cent nitrogen was saved besides comparable tuber yields of 51.6 t ha^{-1} with surface irrigation (WMS, 1998). Experiments conducted at Agricultural Research Station, Bhavanisagar in banana crop had disclosed that drip irrigation once in 2 days at 24 L per plant had out-yielded check basin irrigation by 9.1per cent (57.25 t ha^{-1}) coupled with 41.6 per cent water saving (WMS, 1997). Research work carried out in the farmer's field at Kalampalayam (Coimbatore) revealed that in grapes, overhead drip irrigation at 48 L per vine per day had registered the highest fruit yield of 46 t ha^{-1} (16 per cent increase), over surface irrigation at 100 L per vine per day, besides 48 per cent water saving (Muthuchamy *et al.*, 1998).

Drip irrigation at 60 per cent ET resulted in significant water saving of 63.07 per cent and 19.43 per cent increased fruit yield of Poovan and Dwarf Cavendish (29.5 and 29.0 t ha^{-1} respectively) compared to ring basin irrigation (Kumathe *et al.*, 2001). Drip irrigation plays a major role in enhancing better plant growth and higher yield of crops. Aniejohn (2000) studied the effect of drip and sprinkler irrigation on bhendi, and found that the plant height, yield and water use efficiency were higher in drip irrigation when compared to sprinkler irrigation. Bressan, 1995 compared three drip irrigation regimes, corresponding to 20, 35 and 50 per cent water depletion of field capacity against flood irrigation and the Sugarbeet yield and sugar content under drip irrigation were higher than those with flood irrigation. Singandhupe *et al.* (2002) reported that 3.7 to 12.5 per cent of higher tomato fruit yield with 31 to 37 per cent saving of water was obtained in the drip irrigation. Water use efficiency in drip irrigation on an average over nitrogen level was 68 to 77 per cent higher over surface irrigation.

Aujla *et al*. (2005) evaluated the effect of various levels of water and N application through drip irrigation on seed cotton yield and water use efficiency (WUE). In this experiment, three levels of water (IW/CPE ratio is 0.4, 0.3 and 0.2) and three levels of N (100, 75 and 50 per cent of recommended N, 75 kg/ha) through drip were compared with check-basin method of irrigation under two methods of planting (normal sowing and paired sowing). The results revealed that when the same quantity of irrigation water and N was applied through drip irrigation system, it increased the seed cotton yield to 2144 from 1624 kg/ha (an increase of 32 per cent) under check-basin method of irrigation. When the quantity of water through drip was reduced to 75 per cent, the increase in seed cotton yield was 12 per cent. However, when water was reduced to 50 per cent, it resulted in 2 per cent lower yield than the check basin.

1.3. Soil moisture distribution

Soil moisture distribution is one of the most important factors involved in successful design and management of a drip system. Bresler *et al*. (1978) described a model for water movement from a point source, according to which the greater the rate of application, the greater the lateral movement of the applied water and the shallower the penetration. Bar-Yosef (1977) noted that only meagre data were available on the simultaneous migration of water and ions from a point source in the field and the plant's response to various moisture and concentration distributions in the soil. Howell et al. (1981) stated that the distribution pattern of soil moisture resulting from the drip irrigation wetting of soil was bulb like auxiliary symmetric pattern and the pattern of wetting would be two dimensional.

Soil moisture distribution mainly depended on the rate of application, amount of water and initial moisture content of the soil (Khepar *et al.,* 1983). Ramesh, 1994 stated that the drip irrigation system maintained soil moisture close to the field capacity whereas furrow irrigation maintained soil moisture at 60-70 per cent of available soil moisture at 0.6 E-pan level. The soil water content distribution in the profiles under drip fertigation treatments was relatively higher near the emitter and decreased as the distance from the emitting point increased (Chakraborty *et al.,* 1998). Similar results were reported by number of researchers in the past [Sivanappan *et al*. (1972); Sivanappan and Padmakumari, (1980); Gajare (1982) and Selvaraj (1997).

1.4. Water Use Efficiency (WUE)

Water use efficiency should be estimated to assess the water used by the plants, water saved throughout the growing period of the crop and productivity per unit of water. Goyal *et al*. (1987) reported that in capsicum, drip irrigation registered 37 per cent higher WUE compared to furrow irrigation. Pawar *et al*. (1993) stated that application of 100 per cent recommended dose of liquid fertilizer through drip irrigation recorded the highest WUE (250 kg ha^{-1} cm^{-1}) in garlic. Chandio and Yaseen (1995) obtained higher WUE under drip irrigation system as much of (1.21 kg m^{-3}) as compared to conventional furrow irrigation (0.44 kg m^{-3}) in chillies.

Higher WUE (2.34 kg m^{-3}) was recorded at the application of 100 per cent recommended dose of Water soluble fertilizers through drip irrigation in Capsicum, which was on par with 75 per cent recommended dose (Muralidhar, 1999). At CAZRI, irrigation studies on gourds and melons showed that trickle irrigation resulted in higher yield and water use efficiency. Drip irrigation increased yield of gourds by 13.5 per cent compared to furrow irrigation with yield increase of 12.1 per cent to 46.8 per cent (Prabhakar, 2000). WUE in chilli was increased quadratically ($0.83 \leq R^2 \leq 0.98$) with days after plant emergence to harvest for the three moisture regimes by trickle irrigation (Ramesh, 1986). Water use efficiency in terms of yield was found to have significant positive correlation with total dry matter (TDM, 0.865 **) and net photosynthesis (0.840**) in Capsicum under drip system of irrigation (Edna Antony and Singandhupe, 2003).

1.4. Irrigation scheduling

Irrigation scheduling is allocating irrigation water based on the individual crop water requirement. Works carried out on irrigation scheduling based on climatic conditions (cumulative pan evaporation values) in different crops resulted in improved plant growth and yield in higher frequency of irrigation (Singaram, 1990; Selvaraju, 1990). Irrigation should be given daily as in drip to match the daily transpiration of the plant or once in 3 or 4 days with longer irrigation (Gopinath, 1994).

Scheduling was an important step in water management in view of minimising the loss through various factors and to increase the water use efficiency (Mishra *et al.*, 1997). Benchamin *et al*. (1997) estimated that Jasmine required about 10 irrigations per crop of 60-70 days duration at an interval of 6-8 days at a rate of 1.5 acre inch per irrigation to obtain maximum leaf yield in flood irrigation method.

The water requirement included the total amount of water for meeting the need of jasmine for the whole period of growth and calculated as:

Water requirement = Consumptive use + Application losses during the irrigation. Consumptive use of water = Evaporation + Transpiration + water used in metabolic activities. The ET of jasmine plant was 5-6 mm per day (Ramakant *et al.*, 1998).

2. Fertigation

In fertigation through drip, the nutrient losses can be minimized to a considerable extent, if the fertilizers are applied in the effective crop root zone in required quantities and by maintaining optimum soil moisture regime. With drip irrigation there was often an intimacy between roots and applied water. So it was feasible through fertigation, to manipulate the nutrition of drip irrigated plants (Keng *et al.*, 1979).

Fertigation permitted application of fertilizer formulations directly to the active root site and thus improved the nutrient use efficiency. Reduction of 20-25per cent in fertilizer dose was reported (Phene *et al.*, 1979). Maximization of crop yield and quality and minimization of leaching below the rooting volume might be achieved by managing fertilizers concentrations in measured quantities of irrigation water, according to crop requirements (Hagin and Lowengart, 1995). Micro irrigation offered potential for fertigation. Through fertigation, accurate and uniform application was possible and the amounts and concentrations of specific nutrients could be adjusted to crop requirements (Bar Yosef, 1982). Jeyabal *et al.* (2000) reported that fertigation was recognized as a very effective and convenient means of maintaining optimal fertility and water supply.

2.1. Fertigation in flower crops

In campanula flower crop, continuation of fertigation late in the fall had significant negative effects on forcing behaviour and the quality of the finished plants that were forced after fertigation was terminated in week 45 (mid-November) had significantly higher leaf nitrogen than controls, plants fertilized later than week 38 had a reduction in post-harvest keeping quality (Dinesen, 1997).

It was found that the irrigation levels affect the flowering (percentage) and flower quality characteristics of gladiolus and a linear relation between water use (WU) and flowering percentage for Peter Pears and Eurovision varieties (R 2 =0.91 and 0.85, P 0.01, respectively) were obtained. Ruhi Bastug (2005) found that every mm of water is increasing the flowering percentage of gladiolus by 0.3%.

2.2. Fertigation in vegetables

Miller *et al.* (1976) indicated that nitrogen as urea was used most efficiently when applied through drip irrigation than furrow irrigation in tomatoes. The marketable yield of large tomato fruits and total marketable yield were 30 and 10 per cent higher respectively with 60 per cent of the N and K applied with irrigation than with all fertilizers applied pre-plant. Yields for the daily and weekly fertigation treatments were similar (Locascio and Smajstrla, 1992).

Fertilizer application through irrigation water (fertigation) to tomato increased crop yield more effectively than the traditional surface banding method of application. Crop yield increased markedly with high fertilization frequency (2 day interval), compared with low frequency (15 day intervals). The highest field water use efficiency (6 L kg^{-1}) was obtained for plants fertilized through drip irrigation at high frequency. Fertigation significantly reduced the cost of crop production compared with surface banding fertilizer application (Ibrahim, 1992).

Maximum yield was recorded in okra due to the readily available N in the vicinity of the root zone in fertigation treatment, resulting in more efficient utilization of applied N than placement method (Kadam *et al.,* 1993). Tomato plants were drip irrigated at 0.7, 1.0 or 1.3 times the maximum evapotranspiration (ETM) and fertigated with 60, 120 or 180 kg N ha^{-1} in trials at Avignon in France. Yield and fruit weight were the highest at 1.0 ETM in the trial, but most quality components (brix, acidity, colour and TSS percentage) were the maximum in irrigation at 0.7 ETM (Branthome *et al.,* 1994).

In lettuce, drip fertigation with ammonium sulphate gave higher head weight per plant, with 22.6 per cent higher yield over control treatment (Klar *et al.*, 1995). In capsicum, higher FUE (37.79 kg of NPK ha^{-1}) was recorded under drip fertigated treatment irrespective of level and source of fertilizer (Muralidhar, 1999).

In okra, application of 100 per cent recommended dose of liquid fertilizer through drip irrigation produced higher plant height (100.3 cm), yield (194.9 q ha^{-1}) and number of fruits per plant (24). It was on par with 75 per cent recommended dose of liquid fertilizer through drip fertigation and 25 per cent saving of fertilizer was observed and drip fertigated tomato recorded higher number of fruits and fruit weight. Besides, factory grade fruits were also higher under fertigation treatment (Tumbare *et al.*, 1999).

Patel and Rajput (2000) observed that drip fertigation in onion resulted in 60 per cent saving of fertilizer for achieving the same level of production as compared to conventional method along with higher FUE of 5.28 kg. kg of NPK^{-1}. In gherkin, higher marketable yield (10.7 t ha^{-1}) was recorded at application of 100 per cent recommended dose of NPK through fertigation in the form of Urea, Mono Ammonium Phosphate, Potassium Nitrate followed by the same form of fertilizer at 75 per cent recommended dose (Sundar Raman *et al.*, 2000).

2.3. Fertigation in fruits

Callesen (1991) reported that both irrigation and fertigation to raspberry increased the yield, but the differences were not significant. Treatments significantly increased fruit size in the 2 dry years, but not in the wet seasons. Wolf *et al.* (1990) found that yields of apple cultivars were higher with soluble NPK fertilizer applied through drip irrigation at a daily rate of 2-4 liter per tree. Fertigation also gave higher leaf N concentration and increased growth. Long-term trials were carried out in vineyards.

There were 5 fertilization / irrigation variants where the NPK fertilizers were applied either to the soil or through drip irrigation. The highest yield (22.9 t ha^{-1}) and economic viability were obtained by applying the fertilizer through drip irrigation six times per growing season and the same treatment wherein fertigation given three times per season gave a yield of 22.3t ha^{-1}. Alway (1993) discussed the advantages and disadvantages of fertigation in apple and pear orchards. The uses of different liquid fertilizers, containing different N sources, were compared and the basic programmes of fertigation using either microsprinklers or drip irrigation were given for one year old and more older trees.

Five year old valencia orange trees on sour orange rootstocks were fertigated through drip with 25, 50 or 75 ppm N for three years. These rates were reduced to 15, 30 and 45 ppm N respectively, for the next three years. The treatments were supplied fertilizers via drip. At the end of six year period, the yield of trees that received the lowest N application rate (100-120 kg N ha^{-1} y^{-1}) was 18 per cent lower than that of trees in the other two treatments (Orphanos *et al.*, 1994). Intrigliolo *et al.* (1994) found that continuous fertigation on orange trees produced significantly improved water, nutritional and physiological plant status and leaf N concentrations compared with the annual application particularly with drip system.

Eleven fertigation treatments using drip and microjet sprays were applied to a 25 year old citrus orchard. Results showed that small volume irrigation by drippers combined with high concentration of NPK resulted in the highest yield, and produced restricted root growth and a dense root system with large number of small roots (Bravdo *et al.* 1994). Drip fertigation was applied to melon either daily or three times a week for various periods with N at the rate of 90 kg ha^{-1} in the form of urea. The crop was harvested twice, 64 and 69 days after planting (DAP). The highest marketable yield of 20.2t ha^{-1} was obtained with daily N fertigation upto 50 DAP (Pinto *et al.*, 1994).

Fertigation provided flexibility in timing of fertilizer application according to crop demand based on physiological stages. High P fertilizer for early growth to encourage rooting, high N fertilizer for vegetative growth and high K fertilizers for fruit and flower production could be administered by fertigation (Satisha, 1997). Drip fertigation with soluble fertilizers like urea (for N) and muriate of potash (for K) at 200 g per plant with 1:2 NK ratio had resulted in 89t ha^{-1} in Banana cv.Robusta (Srinivas, 2000). Mahalakshmi *et al.* (2001) reported that fertigation in banana had proved to economise water and fertilizer levels with a corresponding lower expenditure in cost of production with labour saving towards weeding, fertilization and water application**.**

2.4. Response of some crops to fertigation through micro irrigation system

Micro irrigation systems make efficient use of the available water resources, as frequent application of water to the plant root zone minimizes losses through seepage. There is considerable saving of water in these systems depending upon the climate, as soil surface wetting is restricted to root zone both in respect of spread and depth, the evaporation was also reduced . Though the initial cost of establishing a micro irrigation system could be high, benefits of saving water and labour, non-interference with cultural practices and distinct possibility of saving fertilizers when given through these systems are very important. Since irrigation and fertilization are regarded as very important input management practices, enterprising farmers and scientists attempt to let the fertilizers be distributed through irrigation with yield advantages.

In fertigation, the chemicals are injected into the micro irrigation systems and is becoming quite popular due to its obvious advantages such as localized placement of plant nutrients, proper movement of applied nutrients in the root zone, labour saving and continuous supply of the required plant nutrients during the growth period (Greeff, 1975).

Fertigation helps in saving of fertilizers and labour cost. This method facilitates easy supply of nutrients, as they are readily available to the plant roots. Fertigation would be difficult when irrigation systems were improperly designed or when poor quality fertilizer materials are used (Koo, 1980). Drip fertigation provides an efficient method of fertilizer delivery and if properly managed, drip fertigation can reduce overall fertilizer application rates and minimize adverse environmental impact on vegetable production (Hartz and Hochmuth, 1996).

Technological innovations are to be exploited to achieve the twin objectives of higher productivity and better water use efficiency. Micro or drip irrigation has revolutionized irrigated agriculture in many countries of the world. It is an accepted method of irrigation even in the developing countries. The fertigation with mineral fertilizers (108kg N per ha + 184 kg K per ha) increased organic matter and total N content of the soil as well as commercial yields in sweet pepper (Moera *et al.,* 2000). Goncalves *et al*. (2000) applied nitrogen fertilizer to lettuce by fertigation and conventional method using two sources of N viz., urea and ammonium sulphate and observed that the crop yield response to urea was better than ammonium sulphate and the fertigation was better than the conventional application of fertilizers. Yoursef *et al*. (2001) indicated that organic manure (25 per cent) + mineral fertilizers (75 per cent) through fertigation best treatment for producing early and total yields as well as fruit total soluble solids in tomato.

Fertigation gives flexibility of fertilization, enabling the specific nutritional requirement of the crop to be met at different stages of its growth. In comparison with conventional methods of irrigation and fertilization, it appears that trickle fertigation, under certain conditions can produce comparable or higher yields with substantial saving in fertilizers. In view of the potential advantages of this technology, area under drip irrigation increased tremendously in India in recent years and has reached 9,12,000 hectares (Sivanappan, 2002).

2.5. Distribution of fertilizers under trickle fertigation

Fertilizer application through trickle irrigation systems is the most common application of the chemical injection techniques. Trickle fertigation is an attractive concept, as it permits application of nutrients directly at the site of a high concentration of active roots and as needed by the crop. However, following application through trickle irrigation, mineral nutrients move into the wetted volume in a manner consistent with the flux of the wetted volume in a manner consistent with the flux of the water in the soil, their solubility and or reactivity with constituents in the soil solution, and their interaction, if any, with the exchange sites of the soil. Since chemical characteristics of fertilizers differ, mineral nutrients are differently distributed in the soil when applied by trickle irrigation (Bar-Yosef, 1977; Goldberg *et al.*, 1971).

The nitrate form of nitrogen does not react with the soil exchange sites and is not held in soils. Nitrates move with other soluble salts to the wetted front. This is of particular interest since $N0_3$-N should always be applied with every irrigation and at that concentration needed by the fertigated crop, as to satisfy its requirement in N from one irrigation to the other (Papadopoulos, 1988a).

Theoretically, and this is in full agreement with experimental results, the distribution of $N0_3$-N application for the fertigated crops might be under the over-fertilization stress at the day of fertilizer application and under deficient stress due to leaching following the irrigation without fertilizer. The same applies, although at a lower degree, and for other nutrients that are not reacting with soil, and almost with all nutrients under pure sandy soils (Papadopoulos, 1988 b; 1991, 1992).

The ammonium form of N derived from ammonium or urea fertilizers is not nearly so subject to immediate leaching losses because temporarily, depending on the soil, may be fixed on exchange sites in the soil. Nitrate status in soil at any time will result from a dynamic equilibrium between addition by trickle irrigation and removal by the plant plus any losses from leaching or de-nitrification. The latter may occur in heavier soils, where oxygen tension may be come limiting (Bar-Yosef and Sheikholslami, 1976). Hence, irrigation design as well as the irrigation scheduling program must be appropriate to maintain desired fertility level in the soil.

Potassium (K) is less mobile than nitrate, and distribution in the wetted volume may be more uniform due to interaction with soil binding sites (Bar-Yosef, 1980; Uriu *et al.,* 1980). Trickle applied K moves both laterally and downward, allowing more uniform spreading of K in the wetted volume of soil. Phosphorus (P), contrary to N and K, is readily fixed in most soils (Bar-Yosef, 1980), although movement of applied P differs with soil texture. Commercial standard P-fertilizers may also precipitate in the irrigation lines in reaction with ions in the irrigation water such as Ca or Mg. Due to soil fixation of the applied P and the problem of low solubility and precipitation of P in the irrigation system, it has been suggested that under such conditions P may not be applied through irrigation systems. However, such an approach reduces the availability of P with consequent significant reduction in the yield. The phosphoric acid is a useful source of P and in recent years widely used particularly in mini-sprinkler and drip fertigation.

3. Mulching

Mulching, apart from numerous other advantages, protects the bed from direct infiltration of excessive precipitation, which reduces the possibility of nutrients leaching from the root zone (Lamont, 1993). In cabbage, the use of drip irrigation either alone or in combination with mulch increased the yield significantly over furrow irrigation to the tune of 65 percent. (Tiwari *et al.*, 2002).

The use of drip, either alone or in combination with mulching , increased the tomato yield substantially over the normal method of irrigation, with about 44 per cent saving in irrigation. Cellulose mulch, being a paper material, is not fully impermeable to water, is microbiologically degradable, particularly in places covered with soil (Stewart and Jenni,1997). Yield of bell pepper in the treatment under black Poly ethylene film was 56 and 42 t per ha under cellulose mulch and the following growing season, yield of 30 and ethylene 21 t per ha were achieved in treatments with black Poly E mulch and cellulose mulch respectively.

Kabocha yield and brix level were significantly improved under a combination of subsurface drip irrigation and mulch (Alam and Zimmerman, 2002). Xie *et al.*, (2005) found that there were increases of 0.9-30.8 per cent in evapo transpiration and 4.0-110.3 per cent in yield for all plastic mulched treatment in spring wheat. The crop coefficient of tomato under drip irrigation with black plastic mulch was lower (Amayreh and Al-Abed, 2005).

4. Post harvest practices

Cold storage of dry branches at 0.00 ± 1.11^{o}C (32 ± 2^{o}F) increased the shelf life of deciduous Holly branches (Michelle L.Jones,2004). Vase life decreased 2 to 8 days as storage temperature increased from 2°C to 10°C. ‘Saturn’ and ‘Charlotte’ were the only varieties where vase life was unaffected by storage temperature.. The most tolerant varieties to stressful storage conditions were ‘Charlotte’, ‘Orlando’ and ‘Saturn’ (Nell and Leonard, 2005). Experiments with cold storage utilized blocks of ice to keep Peonies stems cool. Cut stems in tight bud could be stored for upto six weeks before being sold as cut flowers. Storage of *Telopea speciosissima* flower at 0^{0}C or 2^{0}C and at 100 per cent Relative humidity for two weeks did not reduce the subsequent vase life at 20^{0}C, but at 6^{0}C for four weeks reduced it from eight days to less than six days in fresh inflorescences (Mayak and Faragher, 1986).

5. Transpirational water use efficiency

At present nearly 7 per cent of the world's population lives in areas where water is scarce but this may rise to 67% of the world's population by 2050(Wallace,2000). Day to day depletion and abused usage of water for irrigation in agriculture leads to water and food scarce. Gaining of carbon is either through C_3 or C_4 or CAM photosynthetic path way by employing water, CO_2, sunlight from nature by the existing agriculture crops.

Many researches had focused on leaf photosynthesis, water use efficiency and stomatal conductance of C_3 and C_4 species (Jones, 1983; Pearcy and Ehleringer, 1984). The proportion of water transpired in relation to evapotranspiration [T/(T+E)] is a measure of water-supply efficiency(Rockstrom,2003). Biomass accumulation is linearly related to the transpiration by the crop (Ben-Gal and Shani, 2002). Linear yield to transpiration relationships have been utilized in plant growth and water uptake model to estimate yield based on predicted transpiration values (Ben-Gal *et al*,2003).The photosynthetic rates and water use efficiency of C4 species are higher than C_3 species. Increased CO_2 and soil water influenced the growth of C_3 and C_4 plants (Derner, 2000). Average transpiration rate of Soybean (C_3) was 731g m^{-2} day^{-1} and for sorghum (C_4) 1128 $g/m^2/day$ (Dugas *et al.*,1997).C_3 plants transpired more water than C_4 plants (Barbara *et al.*,1981).

Maize (medium maturity) requires between 500 and 800 mm of water (depending on the climate) to give the maximum yield (FAO report 1979). The transpiration efficiency of field grown maize is 7.4 pa, close to the mean of 8.0 pa obtained by others for maize in more arid climates.

Assimilation of the C_4 species was greater than that of C_3 species, but maximum carboxylation rate (Vc, max) was higher in C_3 species (48% higher) than C_4 species (Shuli Nin *et al.,* 2005).Transpiration for starto and wheat were 4.2 $kgm^{-2}day^{-1}$ and 3.2 kg m^{-2} day^{-1} at 28 DAS and water loss per plant was 39g day^{-1} and 49g day^{-1} for siratro and wheat respectively(James I.L,1984).The average ETc for maize at the maximum crop coefficient after 80DAS was 424 mm (Shaozhong Kang, 2003).

For maize, daily evapotranspiration based on Leaf area index was given by Al-Kaisi (1989). Increased water availability increased the dry matter of chick pea (3617 kg/ka) (Zhang, 2000).Chickpea has less WUE than barely but Transpiration efficiency was much higher than WUE in chickpea (Thomas and Fukai,1995). At 120DAS the net photosynthetic rate of chickpea was increased and 155 DAS it reduced steeply.

The total water use of Chickpea was 186mm under rainfed conditions .Water loss in terms of transpiration was peak at 1 pm (110 $mg/mm^2/hr$) and WUE was maximum at 2 pm (16$gmCO_2$ / gH_2O X 10^{-3}) (Sinclair *et al*,1975). Chickpea 90 DAS started to transpire more upto 120DAS and after that it started to decline (A.Soltani, 2000). Chickpea seed yield was 2500 $kgha^{-1}$ if the water used per season was 450 mm (Siddique, 2001). Chickpea produced 2.54 g of dry matter per kg of transpiration in the irrigated treatment (Piara singh and Sri rama, ICRISAT, 1989).

Growers want their crop to gain more carbon with applied water at each phenological growth stages, but still the exact quantification of water to be irrigated at each phenological development from above reports are vague. Scientists still conducted experiments with reference to evapotranspiration and in field conditions. The aim of this research is to judge the amount of water utilized at each stages of the crop only through transpiration for gaining carbon at its whole life cycle.

6. Aquaporins

For effective water transport, plants are equipped with water channels, Aquaporins, which facilitate water diffusion across cell membranes (Chrispeels and Maurel, 1994; Maurel, 1997). Aquaporins, are found in almost all living organisms, and are membrane-intrinsic proteins that form water-permeable complexes. Due to difficulties in measuring the water channel functionality in plants, homologous system, an alternative, heterologous system, of *Xenopus* oocytes expression and measurement of plant aquaporins was adopted (Maurel *et al.,* 1993). In plants, this large family consists of more than 30 members some of which do not transport just water but other small and uncharged molecules such as CO_2, H_2O_2, NH_3, urea, glycerol, Boron and Silicone (Tyerman *et al.,* 2002).

7. Cost -Benefit Ratio

The benefits of drip irrigation may include better crop survival, earlier harvest, greater yields, more efficient distribution of nutrients, less plant stress, reduced yield variability and improved crop quality (Doorenbos and Kassam, 1979; Martin *et al.,* 1994). According to Israel condition, growers with typical drip irrigation systems can expect investments of rupees 89760 ha^{-1} with 1.6 ha blocks of olives. Analysis of survey findings indicated that net present value was rupees 138560 ha^{-1} after an initial investment of rupees 89760 ha^{-1} (B.Çetin, 2003).

It was reported that the net profit per mm of water used in tomato crop under drip irrigation and conventional system were Rs. 278.43/- and Rs. 66.47/-, respectively, and the water use efficiencies were 123.8 and 27.95 kg ha^{-1} cm^{-1}, respectively (Anonymous, 1995). Sivanappan (1996) reported that an extra income of Rs.49, 280/- could be obtained under drip irrigation in tomato over surface irrigation and the pay back period of drip system cost was only six months.

Batchler *et al*. (1996) reported that the micro irrigation that was evaluated included low- head drip irrigation, pitcher irrigation and subsurface irrigation using clay pipes. From these methods, subsurface irrigation using clay pipes was found to be cheap, simple and easy to use. The cost economics of micro irrigation system and optimization performed to assess minimum input cost of tomato, considering the advent of mechanically moved portable drip sets, with every second day irrigation. Approximately 50 per cent saving on initial investment of drip set could be achieved as the same set could irrigate double the area (Dalvi *et al.,* 1999). Drip fertigation with 100 per cent water soluble fertilizers applied to potato recorded higher net profit of Rs. 38720/- ha^{-1} when compared to drip fertigation with 100 per cent normal fertilizers (Rs. 33604/- ha^{-1}) and furrow irrigation with 100 per cent normal fertilizer (Rs. 32583/- ha^{-1}).

Nitrogen at 80 per cent of recommended level registered the highest gross income of Rs.53,380 per hectare because of high yield due to effective and optimal nitrogen uptake. The benefit-cost ratio was also higher (2.01:1) in this treatment than all other treatments. Michael (1978) reported that subsurface drip irrigation with 80 per cent of surface irrigation registered the highest gross income of Rs.75280/- per ha and greater benefit-cost ratio of 2.98:1.

CHAPTER III

MATERIALS AND METHODS

Field experiments were conducted from November 2005 to August 2006 at Botanic Garden, TNAU, to evaluate the performance of drip fertigation on the growth parameters and yield of Jasmine (*Jasminum grandiflorum*) var CO. 2 and the same experiment was conducted at The Hebrew University of Jerusalem, Israel with *Jasminum grandiflorum* (unknown variety) to evaluate the water use efficiency and molecular mechanisms for the conduction of water inside the plant.

I. Work at Tamil Nadu agricultural university (TNAU), India

3.1. Materials

3.1.1. Field location

The experimental field is located at 11°02" North latitude and 76°57" East longitude at an altitude of 426.72 m above MSL. Field experiments were conducted in Field No. 10 D of Botanic Garden, Tamil Nadu agricultural university, Coimbatore, Tamil Nadu.

3.1.2. Weather condition during crop period

Jasminum grandiflorum is a perennial crop and after pruning from the month of November it attains different growth stages until flowering. *Jasminum grandiflorum* is very sensitive to weather change and success or failure in terms of yield and concrete recovery is very much related to the prevailing weather conditions. Heavy rainfall leads to poor flower set and in association with high humidity leads to disease infections. Increase in temperature with reduction in RH at flowering increases the transpiration rate resulting in abscission of buds and flowers. Water stagnation or saturation condition of soil for more than 24 hours is highly detrimental to jasmine at flowering stage.

In the present study, jasmine crop experienced favourable weather and environment for its growth and yield, during all the seasons. The mean temperature indicate day and night or maximum and minimum temperature (26^0C) and RH (80 per cent) during cropping period was nearer to optimum, which favoured crop growth. The sunshine hours were at the optimum level. Among the study period, the sunshine hours was higher in November 2005 than other months at 2006 (Appendix I).

During the experimental period, the maximum temperature ranged from 22.0 to 33.7° C with a mean of 29.9° C and minimum temperature ranged from 13.0 to 25.0° C with a mean of 20.8° C. The relative humidity ranged from 63 to 98 per cent with a mean of 90.5 per cent. The bright sunshine hours and wind velocity ranged from 0.0 to 11 h d^{-1} and from 1.8 to 18.8 km h^{-1} with a mean of 5.9 h d^{-1} and 4.7 km h^{-1}, respectively. The total rainfall received was 550.9 mm in 27 rainy days. The pan evaporation value ranged from 1.2 to 8.6 mm with a mean of 3.7 mm. Weather data during the experimental seasons are presented in appendices.

3.1.3. Soil

Performance of Jasmine (*Jasminum grandiflorum)* is highly dependant on the soil it grows on. The soil type and pH, which influence the growth of plants, vary from site to site. Therefore, soil testing is essential before planning for *Jasminum grandiflorum* plantation. Before the initiation of the experiment, 12 soil samples were taken from three depths i.e., 15, 30 and 45 cm from the experimental plot. Soil samples were air dried and passed through 2 mm sieve and were analysed for soil pH, organic carbon, nitrogen, phosphorus and potash. The soil of experimental field was clay loam, low in available nitrogen, medium in available phosphorus and high in available potassium. The soil analysis data is given in Table 3.3.

3.1.4. Crop and variety

It is essential to select *Jasminum grandiflorum* variety according to the agro-climatic conditions of the area. The varieties selected should have good agro-economic efficiency in terms of their response to applied water or water use efficiency (WUE), fertilizers or fertilizer use efficiency (FUE), disease resistance and drought tolerance. The flowers of a selected variety should have good yield, shelf life, concrete content and economic value. The test crop variety was CO. 2 (Coimbatore-2), the familiar Jasmine variety evolved by Tamil Nadu Agricultural University, Coimbatore, holds high potentials under irrigated and rainfed conditions in South India. This superior *Jasminum grandiflorum* variety is suitable to different agro-climatic conditions that not only yield better, but also will be of high quality to support the concrete industries and resistant to climatic hazards, diseases and insects. It is most suitable for semi- arid region.

3.1.5. Irrigation source

The source of irrigation water was borewell. Water from the borewell was analyzed for pH, EC, total alkalinity, Cl_2, SO_4, Ca, Mg, Na, K, RSC, Sodium absorption ratio (SAR) and total soluble salts. The details of quality of irrigation water are presented in Table 3.4.

3.2. Methods

3.2.1. Field lay-out

The *Jasminum grandiflorum* plants were three years older and all the plants were pruned at November, 2005. Then lay-out was taken up and drip system installed. For surface irrigation treatments check basins were formed (Plate 2).

3.2.2. Soil wetted diameter and depth

Wetting front advance and depth of wetting in drip irrigation treatments as 5, 10 and 15 Liters per day (LPD) with 4 Liters per hour (LPH), 8 LPH and 12 LPH drippers were recorded at different times of emission.

3.2.3. Design and lay-out of drip system

Drip irrigation for *Jasminum grandiflorum* was designed by careful analysis of the design capacity, optimum size of the pipelines, discharge of drippers, capacity of filter and pump capacity. The planting was taken up at a spacing of 2.0 X 1.5 m. The system was operated at the pressure of 1.2 ksc. This pressure head was sufficient for irrigating the experimental area with paired row drip. Reduction in cost can be achieved by the adoption of suitable crop geometries, especially paired row. Adoption of this system further reduces the cost of infrastructure and mechanization and this is an added advantage. From the water source, water was pumped through 7.5 H.P motor and conveyed to the field using PVC pipe (63 mm OD) after filtering through the screen filter. By-pass arrangement was provided and used for maintaining a pressure head of 1.2 ksc in the system for irrigation.

The plot size was 25 m^2 (5 m $\times$5 m). Each plot had 4 rows and each row had 4 plants thus there were 16 plants per plot. Paired row drip system was installed with 12 mm laterals laid in between pairs and rows. In paired row drip system one of 4 LPH, 8LPH dripper for single plant was installed depend upon the requirement of water to be irrigated. Lay-out plan of different geometries is given in Figure 1. Experimental field, check basin irrigation, and paired row drip system are shown in Plates 1 & 2.

3.2.3.1. Treatments

a. Field experiment

The experiment was conducted by adopting the following treatments.

Main plot: Irrigation quantity (Three levels)

W_1 = 5 Liters per day (LPD)

W_2 = 10 Liters per day (LPD)

W_3 = 15 Liters per day (LPD)

Sub plot: Fertilizer quantity (Three)

F_1 = 50% of Recommended dose of fertilizers (RDF)

F_2 = 75% of Recommended dose of fertilizers (RDF)

F_3 = 100% of Recommended dose of fertilizers (RDF)

Recommended dose of fertilizers 120: 240: 120 kg NPK ha^{-1} yr^{-1}

Sub-sub plot: Mulch frequency (Two levels)

M_1 = with black polyethylene mulch

M_2 = without mulch

Control **:** Basin application + Manual fertilizer application of recommended dose of fertilizers.

Replication **:** Three

Design **:** Split plot

b. Post harvest experiment:

Packing methods (Two)

P_1 = Normal packing

P_2 = Vacuum packing

Storage temperature (Three levels)

T1 = 5^o C storage

T2 = 10^o C storage

T_3 = 15^o C storage

Control : Normal packing, vacuum packing and room temperature

Replication : Six

Design : CRD

3.2.4. Pruning

Pruning is a periodical practice of removing older branches in *Jasminum grandiflorum* plants. It is necessary to carry out systematic pruning along with trimming to maintain the *Jasminum grandiflorum* plants in proper form. The plants, when attained required growth and girth after planting were pruned. The first pruning was done 10 months after planting. Thereafter 3-4 branches raised from the main stem and from each of which 3-4 secondary branches were allowed to develop. These branches were further pruned for leaving 30 – 45 cm stumps for observing yield. There was single pruning during the last week of November every year.

3.2.5. Irrigation scheduling

Irrigation scheduling is the decision of when and how much water to be applied to a crop. Its purpose is to maximize irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level.

3.2.6.1. Optimal scheduling through drip irrigation system

The purpose of optimal scheduling is to determine the irrigation time and amount of water to be applied to the crop for maximizing yield per unit of water.

3.2.6.2. Drip irrigation scheduling

The depth of water needed was calculated based on the following formula (Michael, 1978).

$$d = \frac{(F.C - W.P) A_s\ D}{100} ASMD\%$$

where

d = depth of water, cm

FC = field capacity of the effective root zone, per cent dry basis

WP = wilting point of the effective root zone, per cent dry basis

As = apparent specific gravity of the soil in effective root zone

D = effective root zone depth, cm

ASMD = allowable soil moisture depletion, per cent

A simple drip irrigation scheduling can be expressed by the following formula, (Wu and Gitlin, 1983).

$$T = \frac{W_m (1 - P_D)}{QE_A} \qquad \text{…. 1.}$$

where

T = irrigation time, hr.

W_M = volume of water required to achieve the maximum yield, L

P_D = per cent deficit which was taken as zero

Q = discharge required for the drip system, LPH

E_A = irrigation application efficiencies, per cent

Irrigation application efficiency (E_A), which is defined as the ratio of irrigation water stored in the rootzone to the total amount applied, can be calculated by the following equation.

$$E_A = X (1 - P_D) \qquad \text{..... 2}$$

where,

X = depth ratio, which was taken as one.

P_D = per cent deficit

3.2.7. Time of operation of drip system

The total irrigation water applied for each crop season (pruning to harvest of flowers) was arrived at separately for different treatments. Surface irrigation was given once in a week and for drip treatments the irrigation was given on daily basis. The time of operation of drip system paired row is given in Table 3.2. The evaporation rate, effective rainfall and quantum of water applied for each treatment for 4 experimental seasons are given in Appendices II, III, IV and V.

Table 3.2. Time of operation of drip system

Surface irrigation	:	Control	5 cm once in 7 days
Drip irrigation, once in a day			
5 liters per day (4 LPH dripper)	:	W_1	1 hr 25 min (application time)
10 liters per day (8 LPH dripper)	:	W_2	1 hr 25 min (application time)
15 liters per day (4+8 LPH dripper)	:	W_3	1 hr 25 min (application time)

3.2.8. Fertigation

Fertigation is a current technology, wherein water and soluble fertilizers are applied simultaneously in a combined form to the soil rootzone resulting in minimal loss of nutrients and water. Urea and Multi K were applied through fertigation in all drip irrigated plots, but in control plot, fertilizers were applied as band placement method. Phosphorus was applied as basal dose for all the plots for each crop season.

3.2.8.1. Fertigation through Venturi

Urea and Multi K were dissolved in water in the ratio of 1:5. Fertilizer solution was prepared in a container from which it was sucked by Venturi assembly and allowed through the irrigation system. Suction by a Venturi is achieved by water passing through a constricted section and is based on the Bernoulli's principle. It delivers the fertilizers at a concentration, which depends on the water flow along the mainline.

3.2.8.2. Fertilizer dose

Fertilizer application for surface irrigation

Fertilizers were applied as per the treatments of surface irrigation. The fertilizer sources for supplying NPK were urea (46% N), single superphosphate (16% P_2O_5) and muriate of potash (60% K_2O), respectively of which full dose of P_2O_5 and 25 per cent N and K_2O were applied as basal. The remaining 75 per cent of N and K_2O were applied in 3 equal splits as top dressing at 30, 60 and 90 Days after pruning (DAP).

Scheduling of fertigation

The fertilizer sources for supplying NPK through drip irrigation were urea, orthophosphoric acid and muriate of potash, respectively. 60 % of phosphorous in terms of single super phosphate was applied as basal at the time of pruning and the rest was given through fertigation at 46-75 and 76-105 days after pruning. Fertigation details are given in Table 3.3. Fertigation was done once in two days starting from 15 DAP upto 135 DAP, regulated by taps provided near the take off points of the sub main.

The success of fertigation techniques encompasses the use of right type of fertilizers and proper scheduling of nutrients based on the requirement of the crop during different stages of growth. The nutrient requirement of *Jasminum grandiflorum* has already been reported as 120:240:120 kg ha^{-1} .From the initial soil sampling revealed that the soil was low in nitrogen content, medium in phosphorous and high in potassium. Based on this, the fertigation schedule was fixed for the present investigation as furnished in table 3.3.

Entire N application was spread over a period from 45 to 130 days after pruning with its maximum share during the peak vegetative phase. The available status of phosphorous was medium and in general, phosphorous was fixed by soil colloids and slowly released, so the entire phosphorous was scheduled during the early phase in such a way that the application was completed within 90 DAP. The application of potassium nutrient was scheduled from 70 to 110 DAP (coinciding with flowering). Since K has pronounced effects on vigorous growth, improved yield and better quality characters.

Table 3.3. Fertigation schedule for *Jasminum grandiflorum*

Source	**Days**				
	30-45	**46-75**	**76-105**	**106-135**	**Total**
Nitrogen					
Split dose kg ha^{-1}	**35.00**	**35.00**	**30.00**	**20.00**	**120.00**
Urea kg ha^{-1} (46 %)	75.95	75.95	65.10	43.40	260.40
Urea through drip, g^{-1} plot^{-1}	7.59	7.59	6.51	4.34	26.04
Phosphorus					
Split dose kg ha^{-1}		**45.00**	**35.00**	**-**	**80.00**
H_3PO_4 kg ha^{-1} (52 %)		86.40	67.20	-	153.60
H_3PO_4 through drip, g^{-1} plot^{-1-1}		8.64	6.72	-	15.36
Potash					
Split dose kg ha^{-1}	**-**	**-**	**60.00**	**60.00**	**120.00**
MOP kg ha^{-1} (60 %)	-	-	100.2	100.2	200.4
MOP g through drip, g^{-1} plot^{-1}	-	-	10.02	10.02	20.04

3.2.8.3. Discharge rate during fertigation

The discharge rate of the emitters at selected points in each plot was measured by collecting the water for a known time directly under the emitters with the help of a measuring jar and a stop watch. Discharge measurements were also taken during fertigation through Venturi for various pressures of 0.5, 0.4 and 0.3 ksc for finding out N and K concentrations.

3.2.9. Soil moisture distribution

The soil samples were taken with a screw auger at 0-15, 15–30 and 30-45 cm depths after 1st, 2nd, 3rd, 4th, 5th, 6th and 7th day of irrigation in control plot. In drip irrigated plots (4, 8 and 12 LPH), soil samples were taken at 0-15, 15-30 and 30-45 cm soil depth at a distance of 0, 15, 30 and 45 cm away from the emitting device. Then the moisture content was determined by oven dry method (USDA, 1970). The moisture content was calculated by

$$\text{Moisture content (per cent)} = \left[\frac{(\text{Wet weight} - \text{dry weight})}{\text{dry weight}}\right] \text{x}\, 100$$

3.2.10. Soil nutrient dynamics under drip irrigation

The soil samples were taken at a radial distance (horizontal) of 15, 30, 45 cm between lateral and 15 and 30 cm between dripper at a depth of 0-15, 15-30 and 30-45 cm (vertical). Soil nutrient dynamics was estimated by analyzing available nitrogen, phosphorus and potassium. Soil samples were collected one week after fertigation for each treatment. Sampling was done near the emitting point, 15, 30 and 45 cm horizontally away from the emitting point at 0-15, 15-30 and 30-45 cm depths. The results are clearly given in figures.

3.2.11. Mulch

The experimental field was laid with black polyethylene mulch of 50 micron thickness for every treatments and control without mulch.

3.2.12. Growth and yield parameters

Data on various growth and yield parameters associated with overall performance were collected for the study period. Observations on various growth parameters *viz*. plant height, number of primary and secondary branches, number and length of primary and secondary roots, First flower initiation, number of flowers per branch, 100 flower weight, length and diameter of flower, concrete content, distribution of flowering and fresh flower yield per plant were recorded. The observations on growth parameters were recorded in four stages as detailed below for yield and other characters.

Stage I	**Pre flowering**	**(December – February)**
Stage II	**Flowering**	**(March-May)**
Stage III	**Peak flowering / Peak season**	**(June – August)**
Stage IV	**Lean flowering / Lean season**	**(September – November)**

The methodology adopted in respect of each attribute is briefly given below.

3.2.12.1. Plant height

The plant height was measured for different months from the bottom of the stem for the randomly selected 6 plants under each treatment and expressed in cm.

3.2.12.2. Number of primary branches per plant

Number of primary branches from the randomly selected six plants in each treatment was counted, averaged and expressed as number of branches per plant.

3.2.12.3. Number of secondary branches per plant

Number of secondary branches for different months from the randomly selected six plants in each treatment was counted, averaged and expressed as number of branches per plant.

3.2.12.4. Number of primary roots per plant

Number of primary roots from the randomly selected three plants in each treatment was counted at the end of eighth month after treatment, averaged and expressed as number of branches per plant.

3.2.12.5. Number of secondary roots per plant

Number of secondary roots from the randomly selected three plants in each treatment was counted at the end of the eighth month after treatment, averaged and expressed as number of branches per plant.

3.2.12.6. Length of primary roots per plant

Length of primary roots from the randomly selected three plants in each treatment was counted at the end of the eighth month after treatment, averaged and expressed in cm.

3.2.12.7. Length of secondary roots per plant

Length of secondary roots from the randomly selected three plants in each treatment was counted at the end of the eighth month after treatment, averaged and expressed in cm.

3.2.12.8. Number of days taken for first flower initiation

Number of days taken for first flower initiation from the randomly selected six plants in each treatment was counted, averaged and expressed as number of days taken for first flower initiation.

3.2.12.9. Number of flowers per branch

Number of flowers per branch from the randomly selected six plants in each treatment was counted for the four seasons of flowering, averaged and expressed as number of flowers per branch.

3.2.12.10. Hundred flower weight

100 flower weight from the randomly selected six plants in each treatment was counted for lean and peak season of flowering, averaged and expressed in gm.

3.2.12.11. Diameter of flower

Diameter of flower from the randomly selected six plants in each treatment was counted for lean and peak season of flowering, averaged and expressed in cm.

3.2.12.12. Length of corolla tube

Length of flower corolla tube from the randomly selected six plants in each treatment was counted for lean and peak season of flowering, averaged and expressed in cm.

3.2.12.13. Length of flower stalk

Length of flower stalk from the randomly selected six plants in each treatment was counted for lean and peak season of flowering, averaged and expressed in cm.

3.2.12.14. Flower distribution

Flower distribution from the randomly selected six plants in each treatment was counted for four seasons of flowering, averaged and expressed in per cent of distribution of flowering.

3.2.13 Concrete content

Concrete content of flowers from the randomly selected six plants in each treatment was analyzed by solvent extraction method with food grade hexane, averaged and expressed in per cent of concrete recovery.

3.2.14. Leaf quality parameters

Throughout the study period, chemical analysis of leaf was carried out for leaf moisture content by oven dry method, nitrogen content by Microkjeldahl method, potassium by Flame photometric method and protein content by Lowry's method. Then the data were statistically analysed.

3.2.14.1. Nitrogen , phosphorous and potassium content of leaf

The plant samples were analysed for available N , P and K content using Kjel plus apparatus (Kjeldahl, 1983) and flame photometer (Jackson, 1973).

3.2.15. Post harvest observations

Data on various post harvest parameters associated with overall performance were collected for the study period. Observations on various post harvest parameters *viz*. physiological loss of weight, moisture content, freshness and shelf life were recorded.

3.2.15.1. Physiological loss of weight (PLW)

The physiological loss of weight was measured for the flowers under post harvest treatment and expressed in cumulative loss of PLW in terms of per cent with cumulative days and dates.

3.2.15.2. Moisture content

The moisture content was measured for the flowers under post harvest treatment and expressed in per cent of moisture content.

3.2.15.3. Freshness

The freshness was measured for the flowers under post harvest treatment and expressed in terms of per cent of freshness.

3.2.15.4. Vase life

The vaselife was measured for the flowers under post harvest treatment and expressed in number of days of freshness.

3.2.16. Miscellaneous

Timely weedings were done to avoid competition for nutrients and water. Adequate plant protection measures were given against pests and diseases as and when needed.

3.2.17. Estimation of effective rainfall

If the rainfall is less than the evaporation then the entire rainfall is taken as effective rainfall. If the rainfall is more than the evaporation then the effective rainfall is equaled to the evaporation. The daily evaporation and rainfall readings were obtained from meteorological department, TNAU. The calculation was made as above for finding out the effective rainfall.

3.2.18. Determination of water use efficiency at India

Water use efficiency (WUE) was calculated for each treatment for each crop season, which is the ratio of yield of the crop in kg ha^{-1} and total water utilized in mm.

$$WUE = Y / W.A$$

where,

WUE = Water use efficiency, kg ha^{-1} mm^{-1}

Y = Yield of the crops, kg ha^{-1}

W.A = Total water utilized, mm

3.2.19. Determination of fertilizer use efficiency

Fertilizer use efficiency (FUE) was calculated for each treatment for each crop season, which is the ratio of yield of the crop in kg ha^{-1} and total nitrogen and potassium fertilizers applied in kg ha^{-1}.

$$FUE = Y / F.A$$

where,

FUE = Fertilizer use efficiency, kg ha^{-1} kg of fertilizer^{-1}

Y = Yield of the crops, kg ha^{-1}

F.A = Total fertilizer applied, kg ha^{-1}

3.2.20. Economics

Gross and net income per ha and benefit-cost ratios were worked out based on the cost of cultivation, cost of input and income from the yield.

3.2.21. Statistical analysis

The data were analysed in Agres package for split plot Factorial Randomized Block Design. Wherever the treatment differences were found significant ('F' test) critical differences were worked out at 5 per cent probability level and the values furnished.

Non-significant treatment differences were denoted by "NS".

PART II

WORK AT THE HEBREW UNIVERSITY OF JERUSALEM, ISRAEL

In order to fulfill the objective "Water use studies in *Jasminum grandiflorum*", the work regarding the quantification of exact water at each phenological growth stages of *Jasminum grandiflorum* and study of DNA quantity in *Jasminum grandiflorum* for the availability of Aquaporin genes were practiced at the Hebrew University of Jerusalem, Israel.

3.3. Plants

Jasminum grandiflorum plants were subjected for the whole experiment and the variety was unknown. The cuttings from the mother plant were planted in pots and the emerged seedlings were utilized for the experiment.

3.3.1. Location

The experiment was carried out in the green house of The Hebrew University of Jerusalem, Israel.

3.3.2. Water loss rate measurement

This method included six highly sensitive, temperature-compensated load cells (weighing lysimeters) that were connected to a data-logger and sampled every 3 minutes. Single potted plants of 3.9 liter capacity were located on the load cells for 1-2 or 3 days. The load-cells readings, taken every 10s and averaged over 3-minutes period, were logged in a data logger. The exact time was decided upon the ability to identify the transpiration pattern of the tested mutants compared to control plants and submerged wick (proving information on the atmospheric demand (VPD)). Evaporation from the pot surface was prevented by covering the growing-medium surface with an aluminum foil. The plants were fertigated (irrigation + fertilizers) at the evening of every day. The pots were submerged in no-transparent plastic container (13x21.5x31.5 cm H, W, L) through a hole in its upper cover in order to keep constant water availability to the roots. The plants were fertigated once in a day (at 20:00) with a commercial fertilizer solution. The buckets were submerged in 2.5cm above the pot base ensuring water availability during the day providing a smooth weight decrease without interruptions by mid-day irrigation events.

During the drought treatment, fertigation was stopped until the plant showed visible a significant lost turgour. At the end of drought stress assays, plants were irrigated again the recovery rate was also recorded. The plants transpiration and the wick evaporation rates were calculated by the first derivative of the measured weight time series. In order to eliminate the amplification of data-related noise that is inherent in the numerical derivative operator, the weight time series was smoothed by the Savitzky-Golay method (Press *et al*., 1988) prior to differentiation.

3.3.3. Data analysis

The rate of water loss from the system, being the negative value of the whole-plant transpiration (WPT) rate, is calculated by the first derivative of the measured-weight time series.

$$WPT \equiv -\frac{dW}{dt} \approx \frac{W_{k+1} - W_k}{t_{k+1} - t_k} \qquad (1)$$

where W_k and W_{k+1} is the measured weight at time t_k and the consequent time step t_{k+1}. In general, differentiation acts as a high-pass filter, thus significantly amplifies the high – frequency noise. Noises are amplified as the measurement (sampling) interval ($t_{k+1} - t_k$, eq. 1) diminishes. On the other hand, the resolution at which momentary variation in transpiration rate can be observed decreases as the sampling interval increases. Consequently, a signal treatment is essential when the noise associated with the transpiration-induced weight decrease is differentiated together with the high-frequency noises associated with the load-cell and data acquisition system, as both embedded in the measured time series, owing to the amplification of the noise introduced by the later. In fact, the measurement errors, which can never be avoided, complicate the differentiation, because this amplifies the noise presents to such an extent that additional signal treatment is essential. The noise associated with differentiation of noisy signals had stimulated a large number of investigations which have led to several solutions both in the time and frequency domain (Savitzky, 1964; Cullum, 1971; Andersse. and Bloomfie.P, 1974, 1974; Wahba, 1975; Rice and Rosenblatt, 1983; Scott and Scott, 1989)

Noise can be reduced or eliminated by smoothing (detrend) the measured data (time series) so that it becomes stationary prior to the following stage of spectral analysis.

Proper smoothing filters out the noise from the measured data while keeping leading variation patterns. The differentiation of a leading variation pattern provides a smoothed pattern WPT rate. Many methods are used for smoothing noisy data in time-series analysis. These methods can be categorized as non-parametric smoothing (e.g. moving average, Savitzky-Golay, and FFT filtering) and non-parametric regression (fitting polynomials of various orders, exponential functions, symmetrical and asymmetrical transition functions, etc. to the measured data). Smoothing should carry out with care since substantially different results may be obtained after differentiation in spite of the high R^2 values that are usually obtained for the different smoothing methods.

It is assumed herein that the container-weight time series follows an additive model

$$W_k = W(t_k) + \varepsilon_k, \qquad 1 \le k \le n \qquad t_1 < t_2 < ..t_k.. < t_n \qquad [2]$$

where $W(t_k)$ is the value that the weight at time t_k would have if it varied smoothly with time, and $\{\varepsilon_k\}$ is the deviation from that value. The system weight oscillations superimposing the smoothed time series are also a time series, and are designated as the 'residual time series' (residuals are the differences between the measured data and the fitted curve). When the mean of the residuals time series is zero, the trend of the measured time-series was properly removed. We presume that the residual time series ε_k (eq. 2) is a superposition of two time series; one is made of residuals that originate from the data acquisition and other system-related noises, ε_{k1}, and the other from residuals originated from the intrinsic oscillations in WPT, ε_{k1}. The independently measured time series for the constant weight, submerged wick and plant runs were used to study the properties of ε_{k1} and ε_{k2} and examine their randomness (white noise) by the autocorrelation function.

The spectrum analysis of ε_k was used to explore the existent of cyclical patterns. The spectral analysis decomposes a complex time series with cyclical components into a few underlying sinusoidal (sine and cosine) functions of particular wavelengths. By identifying the important underlying cyclical components, the characteristics of the phenomenon of interest could be realized, namely, identify the wave lengths and importance of underlying cyclical component in the WPT rate. This spectrum analysis enables to uncover few cycles of different lengths in the time series of interest, which at first looked more or less like random noise.

The spectrum (amplitudes vs. frequencies) of the residual time series was calculated by the Fast Fourier Transform (FFT), which decomposes a time-domain signal or time series into complex exponentials (sines and cosines). The spectrum of the constant-weight residual time series, ε_{k2}, will be used to determine the frequency threshold that will be used to filter out the high frequency noises (low-pass filter) from the plant-weight residual time series, ε_{k1}. Subsequently, the filtered spectrum is reconstructed back to a time series (in the time domain) by the inverse FFT. The time derivative of the reconstructed low-pass-filtered time series $d(\varepsilon_k')/dt$ (ε_k' is the low-pass filter of ε_k) provides the oscillatory transpiration rate that superimposes the smoothed WPT rate.

3.3.4. Stomatal study

Leaves from upper part of the plants are freshly harvested and immediately poured upside down in a solution enhances the stomatal opening. By keeping the leaves as fresh as by covering the Petri dishes with parafilm the enhancement of opening stomata at higher water potential. Then the lower epidermis get peeled, the peeled and dissected samples be kept in strong fluorescent light for 2 hrs to open the stomata. The samples then subjected to motorized inverter microscope (ZEISS) at 20X and 40X for number and aperture respectively. After the images captured through ZEISS, the images are analysed for the stomata density and aperture with Image j. software.

Stomatal solution (Stock 10 x)

Potassium chloride of 500mM

Calcium chloride of 0.1 mM

MES of 100mM

p^H 6.15

3.3.5. Photosynthesis measurement

To measure the photosynthesis, stomatal conductivity and carbon dioxide level at different intracellular concentration of subcellulars, we used (Li-6400, portable photosynthesis meter, Li-Cor Inc., Lincoln, NE, USA). We fixed the CO_2 values from 50, 100, 150, 200, 250, 300, 350, 400, 600, 800, 1000, 1200 and 1500.

The Licor-6400 is to be calibrated in order to fix the carbon dioxide and relative humidity inside the flow chambers and the quantum in terms of different light flux viz., red, blue, green and far red is to be fixed as 1200, 12% to get the accurate data.

Care should be taken while handling the CO_2 baloons in the chamber, also while adjusting the full scrub and full bypass time.

3.3.6. Porometer

Total leaf transpiration was determined using Porometer (Li-1600 steady State Porometr, Li-Cor Inc., Lincoln, NE, USA) on leafs of jasmine plants.

3.4. Molecular work

Aquaporins are the membrane intrinsic proteins (MIP) that gates the movement of water and other ions inside the membranes.

Here the availability of DNA bandwidth coinciding with Aquaporins was compared.

3.4.1. Isolation and purification of nucleic acids

DNA extraction protocol

Reagents / Chemicals

S-buffer: Store at room temperature - should be clear and transparent

1M Tris pH 8.5	100 ml
5M NaCl	20 ml
0.5M EDTA, pH 8.0	100 ml
SDS	20 g

Make volume to 1L by adding sterile distilled water; for use pre-heat at 65^0C

Proteinase K: 10mg/mL stock

Phenol:Chloroform : Isoamylalcohol (25:24:1v/v/v): Prepare fresh before use (Phenol needs to be molecular grade and buffered to pH 8.0)

***iso*-Propanol:** Keep at -20^0C

70 % ethanol

$T_{50}E_{10}$

RNAse: 10 mg/ml stock

3M Sodium Acetate

100 % Ethanol: Kept at –20^0C;

$T_{10}E_1$

Liquid Nitrogen

Equipments: 65^0C and 37^0C water bath, Sorvall Centrifuge, Fumehood

1. Aliquot 15 ml of S-buffer into sterile polypropylene tubes (plastic with conical base) and keep them at 65^0C in a water bath. Grind the leaf samples in a pre-cooled pestle and mortar under liquid Nitrogen to a fine powder and transfer ground tissue to pre-heated

   S-buffer (65^0C) containing tubes; make sure clumps are suspended by mixing thoroughly on a rotor for 5-10 minutes and incubate samples at 65^0C in a water bath for 30 minutes

2. Bring the samples to room temperature (RT) and add 60 uL Proteinase K per sample, mix thoroughly and keep at 55^0C water bath (stirrer on) for 1-1.5 hours and in between keep mixing manually also

3. Bring the samples to room temperature (RT) and add equal volume (15 ml) of freshly prepared Phenol: Chloroform: *iso*- Amyl alcohol (25:24:1v/v/v) per sample, mix well by gently inverting tubes and transfer to new tubes (plastic with round base) for centrifugation

4. Before centrifugation, balance tubes and centrifuge at 2000-3000 rpm for 20 minutes at 4^0C

5. Transfer the supernatant to clean plastic tubes (with conical base), add 9 ml of cold Isopropanol

6. Mix gently by inversion and keep at –20^0C for 10-15 minutes (if required); spool out DNA with the help of glass hook into fresh 15 ml glass tubes containing 3-4 ml of 70 % Ethanol

7. Centrifuge at 3000 rpm for 5 minutes at 4^0C, pour off the supernatant; repeat 70 % Ethanol wash and air dry the pellet for 20-25 minutes

8. Suspend the pellet in 2 ml of $T_{50}E_{10}$ containing 100-150 µg of Ribonuclease A and leave it overnight at RT

9. The next day, keep the samples at 37^0C for 1 hour. In the same tubes, add 2 ml of Phenol: Chloroform: iso- Amyl alcohol and mix gently by inversion

10. Centrifuge at 2000 rpm for 5 minutes at 4^0Cafter ensuring that the tubes are balanced

11. Transfer the supernatant to clean 15 ml glass tubes with the help of Pasteur pipette by carefully avoiding the precipitate at the interface and add 2mL of Chloroform

12. Mix gently by inversion to form an emulsion and then centrifuge at 2000 rpm for 10 minutes at 4^0C

13. Transfer supernatant to clean 15 ml glass tubes and add $1/10^{th}$ volume of 3M Sodium Acetate and 3-4 ml of 100 % Ethanol (kept at –20^0C). Mix gently by inversion and if required keep at –20^0C for 10-15 minutes

14. Spool out DNA with a glass hook into a microcentrifuge tube containing 1 ml of 70 % ethanol. Centrifuge at 8000 rpm for 5 minutes, pour off ethanol and repeat washing once more

15. Air dry for 30 minutes and suspend pellet in appropriate volume of $T_{10}E_1$ buffer and store the samples at 4^0C for short term and freeze them for long term storage

Determination of DNA purity and concentration

The concentration and purity of DNA can be determined by measuring the absorbance at 260nm(A_{260}) and 280 nm(A_{280}) in a spectrophotometer. Purity is determined by calculating the ratio of absorbance at 260 nm to absorbance at 280 nm. Pure DNA has an A_{260} / A_{280} ratio of 1.7-1.9

1. Dilute 2 ul of DNA in 1 ml of sterile dH_2O and mix thoroughly
2. Measure the absorbance at a wavelength of 260 and 280 nm in a spectrophotometer.
3. Calculate the DNA concentration using the formula

$$\text{DNA concentration in µg/µl} = \frac{A_{260} \times 50}{2(\text{Volume taken for measurement})}$$

Quality check and Quantitation of DNA by agarose gel electrophoresis

1. Prepare 0.8% agarose gel in 0.5X TBE buffer by weighing the required quantity of agarose and heat the solution in microwave oven
2. Cool and add Ethidium Bromide for staining to a concentration of 50 µg/ 100 mL
3. Pour agarose in the gel unit and make sure there are no air bubbles
4. Mix 1 µL of DNA sample with 5 µL of $T_{10}E_1$ and 4 µL orange dye
5. Load DNA samples along with lambda DNA of known concentrations
6. Run at 80- 100 V for 30-45 minutes and view the gel in a Gel documentation system
7. Determine the concentration from the gel after documenting the results for future use

3.4.2. Gel electrophorosis

Preparing the agarose gel

- Measure 1.25 g Agarose powder and add it to a 500 ml flask
- Add 125 ml TAE Buffer to the flask. (the total gel volume well vary depending on the size of the casting tray)
- Melt the agarose in a microwave or hot water bath until the solution becomes clear. (if using a microwave, heat the solution for several short intervals - do not let the solution boil for long periods as it may boil out of the flask)
- Let the solution cool to about 50-55°C, swirling the flask occasionally to cool evenly

- Seal the ends of the casting tray with two layers of tape
- Place the combs in the gel casting tray
- Pour the melted agarose solution into the casting tray and let cool until it is solid (it should appear milky white)
- Carefully pull out the combs and remove the tape
- Place the gel in the electrophoresis chamber
- Add enough TAE Buffer so that there is about 2-3 mm of buffer over the gel

Loading the gel

- Add 6 μl of 6X Sample Loading Buffer to each 25 μl PCR reaction
- Record the order each sample will be loaded on the gel, including who prepared the sample, the DNA template - what organism the DNA came from, controls and ladder
- Carefully pipette 20 μl of each sample/Sample Loading Buffer mixture into separate wells in the gel
- Pipette 10 μl of the DNA ladder standard into at least one well of each row on the gel

Running the gel

- Place the lid on the gel box, connecting the electrodes.
- Connect the electrode wires to the power supply, making sure the positive (red) and negative (black) are correctly connected. (Remember – "<u>Run</u> to <u>Red</u>")
- Turn on the power supply to about 100 volts. Maximum allowed voltage will vary depending on the size of the electrophoresis chamber – it should not exceed 5 volts/cm between electrodes!
- Check to make sure the current is running through the buffer by looking for bubbles forming on each electrode

- Check to make sure that the current is running in the correct direction by observing the movement of the blue loading dye – this will take a couple of minutes (it will run in the same direction as the DNA)
- Let the power run until the blue dye approaches the end of the gel
- Turn off the power
- Disconnect the wires from the power supply
- Remove the lid of the electrophoresis chamber
- Using gloves, carefully remove the tray and gel

Gel Staining

- Using gloves, remove the gel from the casting tray and place into the staining dish
- Add warmed (50-55°) staining mix
- Allow gel to stain for at least 25-30 minutes (the entire gel will become dark blue)
- Pour off the stain (the stain can be saved for future use)
- Rinse the gel and staining tray with water to remove residual stain
- Fill the tray with warm tap water (50-55°). Change the water several times as it turns blue. Gradually the gel will become lighter, leaving only dark blue DNA bands. Destain completely overnight for best results
- View the gel against a white light box or bright surface
- Record the data while the gel is fresh, very light bands may be difficult to see with time

Soil characteristics of the experimental field

The soil of experimental field is clay loam, low in available nitrogen, medium in available phosphorus and high in available potassium. The soil analysis data is given in the following Table 3.4.

Table 3.4. Soil characteristics of the experimental field

S.No.		Particulars	Composition
A.		**Textural Composition**	
	i	Coarse sand, per cent	25.24
	ii	Fine sand, per cent	11.98
	iii	Silt, per cent	29.51
	iv	Clay, per cent	33.27
	v	Textural class	Clay loam
B.		**Chemical properties**	
	i	Available N, kg ha^{-1}	244
	ii	Available P, kg ha^{-1}	16
	iii	Available K, kg ha^{-1}	485
	iv	pH	8.2
	v	Electrical conductivity, dSm^{-1}	1.15
	vi	Organic carbon, per cent	0.67
C.		**Physical characters**	
	i	Bulk density, g cc^{-1}	1.34
	ii	Field capacity, per cent	27.92
	iii	Permanent wilting point, per cent	15.44

Quality of irrigation water

The source of irrigation water is borewell. Water from the borewell was analyzed for pH, EC, total alkalinity, Cl_2, SO_4, Ca, Mg, Na, K, RSC, SAR and total soluble salts. The details of quality of irrigation water are presented below .

Table 3.5. Quality of irrigation water

Properties	Values
pH	7.08
EC (dS m^{-1})	4.33
Total alkalinity (meq L^{-1})	11.20
Cl_2 (meq L^{-1})	19.60
So_4 (meq L^{-1})	0.62
Ca (meq L^{-1})	4.64
Mg (meq L^{-1})	5.45
Na (meq L^{-1})	17.54
K (meq L^{-1})	0.26
RSC (meq L^{-1})	1.11
SAR	7.81
Total soluble salts (ppm)	2771.20

CHAPTER IV

EXPERIMENTAL RESULTS

The results of the field experiments conducted at the Horticultural College and Research Institute, Tamil Nadu Agricultural University, Coimbatore during 2005-06 in four seasons to standardize the irrigation, fertigation and plasticulture in jasmine (*Jasminum grandiflorum*) var CO.2 and the water management related research conducted at The Hebrew University of Jerusalem, Israel are presented in this chapter.

4.1. Work at TNAU, Coimbatore

4.1.1. Effect of irrigation, fertigation and mulching on growth parameters

Plant growth characters reflect on the growth, vigour and stand of the crop, which ultimately decide the yield. In the present investigation the growth parameters were observed at all stages *viz.*, from pruning (December), pre flowering (February to March), initial flowering (April and May) and peak flowering (June to August) to study the effects of the treatments on growth.

4.1.1.1. Plant height

The data on the plant height at 30, 60, 90, 120, 150, 180, 210, 240 and 270 days after pruning as influenced by different levels of irrigation, fertigation and mulch are presented in Tables 4.1, 4.2 and 4.3.

December, January and February

Growth in terms of plant height at all stages of development showed significant difference among fertigated and control field conditions with different levels of irrigation and fertigation during all the four experimental seasons. Plant height under drip irrigation was significantly higher than under flood irrigated condition. The treatment W_2 recorded higher plant height of 62.64, 72.33 and 84.35 cm while it varied from 61.11, 70.68 and 81.3 cm with treatment W_3 whereas the control recorded plant height of 54.81, 69.41 and 73.45 cm at December, January and February months respectively in the control.

Among the sub plot treatments, 75 per cent recommended dose of fertilizer recorded the highest plant height of 62.64, 72.33 and 84.35 cm while it was 54.81, 69.41 and 73.45 cm in control at December, January and February months respectively.

The interaction effects showed significant differences. Application of 10 litres of water per day with 75 per cent recommended dose of fertilizers under mulch ($W_2F_2M_1$) registered the highest plant height of 62.64, 72.33 and 84.35 cm. The plant height in control was 54.81, 69.41 and 73.45 cm in December, January and February respectively.

March, April and May

The same trend was observed in the months of March, April and May where also the treatment W_2 recorded higher plant height of 98.08, 117.7 and 154.13 cm respectively while it was 96.07, 115.36 and 150.39 cm in treatment W_3 (15 LPD) and 93.65, 109.88 and 141.36 cm in control.

Among the sub plot treatments 75 per cent recommended dose of fertilizer recorded the highest plant height of 98.08, 117.7 and 154.13 cm while in control the plant height was 93.65, 109.88 and 141.36 cm in March, April and May months respectively.

The interaction effects showed significant differences. Application of 10 litres of water per day with 75 per cent recommended dose of fertilizers under mulch ($W_2F_2M_1$) registered the highest plant height of 98.08, 117.7 and 154.13 cm. The plant height was observed under control condition as 93.65, 109.88 and 141.36 cm in March, April and May months respectively.

June, July and August

Plant height under drip irrigation was significantly higher than flood irrigated condition. The treatment W_2 recorded higher plant height of 172.73, 196.55 and 216.44 cm while it varied from 170.43, 192.64 and 211.77 cm with treatment W_3 (15 LPD) whereas the control field condition recorded plant height of 168.88, 176.65 and 205.15 cm in June, July and August months respectively.

Among the sub plot treatments 75 per cent recommended dose of fertilizer recorded the highest plant height of 172.73, 196.55 and 216.44 cm while in control the plant height was168.88, 176.65 and 205.15 cm in June, July and August months respectively.

The interaction effects showed significant differences. Application of 10 of litres of water per day with 75 per cent recommended dose of fertilizers under mulch ($W_2F_2M_1$) registered the highest plant height of 172.73, 195.55 and 216.44 cm. The plant height in control was 168.88, 176.65 and 205.15 cm in June, July and August months respectively.

4.1.1.2. Primary branches per plant

Under fertigated and control conditions, there were significant differences among the treatments for the number of primary branches produced per plant (Table 4.4).

In drip irrigated and fertigated condition, the mean number of primary branches was higher and significant difference was noticed between the lean and peak seasons. Higher mean number of primary branches (8.22) was found under water level of 10 LPD (W_2) and mulch followed by 15 LPD (W_3) as 7.31 whereas the number was 6.11 in control in the lean season. In the peak it was reverse and W_3 recorded 12.14 primary branches, W_2 had 11.32 branches and the control had only 7.64 branches.

Application of 75 per cent recommended dose of fertilizers recorded the highest number of primary branches per plant compared with other levels of fertigation treatments. Highest mean number of laterals (8.22) was noticed in F_2 and 100 per cent of RDF had 7 branches and control had 6 in lean season. In peak season 50 per cent of RDF recorded more number of primary branches (12.14) and it was followed by 75% RDF (11.32) with mulch. The least number of branches (7.31) was observed in control.

The treatment $W_2F_2M_1$ recorded the highest number of primary branches (8.22) in lean season whereas $W_3F_3M_1$ recorded more (12.14) in peak season.

4.1.1.3. Secondary branches

During different growing seasons, the number of secondary branches under fertigated and control condition showed significant differences among the treatments. The data on the number of secondary branches at 30, 60, 90, 120, 150, 180, 210, 240 and 270 Days after pruning as influenced by different levels of irrigation, fertigation and mulch are presented in Tables 4.5, 4.6 and 4.7.

Growth in terms of number of secondary branches at all stages of development showed significant difference among fertigated and control field conditions with different levels of irrigation and fertigation during all the four experimental seasons. Number of secondary branches under drip irrigation levels was significantly higher than flood irrigated condition. The treatment W_2 recorded higher number of secondary branches of 28.02, 29.03 and 30.01 while it varied from 26.24, 27.03 and 29.03 with treatment W_3 whereas the control field condition recorded number of secondary branches as 14.01, 14.63 and 15.22 at December, January and February months respectively.

Among the sub plot treatments 75 per cent recommended dose of fertilizer recorded the highest number of secondary branches of 28.02, 29.03 and 30.01 while it 14.01, 14.63 and 15.22 in control at December, January and February months respectively.

The interaction effects showed significant differences. Application of 10 litres of water per day with 75 per cent recommended dose of fertilizers under mulch ($W_2F_2M_1$) registered the highest number of secondary branches of 28.02, 29.03 and 30.01. The lowest plant height was observed under control condition as 14.01, 14.63 and 15.22 at December, January and February months respectively.

The same trend was observed in the months of March, April and May as the treatment W_2 recorded highest number of secondary branches of 32.4, 38.04 and 39.26 while it was varied from 30.31, 31.11 and 32.22 with treatment W_3 whereas the control field condition recorded the lowest number of secondary branches of 18.11, 18.76 and 19.23.

Among the sub plot treatments 75 per cent recommended dose of fertilizer recorded the highest number of secondary branches of 32.4, 38.04 and 39.26 while it was 18.11, 18.76 and 19.23 in control at March, April and May months respectively.

The interaction effects showed significant differences. Application of 10 litres of water per day with 75 per cent recommended dose of fertilizers under mulch ($W_2F_2M_1$) registered the highest number of secondary branches of 32.4, 38.04 and 39.26. The lowest number of secondary branches was observed under control condition as 18.11, 18.76 and 19.23 at March, April and May months respectively.

Number of secondary branches under drip irrigation was significantly higher than flood irrigated condition. The treatment W_2 recorded highest number of secondary branches of 35.44, 41.01 and 42.04. The values were 33.56, 34.36 and 35.36 in treatment W_3 whereas the control field condition recorded 19.88, 20.12 and 20.6 secondary branches in June, July and August months respectively.

Among the sub plot treatments, 75 per cent recommended dose of fertilizer recorded the highest number of secondary branches of 35.44, 41.01 and 42.04 while in control it was 19.88, 20.12 and 20.6 in June, July and August months respectively.

The interaction effects showed significant differences. Application of 10 litres per day with 75 per cent recommended dose of fertilizers under mulch ($W_2F_2M_1$) registered the highest number of secondary branches of 38.04, 41.01 and 42.04. The lowest numbers of secondary branches were observed under control condition as 168.88, 176.65 and 205.15 cm in June, July and August months respectively.

Among the subplots F_2 registered the highest number of secondary branches of 38.04, 41.01 and 42.04 and lowest was noted in control with 19.88, 20.12 and 20.76 in June, July and August months respectively.

4.1.1.4. Number of primary roots

The data on number of primary roots due to the influence of irrigation and fertigation with mulch are presented in Table 4.8.

Among the main plot treatments, W_2 (10 LPD) recorded the highest number of primary roots of 4.5, whereas control recorded 3.8

Different levels of fertigation showed significant differences in number of primary roots registered. The highest number of 4.5 was recorded with 75 per cent recommended dose of fertilizer (F_2) and it was followed by 100 per cent recommended dose of fertilizer (F_3) with 4.33 roots whereas the control recorded 3.8 roots.

The interaction $W_2F_2M_1$ was found to register the highest number of primary roots followed by $W_2F_3M_1$ and the treatments exhibited significant differences.

4.1.1.5. Primary root length

The data on root length due to the influence of irrigation and fertigation are presented in Table 4.9.

Among the main plot treatments, W_2 (10 LPD) recorded the highest root length of 32.08 cm and control recorded the lowest value of 28.69 cm.

Different levels of fertigation showed significant differences for root length. The value was the highest with 75 per cent recommended dose of fertilizer (F_2) (32.08 cm) and it was closely followed by 100 per cent recommended dose of fertilizer (F_3) with mulch (31.92 cm).

The interaction $W_2F_2M_1$ registered the highest root length followed by $W_2F_3M_1$ with 32.08 cm and 31.92 cm respectively and the treatments exhibited significant differences.

4.1.1.6. Number of secondary roots

The data on number of secondary roots due to the influence of irrigation and fertigation with mulch are presented in Table 4.10.

Among the main plot treatments, W_2 (10 LPD) recorded the highest number of secondary roots of 12.76, whereas control recorded the lowest (10.45).

Different levels of fertigation showed significant differences. The number of secondary roots registered was highest (12.76) at 75 per cent recommended dose of fertilizer (F_2) and it was followed by 100 per cent recommended dose of fertilizer (F_3) with mulch (12.51), whereas the control recorded the lowest value (10.45).

The interaction $W_2F_2M_1$ registered the highest number of secondary roots followed by $W_2F_3M_1$ (12.76) and (12.51) respectively and the treatments exhibited significant differences.

4.1.1.7. Secondary root length

The data on root length due to the influence of irrigation and fertigation with mulch are presented in Table 4.11.

Among the main plot treatments, W_2 (10 LPD) recorded the highest root length 24.78 cm and control recorded the lowest value of 21.36 cm.

Different levels of fertigation showed significant differences. The root length registered was the highest (24.78 cm) at 75 per cent recommended dose of fertilizer (F_2), and it was closely followed by 100 per cent recommended dose of fertilizer (F_3) with mulch (24.58 cm).

The interaction $W_2F_2M_1$ registered the highest root length followed by $W_2F_3M_1$ (24.78 cm) and (24.58 cm) respectively and the treatments exhibited significant differences.

4.1.1.8. Foliar nitrogen content (%)

The data related to foliar nitrogen content are given in Table 4.12.

During the four seasons, significant differences among the main plots were noticed. Under 15 litres of water per day (W_3), the nitrogen content was higher (2.01, 2.59, 2.13 and 1.89%) while under 10 LPD (W_2) the values were (1.99, 2.35, 1.98 and 1.64%) during seasons I, II , III, and IV respectively.

Among the sub-plot treatments, F_3 (100 per cent recommended dose of fertilizer) with mulch recorded the highest per cent of foliar nitrogen content (2.01, 2.59, 2.13 and 1.89%) followed by F_2 (75 per cent recommended dose of fertilizer) with mulch (1.99, 2.35, 1.98 and 1.84%) during seasons I, II, III, and IV respectively. whereas the control recorded the lowest value of 1.78, 2.06, 1.23 and 1.72% during all the four seasons.

The treatment combination $W_3F_3M_1$ (15 LPD, 100 per cent recommended dose of fertilizer under mulched condition) recorded the highest foliar nitrogen content followed by $W_2F_3M_1$ in all the four seasons.

4.1.1.9. Foliar phosphorous content (%)

The foliar phosphorous content under various treatments for four seasons are given in Table 4.13.

During the four seasons, significant differences among the main plots were noticed. Under 15 litres of water per day (W_3), the phosphorous content was higher (0.26, 0.22, 0.28 and 0.26 %) while under 10 LPD (W_2) the values were (0.26, 0.22, 0.27 and 0.25%) during seasons I, II, III and IV respectively.

Among the sub-plot treatments, F_3 (100 per cent recommended dose of fertilizer) with mulch recorded the highest foliar phosphorous content (0.26, 0.22, 0.28 and 0.26 %) followed by F_2 (75 per cent recommended dose of fertilizer) with mulch (0.26, 0.22, 0.27 and 0.25%) during seasons I, II, III and IV, whereas the control recorded the lowest values of 0.24, 0.16, 0.19 and 0.17 % during all the four seasons.

The treatment combination $W_3F_3M_1$ (15 LPD, 100 per cent recommended dose of fertilizer under mulched condition recorded the highest foliar phosphorous content followed by $W_2F_3M_1$ in all the four seasons.

4.1.1.10. Foliar potassium content (%)

The foliar potassium content under various treatments for four seasons are given in Table 4.14.

During the four seasons, significant differences among the main plots were noticed. Under 15 litres of water per day (W_3), the potassium content was higher (1.42, 1.41, 1.51 and 1.53 %) while under 10 LPD (W_2) the values were (1.41, 1.32, 1.49 and 1.53 %) during seasons I, II, III and IV respectively.

Among the sub-plot treatments, F_3 (100 per cent recommended dose of fertilizer) with mulch recorded the highest per cent of foliar potassium content (1.42, 1.41, 1.51 and 1.53%) followed by F_2 (75 per cent recommended dose of fertilizer) with mulch (1.41, 1.32, 1.49 and 1.53 %) during seasons I, II, III, and IV respectively, whereas the control recorded 1.26, 1.28, 1.31 and 1.39 % during all the four seasons.

The treatment combination $W_3F_3M_1$ (15 LPD, 100 per cent recommended dose of fertilizer under mulched condition) recorded the higher foliar potassium content followed by $W_2F_3M_1$ in all the four seasons.

4.1.2. Effect of irrigation, fertigation and mulching on flowering, yield and quality parameters of *Jasminum grandiflorum* var CO. 2

4.1.2.1. Number of days taken for flower bud initiation

The influence of irrigation, fertigation and mulch on days taken for first flowering is presented in Table 4.15. W_2 (10 LPD) registered early flowering (44.03 days after pruning) and it was followed by W_3 (15 LPD) (44.43 days after pruning). In control there was delayed flowering.

Application of 75 per cent recommended dose of fertilizer (F_2) with mulch showed early flowering (44.03 days after pruning), it was closely followed by 100 per cent recommended dose of fertilizer (F_3) (44.43 days after pruning), whereas control needed 50 days after pruning for first flower initiation.

In the interactions, application of 10 LPD, 75 per cent recommended dose of fertilizer under mulched condition ($W_2F_2M_1$) registered the lowest number of days for first flowering (44.03 days from date of pruning). This was closely followed by $W_2F_3M_1$ (10 LPD, 100 % RDF with mulch) (44.43 days after pruning) for first flower bud initiation.

4.1.2.2. Number of flowers per branch

The data related to number of flowers per branch are given in Table 4.16 .

During the four seasons, significant differences among the main plots were noticed. Under 10 litres of water per day (W_2), higher number of flowers per branch of 277.27, 344.34, 369.36 and 387.56 was observed than 15 LPD which recorded 277.21, 324.32, 344.34 and 356.66 during seasons I, II, III and IV respectively.

Among the sub-plot treatments, F_2 (75 per cent recommended dose of fertilizer) with mulch recorded the highest number of flowers per cluster with 277.27, 344.34, 369.36 and 387.56 followed by F_3 (100 per cent recommended dose of fertilizer) with mulch as 277.21, 324.32, 344.34 and 356.66.during seasons I, II ,III and IV .

The treatment combination $W_2F_2M_1$ (10 LPD, 75 per cent recommended dose of fertilizer under mulched condition) recorded the highest number of flowers per cluster (277.27, 344.34, 369.36 and 387.56), control recorded lowest number of flowers per branch (245.65, 271.48, 298.89 and 312.45) during seasons I, II, III and IV respectively.

4.1.2.3. Flower yield

The data related to number of flowers per plant are given in Table 4.17.

Significant differences among the main plots were noticed. Under 15 litres of water per day (W_3), the highest yield per plant of 2531.51g per plant was observed than 10 LPD which recorded 2498 g per plant.

Among the sub-plot treatments, F_3 (100 per cent recommended dose of fertilizer) with mulch recorded the highest yield of 2531.51g per plant and on par with F_2 (75% RDF) with mulch which recorded 2498 g per plant.

The treatment combination $W_3F_3M_1$ (15 LPD, 100 per cent recommended dose of fertilizer under mulched condition) recorded the highest yield and was on par with $W_3F_2M_1$ (15 LPD, 75 per cent recommended dose of fertilizer under mulch) (2515.51 g per plant), whereas the control recorded the lowest yield of 2217 g per plant.

4.1.2.4. Hundred flower weight

The results showed that the average 100 flowers weight was highest under drip irrigation with 10 LPD as 11.21 and 11.91g while the values in control were the lowest with 9.81and 10.21g in lean and peak seasons of flowering respectively (Table 4.18).

Different levels of fertigation showed significant differences among the treatments. Application of 75 per cent recommended dose of fertilizer (F_2) with mulch exhibited the highest 100 flowers weight of 11.21 and 11.91g during lean and peak seasons respectively, it was followed by F_3 (at 100 per cent recommended dose of fertilizer) as 10.87 in lean season and 11.01g in peak season.

The interaction $W_2F_2M_1$ (10 LPD, 75 per cent recommended dose of fertilizer under mulched condition) registered the highest 100 flowers weight of 11.21 and 11.91g followed by $W_2F_3M_1$ (10 LPD, 100 % RDF with mulch) with 10.87 in lean and 11.01g at peak seasons respectively.

4.1.2.5. Flower diameter

Data pertaining to flower diameter are given in the Table 4.19. Among the main plot treatments W_2 (10 LPD) recorded the highest flower diameter at lean and peak seasons with 3. 8 and 3. 9 cm while control registered 3.28 and 3.51 cm respectively.

Significant differences were noticed due to treatments. Application of 75 per cent recommended dose of fertilizer (F_2) with mulch registered 3.8 cm and 3.9 cm at lean and peak seasons respectively. The flower diameter increased with increased level of fertilizers through fertigation. It was followed by 100 per cent recommended dose of fertilizer (F_3) with mulch as 3.7 and 3.8 cm at lean and peak seasons respectively.

During all the two seasons, application of water 10 LPD, 75 per cent recommended dose of fertilizer with mulch ($W_2F_2M_1$) recorded maximum flower diameter 3.9 cm which was closely followed by application of water 10 LPD, 100 per cent recommended dose of fertilizer with mulch $W_3F_3M_1$. The minimum flower diameter was recorded in the control (3.28).

4.1.2.6. Length of the corolla tube

Data pertaining to corolla tube length are given in the Table 4.20. Among the main plot treatments W_2 (10 LPD) recorded the highest corolla tube length at lean and peak seasons as 2.2 and 2.3 cm respectively while control registered the lowest values of 1.61 and 1.85 cm.

Significant differences were noticed due to treatments and application of 75 per cent recommended dose of fertilizer (F_2) with mulch registered 2.2 cm and 2.3 cm at lean and peak seasons respectively. It was followed by 100 per cent recommended dose of fertilizer (F_3) with mulch as 2.1 cm both in lean and peak seasons. The corolla tube length increased with increased level of fertilizers through fertigation

During all the two seasons, application of water 10 LPD, 75 per cent recommended dose of fertilizer with mulch ($W_2F_2M_1$) recorded the highest corolla tube length of 2.3 cm which was closely followed by application of water 10 LPD, 100 per cent recommended dose of fertilizer with mulch $W_3F_3M_1$ as 2.1cm.

4.1.2.7. Length of the flower stalk

Data pertaining to length of flower stalk are given in the Table 4.21. Among the main plot treatments W_2 (10 LPD) recorded the highest flower stalk length at lean and peak seasons (2.6 and 2.7 cm respectively) while control registered the lowest of 2.21 and 2.25 cm respectively.

Significant differences were noticed due to treatments and application of 75 per cent recommended dose of fertilizer (F_2) with mulch registered 2.6 and 2.7 cm at lean and peak seasons respectively. The flower stalk length increased with increased level of fertilizers through fertigation. It was followed by 100 per cent recommended dose of fertilizers (F_3) with mulch as 2.5 and again 2.6 cm at lean and peak seasons respectively.

During lean and peak flowering seasons, application of water 10 LPD, 75 per cent recommended dose of fertilizer with mulch ($W_2F_2M_1$) recorded the highest flower stalk length of 2.7 cm which was closely followed by application of water 10 LPD, 100 per cent recommended dose of fertilizer with mulch $W_2F_3M_1$ as 2.6cm..

4.1.2.8. Concrete content

The data on concrete content due to the influence of irrigation and fertigation are presented in Table 4.22.

Among the main plot treatments, W_2 (10 LPD), W3 (15 LPD) recorded higher per cent of concrete recovery as 0.3% and control recorded 0.27%.

Different levels of fertigation showed significant differences for concrete recovery. 75 per cent recommended dose of fertilizer (F_2) with mulch recorded the highest value (0.3%) and it was on par with 100 per cent recommended dose of fertilizer (F_3) with mulch (0.3%).

The interaction $W_2F_2M_1$ registered the highest per cent of concrete recovery and was on par with $W_2F_3M_1$ and $W_3F_3M_1$ and the treatments exhibited significant differences.

4.1.2.9. Distribution of flowering

The distribution of flowering percentage observed during seasons I, II , III and IV are presented in Table 4.23. Distribution of flowering in W_2 (10 LPD) and W_3 (15 LPD) were on par with each other. The values were 5.70, 46.62, 49.60 and 8.20% in W_2 and 5.70, 46.37, 49.40 and 8.21% in W_3 during the four seasons respectively. Control recorded 5.10, 42.56, 46.24 and 6.46% during the four seasons respectively.

Among the different levels of fertigation in sub-plot treatments, 75 per cent recommended dose of fertilizer (F_2) with mulch exhibited a distribution pattern of 5.70, 46.62, 49.60 and 8.20 % and it was on par with F_3 (100% of RDF with mulch) 5.70, 46.37, 49.40 and 8.21% whereas the control recorded a distribution pattern of 5.10, 42.56, 46.24 and 6.46% during seasons I, II, III and IV respectively.

Among the interactions, application of water 10 LPD, 75 per cent recommended dose of fertilizer with mulch ($W_2F_2M_1$) recorded a distribution pattern of 49.60 which was closely followed by application of water 10 LPD, 100 per cent recommended dose of fertilizer with mulch $W_3F_3M_1$ as 49.54 during the peak flowering season. The treatments differed significantly among themselves.

4.1.2.10. Yield per hectare

The data related to yield per hectare are given in Table 4.24.

Significant differences among the main plots were noticed. Under 15 litres of water per day (W_3), the highest yield per hectare of 14,437.52 kg was observed than 10 LPD which recorded 14,37.47 kg.

Among the sub-plot treatments, F_3(100 per cent recommended dose of fertilizer) with mulch recorded the highest yield of 14,437.52 kg per hectare and this was on par with F_2 (75% RDF) with mulch which recorded 14,327.47 kg per hectare.

The treatment combination $W_3F_3M_1$ (15 LPD, 100 per cent recommended dose of fertilizer under mulched condition) recorded the highest yield and was on par with $W_3F_2M_1$ (15 LPD, 75 per cent recommended dose of fertilizer under mulch) , whereas the control recorded the lowest yield of 7390.02 kg.

4.1.2.11. Post harvest parameters

a) Physiological loss of weight (PLW)

The physiological loss of weight in terms of per cent was given in Table 4.25 with many parameters.

b) Cumulative (days)

The physiological loss of weight was lesser at 5^0C with vacuum packing upto 6-9 cumulative days and rapid after 9-21 days. Whereas the controlled storage with normal packing and control showed higher PLW(%) at 0-3 days itself and from 3-6 days the flowers get shriveled and rotted.

c) Moisture content (%)

The moisture content was constant upto 6-9 days with vacuum packed and refrigerated storage at 5^{o}C and the per cent of moisture loss was less upto 6-9 days then the loss was more rapid from 12-15 days upto15.55% then on 21st day after treatment and the loss was 42.89 % in vacuum packed flowers and 44.36 by normally packed flowers whereas the control of flowers with vacuum and normal packing under ambient room temperature lost its moisture content rapidly from the 1st day as 2.72% to 96.36 % at 18-21 days.

d) Freshness (%)

Upto 9-12 days under refrigerated treatment at 5^{o}C with vacuum showed more freshness upto 96.94% and at 18-21 days after storage the freshness was 91.87 % with vacuum packing and 90.87 with normal packing whereas the control lacked its freshness on 1st day itself with both vacuum and normal packing.

e) Shelf life (Days)

Flowers which were normally packed and stored at 5^{o}C had the longest shelf life (4.2 days) with lack of colour whereas control had a vase life of 2 days only vacuum packing and storage at 5^{o}C recorded a shelf life of 4.6 days but the flowers were damaged because of vacuum suction

4.1.3. Soil and water conservation parameters

4.1.3.1. Soil temperature

At morning

The soil temperature from the plant was measured at morning with mulch and without mulch at four different distances (5 15, 30 and 45 cm) from the plant were measured and given below (Table 4.26)

a) 5 cm distance from the plant

At the distance of 5 cm from the plant, the soil temperature was maximum (36.50°C) with the drip irrigation of 15 LPD, 50 per cent of RDF with mulch. It was closely followed by the drip irrigation with 15 LPD, 75 per cent RDF under mulch as 36.40^{o}C.

b) 15 cm distance from the plant

Maximum soil temperature was found at 15 cm distance from the plant with the drip irrigation of 15 LPD, 50 per cent RDF with mulch as 36.40^{o}C. Drip irrigation with 15 LPD, 75 per cent RDF with mulch registered the soil temperature as 36.30^{o}C.

c) 30 cm distance from the plant

As the distance from the plant increased the soil temperature get decreased to 36.30^{o} C with the drip irrigation of 15 LPD, 50 per cent RDF with mulch. Further reduction in soil temperature (36.20^{o}C) was noticed with the drip irrigation of 15 LPD, 75 per cent RDF under mulch

d) 45 cm distance from the plant

The temperature registered through the drip irrigation of 15 LPD, 50 per cent RDF under mulch recorded the highest soil temperature as 36.30 ^{o}C and it was more close to the treatment $W_3F_2M_1$ (15 LPD, 75 per cent RDF with mulch) as 36.20 ^{o} C which was on par with $W_2F_2M_1$(10 LPD, 50 per cent RDF with mulch).

At noon

At noon the soil temperature was measured for various distances from the plant *viz.*, 5, 15, 30 and 45 cm for different irrigation and fertigation levels with and without mulch. (Table 4.27)

a) 5 cm distance from the plant

Treatments having the drip irrigation of 15, 10 LPD with 100 and 75 per cent RDF under mulch recorded the maximum temperature of 41.10 ^{o} C and it was more close to the treatment of drip irrigation with 15 LPD, 50 per cent RDF with mulch as 41.00 ^{o} C.

b) 15 cm distance from the plant

Drip irrigation with 10 LPD, 50 per cent RDF with mulch recorded the maximum temperature as 41.00 ^{o} C and the treatment with 15 LPD, 100 per cent RDF under mulch recorded the temperature of 40.90 ^{o} C.

c) 30 cm distance from the plant

The temperature with the treatment of drip irrigation at 10 LPD, 50 per cent RDF with mulch showed highest temperature as 40.90 ^{o} C at 30 cm from the plant and it was followed by drip irrigation with 10 LPD, 100 per cent RDF with mulch sowed 39.90 ^{o} C.

d) 45 cm distance from the plant

Drip irrigation of 10 LPD, 50 per cent RDF under mulch recorded highest temperature of 40.90^{o} C at 45 cm away from the plant and it was more close to the treatment with drip irrigation of 10 LPD, 100 per cent RDF under mulch as 39.90 ^{o}C.

4.1.3.2. Soil Moisture Distribution

Surface irrigation

In surface irrigation, soil samples were collected at 0-10, 10-20, 20-30 and 30-40 cm depths at every 48 hours interval after irrigation during one rain free irrigation cycle (Table 4.29 and Figs. 2 to 5) and soil moisture depletion pattern was studied. The results showed that soil moisture depletion was faster during initial period of observations and slowed down during later period and also just before irrigation. Unlike drip irrigation the soil moisture content under surface irrigation method steeply declined from 22.63 per cent in the top layer of 0-10 cm depth at 2 days after irrigation to 10.72 per cent on 14 days after irrigation.

Among the different layers, it is interesting to note that the amount of moisture depleted from the top layer was much higher than from deeper layer. Thus, with increase in the depth of soil, the moisture depletion rate decreased.

The soil moisture content observed with surface irrigation was comparable with that of drip irrigation treatments upto a period of 48 hrs and thereafter there was a steady and steep decline in soil moisture content resulting in greater moisture stress to plants.

Drip irrigation

The drip irrigation treatment schedule of 5, 10 and 15 litres of water per day was analyzed for moisture dynamics in soil. The soil moisture content was estimated upto a depth of 30-40 cm at a distance up to 40 cm between lateral and 30 cm along the lateral at 10 cm interval. The soil moisture content was estimated at 24 and 48 hrs after drip irrigation (Tables 4.28a and 4.28b).

In case of drip irrigation, the soil moisture content after 48 hrs of drip irrigation upto 10 cm distance from dripper either along or between lateral in all the irrigation regimes was almost consistent and nearer to field capacity. Under drip irrigation, the soil moisture content with 15 litres of water per day was observed to be always maintained above 80 per cent available soil moisture even at 30 cm distance both along and between laterals. When application rate was decreased in drip irrigation the moisture content decreased distinctly with increased distance from dripper. Hence, it is evident that drip irrigation at reduced levels *viz*., 10 and 5 litres of water per day has resulted in lesser soil moisture content near the plant.

4.1.3.3. Fertilizer use efficiency

The influence of irrigation and fertilizer levels on N fertilizer use efficiency is furnished in Tables 4.30 and 4.31 for the mean yield data. Increased fertilizer use efficiency with the decreased level of fertilizer dose through drip was observed. The highest N fertilizer use efficiency of 48.65 kg ha^{-1} kg of N^{-1} was recorded in drip irrigation treatment at 15 LPD drip irrigation level with 75 per cent of recommended fertilizer dose under mulch followed by the above treatment without mulch as 48.22 kg ha^{-1} kg of N^{-1} and 15 LPD, 100% RDF under mulch as 46.27 kg ha^{-1} kg of N^{-1}, surface irrigation with 100 per cent of recommended fertilizer level i.e., control as 23.69 kg ha^{-1} kg of N^{-1} .

The influence of irrigation and fertilizer levels on K fertilizer use efficiency are furnished in Table 35 for the mean yield data. Like N fertilizer use efficiency, increased K fertilizer use efficiency with the decreased level of fertilizer dose through drip was noted. The highest K fertilizer use efficiency of 75.74 kg ha^{-1} kg of K^{-1} followed by 75.08 and 72.04 kg ha^{-1} kg of K^{-1} were observed in $W_3F_2M_1$, $W_3F_2M_0$ and $W_2F_2M_1$ respectively. The least efficiency was noted in control (36.87 kg ha^{-1} kg of K^{-1}), surface irrigation with 100 per cent of recommended fertilizer level.

4.1.3.4. Water use efficiency

Significant variation was observed both by irrigation regimes and fertilizer levels with respect to water use efficiency (WUE) (Table 4.32).

Among the irrigation regimes, drip irrigation with 10 litres of water per day resulted in significantly higher WUE (10.35 kg ha^{-1} mm^{-1}), than other drip irrigation levels and surface irrigation and it was followed by drip irrigation with 15 litres of water per day. The WUE was very poor in surface irrigation (2.75 kg ha^{-1} mm^{-1}), respectively compared to at all levels of drip irrigation. The WUE decreased with increased level of drip irrigation. Similar results were recorded during both the years and pooled data.

The WUE varied due to different level of fertilizer dose also. The WUE was significantly superior in the treatment that received 100 per cent RDF (10.35 kg ha^{-1} mm^{-1}) and it was followed by treatment received 75 per cent RDF.

Interaction effect between irrigation regimes and fertilizer levels was significant on water use efficiency.

4.1.4. Soil nutrient dynamics under drip irrigation

The soil samples were taken at a radial distance (horizontal) of 15, 30, 45 cm between laterals and 15 and 30 cm between drippers at a depth of 0-15, 15-30 and 30-45 cm (vertical). The results are presented in tables 4.33 to 4.38 and Figs. 6 to 15.

4.1.4.1. Nitrogen dynamics in soil

a) After second fertigation

Nitrogen dynamics after end of second fertigation between the lateral and along the lateral for depths from 0-45 cm are given below. Nitrogen concentration was highest at 15-30 cm depth as 263 kg ha^{-1} between the lateral and 265 kg ha^{-1} along the lateral during the end of second fertigation with 100 per cent RDF. In 75 per cent RDF higher nitrogen concentration was found at depth of 15-30 cm as 260 kg ha^{-1} between the lateral and 262 kg ha^{-1} along the lateral. The same trend was observed in 50 per cent RDF as 243 kg ha^{-1} between the lateral and 242 kg ha^{-1} along lateral at the end of second fertigation.

b) After final fertigation

Nitrogen dynamics after end of final fertigation between the lateral and along the lateral for depths from 0-45 cm are given below. Nitrogen concentration was highest 256 kg ha^{-1} between the lateral and 255 kg ha^{-1}along the lateral with 100 per cent RDF at

15-30 cm depth. 250 kg of nitrogen ha^{-1} between the lateral and 246 kg of nitrogen ha^{-1} along the lateral were the highest concentration observed by 75 per cent RDF. 50 per cent RDF recorded the same trend as 240 kg of nitrogen ha^{-1} between the lateral and 242 kg ha^{-1} along lateral after the end of final fertigation.

4.1.4.2. Phosphorous dynamics in soil

a) After second fertigation

Rest of the phosphorous apart from basal applied was subjected to fertigation and the phosphorus dynamics after end of second fertigation between the lateral and along the lateral for depths from 0-45 cm are given below. Phosphorous concentration was highest 28.47 kg ha^{-1} between the lateral and 23.87 kg ha^{-1} along the lateral with 100 per cent RDF at 0-15 cm depth. In 75 per cent RDF highest phosphorous concentration was found as 27.97 kg ha^{-1} between the lateral and 23.24 kg ha^{-1} along the lateral during end of second fertigation. The same trend was observed in 50 per cent RDF as 27.27 kg of phosphorous ha^{-1} between the lateral and 22.15 kg of phosphorous ha^{-1} along lateral.

b) After final fertigation

Phosphorous dynamics after end of final fertigation between the lateral and along the lateral for depths from 0-45 cm are given below. Phosphorous concentration was highest with 100 per cent RDF as 24.50 kg ha^{-1} between the lateral and 21.95 kg ha^{-1} along the lateral at 0-15 cm depth. 75 per cent RDF had the highest phosphorous concentration found between 0-15 cm depth as 24.07 kg ha^{-1} between the lateral and 21.37 kg ha^{-1} along the lateral respectively. 23.47 kg of phosphorous ha^{-1} between the lateral and 20.37 kg of phosphorous ha^{-1} along the lateral was observed in 50 per cent RDF at the end of final fertigation.

4.1.4.3. Potassium in soil

a) After second fertigation

Potassium dynamics after end of second fertigation between the lateral and along the lateral for depths from 0-45 cm are given below. Potassium concentration was highest with 100 per cent RDF at 0-15 cm depth between lateral as 376 kg ha^{-1} and along lateral as 371 kg ha^{-1} respectively.

b) After final fertigation

Potassium dynamics after end of final fertigation between the lateral and along the lateral for depths from 0-45 cm are given below. Potassium concentration was highest with 100 per cent RDF at 0-15 cm depth as 428 kg ha^{-1} between the lateral and 426 kg ha^{-1} along the lateral. In 75 per cent RDF higher potassium concentration was found between 0-15 cm depth as 420 kg ha^{-1} between the lateral and 411 kg ha^{-1} along the lateral. The same trend was observed in 50 per cent RDF as 410 kg ha^{-1} between the lateral and 391 kg ha^{-1} along the lateral at the end of final fertigation.

4.1.5. Economics

The data on the economics of fertigation through drip irrigation for jasmine are presented in Tables from 4.40a to 4.40c.

The life span of drip system varies from 10 to 15 years depending upon quality and maintenance of the drip system. Hence a normal life span of 10 years was considered here for computation. Though the initial capital investment for drip irrigation systems is higher, the cumulative benefit would be greater, considering the longer life of the system. Cost of cultivation in drip and surface irrigation was worked out for various treatments. The fixed cost towards installation of drip system was worked out to be Rs. 71,000/- ha^{-1} (including Rs. 5,000/- for mulch) taking into account the prevailing rates (Appendix IV and V).

Drip irrigation with 15 litres of water per day recorded the highest seasonal net income and it was followed by drip irrigation with 10 litres of water per day. Surface irrigation recorded higher net seasonal income compared to drip irrigation with 5 litres of water per day. With respect to 100 per cent RDF, irrigation scheduled with 15 LPD through drip recorded the highest seasonal net income of Rs. 2,59,866/- closely followed by irrigation by10 LPD producing a seasonal net income of Rs. 2,57,886/- With regard to fertilizer application, there was significant difference between each increment, as such application of 100 per cent RDF is considered to be better in realizing the higher seasonal net income. The lowest level of 5 LPD and 50 per cent RDF recorded the lowest seasonal net income of Rs. 1,33,020/-.

The seasonal benefit cost ratio for various treatments was computed and the results revealed that drip fertigation with 15 LPD and 100 per cent RDF with mulch recorded the highest cost benefit ratio of 1:3.70. This was closely followed by drip irrigation with 10 LPD recording a ratio of 1:3.69. With regard to fertigation levels application of 100 per cent RDF registered the highest BCR under all the levels of irrigation regimes. The ratio recorded under 15 and 10 litres of water per day was closely comparable by surface irrigation. Here again lower moisture level of 5 litres of water per day had lower level of BCR of 2.21:1. Similar trend was observed under the remaining RDF treatments *viz*., namely 75 and 50 per cent under all levels of drip irrigation.

With respect to marginal benefit cost ratio (MBCR) which was computed for all levels of drip irrigation taking the base value as zero in surface irrigation, it was clear from the data that the MBCR values for drip irrigation with 15 and 10 litres of water per day gave almost similar value indicating the comparable nature in the production of MBCR.

4.2. Work at The Hebrew University of Jerusalem, Israel

4.2.1. Transpirational water loss measurement through load cells weighing lysimeter

The rate of water loss for every three seconds by *Jasminum grandiflorum* from seedling to flowering (270 days after planting) was measured and represented in Figures 16 to 23.

a) At seedling stage

The jasmine seedlings (45 days after planting) were measured for transpirational loss of water and compared with PAN. The uptake rate was very low at this stage i.e., 12 $ghr^{-1}m^{-2}$ and the momentary rate of uptake was higher at 10.00 hrs when compared with control (PAN) at ambient condition.

The seedlings after 60 days of planting were analyzed for water uptake rate and transpirational loss of water. Here also the same pattern as above was observed but uptake rate was higher (16 $ghr^{-1}m^{-2}$) and the momentary rate was maximum at 13.00 hrs, whereas the control (PAN) recorded as 40 $g/hr/m^{-2}$.

At 75 DAP, the rate of water uptake and transpirational loss of water increased to 26 $ghr^{-1}m^{-2}$ and the momentary rate was maximum at 13:00 hrs, the control (PAN) recorded as 30 $ghr^{-1}m^{-2}$.

b) At vegetative stage

The seedlings after 150 days after planting developed a bushy stature and during this stage the rate of water uptake and loss of water through transpiration was higher as (47 $ghr^{-1}m^{-2}$) at 12:00 hrs and the PAN recorded the peak as 31 $ghr^{-1}m^{-2}$ at 14:00 hrs.

c) At early vegetative stage (180 DAP)

Here the growth of the plants was faster and also the rate of water uptake was more (69 $ghr^{-1}m^{-2}$) at 12:00 hrs. The control (PAN) recorded the water loss rate of 31 $ghr^{-1}m^{-2}$ at 14:00 hrs.

d) Late vegetative stage (210 DAP)

The rate of water loss at this stage was 92 $ghr^{-1}m^{-2}$ at 12:00 hrs and the PAN recorded the maximum as 32 $ghr^{-1}m^{-2}$ at 12:00 hrs.

e) At pre flowering stage (240 DAP)

The plants started to consume a huge amount of water after 240 days after planting to flowering stage. The rate of water uptake was maximum (134 $ghr^{-1}m^{-2}$) at 12:00 hrs as by the jasmine plant and the control (PAN) recorded the maximum as 48 $ghr^{-1}m^{-2}$ at 12:15 hrs.

f) At flowering stage (270 DAP)

Flower initiation occurred 270 Days after planting. More interestingly the plants while started to bear flowers it reduces itself the uptake of water. The rate of water uptake was 110 $ghr^{-1}m\text{-}^{2}$ at 11:40 hrs. The control (PAN) registered the water uptake and more water loss as 32 $ghr^{-1}m^{-2}$ at 13:00 hrs.

4.2.2. **Water stress studies**

The data pertaining to water stress studies in jasmine are presented in Table 4.39.

Through normal irrigation, jasmine plants at peak vegetative phase transpired a huge amount of water (10788.5 $g/day/m^2$ ±1391.49 (3)) and the leaf transpiration rate was

7.02 mmho/s/m^2 ± 0.84 (9), 9.23 mmol/s/m2 ± 0.39 (9) of with the actual transpiration area of 56108.27 (m^2/m^2) ± 1953.14, N=8 from both adaxial and abaxial stomata respectively. At normal irrigation condition the relative water content of jasmine was 90.74 % ± 1.32 (6).

At the first day of withholding irrigation, jasmine plants showed a water loss of 10313.74 g/day/m^2 ± 2218.99* (3) and a leaf transpiration rate of 7.05 mmol/s/m^2 ± 0.81 (9), 8.88 mmol/s/m^2 ± 0.31 (9) of with the actual transpiration area of 56108.27 (m^2/m^2) ± 1953.14, N=8 from both adaxial and abaxial stomata respectively. On first day of drought stress condition the relative water content of jasmine was 86.35 % ± 5.1 (6).

After the first day of withholding irrigation, jasmine plants showed a transpirational water loss as 7542.59 g/day/m^2 ± 3277.78 (3)and a leaf transpiration rate 6.6 mmol/s/m^2 ± 0.55 (9), 8.61 mmol/s/m2 ± 6.22*(9)of with the actual transpiration area of 56108.27 (m^2/m^2) ± 1953.14, N=8 from both adaxial and abaxial stomata respectively. On the second day of drought stress condition the relative water content of jasmine was 78.15 % ± 7.66 (6).

After the second day of withholding irrigation, jasmine plants showed a water loss as 5487.84 g/day/m^2 ± 2604.54(3)and a leaf transpiration rate 6.47 mmol/s/m2 ± 0.56 (9), 8.1 mmol/s/m2 ± 0.21* (9)of with a actual transpiration area of 56108.27 (m^2/m^2) ± 1953.14, N=8 from both adaxial and abaxial stomata respectively. On the third day of drought stress condition the relative water content of jasmine was 67.95% ± 6.3(6).

After the third day of withholding irrigation, jasmine plants showed a water loss as 5054.83 g/day/m^2 ± 2540.67(3)and a leaf transpiration rate 6.35 mmol/s/m^2 ± 0.58 (9), 7.66 mmol/s/m^2 ± 0.17* (9)of with a actual transpiration area of 56108.27 (m^2/m^2) ± 1953.14, N=8 from both adaxial and abaxial stomata respectively. On the fourth day of drought stress condition the relative water content of jasmine was 64.60 % ± 3.12(6).

After the fourth day of withholding irrigation, jasmine plants showed a water loss as 2918.70 g/day/m^2 ± 1437.62(3) and a leaf transpiration rate 6.17 mmol/s/m^2 ± 0.51 (9), 7.4 mmol/s/m^2 ± 0.19* (9) of with a actual transpiration area of 56108.27 (m^2/m^2) ±

1953.14, N=8 from both adaxial and abaxial stomata respectively. On the fifth day of drought stress condition the relative water content of jasmine was 61.58% ± 5.88(6).

After the fifth day of withholding irrigation, jasmine plants showed a water loss as 1521.66 g/day/m^2 ± 679.90 (3)and a leaf transpiration rate 6.03 mmol/s/m^2 ± 0.5(9), 6.65 mmol/s/m^2 ± 0.16 *(9)of with the actual transpiration area of 56108.27 (m^2/m^2) ± 1953.14, N=8 from both adaxial and abaxial stomata respectively. On the sixth day of drought stress condition the relative water content of jasmine was 58.25% ± 8.2(6).

On the day of recovery from drought stress, jasmine plants showed a water loss as 4655.61 g/day/m^2 ± 1807.91(3)and a leaf transpiration rate 6.22 mmol/s/m^2 ± 0.44 (9), 6.8 mmol/s/m^2 ± 0.11*(9) of with a actual transpiration area of 56108.27 (m^2/m^2) ±1953.14, N=8 from both adaxial and abaxial stomata respectively. On recovery from drought stress condition the relative water content of jasmine was 91.32 % ± 1.32(6).

4.2.3. Aquaporin genes

The DNA extracted from different plant samples of *Jasminum grandiflorum* for the quantification analysis was more positive. The bandwidth lies between 100 to 150 base pairs (bp) with reference to ladder. This confirms the occurance of aquaporin genes within this band width (Fig.24).

CHAPTER V

DISCUSSION

The results of the field experiments conducted at the Horticultural College and Research Institute of Tamil Nadu Agricultural University, Coimbatore and the Hebrew University of Jerusalem, Israel during 2005 to 2007, to standardize irrigation and fertigation techniques in jasmine (*Jasminum grandiflorum*) are discussed in this chapter.

With availability of irrigation water dwindling day-by-day, it has become necessary to resort to alternate water saving methods like drip irrigation which provides continuous supply of water in drops right at the root zone of the plant. The scarcity of water is becoming more acute due to erratic and improper distribution of rainfall and faulty water management practices (Bafna *et al.*, 1993).

Jasmine (*Jasminum grandiflorum*) is an important commercial flower crop grown in South India. Although, *Jasminum grandiflorum* is a crop of tropics, if the temperature goes beyond certain limit, it becomes detrimental to flower production. Very high temperatures limit or prevent field production of jasmine flowers during summer in many regions of India and parts of the world and can depress yield because of flower drop. High day and night temperatures interfere with jasmine flower set (Berry and Uddin, 1988). Incorporating genetic resistance to offset the detrimental effects of high temperature on jasmine flower production has not yielded considerable success. Hence cultural methods are needed to supply jasmine flowers to the existing market windows during off-season. Also jasmine requires a balanced fertilizer management for the normal growth and development. It is a heavy feeder of nutrients and high yield can be sustained only through the application of nutrients at optimum doses in balanced proportion. The major nutrients not only improve yields but also benefit various aspects of quality. In order to economize water and fertilizer, both have to be combined at the right proportion and applied to the crop.

Fertigation which involves the application of fertilizers through drip irrigation has gained popularity recently in developed countries and it has proved beneficial with respect to efficient and uniform application of both water and fertilizers with minimum labour input.

Drip irrigation and fertigation have resulted in great success in a wide range of horticultural crops. In *Jasminum grandiflorum* fertilizer and water management play a vital role in determining the yield and quality of flowers since it readily responds to optimum application of water (Hegde and Srinivas, 1989). Fertigation is fairly a new technology of distributing fertilizers to the crops along with irrigation water through drip system on a continuous basis. Fertigation increases the nutrient use efficiency by minimizing leaching losses. Thus it is possible to modernize farming by adopting fertigation practices not only to make monetary gain but also to provide ecological safety and avoid pollution of ground water resources.

To utilize the full potential of the drip irrigation and fertigation technology in *Jasminum grandiflorum*, understanding the influence of micro environment on its growth and rational utilization of available water resources and fertilizers by adopting modern management technologies become inevitable. With the above background, the present investigation was designed to determine whether fertigation could increase yields and the extent of jasmine production during summer and winter seasons. Mulching which is also a proven technique of water conservation was also included in the present study. The effects of different treatment combinations were assessed and conclusions drawn based on wide range of observations.

5.1. Work at Tamil Nadu Agricultural University, Coimbatore, India

5.1.1. Impact of the experiments on growth influencing factors

5.1.1.1. Moisture distribution pattern

Soil water content just below the dripper, (*i.e*., 0 cm away from the dripper) was more to field capacity (~23.9) (Figs. 2to 5). Soil moisture at 45 cm away from the dripper was lesser than that at 0, 15 and 30 cm at all soil depths. The soil water content was less in treatments that received lesser amount of water. In the treatment involving 15 LPD the soil moisture content in the root zone was always nearer to 80 per cent. In 10 LPD the soil moisture content was less than 80 % and in 5 LPD it was nearly 50%. This was in conformity with the findings of Rajput *et al*., (2005) in onion.

Thus in the present study, moisture content decreased as the distance increased from the emitting point. Further the soil moisture distribution mainly depended on the rate of application, amount of water and initial moisture content of the soil as already reported by Khepar *et al.* (1983).

In surface irrigation, the interval between the two successive irrigations was higher due to which the available soil moisture content varied from the field capacity (at the time of irrigation) to stress condition (just before consecutive irrigation). These two extremes of moisture availability cause poor physiological activity of the crop, ultimately reflecting on the growth, as already reported by many earlier workers *viz.*, Sivanappan *et al.* (1972), Sivanappan and Padmakumari (1980), Gajare (1982), Selvaraj (1997), and Chakraborty *et al.* (1998)

5.1.1.2. Soil temperature

The experimental field laid under black polythene mulch with 50 micron thickness and plots without mulch were tested for the soil temperature in order to check the ambient nature of rhizosphere for better crop growth and weed suppression. In general the plots laid with mulch showed ambient soil temperature (36 to 40 ^{o} C) for the activity of microbes leading to enhanced mobility of the applied nutrients.

5.1.1.3. Nutrient dynamics in soil

Nitrogen dynamics

Plant nutrient availability in the soil is very important for achieving higher production. The applied nutrients at any stage of application should properly reflect in terms of available nutrient in the soil, so that the plants could absorb these nutrients without hindrance.

In the present study the mobility of nutrients was well pronounced under drip fertigation system. In all the drip irrigation levels, the nitrogen concentration in the soil increased from the emitter upto certain depth and declined thereafter. The nitrogen concentration in upper soil layer (0-15 cm) was lower than bottom layer (15-30cm) under all the fertigation levels and at all the distances from the emitting pointing (Figs.6 to 9). The peak nitrogen concentration was recorded in the layer of 15-30 cm depth and at a distance of 30 cm from the dripper.

The nitrate ion being mobile has a tendency to move away from the emitter to the periphery of the waterfront (Haynes, 1990). Data from the present experiment on the distribution of NO_3-N (Tables 4.33 and 4.34) in the soil profile has shown that it neither accumulates at the periphery of the wetting front nor is leached from the root zone under drip system. These are in accordance with the findings of Chakraborty *et al*. (1999). Under this circumstance, paired row system of planting with one drip line in the middle of the rows is more advantageous as already observed by Shramiladevi (2005).

Phosphorus dynamics

In the present study, a spectacular movement of phosphorus in the soil was found under all the drip fertigation levels. Unlike nitrogen, the higher concentration of phosphorus was seen at 0 – 15 cm soil layer than the 15 – 30 cm layer at all the distances from the dripper (Figs.10 to 13). The phosphorus concentration decreased with increase in depth from the dripper. The restricted mobility of phosphorus might be due to its strong retention by soil colloids and clay minerals as already reported by Sureshkumar (2000). Higher availability of phosphorus was noticed under the treatment receiving 100 per cent recommended dose of fertilizer and decreased with decreased level of fertilizer dose.

Potassium dynamics

Distribution of K varied both vertically and horizontally from the emitting point. Before the fertigation, the initial K indicated the decreasing trend with respect to the depth. However, with respect to horizontal distance from emitter before fertigation the K concentration was found to be fairly uniform. After the end of fertigation cycle the highest K concentration was found in 0-15 cm soil depth and lower concentration was found in the lower layers *i.e.*, 30 – 45 cm depth. The peak quantity of K was observed in the 0 – 15 cm depth of emitter (Figs. 14 and 15).This falls in line with the findings of Singh *et al*. (2002) in mandarine orange.

5.1.1.4. Root distribution pattern

Root morphology comprises number of primary and secondary roots and length of primary and secondary roots. Apart from plant genetics and other environmental factors like soil aeration and soil hardness, the root pattern is also determined by the irrigation pattern, nutrient distribution and uptake.

In the present experiments with drip irrigation, nearly 80 per cent of the roots were concentrated at upper soil profile (15 to 30 cm) with less tap root length because of the lesser depth of irrigation and continuous availability of moisture in that layer. This is in agreement with the earlier findings of Goldberg and Shmueli (1971).Under surface irrigation, the plants produced fewer secondary roots of lesser length and density but with longer tap roots. The production of lengthier roots clearly indicates that the plant has tried hard to extract water from deeper layers to meet its water requirement. Under water stress condition, as a result of longer interval between successive surface irrigations, the root length had increased but the root biomass decreased. Drip irrigation at 10 LPD and 15 LPD under mulch had produced longer roots with more primary and secondary roots on either side, whereas in drip irrigation at lower level (5LPD) the root spread was towards the direction of dripper located at the centre of two plants and the root growth was limited due to lower wetting, as earlier observed by Martinz Hernandez *et al*. (1991).

Drip fertigation with 100 per cent RDF and 75 percent RDF with mulch had produced higher root length than 50 per cent of fertigation level since higher availability of nutrients might have induced more root growth, hence, higher root volume. This showed the positive response of jasmine in producing longer roots under favourable nutrient status, as already reported by Leskovar *et al*. (1989).

Further, application of P at the active root zone might have encouraged better root growth as already observed by Besford (1979), Pandey *et al*. (1996) and Bieleski and Rao (1986).

5.1.1.5. Leaf nutrient status

The least leaf nitrogen and phosphorous content was found in surface irrigation treatment (Control). This might be due to leaching of fertilizers unlike in fertigation through drip irrigation.

In fertigation, application of 100 per cent of recommended dose of fertilizers registered the maximum plant nitrogen and phosphorous content. There was no interaction effect between irrigation and fertigation. Earlier this was reported by Parikh *et al.,* (1994) that the nitrogen content in banana finger was found significantly higher in all fertigation treatments when compared to surface irrigation treatments.

The least leaf potassium content was noticed in surface irrigation treatment (T_1). This may be due to band placement of fertilizers and flooding of irrigation water, which led to leaching. Among fertigation levels, 100 per cent of recommended fertilizers registered maximum leaf potassium content. This was coincided with findings of Shankar *et al.* (1995).

5.1.2. Impact of the experiments on growth, yield and quality parameters

5.1.2.1. Morphological parameters

The influences of drip fertigation with mulch in comparison with surface irrigation on the growth parameters were recorded and the results are discussed here under. Growth and development in plants are a consequence of excellent coordination of several processes operating at different stages of plant. In the present study the growth of jasmine, as influenced by the various treatments, has been elucidated through plant height, number of primary, secondary branches and roots, primary and secondary root length, foliar nitrogen, phosphorous and potassium content.

The growth of jasmine in terms of plant height showed a linear trend during different stages and it significantly increased by the application of 75 per cent recommended dose of fertilizer under mulch with the application of drip irrigation at 10 LPD. Higher plant height at 10 LPD might be due to the fact that frequent irrigations maintained most of the root zone at well aerated condition and at adequate soil moisture content there were no fluctuations between wet and dry extremes (Patil and Janawade, 1999). The luxuriant growth of the plant might also be attributed to the optimum heat units and water conservation by the mulch. Lesser plant height in drip irrigation at 5 LPD might be due to more moisture stress on plant.

The least plant height during summer season may be due to the prevalence of high temperature coinciding with the early stage of crop growth, which might have forced the plants to enter into reproductive phase early. Reduction in plant height under open condition might be due to higher respiration and transpiration rates, which could have exhausted the plants of both water and carbohydrates. It could have also been probably by decreased levels of auxin through destruction by light intensity. Rao and Sree Vijayapadma (1991) and Kadam *et al.* (1991) also found that heat stress induced significant reduction in plant height at all stages of crop growth compared to non-stressed plants.

On sufficient supply of nutrients (75 per cent RDF), the production of IAA might have increased which consequently would have showed stimulatory action in terms of cell elongation, thus resulting in increased plant height. Pafli (1965) suggested that nitrogen, being the chief constituent of chlorophyll, protein and amino acids, is accelerated through increased supply of nitrogen to the plants at appropriate time.

Higher frequency of irrigation and increased soil moisture under drip method of irrigation might have led to effective absorption and utilization of nutrients resulting in quick growth as observed by Sushama *et al.* (1982) and Nayar *et al.* (1986) in cassava by Jayachandran (1994) in sorghum.

Reduced irrigation level resulting in water deficit might manifest many changes in plant anatomy such as decrease in size of cells and inter cellular spaces limiting cell division and elongation resulting in overall decrease in plant growth (May and Milthrope, 1962).

Number of primary and secondary branches were less under lower fertigation dose and ultimately resulted in reduced leaf area further leading to poor yield. Better availability of nutrient in the higher fertigation would have helped better protein synthesis resulting in production of more branched plants with large leaf area as already observed by Neary *et al*. (1995). Sufficient supply of irrigation and nutrients increased the leaf area which is the main consequent for the photosynthates that in turn influenced the yield.

Unlike surface irrigation and conventional fertilization, frequent application of nutrients in small doses under drip fertigation resulted in lesser nutrient losses. Each plant under drip fertigation received a regular and equal share of both water and nutrients supplied directly to the root zone. The results are in line with the findings of Bachchhav (1995) and Asokaraja (1997). In case of surface irrigation, highly fluctuating moisture regimes resulted in stress to the crop and due to the excess irrigation, nutrients might have been leached away from the root zone as enlightened by Paul *et al*. (1996).

5.1.2.2. Flowering and yield parameters

The present study revealed that lower level of water and fertilizers prolonged the first flowering compared to optimal water and nutrient with mulch condition. This might be due to increased vegetative growth induced by poor availability of moisture and nutrients in soil. Consequently, the number of days to first flowering was also increased. These results are in accordance with Romano and Leonardi (1994). Early flowering in fertigated field than under surface irrigated condition. This might be due to prevalence of comparatively higher temperature under mulch condition. Late flowering under surface irrigated condition and without mulch may be due to low solar radiation absorption by plant as interfered by shade by plants itself. Sagi *et al.* (1979) also obtained hastened flowering at high solar radiation. Under fertigated and mulch condition, due to high temperature the plants readily enter into the reproductive phase, which is an induced response of the plant.

Application of 100 per cent recommended dose of fertilizer recorded early flowering than with 15 LPD and mulch. This might be due to availability of nutrients in the root zone throughout the crop growth period. This is in line with the findings of Jaworski (1978), Keng *et al.* (1981) and Takahashi *et al.* (1993).

Increased number of flowers per branch noticed under optimal water and nutrient i.e., 10 LPD with 75 percent RDF and mulch may be because of the prevalence of favourable conditions required for flowering under mulch. The number of flowers per branch was lower under open condition possibly due to depletion of carbohydrate by increased respiration at higher temperature. These findings are in accordance with the results of Suchindra (2002). Reduction in number of flowers might also be due to increased photorespiration during high light intensity, high temperature and long photoperiod, thereby allowing poor availability of metabolites to the reproductive parts under surface irrigated field.

Generally flowering is increased with increased levels of fertigation mainly due to early vigour shown by the crop. This could be attributed to the availability of optimum plant nutrients along with sufficient soil moisture for early development of plant parts and root system, which might have enhanced more uptake of nutrients. Availability of nutrients to roots at right stage would have enhanced synthesis of hormones such as cytokinin. Further better uptake of potassium by fertigation treatment would have helped transport of cytokinin and metabolites towards the sink.

This is in accordance with the findings of Prabhakar *et al*. (2001) and Meenakshi and Vadivel (2003). Drip irrigation and fertilizer levels positively influenced the yield of jasmine. Tumbare and Nikam (2004) also pointed out that fertigation of RDF at every irrigation upto 70 days resulted in significantly higher yield of flower buds.

Higher yield was recorded under drip irrigation (15 LPD) and 100 per cent recommended dose of fertilizers with mulch compared to other drip irrigations, fertilizer doses and surface irrigation under non mulched condition. Yield was increased with increase in drip irrigation levels and fertilizer levels with mulch, during peak flowering season, however it was on par with 75 per cent recommended dose of fertilizers with 10 LPD under mulch. Therefore drip irrigation at a schedule of 10 LPD and 75 per cent RDF with mulch is found sufficient for realizing the maximum yield. In surface irrigation the yield was very much lesser than the drip irrigation of 10, 15 LPD with 75 and 100 per cent recommended dose of fertilizers.

Application of 100 per cent RDF, 15 LPD with mulch recorded increased yield per hectare. These results are in line with the findings of AICRP (2005) reported that there was no yield reduction in some horticultural crops upto drip irrigation at 40 per cent CPE and yield was increased with increased level of recommended dose of fertilizers.

The increase in yield was due to the improvement of all crop growth and yield attributing characters due to better availability of soil moisture environment and availability of plant nutrients throughout the crop growth period under drip fertigation system. This is in concordance with the findings of many scientists.

Even the same level of fertilizer application though fertigation produced higher flower yield over furrow irrigation. Application of 100 per cent RDF through fertigation produced 51.49 per cent higher yield in drip irrigation at 15 and 10 LPD with mulch over surface irrigation with manual application of RDF. Drip irrigation maintains the soil moisture around the field capacity between two irrigation intervals. On the other hand, surface irrigation has high fluctuation of moisture between field capacity and permanent wilting point. This might have resulted in lower flower yield under surface irrigation. These results collaborate with the findings of Veeranna (2000).

5.1.2.3. Flower quality parameters

Quality parameters such as 100 flowers weight, diameter of flower, length of corolla tube, length of flower stalk, concrete content, distribution of flowers were more under the increased water and fertilizer doses.

These results are in accordance with the findings of Yadav and Bhupender Singh (1991), Locascio and Smajstrala (1995) and Salvadore *et al.* (1997), Prabhakar (1997) also reported that the continuous supply of irrigation water through drip irrigation resulted in increased quality parameters in capsicum and higher yield under protected cultivation using micro irrigation system.

5.1.2.4. Water Use Efficiency

The details of irrigation water applied, for surface irrigation and drip irrigation treatments are depicted in Table 4.32. The amount of water required to meet the demand of evapotranspiration and metabolic activity of jasmine constitute the consumptive use of water including the effective rainfall during the crop growing season. During both the years of study consumptive use of water was higher under surface irrigation compared to drip irrigation.

Saving of irrigation water was found in all drip treatments. Similar findings on water saving by drip irrigation were reported by, Ahluwaalia *et al.* (1993); Bafna *et al.* (1993); Pawar *et al.* (1993) and Ramesh *et al.*, (1994),

Irrigating the crop at 15 LPD through drip irrigation resulted in a net saving of 20.1%, whereas it was 33.0 per cent at 10 LPD, 45.3 at 5 LPD when compared to surface irrigation. However since drip irrigation at 10 LPD was found to influence all the growth and yield characters significantly in both the years, this treatment is superior over the rest of the treatments.

Water use efficiency indicates the effectiveness of the applied water in terms of crop yield per unit quantity of water used. The WUE was higher under drip irrigation compared to surface irrigation, the values being 8.37, 10.35 and 6.90 kg ha^{-1} mm^{-1} in drip irrigation with15, 10 and 5 LPD respectively. Surface irrigation recorded lesser WUE (2.75 kg ha^{-1} mm^{-1}). These results are in conformity with the findings of Bobade (1999) and AICRP (2005) in various horticultural crops.

The water use efficiency increased with increasing level of recommended dose of fertilizer. Application of 100 per cent RDF recorded significantly higher WUE. This might be attributed to effective utilization of fertilizers along with water as reported earlier by Chakraborty *et al*. (1999) and Bobade (1999) and Ramesh (1986) in vegetables.

Similar increase in water use efficiency were reported by Keshavaiah and Kumarasamy (1993); Intrigiliolo *et al.* (1994); Hagin and Lowengart (1995) and Parikh *et al.* (1996). Savings in fertilizers when applied through drip irrigation was reported by Ibrahim (1992); Deshmuk *et al.* (1996) and Parikh *et al.* (1996).

Similar observations have also been reported by Kadam *et al.* (1993) in bhendi who obtained higher water use efficiency in fertigation with 100 per cent N dose. Pawar *et al.* (1993) found that the application of 100 per cent N and P_2O_5 through liquid fertilizer gave higher as well as maximum water use efficiency in drip irrigation system.

5.1.2.5. Fertilizer Use Efficiency

In the present investigations, increased fertilizer use efficiency with the decreasing level of fertilizer dose through drip was observed. The influence of irrigation and fertilizer levels on K and N fertilizer use efficiency are furnished in Tables 4.30 and 4.31.

These observations are in line with those of Parikh *et al.* (1994) who reported that all the drip treatments in banana resulted in higher water expense efficiency (48 to 60 kg. ha^{-1} mm^{-1}, better fertilizer use efficiency 110 to 248 kg ha^{-1} N^{-1}) as compared to surface irrigation and normal fertilizer application technique.

5.1.2.6. Post harvest handling of jasmine

At 5^{o} C refrigerated storage with vacuum packing the flowers showed very less physiological loss of weight, more moisture content, more freshness and long shelf life of 4.6 days but the flowers get shriveled than the flowers with normal packing recorded shelf life of 4.2 days. The results indicated that reduced temperature and maintenance of high relative humidity around the produce improved the quality. The vacuum packed flowers kept longer due to delayed ethylene production.

5.1.2.7. Economics

Drip irrigation with 15 liters per day of water and 100 percent recommended dose of fertilizers with mulch resulted in additional net income compared to surface irrigation with same level of fertilizer dose. In terms of BCR, drip irrigation with 15 liters per day with 100 percent recommended dose of fertilizers with mulch was found economical because of higher yield obtained under drip fertigation.

With respect to 100 per cent RDF, irrigation scheduled with 15 liters per day with mulch recorded higher seasonal net income of Rs. 2,59,866/- and closely followed by irrigation with 10 liters of water per day which produced a seasonal net income of Rs. 2,57,886/- (Tables 4.40a to 4.40c).

Drip fertigation with 15 liters per day with 100 percent RDF under mulch recorded highest benefit cost ratio of 3.70:1. This was on par (3.69:1) with drip irrigation of 10 liters per day and 100 percent RDF under mulch. With regard to fertigation levels applications of 100 percent RDF registered higher BCR under all levels of irrigation regimes. Similar results on cost benefit analysis under drip irrigation and fertigation was reported by Asokaraja (1998) in tomato.

Marginal benefit cost ratio (MBCR) was computed for all levels of drip irrigation taking the base value as zero in surface irrigation. It was clear that from the data that the MBCR values for 15 liters per day and 10 liters per day, gave almost similar value indicating the comparable nature in the production of MBCR. It is due to increased yield over conventional method. This result is accordance with the findings of Sureshkumar (2000). The initial cost of drip system can be recovered from the second crop.

Yield from drip irrigation with 10 liters per day was comparable to that of drip irrigation with 15 liters per day and water use efficiency at 10 LPD was higher than that with 15 LPD. Therefore, the treatment combination of drip irrigation with 10 liters per day with 100 per cent level of RDF with mulch is the best treatment.

Similar observation was made earlier by Moll(1996) who observed that, though the flood irrigation system is considerably cheaper, the low annual operating cost in drip method outweighs its initial expense and makes it the most financially and environmentally attractive system.

5.2. Work at The Hebrew University of Jerusalem, Israel

Major issues related to water and its concordance with water channels inside the plant given in graphs and tables are discussed hereunder.

5.2.1. Water uptake pattern at different phenological growth stages of jasmine

The water requirement increased with progress in growth and development. The transpiration rate increased gradually after planting up to early vegetative stage and upto onset of flowering. (Figs.16 to 23 and Plates 7 and 8).

At ambient atmospheric condition the requirement of water for plant growth and development is optimal and depends on the opening and closing of stomata which determines the actual transpiring area, decided by the sun shine hours, vapour pressure and requirement for different metabolic activities.

The water uptake pattern (oscillations for whole day) in whole plant transpiration (WPT) rate reveals a synchronized physiological process at the whole-plant level. According to Buckley (2005), stomatal control has two obvious, but different, goals: 1) to maximize the amount of carbon gained per unit of water lost, 2) to prevent runaway xylem cavitation by preventing leaf/xylem water potential from crossing respective thresholds values. Furthermore, Buckley (2005) argued that cavitation avoidance is an aspect of the resource constraint rather than a competing goal and in every case when the leaf / xylem potential will reach a critical value, the plant will choose to violate the first goal and prevent cavitation. Combining the observed uptake pattern WPT rate (Figs.16 to 23) with the above rational, we hypothesize that the uptake pattern in WPT rate are the mean that the plant uses to prevent cavitation and further embolism runaway in the xylem by regulating the water-potential.

According to Tardieu and Simonneau (1998) a positive correlation exists between the daily water uptake pattern and variation in xylem water-potential. In an isohydric plant, which maintain nearly constant leaf water potential during the day at a value which does not depend on soil water status, it is expected that the uptake pattern in WPT rate will initiate when xylem water potential reaches a critical value at which cavitation may be initiated, the total crop water potential (Ψ_{cr}). Indeed, the jasmine (considered as isohydric plant) had low uptake pattern in WPT rate during the early morning hours when leaf-water potential is low. Nevertheless, at subsequent hours, when xylem potential and atmospheric demand increased and presumably the xylem tension as well, uptake pattern had initiated and persisted throughout the noon and late afternoon hours (Figs.16 to 23), seemingly to keep water potential below the total crop water potential (Ψ_{cr})Supporting information regarding the relation between xylem water potential and fluctuations in leaf transpiration rate (measured as changes in leaf conductance, g_L) is provided by Salleo *et al*., (2000). Nevertheless, Salleo *et al*. assumed that these fluctuations result by variation in the xylem hydraulic conductivity due to the cavitation formation and repair. These fluctuations take place at the vicinity of total crop water potential (Ψ_{cr}).

A root-initiated synchronized long distance signal that simultaneously controls the plant's stomata aperture (Plate.13) becomes active during periods of high transpiration levels. From the chemical signals termed "active" by Buckley (2005), ABA is most likely the leading candidate. Although it is well known that ABA is generated in the root in response to different stresses, recent studies have shown that this is not always the case (Holbrook *et al.*, 2002). Residual concentration of ABA exists on a regular basis in xylem sap even under well irrigated and unstressed conditions (~40 nM in tomato), (Holbrook *et al*., 2002); ~ 25 nM in tobacco, (Davies *et al.*, 2005).

Assuming that hydraulic long-distance signal transduction is controlling the uptake pattern in WPT rate, some issues should be considered: 1) what are the tension *sensors* and where are they located in the plant, 2) what are the transmitted *signals*, 3) what is their *pathway* to the whole plant guard cells, and 4) how does the long-distance signal get *transformed* into a whole-plant synchronized transpiration pattern. The following signal-transduction pathway is hypothesized: the changes in xylem-water potential initiates a hydraulic long distance signal that is transformed to chemical signal at the guard cells. As the xylem is made of dead elements that could not sense, we presume that the tracheid neighboring living cells complexes (xylem parenchyma and / or bundle-sheath cells) are the tension *sensors* that triggers the hydraulic signals. The change in xylem pressure then trigger aquaporins and stretch-activates ion channels located in the plasma membrane of the tracheid surrounding cells. Stretch activated ion channels in the plasma membrane has been known in animals, bacteria and plants Falke *et al*. (1988); Sorgato *et al*. (1989); Garrill *et al*. (1994); Qi *et al*. (2004); Aquaporin tension-induced gating in plants plant were measured by (Wan *et al*., 2004; Ye *et al*., 2004) in maize roots and Chara, respectively. An instantaneous gating of aquaporin in response to a specific tension value (that can be considered as a Ψ_{cr}) releases water pulse to the xylem. This instantaneous water release causes a sharp pressure change (impulse) that spreads throughout the xylem all the way to the guard cells (long-distance hydraulic signal). The pressure pulse in the xylem reaches the guard cells through the shortest pathway; namely, shoot petiole leaf xylem, bundle sheath and epidermis. The existence of such liquid continuum, that enables a fast pressure-pulse advance, was suggested for several angiosperms by Zwieniecki (2007). Supportive evidence to the existence of a coupled pressure pulse and ion-induced current in the xylem sap were reported by Wegner and Zimmermann (1998). The mechanisms associated with the transformation of hydraulic signals into chemical signals in the guard cells that control the stomata dynamics are very complex and to the best of our knowledge. As the plant's vascular tissue is tightly surrounded by living cells, which most likely to contain the tension sensing sites, the resulting hydraulic signal can be initiated at different locations along this tissue. Thus, the spatial extent of the oscillatory transpiration, namely, leaf patches, whole leaf, and whole plant depends on the location where the hydraulic signal transmitted forms and its intensity. For example, if the hydraulic signal initiates along the vein edge tracheids, it will reach the nearby group of guard cells that will oscillate simultaneously, namely, patchy oscillations. However, if the signal initiates at the leaf petiole, the whole-leaf guard cells will oscillate simultaneously, and so forth. The hydraulic-signal intensity is presumed to depend on the living cells density, which is expected to be correlated with the vessel diameter, namely, vascular-initiated hydraulic signals will be stronger than the single-tracheid initiated signal. Consequently, the spatial distribution of the sensing spots along the plant vascular tissue generates a hierarchy determined by the number of controlled (simultaneously oscillating) guard cells.

Water uptake pattern in whole plant transpiration (WPT) with wave length of 20 to 50 minutes were measured for jasmine (*Jasminum grandiflorum*). These uptake pattern are triggered by a central hydraulic signal that spreads through the xylem system. The role of these oscillations is to prevent cavitation rather than being formed by cavitation – cavitation prevention theory. If cavitation would have been formed during the periods of high transpiration rates, as has been widely suggested, this high transpiration rate could not be reached due to the decrease of hydraulic conductivity. This suggested hydraulic signal formation and propagation provides a clue regarding the role of aquaporins in fast change of the xylem-surrounding-cells water permeability.

Behaviour of the plants during drought is depicted in Table 4.39 and Fig. 25.The data indicated that the amount of water required by jasmine is 10.1 liters per day, thus confirming the result obtained from the experiments carried out at The Hebrew University of Jerusalem, Israel.

5.3. Aquaporins

Since the aquaporin genes are the gatting tools for water for the entire function of the plant through cell membranes. The DNA was extracted for jasmine, maize, chick pea and tomato for quantification of DNA by comparison with standard ladder (Fig.24).

From the research work taken up at TNAU, India and The Hebrew University of Jerusalem, Israel, the exact water requirement for *Jasminum grandiflorum* at each phenological stage was quantified. It was observed that *Jasminum grandiflorum* at the late vegetative and early flowering stage requires 10 liters per day. Since *Jasminum grandiflorum* is an isohydric plant, the plant behaviour is same with the withdrawl of irrigation water until its water potential reaches below average.

From the DNA studies, it could be observed that the DNA band width lies between 100 to 150 bp (base pairs), revealing the high chances of availability of aquaporin genes in the plant membranes.

Hence drip irrigation with 10 litres of water per day with 75 per cent of recommended dose of fertilizers with much showed beneficial growth parameters and maximum yield with high benefit cost ratio of 3.69:1.

CHAPTER VI

SUMMARY

Field experiments were conducted at the Botanic Gardens, TNAU, Coimbatore to evaluate the performance of drip fertigation on growth, yield and water use in jasmine.

Subsequently greenhouse experiments for water use efficiency and identification of aquaporin genes in jasmine were conducted at The Hebrew University of Jerusalem, Israel. The field experiments were conducted during November, 2005 to August ,2006 at TNAU, India in split plot design with irrigation regimes in main plots *viz.,* W_1- Drip irrigation with 5 litres of water per day (LPD), W_2- Drip irrigation with 10 LPD , W_3- Drip irrigation with 15 LPD and fertilizer level in sub plots viz., F_1-50 percent of recommended dose of fertilizers(RDF), F_2- 75 per cent RDF, F_3- 100% RDF and sub plots with black polyethylene mulch as M_1 and without mulch as M_0 with three replications.

From August 2006 to September 2007 the second part of experiment was conducted at The Hebrew University of Jerusalem, Israel to quantify the water amount at different phenological stages with jasmine and control as PAN (submerged wick) and quantification of DNA to check the availability of aquaporin genes.

Jasmine (*Jasminum grandiflorum*) var CO 2 was used as the test variety. Package of practices were carried out as per recommendations. Relevant observations on growth parameters at periodical intervals, yield attributes, yield and quality parameters of jasmine were recorded and economics *viz.,* gross return, net return, B: C ratio and MBC ratio were calculated.

The drip irrigation was scheduled as per the treatment schedule of 5 LPD, 10 LPD and 15 LPD. The nutrients for the treatment schedule as 50, 75 and 100 % recommended dose of fertilizers were scheduled as depicted in Table 5. Entire nitrogen application was spread over a period of 45 to 120 days after pruning with its maximum share during the peak vegetative phase. 60 percent of phosphorous was applied as basal in the beginning and the rest was applied through fertigation. The application of potassium nutrient was scheduled right from 75 to 130 Days after planting (coinciding with flowering phase).

The application of major nutrients, *viz.,* NPK was scheduled as per the time of requirement of jasmine, based on uptake pattern.

The soil moisture content was estimated upto a depth of 30-40 cm at a distance upto 40 cm between lateral and 30 cm along the lateral at 10 cm interval. The soil moisture content was estimated at 24 and 48 hrs after drip irrigation. Soil nutrient dynamics was estimated by analyzing nitrate nitrogen, available phosphorous and potassium. The soil samples were taken at a radial distance (horizontal) of 15, 30, 45 cm and 15 and 30 cm between dripper at a depth of 0-15, 15-30 and 30-40 cm (vertical) from the dripper.

The results obtained from the field experiments are summarized below.

6.1. Summary

In general, growth and yield of *Jasminum grandiflorum* were normal and it gave flower yield of 7.3 tonnes per hectare (under surface method of irrigation with 100 per cent RDF) in 160 days under irrigated condition.

- Drip irrigation with 10 litres of water per day (LPD) and 75 percent of recommended dose of fertilizers (RDF) with black polyethylene mulch recorded highest values for growth and flower quality parameters *viz.,* plant height of 62.64, 72.33, 84.35, 98.08, 117.7, 154.13, 172.73, 196.55 and 216.44 cm, and number of secondary branches of 28,02, 29.03, 30.01, 32.4, 38.04, 39.26, 35.4, 41.01 and 42.4 during December, January , February ,March, April, May , June, July and August months respectively.

- Number and length of primary roots (4.5 and 32.08cm), secondary roots (12.76 and 24.78 cm) were maximum with the application of 10 LPD, 75 per cent RDF with mulch.

- Drip irrigation with 15 LPD, 100 per cent RDF with mulch recorded highest foliar Nitrogen (2.01, 2.59, 2.18 and 1.89 %), Phosphorous (0.26, 0.22, 0.28 and 0.26 %) and Potassium (1.42, 1.41, 1.51 and 1.53 %) content during I, II, III and IV seasons respectively.

- Drip irrigation with 10 LPD, 75 per cent RDF with mulch required least number of days (44.03) for initiation of flower bud and recorded maximum number of flowers per branch (277.27, 344.34, 369.36 and 387.56) during I, II, III and IV seasons respectively.
- Drip irrigation with 15 LPD, 100 per cent RDF with mulch recorded the maximum flower yield of 2531.51 g per plant and 14,437.52 kg per hectare respectively.
- Drip irrigation with 10 LPD, 75 per cent RDF with mulch recored highest 100 flower weight (11.21 and 11.91 gm), flower diameter (3.8 and 3.9 cm), length of corolla tube (2.2 and 2.3 cm), and length of flower stalk (2.6 and 2.7 cm) during the lean and peak flowering seasons respectively.
- The maximum percent of flower distribution for the four flowering seasons were observed with drip irrigation of 10 LPD, 75 per cent RDF with mulch as 5.70, 46.62, 49.40 and 8.20 % respectively.
- Drip irrigation with 15 LPD maintained maximum soil moisture (80%) at 15 – 30 cm depth.
- Highest Nitrogen and Potassium fertilizer use efficiency (48.65 kg ha^{-1} kg of N^{-1}) and (75.74 kg ha^{-1} kg of K^{-1}) were recorded with the application of 15 LPD, 75 per cent RDF with mulch respectively.
- Drip irrigation of 10 LPD with 100 per cent RDF under mulch recoded maximum water use efficiency (WUE) of 10.35 kg ha^{-1} mm^{-1}.
- 100 per cent of RDF recorded the highest Nitrogen concentration at 15-30 cm depth between and along the lateral as 263, 265 kg ha^{-1} and 256, 255 kg ha^{-1} after second and final fertigation respectively.
- Highest Phosphorous was observed at 15-30 cm depth between and along the lateral with 100 per cent RDF as 28.47, 23.87 kg ha^{-1} and 24.50, 21.95 kg ha^{-1} after second and final fertigation respectively.

- Highest Potassium concentration of 376, 371 kg ha^{-1} and 428, 426 kg ha^{-1} were observed at 0-15 cm depth through the application of 100 per cent RDF after second and final fertigation respectively.

- Water uptake studies indicated that after 45, 60, 75, 150, 10, 210, 240 and 270 days of planting the water uptake rate increased from 12, 16, 30, 47, 69, 92 to 134 gm hr^{-1} m^{-2} upto pre flowering stage and at flowering stage the rate of uptake was reduced to 110 gm hr^{-1} m^{-2}.

- Studies n DNA quantification indicated that, *Jasminum grandiflorum* had a band width upto 100 bp (base pairs).

- Treatments with 15 litres of water per day, 100 per cent RDF with black polyethylene mulch showed the highest BCR of 3.70:1.

- The MBCR values for 15 and 10 LPD with 100 per cent RDF under mulch gave almost similar value indicating the comparable nature in the production of MBCR.

6.2. Conclusion

From the above results it is concluded that adoption of drip fertigation in *Jasminum grandiflorum* is a viable proposition for the farmers who aim for greater income benefits from additional investments with less amount of water. Drip fertigation of 10 litres of water per day with 75 per cent recommended dose of fertilizer under mulch would be an ideal practice to achieve greater yield, income and water saving benefits as compared to surface irrigation. This result has been confirmed by the studies on water related issues (transpirational water loss, water uptake rate, progressive water stress and molecular) work taken up at The Hebrew University of Jerusalem, Israel.

6.3. Recommendation

Drip fertigation with 10 litres of water per day with 75 per cent recommended dose of fertilizer(120:240:120 kg of N, P and K per hectare per year) and black polyethylene mulch of 50 micron thickness would be an ideal practice to achieve greater yield, income and water saving benefits as compared to surface irrigation.

Table 4.1. Effect of Irrigation, fertigation and mulching on plant height (cm) of *Jasminum grandiflorum* var CO. 2 (Dec. to Feb.)

		December			January			February		
		Mo	**M1**	M ean	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	48.17	51.38	49.77	58.18	61.32	59.75	67.94	69.39	68.67
	F2	50.73	53.73	52.22	60.75	60.77	60.76	70.19	72.33	71.26
	F3	54.18	56.27	55.23	65.05	65.31	65.18	73.73	75.33	74.55
	Mean	51.03	53.77	52.41	61.33	62.47	61.9	70.62	72.35	71.49
W2	F1	40.96	54.30	47.63	48.23	64.65	56.44	54.39	73.74	64.07
	F2	60.20	62.64	61.42	70.86	72.33	71.75	81.64	84.35	82.99
	F3	60.51	61.49	61.01	70.52	71.62	71.08	79.3	81.34	80.32
	Mean	53.89	59.48	56.69	63.21	69.64	66.42	71.78	79.81	75.79
W3	F1	54.91	55.74	55.33	64.29	66.05	65.17	73.63	75.97	74.8
	F2	57.42	59.30	58.36	67.32	69.43	68.38	77.53	78.23	77.88
	F3	60.92	61.11	60.90	70.66	70.68	70.69	79.52	81.3	80.41
	Mean	57.75	58.64	58.19	67.42	68.72	68.07	76.89	78.5	77.7
	F1	48.12	53.80	50.91	56.90	64.01	60.45	65.32	73.03	69.18
	F2	56.11	58.55	57.33	66.31	67.61	66.96	76.45	78.3	77.38
	F3	58.57	59.55	59.05	68.75	69.20	68.97	77.52	79.33	78.42
	Mean	54.22	57.3	55.76	63.99	66.94	65.46	73.1	76.89	74.99
Control		54.81		54.81	69.41		69.41	73.45		73.45

December

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	1.76032	1.49346	1.2194	2.74946	2.30849	2.11207	2.58674	2.11207
CD	4.8875**	3.05008**	2.49038*	6.44267**	5.70014*	NS	5.2829**	4.31347*

January

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	2.19085	1.89553	1.54769	3.46206	2.89704	2.68068	3.28315	2.68068
CD	6.08286**	3.87124**	3.16085*	8.08844**	7.13302*	NS	6.70518**	5.47476*

February

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	2.53971	2.22505	1.81675	4.04375	3.37654	3.1467	3.85391	3.1467
CD	7.05149**	4.54422**	3.71034*	9.42963**	8.29841*	NS	7.87082**	6.4265*

Table 4.2. Effect of Irrigation, fertigation and mulching on plant height (cm) of *Jasminum grandiflorum* var CO. 2 (Mar. to May)

		March			**April**			**May**		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	82.33	83.41	82.86	102.33	103.66	102.99	127.38	128.69	128.04
	F2	84.20	84.64	84.42	104.66	104.98	104.82	129.82	130.34	130.08
	F3	86.07	86.64	86.36	105.75	106.47	106.11	131.35	132.26	131.8
	Mean	84.19	84.90	84.58	104.25	105.04	104.64	129.54	130.42	129.97
W2	F1	88.21	89.73	88.97	102.51	109.36	105.94	133.95	135.59	134.77
	F2	96.63	98.08	97.37	116.33	117.7	117.01	149.48	154.13	151.81
	F3	94.97	95.21	95.1	114.32	115.6	114.96	135.36	137.43	136.39
	Mean	93.27	94.35	93.81	111.05	114.22	112.64	139.59	142.38	140.99
W3	F1	90.31	90.98	90.65	110.3	111.01	110.65	140.35	142.47	141.41
	F2	92.65	93.56	93.11	112.65	113.3	112.98	146.36	147.35	146.86
	F3	94.90	96.07	95.50	114.32	115.36	114.84	149.26	150.39	149.82
	Mean	92.62	93.54	93.09	112.43	113.22	112.82	145.32	146.74	146.03
	F1	86.94	88.04	87.49	105.05	108.07	106.53	133.89	135.58	134.73
	F2	91.16	92.09	91.63	111.21	111.99	111.6	141.88	143.94	142.91
	F3	91.98	92.64	92.31	111.47	112.47	111.97	138.65	140.02	139.33
	Mean	90.03	90.92	90.48	109.24	110.82	110.82	138.14	139.85	138.99
Control		93.65		93.65	109.88		109.88	141.36		141.36

March

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.53877	0.11832	0.09661	0.56415	0.5516	0.16733	0.20494	0.16733
CD	1.49588**	0.24165**	0.1973*	1.52992**	1.51289*	NS	0.41854**	0.34174*

April

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	1.14521	0.742	0.60584	1.55326	1.36457	1.04934	1.28518	1.04934
CD	3.17966**	1.51538**	1.2373*	3.79214**	3.4925*	NS	2.62471**	2.14307*

May

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.8528	0.24499	0.20003	0.92049	0.88729	0.34646	0.42433	0.34646
CD	2.36779**	0.50033**	0.40852*	2.45999**	2.41389*	NS	0.8666**	0.70758*

Table 4.3. Effect of Irrigation, fertigation and mulching on plant height (cm) of *Jasminum grandiflorum* var CO. 2 (Jun. to Aug.)

		June			**July**			**August**		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	147.71	148.71	148.21	167.73	168.69	168.22	187.41	188.45	187.93
	F2	149.70	151.27	150.49	169.52	171.73	170.63	189.64	191.41	190.53
	F3	151.38	152.48	151.93	172.62	173.05	172.83	192.75	193.41	193.09
	Mean	149.6	150.82	150.21	169.96	171.17	170.56	189.93	191.09	190.51
W2	F1	148.11	155.81	151.96	163.67	178.74	171.21	177.75	199.08	188.42
	F2	169.29	172.73	171.01	189.74	196.55	193.14	209.43	216.44	212.93
	F3	155.48	158.05	156.79	175.84	191.55	176.96	195.42	197.42	196.42
	Mean	157.63	162.2	159.91	176.42	184.45	180.43	194.2	204.31	199.26
W3	F1	160.39	162.72	161.56	180.63	182.54	181.59	200.32	202.56	201.44
	F2	167.06	167.37	167.22	186.73	187.75	187.23	206.76	207.86	207.31
	F3	170.04	170.43	170.23	189.74	192.64	191.2	209.87	211.77	210.83
	Mean	165.83	166.84	166.34	185.7	187.66	186.67	205.65	207.4	206.52
	F1	152.07	155.76	153.91	170.68	176.67	173.67	188.51	196.7	192.59
	F2	162.02	163.79	162.9	181.99	185.34	183.67	201.94	205.23	203.59
	F3	158.99	160.39	159.64	179.86	181.25	180.32	199.35	200.89	200.11
	Mean	157.68	159.95	158.82	177.36	181.08	179.22	196.59	200.93	198.76
Control		168.88		168.88	178.65		178.65	205.15		205.15

June

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	1.23421	0.718	0.58625	1.59822	1.42786	1.01541	1.24361	1.01541
CD	3.42676**	1.46637**	1.19729*	3.96381**	3.69937*	NS	2.53983**	2.07376*

	W	F	M	WxF	WxM	FxM	FxW	MxW
	July							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	2.01644	1.5695	1.28149	2.99878	2.55526	2.2196	2.71845	2.2196
CD	5.59862**	3.20538**	2.61718*	7.11988**	6.38687*	NS	5.55188**	4.53309*
	August							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	2.73578	2.34452	1.91429	4.29861	3.60296	3.31565	4.06083	3.31565
CD	7.59588**	4.78821**	3.90956*	10.05738**	3.31565*	NS	8.29342**	6.77155*

Table 4.4. Effect of Irrigation, fertigation and mulching on number of primary branches of *Jasminum grandiflorum* var CO. 2

		Lean Season			Peak Season		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	3.10	3.16	3.30	5.11	6.12	5.5
	F2	4.13	4.01	4.10	8.32	8.44	8.31
	F3	5.01	6.11	5.50	8.14	9.12	8.51
	Mean	4.11	4.33	4.17	7.28	7.66	7.34
W2	F1	4.21	5.09	4.50	6.23	8.34	7.43
	F2	7.24	8.22	4.50	10.11	11.32	10.51
	F3	7.42	7.40	7.00	10.56	10.12	10.21
	Mean	6.31	6.66	6.17	8.66	9.66	9.18
W3	F1	6.16	6.20	6.00	6.12	7.21	6.55
	F2	7.21	7.33	7.50	11.31	12.14	11.5
	F3	7.31	7.33	7.50	11.24	12.14	11.5
	Mean	6.66	7.03	6.67	9.33	10.33	9.50
	F1	4.13	5.10	4.84	6.33	6.38	6.33
	F2	5.11	7.02	5.50	9.67	10.34	10.00
	F3	5.31	6.42	6.67	9.69	10.14	9.68
	Mean	5.67	5.68	5.68	8.56	8.78	8.68
Control		6.11		6.11	7.64		7.64

	Lean Season							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.28241	0.2738	0.22356	0.47926	0.39335	0.38722	0.47424	0.38722
CD	0.7841**	0.55919**	0.45657*	1.10097**	0.9522*	NS	0.96854**	0.79081*
	Peak Season							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.27355	0.31338	0.25588	0.52081	0.41598	0.44319	0.54279	0.44319
CD	0.75951**	0.64002**	0.52257*	1.16915**	0.98163**	NS	1.10855**	0.90513*

Table 4.5. Effect of Irrigation, fertigation and mulching on number of secondary branches of *Jasminum grandiflorum* var CO. 2

		December			January			February		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	14.02	16.2	15.02	15.16	15.78	15.01	16.02	17.11	16.51
	F2	16.02	18.56	17.02	16.02	19.54	17.52	18.17	20.02	19.02
	F3	17.03	19.67	18.12	18.16	20.16	19.02	19.44	22.03	20.51
	Mean	15.68	17.86	16.68	16.35	18.01	17.18	17.69	19.54	18.68
W2	F1	15.11	18.16	16.57	17.96	19.01	18.49	18.67	20.03	19.34
	F2	25.06	28.02	26.53	27.03	29.03	28.03	29.03	30.01	29.53
	F3	25.03	24.98	24.53	27.02	28.89	26.53	29.03	28.03	28.83
	Mean	21.72	23.35	22.54	24.01	24.69	24.35	25.57	26.02	25.8
W3	F1	19.67	20.87	19.52	20.08	21.22	20.52	22.02	23.06	22.52
	F2	22.02	25.26	23.51	23.02	26.56	24.58	24.23	28.12	26.02
	F3	24.33	26.24	25.15	26.01	27.03	26.35	28.03	29.03	28.23
	Mean	21.69	23.7	22.69	23.22	24.69	23.86	24.69	26.71	25.69
	F1	16.05	18.01	17.03	17.66	18.35	18.01	18.9	20.02	19.46
	F2	21.23	23.63	22.35	22.02	24.71	23.36	23.69	26.02	24.85
	F3	22.25	23.02	22.52	23.69	24.36	24.02	25.35	26.35	25.86
	Mean	19.7	21.58	20.64	21.13	22.47	21.8	22.65	24.13	23.39
Control		14.01			14.63			15.22		

	December							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.43065	0.13075	0.10675	0.46866	0.45006	0.1849	0.22646	0.1849
CD	1.19568	0.26702	0.21802	1.24768	0.1849	0.37763	0.4625	0.37763
	January							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.62385	0.26207	0.21398	0.72564	0.67666	0.37062	0.45392	0.37062
CD	1.7321	0.53523	0.43701	1.87574	1.80421	0.75693	0.92704	0.75693
	February							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.65796	0.29492	0.2408	0.77902	0.72103	0.41708	0.51081	0.41708
CD	1.82683	0.60231	0.49178	1.9989	1.91338	0.85179	1.04323	0.85179

Table 4.6. Effect of Irrigation, fertigation and mulching on number of secondary branches of *Jasminum grandiflorum* var CO. 2

		March			April			May		
		Mo	M1	Mean	Mo	M1	Mean	Mo	M1	Mean
W1	F1	17.01	18.16	17.52	18.12	19.16	18.51	19.11	20.18	19.52
	F2	19.02	21.02	20.02	20.06	22.21	21.01	21.01	23.21	22.02
	F3	20.67	23.02	21.52	21.11	24.32	22.52	22.02	25.61	23.53
	Mean	18.68	20.69	19.69	19.69	21.86	20.66	20.68	22.68	21.69
W2	F1	19.38	22.02	20.7	21.51	23.22	22.27	22.67	24.03	23.12
	F2	31.03	32.4	31.53	33.03	38.04	35.53	34.03	39.26	36.52
	F3	31.03	29.12	30.03	35.23	30.59	32.53	36.05	38.66	34.65
	Mean	27.15	27.7	27.42	29.81	30.36	30.11	30.76	31.36	31.07
W3	F1	23.03	24.15	23.52	24.01	26.21	25.02	25.02	27.23	26.02
	F2	26.03	29.13	27.53	27.23	31.03	29.03	28.26	32.22	30.01
	F3	29.03	30.31	29.53	30.03	31.11	30.53	31.33	32.09	31.53
	Mean	26.02	27.7	26.86	27.09	29.98	28.2	28.28	30.36	29.2
	F1	19.81	21.33	20.58	21.19	22.66	21.98	22.09	23.69	22.89
	F2	25.36	27.36	26.36	26.7	30.36	28.51	27.69	31.36	29.53
	F3	26.7	27.36	27.03	28.68	28.36	28.53	29.69	29.89	29.56
	Mean	23.95	25.36	24.66	25.52	27.14	26.33	26.49	28.14	27.32
Control		18.11			18.76			19.23		

March

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.72345	0.32381	0.26439	0.8562	0.79261	0.45794	0.56086	0.45794
CD	2.00864**	0.66132**	0.53997*	2.19742**	2.10355*	NS	1.14545**	0.93525*

April

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.91944	0.44543	0.36369	1.11454	1.02166	0.62994	0.77151	0.62994
CD	2.55282**	0.90971**	0.74277*	2.8331**	2.69404*	NS	1.57566**	1.28652*

May

	W	F	M	WxF	WxM	FxM	FxW	MxW

SED	0.95455	0.48242	0.39389	1.17329	1.06952	0.68224	0.83577	0.68224
CD	2.65028**	0.98523**	0.80444*	2.96637**	2.80976*	NS	1.70648**	1.39333*

Table 4.7. Effect of Irrigation, fertigation and mulching on number of secondary branches of *Jasminum grandiflorum* var CO. 2

		June			July			August		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	20.01	21.02	20.52	21.11	22.02	21.52	22.02	23.03	22.52
	F2	22.02	24.02	23.02	23.05	25.04	24.02	24.03	26.67	25.02
	F3	25.03	26.03	25.52	26.01	27.11	26.52	27.1	28.02	27.52
	Mean	22.35	23.69	23.02	23.36	24.69	24.02	24.33	25.7	25.02
W2	F1	22.94	25.03	23.98	23.65	26.03	24.83	24.36	27.03	25.7
	F2	35.03	38.04	37.53	36.04	41.01	38.53	37.03	42.04	39.54
	F3	35.44	33.89	35.53	38.04	34.03	36.07	39.04	35.03	37.03
	Mean	32	32.7	32.35	32.57	33.7	33.18	33.48	34.7	34.09
W3	F1	26.03	28.02	27.03	27.03	29.33	28.03	28.26	30.03	29.02
	F2	29.03	33.32	31.3	30.03	34.26	32.02	31.03	35.33	33.03
	F3	32.03	33.56	32.53	30.36	34.36	34.33	35.03	35.36	35.32
	Mean	29.03	31.36	30.19	185.7	187.66	31.37	31.36	33.37	32.37
	F1	22.99	24.69	23.84	23.90	25.7	24.8	24.80	26.69	25.74
	F2	28.69	32.37	30.53	29.71	33.36	31.53	30.7	34.37	32.53
	F3	31.71	30.71	31.2	32.7	31.71	32.2	33.7	32.69	33.2
	Mean	29.25		29.25	30.25		30.25	31.25		31.25
Cotrol		19.88			20.12			20.76		

	June							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.99255	0.5177	0.4227	1.23336	1.11945	0.73214	0.89669	0.73214
CD	2.75581**	1.0573**	0.86328*	3.10534**	2.93237*	NS	1.8313**	1.49525*
	July							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	1.0177	0.55667	0.45452	1.28665	1.16	0.78725	0.96417	0.78725
CD	2.82564**	1.13688**	0.92826*	3.21873**	3.02459*	NS	1.96913**	1.60779*
	August							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	1.05408	0.59458	0.48547	1.34838	1.21021	0.84086	1.02984	0.84086
CD	2.92665**	1.21431**	0.99148*	3.35879**	3.14568*	NS	2.10324**	1.71729*

Table 4.8. Effect of Irrigation, fertigation and mulching on number of primary roots of *Jasminum grandiflorum* var CO. 2

		Mo	**M1**	**Mean**
W1	F1	2.7	2.75	2.72
	F2	2.85	2.88	2.87
	F3	2.94	2.99	2.97
	Mean	2.83	2.87	2.86
W2	F1	3.45	3.86	3.65
	F2	4.00	4.5	4.25
	F3	4	4.33	4.17
	Mean	3.82	4.23	4.02
W3	F1	3.6	3.95	3.8
	F2	4.12	4.25	4.1
	F3	4.31	4.16	4.24
	Mean	4.03	4.12	4.07
	F1	3.27	3.52	3.39
	F2	3.66	3.88	3.77
	F3	3.75	3.83	3.7
	Mean	3.56	3.75	3.65
Control		3.8		3.8

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.07245	0.01115	0.0091	0.07414	0.0733	0.01577	0.01931	0.01577
CD	0.20115	0.02277	0.01859	0.2034	0.202228	NS	0.03944	0.0322

Table 4.9. Effect of Irrigation, fertigation and mulching on length of primary roots of *Jasminum grandiflorum* var CO. 2

		Mo	**M1**	**Mean**
W1	F1	24.67	25.98	25.33
	F2	26.47	27.25	26.86
	F3	28.02	28.09	28.05
	Mean	26.39	27.11	26.74
W2	F1	27.26	28.71	27.98
	F2	31.26	32.08	31.67
	F3	30.28	31.68	30.98
	Mean	29.6	30.82	30.21
W3	F1	28.65	29.56	29.11
	F2	30.29	31.14	30.71
	F3	31.72	31.92	31.82
	Mean	30.22	30.87	30.55
	F1	26.86	28.09	27.48
	F2	29.34	30.15	29.75
	F3	30.01	30.56	30.29
	Mean	28.73	29.61	29.17
Control		28.69		28.69

	December							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.22018	0.06456	0.05272	0.23836	0.22945	0.09131	0.11183	0.09131
CD	0.61133**	0.13186**	0.10766*	0.63613**	0.62373*	NS	0.22839**	0.18648*

Table 4.10. Effect of Irrigation, fertigation and mulching on number of secondary roots of *Jasminum grandiflorum* var CO. 2

		Mo	**M1**	**Mean**
W1	F1	5.5	5.7	5.6
	F2	6	6.2	6.1
	F3	7	7.2	7.1
	Mean	6.18	6.37	6.28
W2	F1	8.51	9.10	8.8
	F2	11.51	12.76	12.13
	F3	10.76	11.51	11.13
	Mean	10.26	11.13	10.69
W3	F1	9.76	10.26	10.01
	F2	11.01	11.76	11.38
	F3	12.01	12.51	12.26
	Mean	10.93	11.51	11.22
	F1	7.93	8.35	8.14
	F2	9.5	10.24	9.87
	F3	9.92	10.41	10.16
	Mean	9.12	9.68	9.4
Control		10.45		10.45

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	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.28371	0.05058	0.0413	0.29259	0.28818	0.07154	0.08761	0.07154
CD	0.78772**	0.10331**	0.08435*	0.79953**	0.79362*	NS	0.17893**	0.1461*

Table 4.11. Effect of Irrigation, fertigation and mulching on length of secondary roots of *Jasminum grandiflorum* var CO. 2

		Mo	**M1**	**Mean**
	F1	14.52	15.26	14.88
W1	F2	15.76	16.02	15.89
	F3	16.35	17.01	16.68
	Mean	15.54	16.1	15.82
	F1	19.14	20.57	19.85
W2	F2	23.68	24.78	24.23
	F3	23.58	24.58	24.08
	Mean	22.14	23.04	22.72
	F1	20.14	21.97	21.05
W3	F2	22.35	23.67	23.01
	F3	24.17	24.51	24.34
	Mean	22.22	23.39	22.81
	F1	17.93	19.29	18.61
	F2	20.6	21.49	21.05
	F3	21.37	22.04	21.7
	Mean	19.96	20.93	20.45
Control		21.36		21.36

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.41771	0.07338	0.05992	0.43041	0.4241	0.10378	0.1271	0.10378
CD	1.15976**	0.14987**	0.12237*	1.17664**	1.1682**	NS	0.25959**	0.21195*

Table 4.12. Effect of Irrigation, fertigation and mulching on foliar nitrogen of *Jasminum grandiflorum* var CO. 2

		Season I			Season II			Season III			Season IV		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	1.22	1.21	1.22	1.42	1.41	1.42	1.1	1.07	1.09	1.22	1.21	1.22
	F2	1.53	1.52	1.52	1.77	1.71	1.74	1.36	1.25	1.3	1.25	1.24	1.24
	F3	1.71	1.68	1.69	2.16	2.01	2.08	1.68	1.63	1.66	1.7	1.48	1.59
	Mean	1.48	1.47	1.48	1.78	1.71	1.75	1.38	1.32	1.35	1.39	1.31	1.35
W2	F1	1.36	1.35	1.36	1.61	1.49	1.55	1.25	1.25	1.25	1.33	1.32	1.32
	F2	2	1.82	1.91	2.63	2.23	2.43	2.11	1.86	1.99	1.88	1.75	1.82
	F3	2.01	1.99	1.99	2.66	2.35	2.51	2.16	1.98	2.07	1.91	1.84	1.88
	Mean	1.78	1.72	1.76	2.3	2.02	2.16	1.84	1.7	1.77	1.7	1.64	1.67
W3	F1	1.51	1.44	1.48	1.62	1.61	1.62	1.45	1.35	1.4	1.45	1.35	1.4
	F2	1.66	1.61	1.64	2.45	2.21	2.33	2.05	1.98	2.02	1.81	1.78	1.8
	F3	2.1	2.01	2.05	2.56	2.59	2.57	2.09	2.13	2.11	1.85	1.89	1.87
	Mean	1.75	1.68	1.72	2.22	2.13	2.17	1.88	1.81	1.85	1.72	1.66	1.7
	F1	1.36	1.33	1.35	1.55	1.51	1.52	1.3	1.22	1.25	1.3	1.29	1.31
	F2	1.73	1.65	1.7	2.28	2.05	2.17	1.84	1.7	1.77	1.84	1.59	1.62
	F3	1.94	1.89	1.92	2.47	2.3	2.39	1.88	1.81	1.95	1.83	1.72	1.78
	Mean	1.68	1.63	1.65	2.1	1.95	2.03	1.7	1.61	1.66	1.61	1.54	1.57
Control		1.78		1.78	2.06		2.06	1.23		1.23	1.72		1.72

	W	F	M	WxF	WxM	FxM	FxW	MxW
Season I								
SED	0.01625	0.01123	0.00917	0.02272	0.01976	0.01588	0.01945	0.0158
CD	0.04513**	0.02293**	0.01872*	0.05495**	0.05017*	NS	0.03972**	0.03243*
Season II	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.03058	0.01691	0.01381	0.0382	0.03494	0.02392	0.02929	0.02392
CD	0.849**	0.03454**	0.0282*	0.09697**	0.09101*	NS	0.05983**	0.04885*
Season III	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.02713	0.01782	0.01455	0.03703	0.03246	0.0252	0.03087	0.0252
CD	0.07532**	0.03639**	0.02972*	0.09022**	0.08294*	NS	0.06304**	0.05147*
Season IV	W	F	M	WxF	WxM	FxM	FxW	MxW

SED	0.02017	0.01068	0.00872	0.0252	0.02283	0.0151	0.0185	0.0151
CD	0.0601**	0.02181**	0.01781*	0.06333**	0.05971*	NS	0.03778**	0.03085*

Table 4.13. Effect of Irrigation, fertigation and mulching on foliar phosphorous of *Jasminum grandiflorum* var CO. 2

		Season I			Season II			Season III			Season IV		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	0.16	0.15	0.15	0.15	0.15	0.15	0.18	0.18	0.18	0.17	0.17	0.17
	F2	0.18	0.18	0.18	0.17	0.16	0.16	0.19	0.19	0.19	0.18	0.18	0.18
	F3	0.22	0.21	0.21	0.2	0.19	0.19	0.21	0.21	0.21	0.18	0.19	0.2
	Mean	0.18	0.18	0.18	0.17	0.17	0.17	0.2	0.19	0.19	0.19	0.18	0.18
W2	F1	0.17	0.17	0.17	0.16	0.16	0.16	0.19	0.18	0.18	0.18	0.17	0.18
	F2	0.25	0.24	0.25	0.21	0.21	0.21	0.24	0.23	0.24	0.24	0.23	0.23
	F3	0.26	0.26	0.26	0.22	0.22	0.22	0.27	0.27	0.27	0.25	0.24	0.24
	Mean	0.22	0.22	0.22	0.2	0.2	0.19	0.23	0.22	0.23	0.22	0.21	0.22
W3	F1	0.18	0.18	0.17	0.17	0.17	0.17	0.21	0.19	0.2	0.21	0.19	0.2
	F2	0.24	0.22	0.23	0.21	0.21	0.21	0.25	0.24	0.24	0.25	0.25	0.25
	F3	0.26	0.26	0.26	0.22	0.22	0.22	0.29	0.28	0.28	0.26	0.26	0.25
	Mean	0.22	0.22	0.22	0.2	0.2	0.2	0.26	0.26	0.25	0.23	0.23	0.23
	F1	0.17	0.16	0.16	0.16	0.16	0.16	0.19	0.18	0.19	0.19	0.18	0.18
	F2	0.23	0.21	0.22	0.2	0.19	0.19	0.23	0.22	0.22	0.22	0.22	0.22
	F3	0.23	0.24	0.24	0.21	0.21	0.21	0.26	0.25	0.25	0.24	0.23	0.23
	Mean	0.21	0.2	0.21	0.19	0.19	0.19	0.23	0.22	0.22	0.21	0.21	0.21
Control		0.24		0.24	0.16		0.16	0.19		0.19	0.17		0.17

	Season I							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.00283	0.00202	0.00165	0.00402	0.00348	0.00285	0.0035	0.00285
CD	0.00787**	0.00412**	0.00337*	0.00968**	0.0088*	NS	0.00714**	0.00583*
	Season II							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.00096	0.00172	0.00141	0.00262	0.00197	0.00243	0.00298	0.00243
CD	0.00267**	0.00352**	0.00287*	0.00561**	0.00437*	NS	0.00609**	0.00497*
	Season III							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.00345	0.00178	0.00145	0.00427	0.00389	0.00252	0.00308	0.00252

CD	0.00959**	0.00364**	0.00297*	0.01078**	0.01019*	NS	0.0063**	0.00514*
	Season IV							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.00314	0.00113	0.00092	0.00353	0.00334	0.0016	0.00196	0.0016
CD	0.00873**	0.00231**	0.00188*	0.00926**	0.00899*	NS	0.004**	0.00326*

Table 4.14. Effect of Irrigation, fertigation and mulching on foliar potassium of *Jasminum grandiflorum* var CO. 2

		Season I			**Season II**			**Season III**			**Season IV**		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**
	F1	1.15	1.15	1.15	1.27	1.26	1.26	1.3	1.3	1.3	1.31	1.3	1.3
W1	F2	1.17	1.17	1.17	1.28	1.27	1.27	1.31	1.31	1.31	1.32	1.32	1.32
	F3	1.37	1.32	1.34	1.33	1.32	1.33	1.4	1.39	1.39	1.41	1.41	1.41
	Mean	1.23	1.21	1.22	1.29	1.29	1.29	1.33	1.33	1.33	1.35	1.34	1.34
	F1	1.26	1.25	1.25	1.27	1.26	1.27	1.31	1.28	1.29	1.32	1.29	1.3
W2	F2	1.4	1.39	1.39	1.3	1.28	1.29	1.42	1.42	1.42	1.52	1.5	1.51
	F3	1.41	1.4	1.4	1.33	1.32	1.33	1.51	1.49	1.5	1.54	1.53	1.53
	Mean	1.35	1.34	1.35	1.3	1.29	1.29	1.41	1.4	1.4	1.46	1.44	1.45
	F1	1.32	1.31	1.31	1.3	1.3	1.3	1.37	1.36	1.36	1.35	1.33	1.34
W3	F2	1.42	1.41	1.41	1.35	1.34	1.35	1.48	1.47	1.48	1.53	1.51	1.52
	F3	1.43	1.42	1.42	1.44	1.41	1.42	1.53	1.51	1.52	1.54	1.53	1.53
	Mean	1.39	1.38	1.38	1.36	1.35	1.36	1.46	1.44	1.45	1.47	1.46	1.46
	F1	1.24	1.24	1.24	1.28	1.27	1.28	1.32	1.31	1.32	1.32	1.31	1.32
	F2	1.33	1.32	1.32	1.31	1.3	1.3	1.4	1.4	1.4	1.45	1.44	1.45
	F3	1.4	1.38	1.39	1.37	1.35	1.36	1.48	1.46	1.47	1.49	1.49	1.49
	Mean	1.32	1.31	1.32	1.32	1.31	1.31	1.39	1.39	1.4	1.42	1.41	1.42
Control		1.26		1.26	1.28		1.28	1.31		1.31	1.39		1.39

	Season I							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.00973	0.00309	0.00252	0.01067	0.01021	0.0437	0.00535	0.00437
CD	0.02702**	0.00631**	0.00515*	0.0283**	0.02765*	NS	0.01093**	0.00892*
	Season II							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.00324	0.00206	0.00168	0.00436	0.00384	0.00291	0.00357	0.00291
CD	0.00899**	0.0042**	0.00343*	0.01066**	0.00985*	NS	0.00728**	0.00595*
	Season III							
	W	F	M	WxF	WxM	FxM	FxW	MxW

SED	0.00702	0.00306	0.0025	0.00824	0.00766	0.00432	0.00529	0.00432
CD	0.01949**	0.00624**	0.0051*	0.0213**	0.02036*	NS	0.01081**	0.00883*
	season IV							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.00776	0.00394	0.00322	0.00955	0.0087	0.00558	0.00683	0.00558
CD	0.02154**	0.00805**	0.00658*	0.02414**	0.02285*	NS	0.01395**	0.01139*

Table 4.15. Effect of Irrigation, fertigation and mulching on days taken for flower initiation of *Jasminum grandiflorum* var CO. 2

		Mo	M1	Mean
W1	F1	57.06	55.06	56.06
	F2	52.05	50.05	51.07
	F3	49.05	47.05	48.04
	Mean	52.78	50.89	51.78
W2	F1	54.06	52.05	53.17
	F2	46.06	45.33	45.54
	F3	46.05	44.03	45.04
	Mean	48.72	47.04	47.88
W3	F1	52.05	50.53	51.17
	F2	45.03	44.43	44.43
	F3	45.43	44.43	44.53
	Mean	47.39	46.67	46.72
	F1	54.39	52.67	53.38
	F2	47.72	46.38	47.01
	F3	46.33	45.04	45.88
	Mean	49.6	47.53	48.7707
Control		50		50

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.27308	0.1617	0.13203	0.35619	0.31737	0.22868	0.28007	0.22868
CD	0.7582**	0.33024**	0.26964*	0.88116**	0.82068*	NS	0.57199**	0.46703*

Table 4.16. Effect of Irrigation, fertigation and mulching on number of flowers per branch of *Jasminum grandiflorum* var CO. 2

		Season I			Season II			Season III			Season IV		
		Mo	M1	Mean	Mo	M1	Mean	Mo	M1	Mean	Mo	M1	Mean
	F1	182.18	190.19	186.19	215.22	244.24	229.73	225.23	254.25	239.74	235.23	266.67	250.75
W1	F2	210.21	213.21	211.71	256.26	268.27	262.26	265.27	288.29	276.77	287.29	299.31	293.29
	F3	224.22	226.25	225.22	277.28	288.29	282.78	298.3	300.3	299.29	310.31	324.32	317.31
	Mean	205.53	209.88	207.71	249.58	266.93	258.29	262.93	280.95	271.94	277.61	296.63	27.12
	F1	201.33	206.21	203.51	210.11	215.22	212.5	278.00	281.12	245.61	245.21	268.88	257.04
W2	F2	269.27	277.27	273.27	325.32	344.34	334.84	354.34	369.36	361.86	384.31	387.56	386.38
	F3	268.27	271.21	269.77	298.29	301.34	299.8	312.31	328.33	320.2	342.23	342.34	342.34
	Mean	228.08	251.59	239.83	263.89	286.95	275.42	281.56	310.31	295.93	306.31	328.99	317.66
	F1	212.21	224.23	218.22	249.25	265.27	257.26	285.23	279.28	271.77	277.28	299.3	288.28
W3	F2	261.26	270.27	265.77	311.31	302.3	306.81	325.11	319.32	322.32	346.34	348.35	347.54
	F3	268.27	270.27	269.27	318.33	324.32	321.32	322.19	344.34	333.33	339.34	356.66	347.84
	Mean	247.25	254.92	251.09	292.96	297.97	295.13	303.98	314.31	309.15	320.98	334.64	327.83
	F1	180.36	206.87	193.62	210.84	241.58	226.2	222.50	255.58	239.04	234.91	273.94	254.43
	F2	246.91	253.59	250.25	297.63	304.97	301.3	314.99	325.65	320.31	339.34	345.35	342.35
	F3	253.59	255.92	254.76	297.98	304.36	301.3	310.98	324.32	317.65	330.66	341.01	335.84
	Mean	226.96	238.79	232.88	268.81	283.73	276.29	282.81	301.86	292.34	301.86	320.09	310.87
Control		245.65		245.65	271.48		271.48	298.89		298.89	312.45		312.45

	W	F	M	WxF	WxM	FxM	FxW	MxW
Season I								
SED	8.78	6.98105	5.7	13.21206	11.21711	9.87269	12.09153	9.87269
CD	24.37759**	14.25737**	11.6411*	31.2675**	27.95433*	NS	24.6945**	20.16297*
Season II	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	9.30162	8.14967	6.65418	14.81062	12.36678	11.52538	14.11565	11.52538
CD	5.82585**	16.64406**	13.58982*	34.53667**	30.39318*	NS	28.82835**	23.53825*
Season III	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	10.23949	8.63452	7.05005	15.93603	13.39411	12.21105	14.95542	12.21105
CD	28.42984**	17.63425**	14.39831*	37.37655**	33.1019*	NS	30.54342**	24.9386*
Season IV								

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	11.35933	9.39135	7.66801	17.47654	14.73879	13.28137	16.263	13.28137
CD	31.53906**	19.17993**	15.66035*	41.11304**	36.52865*	NS	33.22061**	27.12452*

Table 4.17. Effect of Irrigation, fertigation and mulching on yield (gm/plant) of *Jasminum grandiflorum* var CO. 2

		Mo	**M1**	**Mean**
W1	F1	1821.82	1863.86	1842.83
	F2	2167.17	2201.2	2184.18
	F3	2234.23	2269.26	2251
	Mean	2074.4	2111.44	2092.92
W2	F1	1911.78	1937.94	1924.85
	F2	2418.42	2498.49	2441.44
	F3	2472.47	2464.46	2485.48
	Mean	2267.56	2300.3	2283.93
W3	F1	1927.92	2038.01	1982.99
	F2	2485.48	2515.51	2500.49
	F3	2505.5	2531.51	2518.51
	Mean	2306.3	2361.69	2333.99
	F1	1887.17	1946.61	1916.89
	F2	2357.02	2393.72	2375.38
	F3	2404.06	2433.1	2418.58
	Mean	2216.08	2257.81	2236.949
Control		2217.23		2217.23

W F M WxF WxM FxM FxW MxW

SED	13.28713	10.78443	8.80545	20.2276	17.11291	15.25149	18.67919	15.25149
CD	36.89**	22.02502**	17.98334*	47.71884**	42.524*	NS	38.14845**	31.14808*

Table 4.18. Effect of Irrigation, fertigation and mulching on 100 flower weight (gm) of *Jasminum grandiflorum* var CO. 2

		Lean Season			Peak Season		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	9.1	9.21	9.15	9.26	9.46	9.36
	F2	9.57	9.67	9.62	9.76	9.89	9.82
	F3	9.9	10.01	9.95	9.97	10.13	10.05
	Mean	9.52	9.63	9.57	9.66	9.82	9.74
W2	F1	9.2	9.56	9.35	10.38	9.69	10.03
	F2	10.87	11.21	10.27	10.97	11.91	11.44
	F3	10.66	10.87	10.39	10.96	11.01	10.98
	Mean	9.5	10.54	10.02	10.77	10.87	10.82
W3	F1	9.53	9.55	9.54	9.82	9.69	9.75
	F2	10.11	10.21	10.16	10.22	10.34	10.28
	F3	10.33	10.57	10.45	10.44	10.53	10.48
	Mean	9.99	10.11	10.05	10.16	10.18	10.17
	F1	8.53	9.44	8.98	9.84	9.61	9.71
	F2	10.18	10.36	10.27	10.31	10.71	10.51
	F3	10.29	10.48	10.39	10.46	10.55	10.5
	Mean	9.6733	10.09	9.88	10.2	10.29	10.24
Control		9.81		9.81	10.21		10.21

	Lean Season							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.34357	0.29869	0.24388	0.57779	0.45525	0.42241	0.51735	0.42241
CD	0.95392**	0.61002**	0.49808*	1.27118**	1.12013*	NS	1.05658**	0.86269*
	Peak Season							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.34357	0.29869	0.24388	0.57779	0.45525	0.42241	0.51735	0.42241

CD	0.95392**	0.61002**	0.49808*	1.27118**	1.12013*	NS	1.05658**	0.86269*

Table 4.19. Effect of Irrigation, fertigation and mulching on diameter of flower (cm) of *Jasminum grandiflorum* var CO. 2

		Lean Season			Peak Season		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	2.8	3.1	3.05	3.1	3.2	3.15
	F2	3.2	3.2	3.2	3.3	3.3	3.3
	F3	3.3	3.3	3.3	3.4	3.5	3.45
	Mean	3.17	3.2	3.18	3.26	3.33	3.3
W2	F1	3	3.40	3.3	3.20	3.5	3.12
	F2	3.50	3.8	3.65	3.8	3.9	3.85
	F3	3.2	3.6	3.3	3.6	3.5	3.55
	Mean	3.18	3.53	3.35	3.38	3.63	3.51
W3	F1	3.1	3.2	3.15	3.2	3.3	3.25
	F2	3.3	3.50	3.4	3.80	3.7	3.75
	F3	3.6	3.7	3.65	3.9	3.8	3.85
	Mean	3.33	3.47	3.4	3.63	3.6	3.61
	F1	2.97	3.23	3.11	3.01	3.33	3.17
	F2	3.33	3.5	3.41	3.63	3.63	3.63
	F3	3.37	3.46	3.42	3.64	3.60	3.62
	Mean	3.22	3.4	3.31	3.42	3.52	3.48
Control		3.28		3.28	3.51		3.51

	Lean Season							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.08919	0.07927	0.06473	0.14326	0.11933	0.1121	0.13731	0.1121
CD	0.24763**	0.1619**	0.13219*	0.33335**	0.29265*	NS	0.28042**	0.22896*
	Peak Season							
	W	F	M	WxF	WxM	FxM	FxW	MxW

SED	0.08509	0.07292	0.05954	0.1337	0.11206	0.103312	0.1263	0.10312
CD	0.23626**	0.14892**	0.12159*	0.31281**	0.27631*	NS	0.25794**	0.21061*

Table 4.20. Effect of Irrigation, fertigation and mulching on length of corolla tube (cm) of *Jasminum grandiflorum* var CO. 2

		Lean Season			Peak Season		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	1.2	1.2	1.2	1.4	1.4	1.4
	F2	1.5	1.4	1.45	1.6	1.7	1.65
	F3	1.5	1.6	1.5	1.6	1.7	1.65
	Mean	1.4	1.4	1.4	1.53	1.6	1.56
W2	F1	1.3	1.50	1.44	1.53	1.8	1.66
	F2	2.20	2.2	2.2	2.3	2.3	2.3
	F3	2.1	2.1	1.9	2.13	2	2.05
	Mean	1.86	1.87	1.86	1.98	2.03	2
W3	F1	1.3	1.4	1.35	1.56	1.6	1.58
	F2	2.1	2.00	2.05	2.10	2	2.05
	F3	2	2.1	2.06	2.11	2.1	2.1
	Mean	1.8	1.83	1.82	1.87	1.83	1.85
	F1	1.29	1.36	1.33	1.44	1.53	1.48
	F2	1.93	1.86	2.2	2	2	2
	F3	1.83	1.86	1.95	1.93	1.93	1.93
	Mean	1.68	1.7	1.69	1.74	1.82	1.78
Control		1.61		1.61	1.85		1.85

	Lean Season							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.02636	0.01274	0.0104	0.03192	0.02927	0.01801	0.02206	0.01801
CD	0.07318**	0.02601**	0.02124*	0.08117**	0.0772*	NS	0.04505**	0.03678*
	Peak Season							
	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.03113	0.01155	0.00943	0.03516	0.0332	0.01633	0.02	0.01633
CD	0.08643**	0.02359**	0.01926*	0.09204**	0.08924*	NS	0.04085**	0.03336*

Table 4.21. Effect of Irrigation, fertigation and mulching on length of flower stalk (cm) of *Jasminum grandiflorum* var CO. 2

		Lean Season			Peak Season		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	1.91	2	1.95	1.95	2	2.05
	F2	2.1	2.2	2.15	2.2	2.2	2.2
	F3	2.1	2.2	2.16	2.1	2.21	2.15
	Mean	2.03	2.13	2.08	2.1	2.16	2.13
W2	F1	1.95	1.99	1.97	2.00	2.1	2.05
	F2	2.50	2.6	2.55	2.6	2.7	2.65
	F3	2.46	2.5	2.45	2.4	2.6	2.45
	Mean	2.21	2.33	2.27	2.25	2.4	2.32
W3	F1	1.98	2	1.99	2.1	2.2	2.15
	F2	2.1	2.20	2.15	2.50	2.5	2.5
	F3	2.2	2.2	2.20	2.6	2.6	2.6
	Mean	2.06	2.03	2.05	2.33	2.3	2.31
	F1	1.85	1.90	1.87	1.88	2	1.95
	F2	2.23	2.33	2.28	2.43	2.47	2.45
	F3	2.25	2.28	2.25	2.36	2.40	2.39
	Mean	2.1	2.16	2.13	2.23	2.3	2.26
Control		2.21		2.21	2.25		2.25

Lean Season

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.03406	0.01811	0.01479	0.04261	0.03857	0.02561	0.03137	0.02561
CD	0.09455**	0.03699**	0.0302*	0.10701**	0.10085*	NS	0.06406**	0.05231*

Peak Season

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.02917	0.01892	0.01545	0.03958	0.03477	0.02676	0.03277	0.02676
CD	0.08098**	0.03865**	0.03155*	0.09662**	0.08897*	NS	0.06694**	0.05465*

Table 4.22. Effect of Irrigation, fertigation and mulching on concrete content (%)of *Jasminum grandiflorum* var CO. 2

		Mo	M1	Mean
W1	F1	0.25	0.26	0.25
	F2	0.26	0.27	0.26
	F3	0.29	0.3	0.29
	Mean	0.26	0.27	0.26
W2	F1	0.29	0.29	0.29
	F2	0.29	0.3	0.29
	F3	0.29	0.3	0.29
	Mean	0.28	0.29	0.28
W3	F1	0.27	0.27	0.27
	F2	0.29	0.30	0.29
	F3	0.29	0.3	0.29
	Mean	0.29	0.3	0.29
	F1	0.25	0.26	0.25
	F2	0.28	0.29	0.28
	F3	0.29	0.3	0.29
	Mean	0.3	0.3	0.3
Control		0.27		0.27

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	0.04202	0.04013	0.03276	0.07061	0.0581	0.05675	0.0695	0.05675
CD	0.11666**	0.08195**	0.07061*	0.16256**	0.14097*	NS	0.14194**	0.11589*

Table 4.23. Effect of Irrigation, fertigation and mulching on distribution of flowers (Percent) of *Jasminum grandiflorum* var CO. 2

		Season I			Season II			Season III			Season IV		
		Mo	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**	**Mo**	**M1**	**Mean**
W1	F1	3.1	3.3	3.2	40.29	40.6	40.44	42.4	43.73	43.06	5.2	5.31	5.25
	F2	3.4	3.6	3.5	41.93	42.36	42.14	44.15	44.93	44.54	5.4	5.61	5.5
	F3	3.9	4	3.95	42.7	43.93	43.31	45.58	45.3	45.66	6.1	6.21	6.15
	Mean	3.47	3.63	3.55	41.64	42.29	41.97	44.04	44.8	44.42	5.57	5.7	5.63
W2	F1	4.3	4.50	4.4	44.6	44.9	44.75	45.93	46.93	46.43	5.57	5.70	6.4
	F2	5.60	5.7	5.65	45.02	46.62	45.82	48.02	49.6	48.81	7.61	8.21	7.91
	F3	5.7	5.4	5.55	45.72	45.93	45.83	48.74	48.91	48.82	7.51	7.7	7.6
	Mean	5.2	5.21	5.2	45.12	45.82	45.47	47.56	48.48	48.02	7.13	7.47	7.3
W3	F1	5.1	5.3	5.2	42.6	43.15	42.88	47.15	47.9	47.52	6.9	7.21	7.05
	F2	5.4	5.60	5.5	43.93	44.29	44.11	48.4	49.03	48.71	7.51	7.80	7.65
	F3	5.7	5.7	5.70	46.02	46.37	46.19	49.27	49.54	49.41	8.1	8.21	8.15
	Mean	5.4	5.53	5.47	44.18	44.6	44.39	48.28	48.82	48.55	7.5	7.74	7.62
	F1	4.12	4.37	4.27	42.50	42.88	42.69	45.16	46.19	45.68	6.13	6.34	6.23
	F2	4.8	4.97	4.88	43.62	44.43	44.02	46.86	47.85	47.36	6.84	7.2	7.02
	F3	5.1	5.03	5.07	44.81	45.41	45.11	47.87	48.06	47.96	7.24	7.37	7.3
	Mean	4.69	4.79	4.74	43.64	44.24	43.94	46.63	47.36	47	6.73	6.97	6.85
Control		5.1		5.1	42.56		42.56	46.24		46.24	6.46		6.46

	W	F	M	WxF	WxM	FxM	FxW	MxW
Season I								
SED	0.1085	0.01877	0.01533	0.1117	0.11011	0.02655	0.03251	0.02655
CD	0.30125**	0.03834**	0.0313*	0.30551**	0.30338*	NS	0.0664**	0.05422*
Season II								
SED	0.18744	0.05349	0.04368	0.20213	0.19493	0.07565	0.09265	0.07565
CD	0.52044**	0.10925**	0.0892*	0.54044**	0.53044*	NS	0.18922**	0.1545*
Season III								
SED	0.27253	0.0717	0.05855	0.29079	0.28181	0.1014	0.12419	0.1014
CD	0.75668**	0.14644**	0.11957*	0.7814**	0.76904*	NS	0.25364**	0.2071*
Season IV								
SED	0.10772	0.03224	0.02633	0.11697	0.11244	0.0456	0.05585	0.0456

CD	0.29908**	0.06585**	0.05377*	0.31173**	0.30541*	NS	0.11406**	0.09313*

Table 4.24 : Effect of Irrigation, fertigation and mulching on yield (kg/ha) of *Jasminum grandiflorum* var CO. 2

		Mo	M1	Mean
W1	F1	6072.13	6212.25	6142.19
	F2	8223.18	8336.6	8279.89
	F3	8446.68	8563.44	8505.06
	Mean	7580.66	7704.09	7642.38
W2	F1	6371.96	6459.15	6415.56
	F2	10,060.59	10,214.05	10,137.32
	F3	14,240.74	14,327.47	14,284.11
	Mean	10,224.43	10,333.56	10,278.81
W3	F1	6425.76	6792.69	6609.22
	F2	11,284.11	11,384.19	11,334.15
	F3	14,350.83	14,437.52	14,394.18
	Mean	10,689.9	10,871.36	10,780.63
	F1	6289.94	6488.01	6388.99
	F2	9855.96	9978.28	9917.12
	F3	12,346.08	12,442.81	12394.45
	Mean	9497.33	9636.37	9566.85
Control		7390.02		7390.02

	W	F	M	WxF	WxM	FxM	FxW	MxW
SED	115.28713	112.78443	110.80545	210.2276	117.11291	115.25149	118.67919	115.25149
CD	316.89**	212.02502**	17.98334*	417.71884**	421.524*	NS	381.14845**	311.14808*

Table 4.25. Effect of refrigerated storage and packing methods for post harvest handling of *J. grandiflorum* var CO. 2

Treatments	Physiological loss of weight PLW (%)													
	Cumulative (Days)							Date (Days)						
	0-3	3-6	6-9	9-12	12-15	15-18	18-21	0-3	3-6	6-9	9-12	12-15	15-18	18-21
AL 5°C														
Normal packing	0.69	0.24	0.29	0.72	0.71	0.76	1.28	0.23	0.37	0.59	1.29	1.96	2.01	2.11
Vacuum packing	0.22	0.13	0.28	0.71	0.68	0.80	1.12	0.32	0.36	0.57	1.28	1.95	2.00	2.10
At 10°C														
Normal packing	1.36	0.57	0.82	2.73	2.71	2.89	3.12	0.28	1.09	1.89	4.56	7.23	9.31	11.36
Vacuum packing	0.28	0.81	0.59	2.72	2.74	2.79	2.98	0.26	1.09	1.88	4.56	7.15	9.30	11.34
At 15°C														
Normal packing	4.22	0.76	1.33	5.13	4.12	6.17	6.72	0.66	1.60	2.88	7.79	11.51	12.14	15.21
Vacuum packing	4.21	0.74	1.31	5.08	4.01	5.21	6.11	0.66	1.60	2.87	7.78	11.50	12.13	15.20
Control														
Normal packing	6.05	38.63	41.33	49.76	53.22	60.12	66.33	8.10	40.13	44.38	52.67	57.36	70.13	74.39
Vacuum packing	4.03	5.14	6.92	36.90	38.56	47.73	53.12	4.04	6.23	8.36	37.83	39.56	51.37	72.36
CD @ 5%	-	0.29	0.24	0.60	0.64	0.68	0.71	-	0.29	0.24	0.60	0.64	0.68	0.71

Table 4.25. (Contd..)

Treatments	Physiological loss of weight PLW (%)													
	Moisture content (%)							Percent(%)						
	0-3	3-6	6-9	9-12	12-15	15-18	18-21	0-3	3-6	6-9	9-12	12-15	15-18	18-21
AL 5°C														
Normal packing	99.43	98.25	97.01	96.27	95.79	94.13	93.69	0.42	0.62	1.92	7.01	16.25	30.18	44.36
Vacuum packing	99.03	98.26	97.66	96.94	95.85	94.96	93.78	0.35	0.55	1.88	6.44	15.55	29.36	42.89
At 10°C														
Normal packing	99.10	98.67	99.92	95.25	94.16	93.36	92.12	1.12	1.23	3.19	15.56	26.42	33.64	45.65
Vacuum packing	99.67	98.64	96.86	95.22	95.19	93.87	92.26	0.84	1.00	3.11	14.77	25.56	31.93	43.81
At 15°C														
Normal packing	99.15	98.12	93.85	91.03	86.19	84.12	81.32	1.54	1.68	8.07	16.10	26.35	36.11	43.36
Vacuum packing	99.24	98.25	93.89	91.04	86.21	84.33	82.16	1.56	1.66	7.41	16.40	26.51	35.81	45.48
Control														
Normal packing	93.15	61.23	58.67	50.24	46.78	39.88	33.67	4.86	10.32	56.12	86.33	91.12	94.73	98.63
Vacuum packing	95.06	89.36	74.25	64.92	61.25	52.27	46.88	2.72	4.16	42.26	80.01	86.13	89.32	96.36
CD @ 5%	-	0.29	0.24	0.60	0.64	0.68	0.71	-	0.29	0.24	0.60	0.64	0.68	0.71

Table 4.25. (Contd..)

Treatments	Physiological loss of weight PLW (%)							
	Freshness (%)							Shelf life (days)
	0-3	3-6	6-9	9-12	12-15	15-18	18-21	
AL 5°C								
Normal packing	99.43	98.29	97.01	96.27	95.79	93.16	90.87	4.2
Vacuum packing	99.03	98.25	97.65	96.94	96.33	95.93	91.87	4.6
At 10°C								
Normal packing	99.05	98.59	99.76	94.82	94.03	93.89	90.11	3.3
Vacuum packing	99.07	98.64	96.86	95.22	94.19	93.96	90.32	3.5
At 15°C								
Normal packing	99.15	98.12	93.85	91.03	86.19	85.06	84.31	2.8
Vacuum packing	99.24	98.25	93.80	91.14	88.22	86.31	84.83	3.1
Control								
Normal packing	90.22	86.31	69.11	56.32	51.16	47.32	40.82	2
Vacuum packing	95.66	89.36	74.24	64.92	61.25	59.86	58.33	2
CD @ 5%	0.30	0.74	0.68	2.06	1.81	0.93	3.19	

Table 4.26. Soil temperature at morning hour under various treatments in field

Soil temperature at Morning	Distance from the Plant			
Treatments	**5cm**	**15cm**	**30cm**	**45cm**
$W_1 F_1 M_0$	28.80	28.50	28.30	28.60
$W_1 F_1 M_1$	34.50	34.20	34.10	34.10
$W_1 F_2 M_0$	28.60	28.50	28.50	28.30
$W_1 F_2 M_1$	34.60	34.50	34.50	34.30
$W_1 F_3 M_0$	28.70	28.60	28.60	28.40
$W_1 F_3 M_1$	34.70	34.60	34.50	34.50
$W_2 F_1 M_0$	29.10	29.00	28.80	28.80
$W_2 F_1 M_1$	36.20	36.10	36.00	36.00
$W_2 F_2 M_0$	29.30	29.20	29.10	29.10
$W_2 F_2 M_1$	36.40	36.30	36.30	36.20
$W_2 F_3 M_0$	29.40	29.30	29.20	29.20
$W_2 F_3 M_1$	36.40	36.30	36.20	36.20
$W_3 F_1 M_0$	29.40	29.40	29.30	29.30
$W_3 F_1 M_1$	36.50	36.40	36.30	36.30
$W_3 F_2 M_0$	29.40	29.30	29.30	29.20

$W_3 F_2 M_1$	36.40	36.30	36.20	36.20
$W_3 F_3 M_0$	29.40	29.40	29.30	29.30
$W_3 F_3 M_1$	36.50	36.40	36.20	36.20
Control	28.50	28.40	28.40	28.20

Table 4.27. Soil temperature at noon hour under various treatments in field

Soil temperature at Noon	Distance from the Plant		
Treatments	**5cm**	**15cm**	**30cm**
$W_1 F_1 M_0$	34.30	34.00	33.80
$W_1 F_1 M_1$	39.50	39.30	39.40
$W_1 F_2 M_0$	34.60	34.30	34.20
$W_1 F_2 M_1$	39.80	39.40	39.30
$W_1 F_3 M_0$	34.60	34.50	34.40
$W_1 F_3 M_1$	39.90	39.80	39.80
$W_2 F_1 M_0$	34.50	34.40	34.30
$W_2 F_1 M_1$	40.10	40.00	39.90
$W_2 F_2 M_0$	34.60	34.50	34.30
$W_2 F_2 M_1$	41.10	41.00	40.90
$W_2 F_3 M_0$	34.70	34.50	34.50
$W_2 F_3 M_1$	41.10	41.00	39.90
$W_3 F_1 M_0$	34.90	34.70	34.70
$W_3 F_1 M_1$	41.00	39.90	39.80
$W_3 F_2 M_0$	35.10	34.90	34.80
$W_3 F_2 M_1$	41.00	39.90	39.50
$W_3 F_3 M_0$	34.90	34.80	34.20
$W_3 F_3 M_1$	41.10	40.90	39.80
Control	34.10	33.80	33.50

Table 28.1 Moisture dynamics after 24 hours of drip irrigation

(Moisture content (%)

Depth (cm)	Distance from dripper (cm)							
	Between lateral					Along lateral		
	0	10	20	30	40	10	20	30
0-10	23.61	23.18	22.58	21.70	20.35	23.19	22.58	22.65
10-20	23.67	23.51	22.64	21.94	20.44	23.52	22.78	22.82
20-30	23.22	22.60	21.98	21.52	20.15	22.60	22.00	22.30
30-40	22.02	22.00	21.80	21.44	20.10	22.01	21.79	21.90

Drip irrigation with 15 LPD

Drip irrigation with 10 LPD

Depth (cm)	Distance from dripper (cm)							
	Between lateral					Along lateral		
	0	10	20	30	40	10	20	30
0-10	23.40	22.98	22.03	20.34	19.35	22.98	22.04	21.97
10-20	23.53	23.32	22.21	21.01	19.91	23.34	22.20	22.09
20-30	23.15	22.10	21.58	20.02	19.18	22.11	21.80	21.80
30-40	21.78	21.73	21.33	19.83	19.03	21.77	21.51	21.00

Drip irrigation with 5 LPD

Depth (cm)	Distance from dripper (cm)							
	Between lateral					Along lateral		
	0	10	20	30	40	10	20	30
0-10	23.36	22.44	19.85	18.20	15.72	22.43	19.87	19.57
10-20	23.45	23.28	21.03	19.02	16.10	23.29	21.08	19.58

20-30	22.09	21.42	19.63	18.16	15.73	21.44	19.64	19.03
30-40	20.38	20.06	18.65	18.20	15.69	20.09	18.88	18.58

Table 4.28b Moisture dynamics after 48 hours of drip irrigation

(Moisture content (%)

Drip irrigation with 15 LPD

Depth (cm)	Distance from dripper (cm)							
	Between lateral					Along lateral		
	0	10	20	30	40	10	20	30
0-10	23.26	22.86	22.22	21.31	20.04	22.84	22.20	22.28
10-20	23.37	23.19	22.29	21.62	20.10	23.24	22.41	22.46
20-30	22.92	22.31	21.65	21.17	19.80	22.29	21.68	21.93
30-40	21.77	21.65	21.52	21.12	19.75	21.68	21.49	21.53

Drip irrigation with 10 LPD

Depth (cm)	Distance from dripper (cm)							
	Between lateral					Along lateral		
	0	10	20	30	40	10	20	30
0-10	22.71	22.04	21.21	19.39	18.56	22.04	21.22	21.31
10-20	22.96	22.36	21.33	19.92	19.09	22.38	21.32	21.39
20-30	22.49	21.28	20.72	19.11	18.47	21.29	20.93	21.01
30-40	21.62	20.98	20.46	19.04	18.37	21.02	20.63	20.14

Drip irrigation with 5 LPD

Depth (cm)	Distance from dripper (cm)							
	Between lateral					Along lateral		
	0	10	20	30	40	10	20	30
0-10	22.67	22.04	19.35	17.69	15.29	21.52	19.29	19.21
10-20	22.88	22.63	20.36	18.29	15.72	22.33	20.56	19.40

20-30	21.46	20.86	19.12	17.57	15.35	20.65	19.08	19.02
30-40	20.22	19.59	18.39	17.95	15.38	19.39	18.73	18.14

Table 4.29. Moisture depletion pattern under surface irrigation

Days after irrigation	Depth (cm)			
	0-10	10-20	20-30	30-40
	Moisture content (%)	Moisture content (%)	Moisture content (%)	Moisture content (%)
2	22.63	23.03	23.37	23.36
4	20.68	21.17	21.5	22.01
6	18.57	19.75	20.12	20.84
8	16.26	17.85	19.01	19.64
10	14.03	16.06	18.28	18.96
12	12.25	14.56	17.32	18.61
14	10.72	13.12	16.99	18.32

Table 4.30. N-Fertilizer use efficiency for the experimental seasons

Treatment	Yield (kg ha^{-1}y^{-1})	N fertilizer applied (kg ha^{-1} y^{-1})	Fertilizer use efficiency (kg ha^{-1} kg of N^{-1})
$W_1F_1M_1$	6212.25	156	39.82
$W_1F_2M_1$	8336.6	234	35.63
$W_1F_3M_1$	8563.44	312	27.45
$W_2F_1M_1$	6459.15	156	41.40
$W_2F_2M_1$	10,214.05	234	43.65
$W_2F_3M_1$	14,327.47	312	45.92
$W_3F_1M_1$	6792.69	156	43.54
$W_3F_2M_1$	11,384.19	234	48.65
$W_3F_3M_1$	14,437.52	312	46.27
$W_1F_1M_0$	6072.13	156	38.92
$W_1F_2M_0$	8223.18	234	35.14
$W_1F_3M_0$	8446.68	312	27.07
$W_2F_1M_0$	6371.96	156	40.85
$W_2F_2M_0$	10,060.59	234	42.99
$W_2F_3M_0$	14,240.74	312	45.64
$W_3F_1M_0$	6425.76	156	41.19
$W_3F_2M_0$	11,284.11	234	48.22
$W_3F_3M_0$	14,350.83	312	45.99
Control	7390.02	312	23.69

	SEd	CD (P = 0.05)
W	1.119	2.343
F	0.501	1.048
M	0.521	1.432
W × F x M	1.583	3.313

Table 4.31. K-Fertilizer use efficiency for the experimental seasons

Treatment	Yield (kg ha^{-1}y^{-1})	K fertilizer applied (kg ha^{-1}y^{-1})	Fertilizer Use Efficiency (kg ha^{-1} kg of K^{-1})
$W_1F_1M_1$	6212.25	100.2	61.99
$W_1F_2M_1$	7336.6	150.3	55.47
$W_1F_3M_1$	7563.44	200.4	42.73
$W_2F_1M_1$	6459.15	100.2	64.46
$W_2F_2M_1$	8214.05	150.3	67.96
$W_2F_3M_1$	8327.47	200.4	71.49
$W_3F_1M_1$	6792.69	100.2	67.79
$W_3F_2M_1$	8384.19	150.3	75.74
$W_3F_3M_1$	8437.52	200.4	72.04
$W_1F_1M_0$	6072.13	100.2	60.60
$W_1F_2M_0$	7223.18	150.3	54.71
$W_1F_3M_0$	7446.68	200.4	42.15
$W_2F_1M_0$	6371.96	100.2	63.59
$W_2F_2M_0$	8060.59	150.3	66.94
$W_2F_3M_0$	8240.74	200.4	71.06
$W_3F_1M_0$	6425.76	100.2	64.12
$W_3F_2M_0$	8284.11	150.3	75.08
$W_3F_3M_0$	8350.83	200.4	71.61
Control	7390.02	200.4	36.87

	SEd	CD (P = 0.05)
W	2.998	6.275
F	1.341	2.806
M	1.432	2.543
W × F x M	4.240	8.874

Table 4.32. Water use efficiency for the experimental seasons

Treatment	Yield (kg $ha^{-1}y^{-1}$)	Total water applied (mm)	Water use efficiency (kg ha^{-1} mm^{-1})
$W_1F_1M_1$	6212.25	1240.96	5.00
$W_1F_2M_1$	8336.6	1240.96	6.72
$W_1F_3M_1$	8563.44	1240.96	6.90
$W_2F_1M_1$	6459.15	1384.66	4.66
$W_2F_2M_1$	10,214.05	1384.66	7.37
$W_2F_3M_1$	14,327.47	1384.66	10.35
$W_3F_1M_1$	6792.69	1724.38	3.93
$W_3F_2M_1$	11,384.19	1724.38	6.6
$W_3F_3M_1$	14,437.52	1724.38	8.37
$W_1F_1M_0$	6072.13	1240.96	4.89
$W_1F_2M_0$	8223.18	1240.96	6.62
$W_1F_3M_0$	8446.68	1240.96	6.8
$W_2F_1M_0$	6371.96	1384.66	4.6
$W_2F_2M_0$	10,060.59	1384.66	7.3
$W_2F_3M_0$	14,240.74	1384.66	10.28
$W_3F_1M_0$	6425.76	1724.38	3.72
$W_3F_2M_0$	11,284.11	1724.38	6.54
$W_3F_3M_0$	14,350.83	1724.38	8.32
Control	7390.02	2684.7	2.75

	SEd	CD (P = 0.05)
T	0.414	0.868
F	0.185	0.388
T × F	0.586	NS

Table 4.33. Nitrogen dynamics after end of second fertigation (kg ha^{-1})

Fertigation at 100 per cent RDF

Depth (cm)	Distance from dripper (cm)					
	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	253	256	260	256	258	263
15-30	255	259	263	258	262	265
30-45	251	249	248	246	250	249

Fertigation at 75 per cent RDF

Depth (cm)	Distance from dripper (cm)					
	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	248	250	254	246	251	258
15-30	253	255	260	250	257	262
30-45	246	245	244	243	245	245

Fertigation at 50 per cent RDF

Depth (cm)	Distance from dripper (cm)					
	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	233	236	240	232	238	240
15-30	238	239	243	237	239	242
30-45	231	230	230	229	231	231

Table 4.34. Nitrogen dynamics after end of final fertigation (kg ha^{-1})

Fertigation at 100 per cent RDF

Depth (cm)	Distance from dripper (cm)					
	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	241	245	250	242	247	252
15-30	246	249	256	246	254	255
30-45	244	243	240	234	244	241

Fertigation at 75 per cent RDF

Depth (cm)	Distance from dripper (cm)					
	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	235	240	244	238	242	250
15-30	243	244	250	238	247	250
30-45	239	238	237	235	238	237

Fertigation at 50 per cent RDF

Depth (cm)	Distance from dripper (cm)					
	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	232	233	238	229	234	239
15-30	235	235	240	234	237	242
30-45	231	230	229	225	230	229

Table 4.35. Phosphorus dynamics after end of second fertigation (kg ha^{-1})

Fertigation at 100 per cent RDF

	Distance from dripper (cm)					
Depth (cm)	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	28.47	23.83	20.85	20.05	23.87	22.62
15-30	22.35	21.85	20.32	19.96	21.92	21.42
30-45	20.36	20.05	19.45	19.12	20.08	20.03

Fertigation at 75 per cent RDF

	Distance from dripper (cm)					
Depth (cm)	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	27.97	23.18	20.25	19.55	23.24	22.03
15-30	21.71	21.19	19.72	19.32	21.23	20.84
30-45	19.77	19.55	18.86	18.57	19.56	19.43

Fertigation at 50 per cent RDF

	Distance from dripper (cm)					
Depth (cm)	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	27.27	22.13	19.66	19.07	22.15	21.44
15-30	21.08	20.54	19.13	18.70	20.55	20.27
30-45	19.12	19.05	18.28	18.03	19.07	18.84

Table 4.36. Phosphorus dynamics after end of final fertigation (kg ha^{-1})

Fertigation at 100 per cent RDF

Depth (cm)	Distance from dripper (cm)					
	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	24.50	21.31	19.80	18.99	21.95	20.61
15-30	21.43	20.82	19.52	19.09	20.97	20.48
30-45	19.39	19.26	18.91	18.84	19.30	18.98

Fertigation at 75 per cent RDF

Depth (cm)	Distance from dripper (cm)					
	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	24.07	20.73	19.23	18.52	21.37	20.07
15-30	20.82	20.19	18.94	18.48	20.30	19.92
30-45	18.82	18.77	18.34	18.30	18.80	18.41

Fertigation at 50 per cent RDF

Depth (cm)	Distance from dripper (cm)					
	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	23.47	19.79	18.67	18.06	20.37	19.53
15-30	20.21	19.57	18.38	17.88	19.66	19.38
30-45	18.21	18.29	17.78	17.77	18.33	17.86

Table 4.37. Potassium dynamics after end of second fertigation (kg ha^{-1})

Fertigation at 100 per cent RDF

	Distance from dripper (cm)					
Depth (cm)	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	376	370	347	359	371	370
15-30	373	367	345	358	367	366
30-45	379	374	370	372	375	374

Table 4.38. Potassium dynamics after end of final fertigation (kg ha^{-1})

Fertigation at 100 per cent RDF

	Distance from dripper (cm)					
Depth (cm)	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	428	421	413	386	426	419
15-30	422	411	400	383	418	404
30-45	387	385	382	375	385	382

Fertigation at 75 per cent RDF

	Distance from dripper (cm)					
Depth (cm)	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	420	409	401	380	411	408
15-30	410	399	388	379	400	393
30-45	385	383	380	374	383	380

Fertigation at 50 per cent RDF

	Distance from dripper (cm)					
Depth (cm)	Between lateral				Along lateral	
	0	15	30	45	15	30
0-15	410	391	389	379	391	390
15-30	398	387	380	377	387	383
30-45	383	381	378	372	381	379

Table 4.39. *Jasminum grandiflorum* under drought stress

At regular irrigation

Plant	Leaf side	Whole plant transpiration ($g/m^2/day$)	Leaf transpiration ($mmol/m^2/s$)	Stomata # (0.1 mm^2)	Stomata aperture (μm^2)	Transpiring area (m^2/m^2)	Relative water content (%)
Jasmine	Adaxial	10788.5±1391.49** (3)	7.02±0.84 (9)	51.77±0.85 (14)	107.5±12.78 (9)	56108.27±1953.14, N=8	90.74±1.32(6)
	Abaxial		9.23±0.39 (9)	11.40±0.86, N=15	95.89±11.42,N=8		

First day of drought stress

Plant	Leaf side	Whole plant transpiration ($g/m^2/day$)	Leaf transpiration ($mmol/m^2/s$)	Stomata # (0.1 mm^2)	Stomata aperture (μm^2)	Transpiring area (m^2/m^2)	Relative water content (%)
Jasmine	Adaxial	10313.74±2218.99* (3)	7.05±0.81 (9)	51.77±0.85 (14)	107.5±12.78 (9)	56108.27±1953.14, N=8	86.35±5.1(6)
	Abaxial		8.88±0.31 (9)	11.40±0.86, N=15	95.89±11.42, N=8		

Second day of drought stress

Plant	Leaf side	Whole plant transpiration ($g/m^2/day$)	Leaf transpiration ($mmol/m^2/s$)	Stomata # (0.1 mm^2)	Stomata aperture (μm^2)	Transpiring area (m^2/m^2)	Relative water content (%)
Jasmine	Adaxial	7542.59±3277.78 (3)	6.6±0.55 (9)	51.77±0.85 (14)	107.5±12.78 (9)	56108.27±1953.14, N=8	78.15±7.66(6)
	Abaxial		8.61±6.22*(9)	11.40±0.86, N=15	95.89±11.42,N=8		

Third day of drought stress

Plant	Leaf side	Whole plant transpiration ($g/m^2/day$)	Leaf transpiration ($mmol/m^2/s$)	Stomata # (0.1 mm^2)	Stomata aperture (μm^2)	Transpiring area (m^2/m^2)	Relative water content (%)

Jasmine	Adaxial	5487.84±2604.54(3)	6.47±0.56 (9)	51.77±0.85 (14)	107.5±12.78 (9)	56108.27±1953.14, N=8	67.95±6.3(6)
	Abaxial		8.1±0.21* (9)	11.40±0.86, N=15	95.89±11.42,N=8		

Fourth day of drought stress

Plant	Leaf side	Whole plant transpiration ($g/m^2/day$)	Leaf transpiration ($mmol/m^2/s$)	Stomata # (0.1 mm^2)	Stomata aperture (μm^2)	Transpiring area (m^2/m^2)	Relative water content (%)
Jasmine	Adaxial	5054.83±2540.67(3)	6.35±0.58 (9)	51.77±0.85 (14)	107.5±12.78 (9)	56108.27±1953.14, N=8	64.60±3.12(6)
	Abaxial		7.66±0.17* (9)	11.40±0.86, N=15	95.89±11.42,N=8		

Fifth day of drought stress

Plant	Leaf side	Whole plant transpiration ($g/m^2/day$)	Leaf transpiration ($mmol/m^2/s$)	Stomata # (0.1 mm^2)	Stomata aperture (μm^2)	Transpiring area (m^2/m^2)	Relative water content (%)
Jasmine	Adaxial	2918.70±1437.62(3)	6.17±0.51 (9)	51.77±0.85 (14)	107.5±12.78 (9)	56108.27±1953.14, N=8	61.58±5.88(6)
	Abaxial		7.4±0.19* (9)	11.40±0.86, N=15	95.89±11.42,N=8		

Sixth day of drought stress

Plant	Leaf side	Whole plant transpiration ($g/m^2/day$)	Leaf transpiration ($mmol/m^2/s$)	Stomata # (0.1 mm^2)	Stomata aperture (μm^2)	Transpiring area (m^2/m^2)	Relative water content (%)
Jasmine	Adaxial	1521.66±679.90 (3)	6.03±0.5(9)	51.77±0.85 (14)	107.5±12.78 (9)	56108.27±1953.14, N=8	58.25±8.2(6)
	Abaxial		6.65±0.16 *(9)	11.40±0.86, N=15	95.89±11.42,N=8		

Recovery from drought stress

Plant	Leaf side	Whole plant transpiration ($g/m^2/day$)	Leaf transpiration ($mmol/m^2/s$)	Stomata # (0.1 mm^2)	Stomata aperture (μm^2)	Transpiring area (m^2/m^2)	Relative water content (%)

Jasmine	Adaxial	4655.61±1807.91(3)	6.22±0.44 (9)	51.77±0.85 (14)	107.5±12.78 (9)	56108.27±1953.14, N=8	91.32±1.32(6)
	Abaxial		6.8±0.11* (9)	11.40±0.86, N=15	95.89±11.42,N=8		

* significant at 5% level

Table 4.40a. Economic viability of drip fertigation system in *Jasminum grandiflorum*

S. No.	Cost economics	100 per cent recommended dose of fertilizer						
		Control	W_1M_1	W_1M_0	W_2M_1	$W2M_0$	W_3 M_1	W_3M_0
1.	Fixed cost including mulch(Rs/ha)	-	76,000	71,000	76,000	71,000	76,000	71,000
a.	Life (years)	-	10	10	10	10	10	10
b.	Depreciation @ 10 per cent	-	7,600	7,100	7,600	7,100	7,600	7,100
c.	Interest @ 8 per cent	-	5,680	5,680	5,680	5,680	5,680	5,680
d.	Repairs and maintenance	-	1,000	1,000	1,000	1,000	1,000	1,000
e.	Total (b+c+d)	-	14,280	13,780	14,280	13,780	14,280	13,780
2.	Cost of cultivation (Rs/ha)	42,686	47,490	47,290	47,490	47,320	47793	47793
3.	Seasonal total cost (2+e) Rs.	42,686	61,770	61,070	61,770	61,100	62,073	61573
4.	Water used (mm)	1650	473	473	595	595	884	884
5.	Jasmine flower yield (kg/ha)	7,390	8,563	8,446	14,327	14,240	14,437	14350
6.	Jasmine price (Rs/kg)	18	18	18	18	18	18	18
7.	Total income (Rs/ha)	1,33,020	154,134	152,028	2,57,886	256320	259866	258300
8.	Net seasonal income (Rs) (7-3)	90,334	92,364	90,958	196116	195220	197793	196727
9.	Additional area cultivated due to saving water (ha)	-	0.79	0.79	0.88	0.88	0.98	0.98
10.	Additional expenditure due to additional area (3x9) (Rs.)	-	48,798	48,245	54357	53768	60831	60341
11.	Additional income due to additional area (8x9) (Rs.)	-	72,967	71,856	172582	171793	193837	192792
12.	Additional net income (11-10) (Rs.)	-	24,169	23,611	118225	118025	133006	132451
13.	Gross cost of production (3+10)	42,686	1,10,568	1,09,315	116127	114868	122904	121914
14.	Gross income (7+11) (Rs.)	1,33,020	2,27,101	2,23,884	430468	428113	453703	451092
15.	Gross Net income (14-13) (Rs.)	1,75,706	1,16,533	1,14,569	314341	313245	330799	329178
16.	Gross benefit-cost ratio (14/13)	3.11	2.05	1.95	3.69	3.62	3.70	3.68
17.	Net profit per mm of water used (8/4) (Rs.)	54.74	195.27	192.30	331.27	328.10	223.74	225.54
18.	Marginal benefit-cost ratio* (Additional investment for drip)		2.21	2.21	3.57	3.37	3.62	3.62

Table 4.40b. Economic viability of drip fertigation system in *Jasminum grandiflorum*

S. No.	Cost economics	75 per cent recommended dose of fertilizer						
		Control (100 % Rdf)	W_1M_1	W_1M_0	W_2M_1	W_2M_0	W_3 M_1	W_3M_0
1.	Fixed cost including mulch(Rs/ha)	-	76,000	71,000	76,000	71,000	76,000	71,000
a.	Life (years)	-	10	10	10	10	10	10
b.	Depreciation @ 10 per cent	-	7,600	7,100	7,600	7,100	7,600	7,100
c.	Interest @ 8 per cent	-	5,680	5,680	5,680	5,680	5,680	5,680
d.	Repairs and maintenance	-	1,000	1,000	1,000	1,000	1,000	1,000
e.	Total (b+c+d)	-	14,280	13,780	14,280	13,780	14,280	13,780
2.	Cost of cultivation (Rs/ha)	42,686	37,102	37,102	37032	37032	37532	37532
3.	Seasonal total cost (2+e) Rs.	42,686	51382	50882	51312	50812	51812	51312
4.	Water used (mm)	1650	473	473	595	595	884	884
5.	Jasmine flower yield (kg/ha)	7,390	8336	8223	10214	10060	11384	11284
6.	Jasmine price (Rs/kg)	18	18	18	18	18	18	18
7.	Total income (Rs/ha)	1,33,020	150048	148014	183852	181080	204912	203112
8.	Net seasonal income (Rs) (7-3)	90,334	98866	97132	132540	130268	153100	151800
9.	Additional area cultivated due to saving water (ha)	-	0.79	0.79	0.88	0.88	0.88	0.88
10.	Additional expenditure due to additional area (3x9) (Rs.)	-	40591	40196	45154	44714	45594	45154
11.	Additional income due to additional area (8x9) (Rs.)	-	78104	76734	116635	114635	134728	133584
12.	Additional net income (11-10) (Rs.)	-	37513	36538	71481	69921	89134	88430
13.	Gross cost of production (3+10)	42,686	91973	91078	96466	95526	97406	96466
14.	Gross income (7+11) (Rs.)	1,33,020	228152	224748	300487	295715	339640	336696
15.	Gross Net income (14-13) (Rs.)	1,75,706	136179	133670	204021	200189	242234	240230

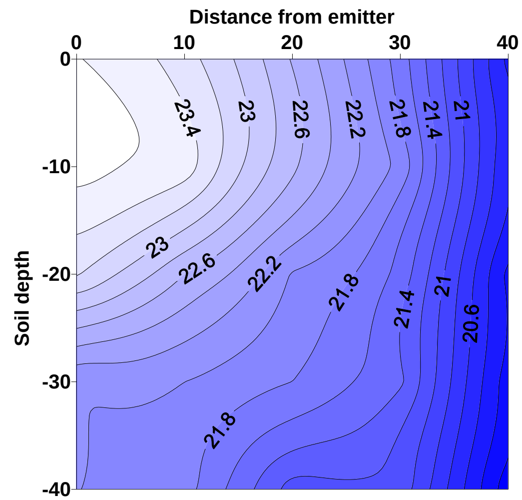
16	Gross benefit-cost ratio (14/13)	3.11	2.49	2.46	3.11	3.09	3.49	3.47
17.	Net profit per mm of water used (8/4) (Rs.)	54.74	209.09	192.30	331.27	218.93	173.19	171.71
18.	Marginal benefit-cost ratio* (Additional investment for drip)		2.21	2.21	3.37	3.37	3.62	3.62

Table 4.40c. Economic viability of drip fertigation system in *Jasminum grandiflorum*

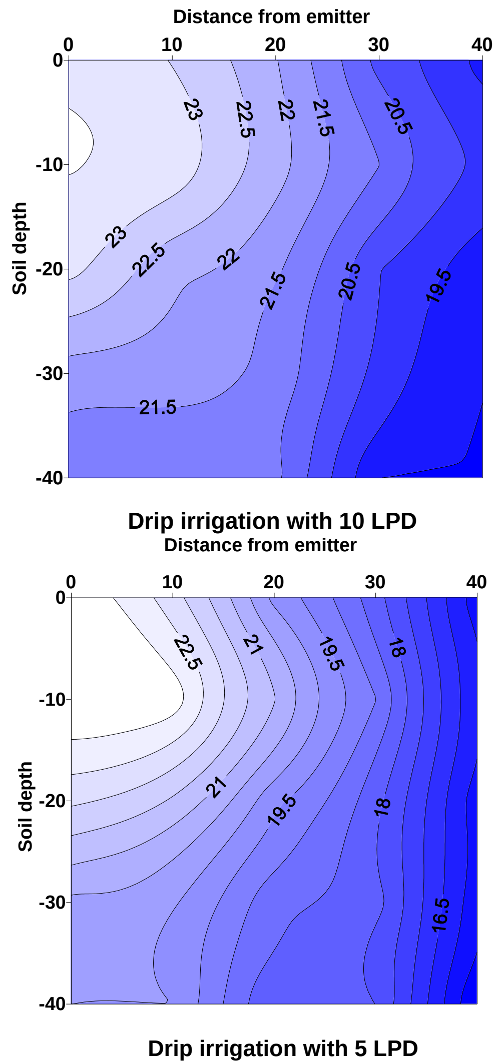
S. No.	Cost economics	50 per cent recommended dose of fertilizer						
		Control (100% Rdf)	W_1M_1	W_1M_0	W_2M_1	$W2M_0$	W_3 M_1	W_3M_0
1.	Fixed cost including mulch(Rs/ha)	-	76,000	71,000	76,000	71,000	76,000	71,000
a.	Life (years)	-	10	10	10	10	10	10
b.	Depreciation @ 10 per cent	-	7,600	7,100	7,600	7,100	7,600	7,100
c.	Interest @ 8 per cent	-	5,680	5,680	5,680	5,680	5,680	5,680
d.	Repairs and maintenance	-	1,000	1,000	1,000	1,000	1,000	1,000
e.	Total (b+c+d)	-	14,280	13,780	14,280	13,780	14,280	13,780
2.	Cost of cultivation (Rs/ha)	42,686	40753	40753	40600	40600	40953	40953
3.	Seasonal total cost (2+e) Rs.	42,686	55033	54533	54880	54380	55233	54733
4.	Water used (mm)	1650	473	473	595	595	884	884
5.	Jasmine flower yield (kg/ha)	7,390	6212	6072	6459	6371	6792	6425
6.	Jasmine price (Rs/kg)	18	18	18	18	18	18	18
7.	Total income (Rs/ha)	1,33,020	111816	109296	116262	114678	122256	115650
8.	Net seasonal income (Rs) (7-3)	90,334	56783	54763	61382	60298	67023	60917
9.	Additional area cultivated due to saving water (ha)	-	0.48	0.48	0.79	0.79	0.79	0.79
10.	Additional expenditure due to additional area (3x9) (Rs.)	-	26415	26175	43355	42960	43634	43239
11.	Additional income due to additional area (8x9) (Rs.)	-	53671	52462	91846	90595	96558	91363
12.	Additional net income (11-10) (Rs.)	-	27256	26287	48491	47635	52924	48124

13.	Gross cost of production (3+10)	42,686	81448	80708	98235	97340	98867	97972
14.	Gross income (7+11) (Rs.)	1,33,020	165487	161758	208108	205273	218814	207013
15.	Gross Net income (14-13) (Rs.)	1,75,706	84039	81050	109873	107933	119947	109041
16.	Gross benefit-cost ratio (14/13)	3.11	2.03	2.04	2.12	2.11	2.21	2.11
17.	Net profit per mm of water used (8/4) (Rs.)	54.74	120.04	115.77	103.16	101.34	75.81	68.91
18.	Marginal benefit-cost ratio* (Additional investment for drip)		2.21	2.21	3.37	3.37	3.62	3.62

Figure 2. Soil moisture distribution under drip irrigation after 24 hrs of drip irrigation Between lateral (from dripper point)



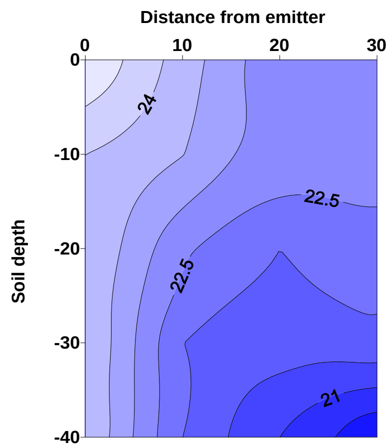
Drip irrigation with 15 LPD



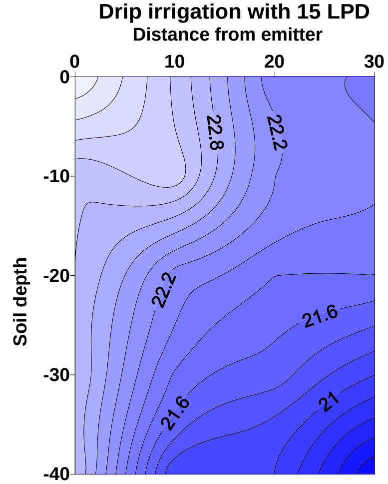
Values in contour are moisture content (%)

Figure 3. Soil moisture distribution under drip irrigation after 24 hrs of drip irrigation

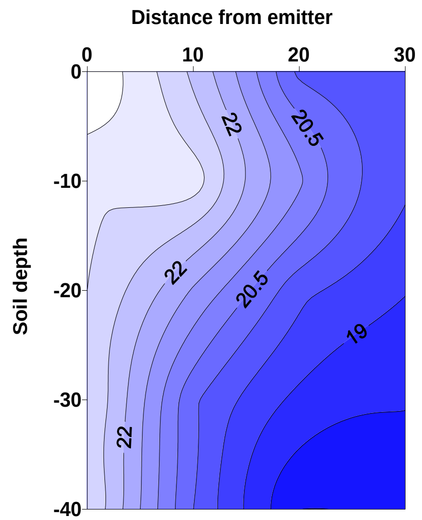
Along lateral (between dripper)



Drip irrigation with 15 LPD



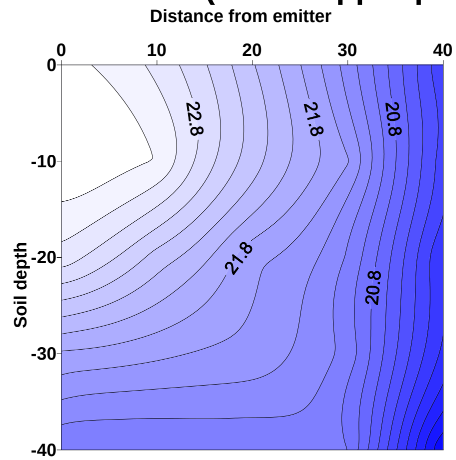
Drip irrigation with 10 LPD



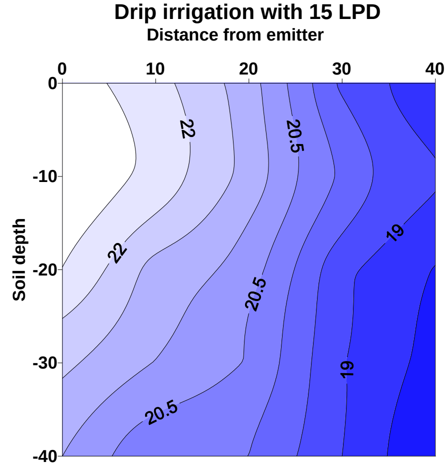
Drip irrigation with 5 LPD

Values in contour are moisture content (%)

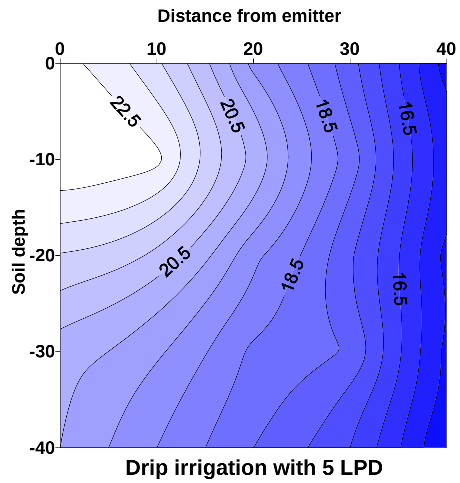
Figure 4. Soil moisture distribution under drip irrigation after 48 hrs of drip irrigation Between lateral (from dripper point)



Drip irrigation with 15 LPD

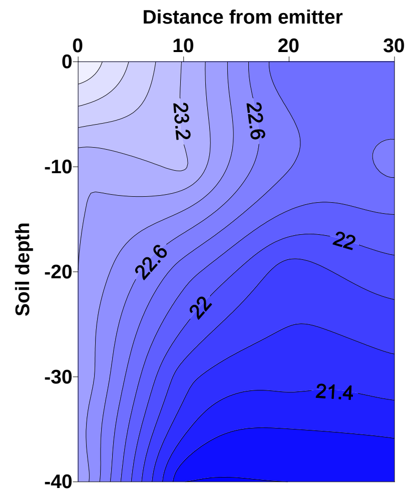


Drip irrigation with 10 LPD

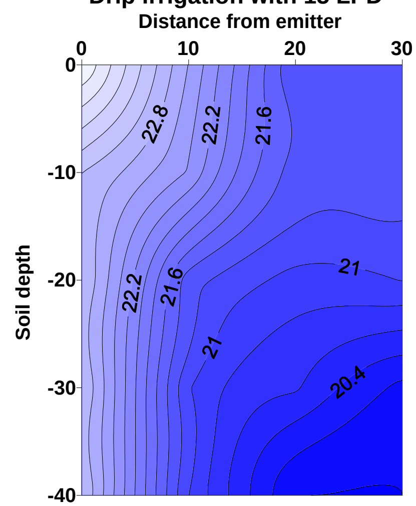


Values in contour are moisture content (%)

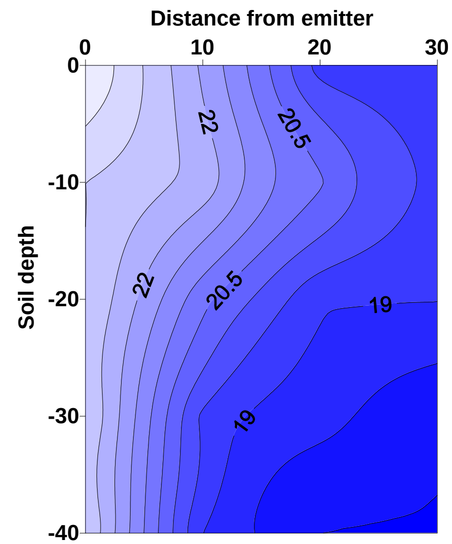
Figure 5. Soil moisture distribution under drip irrigation after 48 hrs of drip irrigation Along lateral (between dripper)



Drip irrigation with 15 LPD

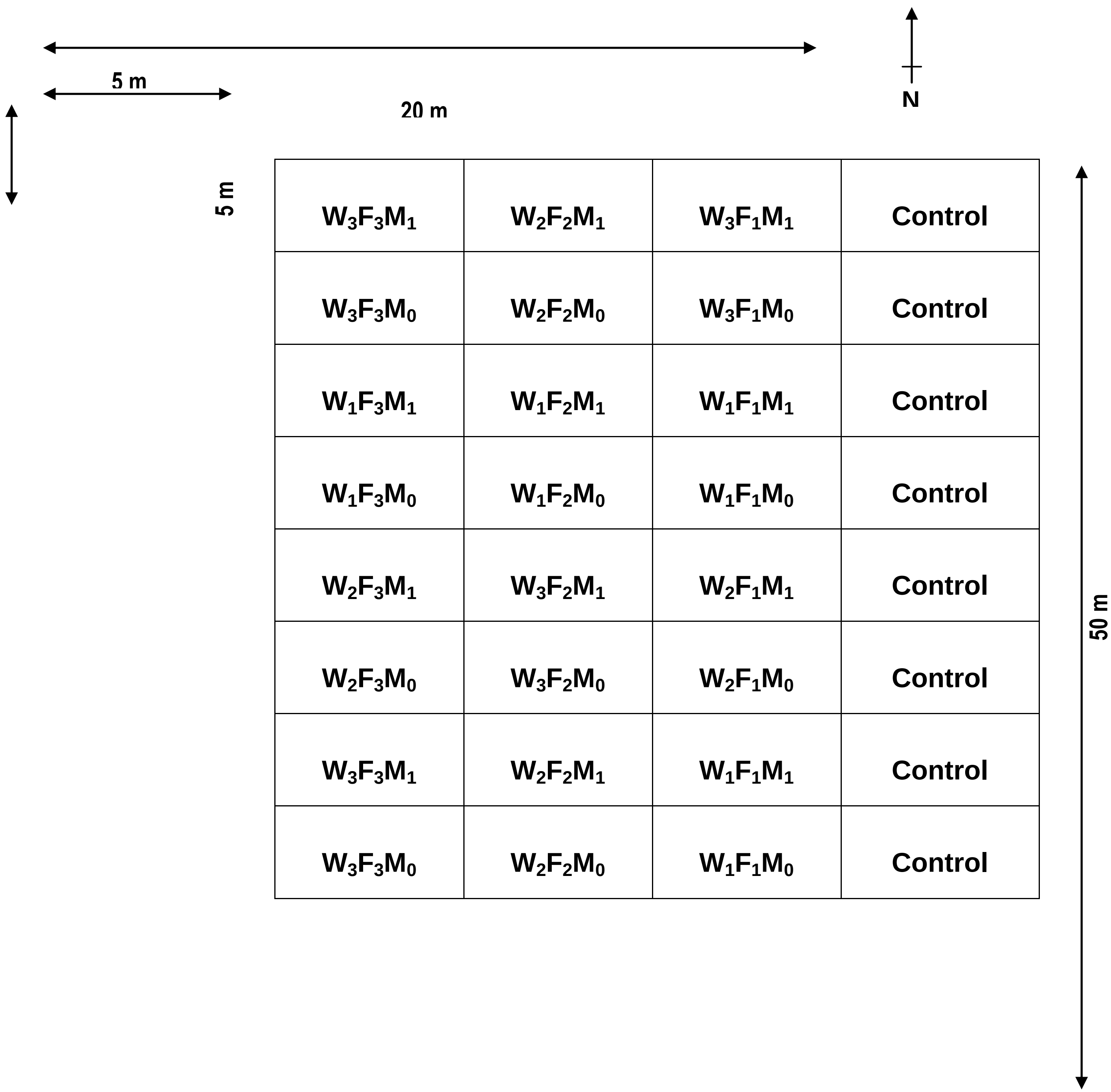


Drip irrigation with 10 LPD



Drip irrigation with 5 LPD

Values in contour are moisture content (%)

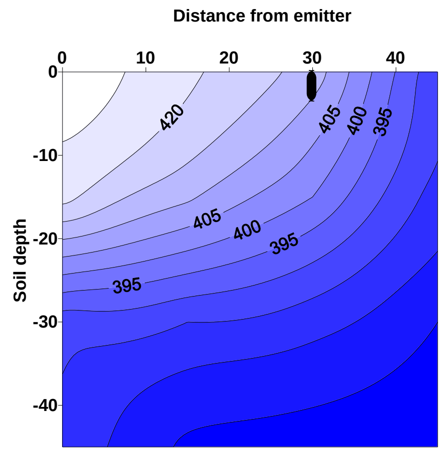


20 m
5 m
5 m
N
50 m
W3F3M1
W2F2M1
W3F1M1
Control
W3F3M0
W2F2M0
W3F1M0
Control
W1F3M1
W1F2M1
W1F1M1
Control
W1F3M0
W1F2M0
W1F1M0
Control
W2F3M1
W3F2M1
W2F1M1
Control
W2F3M0
W3F2M0
W2F1M0
Control
W3F3M1
W2F2M1
W1F1M1
Control
W3F3M0
W2F2M0
W1F1M0
Control

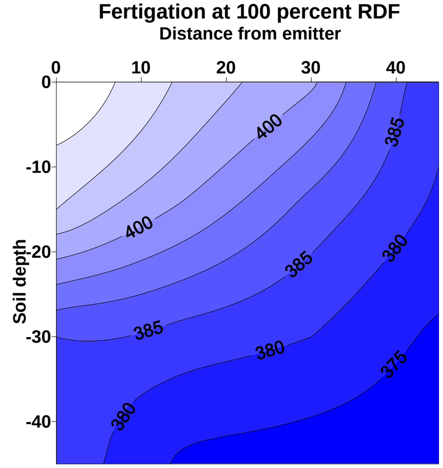
$W_1F_3M_1$	$W_3F_2M_1$	$W_3F_1M_1$	Control
$W_1F_3M_0$	$W_3F_2M_0$	$W_3F_1M_0$	Control
$W_2F_3M_1$	$W_1F_2M_1$	$W_2F_1M_1$	Control
$W_2F_3M_0$	$W_1F_2M_0$	$W_2F_1M_0$	Control

Fig. 1. Field lay-out plan

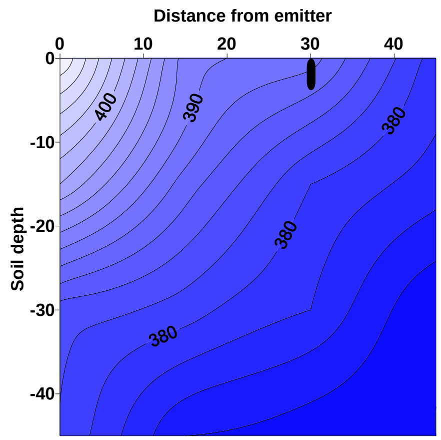
Figure 14. Potassium mobility under drip fertigation after final fertigation cycle Between lateral (From dripper point)



Fertigation at 100 percent RDF



Fertigation at 75 percent RDF

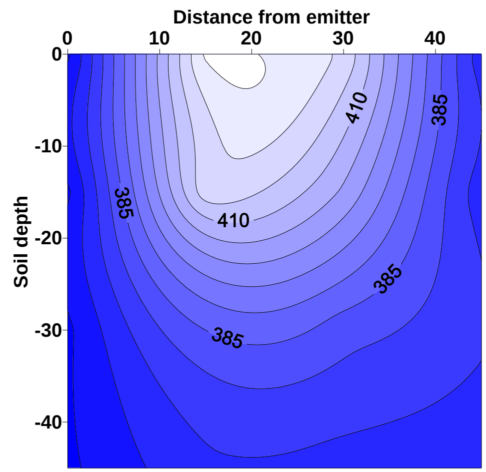


Fertigation at 50 percent RDF

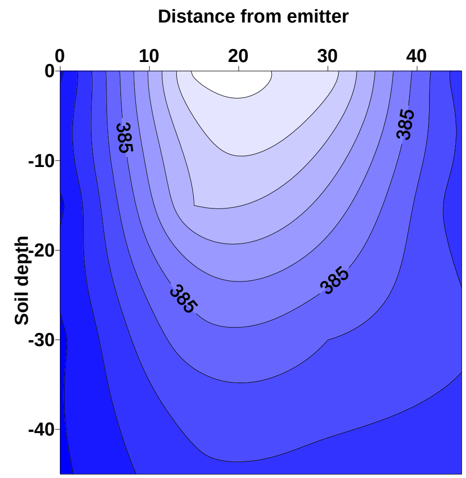
Plant

Values in contour is potassium content in kg per ha

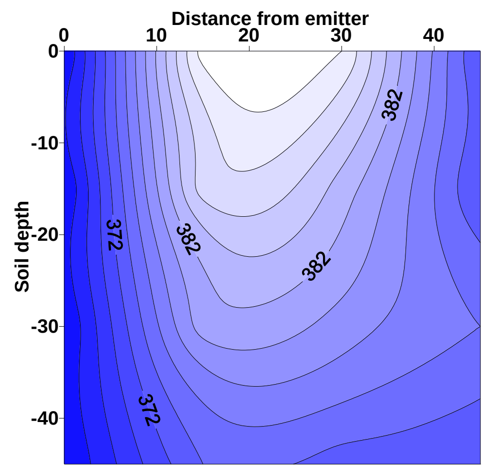
Figure 15. Potassium mobility under drip fertigation after final fertigation cycle Along lateral (Between dripper)



Fertigation at 100 percent RDF

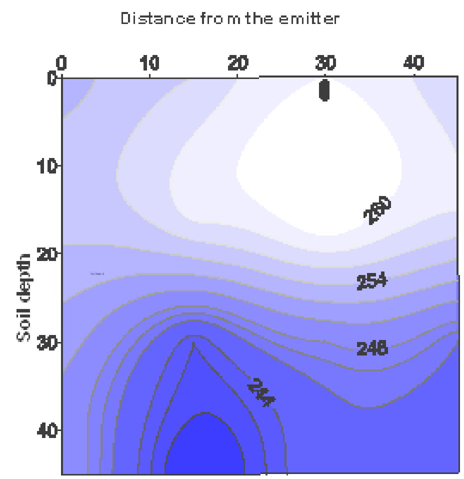


Fertigation at 75 percent RDF

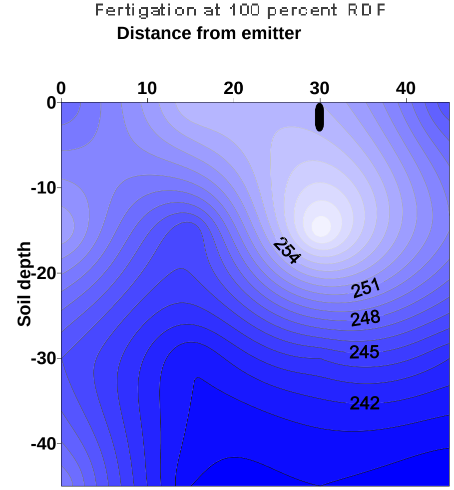


Fertigation at 50 percent RDF

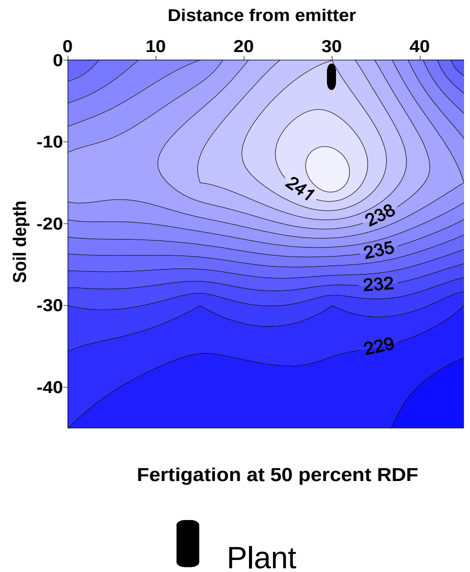
Figure 6. Nitrogen dynamics under drip fertigation after second fertigation cycle Between lateral (from dripper point)



Fertigation at 100 percent RDF

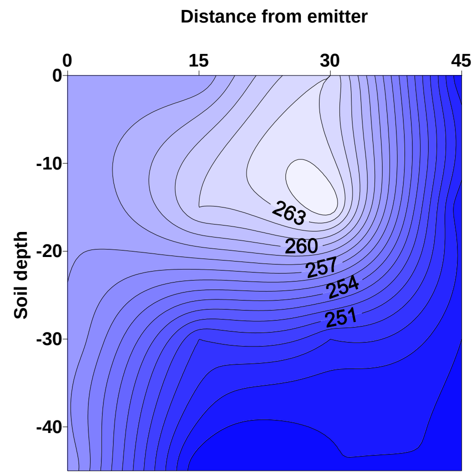


Fertigation at 75 percent RDF

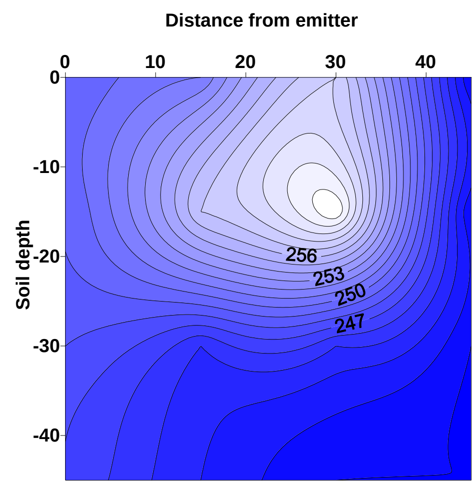


Values in contour is nitrogen content in kg per ha

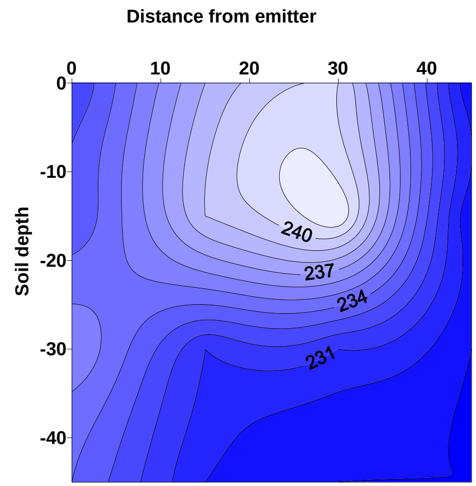
Figure 7.Nitrogen dynamics under drip fertigation after second fertigation cycle Along lateral (between dripper)



Fertigation at 100 percent RDF



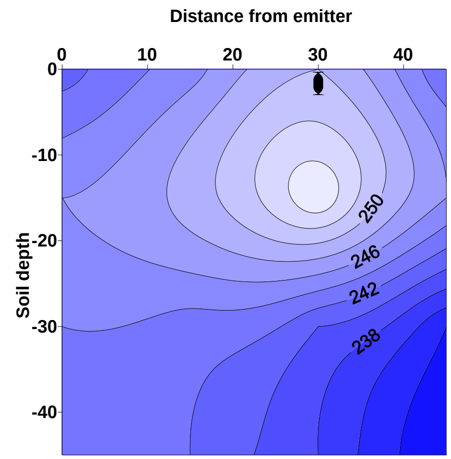
Fertigation at 75% RDF



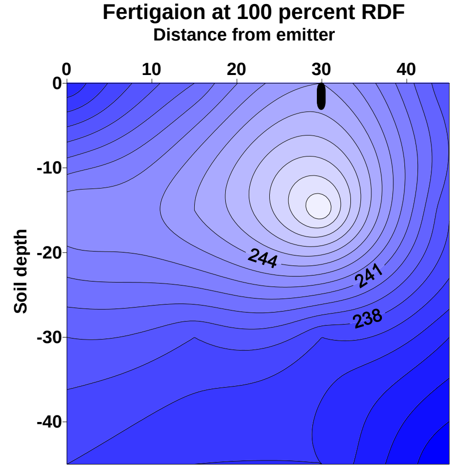
Fertigation at 50 percent RDF

Values in contour is nitrogen content in kg per ha

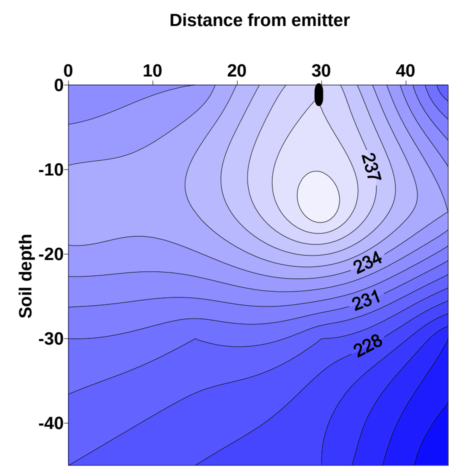
Figure 8. Nitrogen dynamics under drip fertigation after final fertigation cycle Between lateral (from dripper point)



Fertigaion at 100 percent RDF



Fertigation at 75 percent RDF

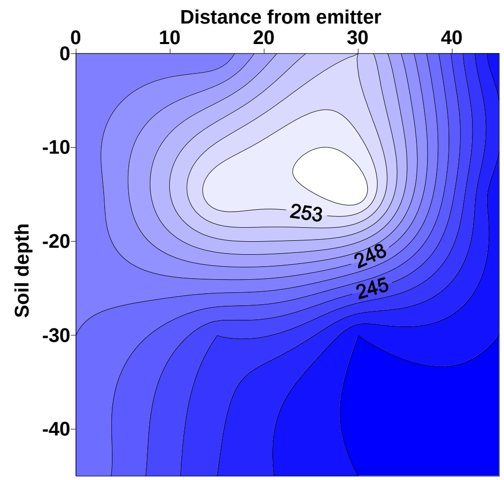


Fertgation at 50 pecent RDF

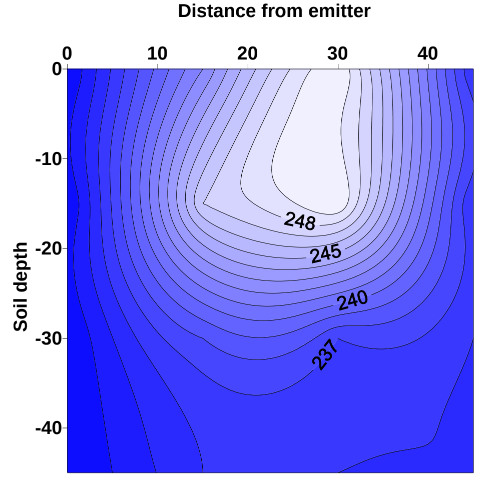
Plant

Values in contour is nitrogen content in kg per ha

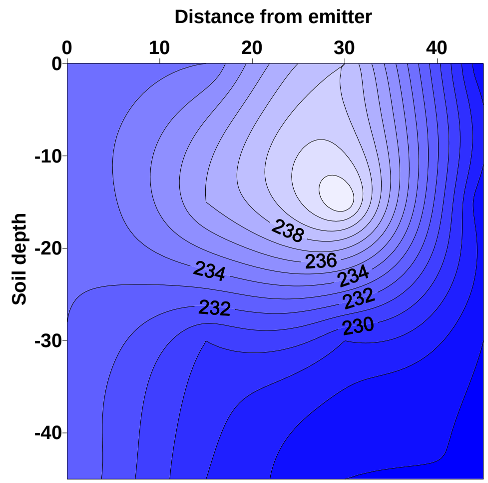
Figure 9. Nitrogen dynamics under drip fertigation after final fertigation cycle Along lateral (between dripper)



Fertigation at 100 percent RDF



Fertigation at 75 percent RDF

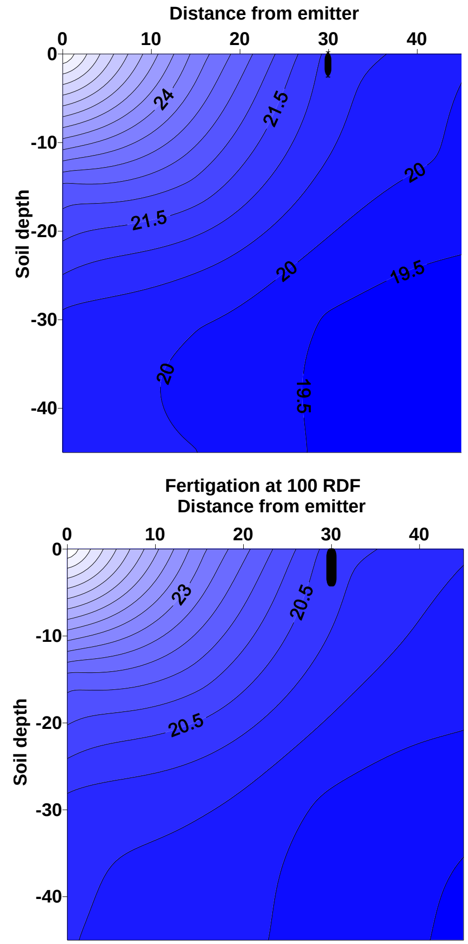


Fertigation at 50 percent RDF

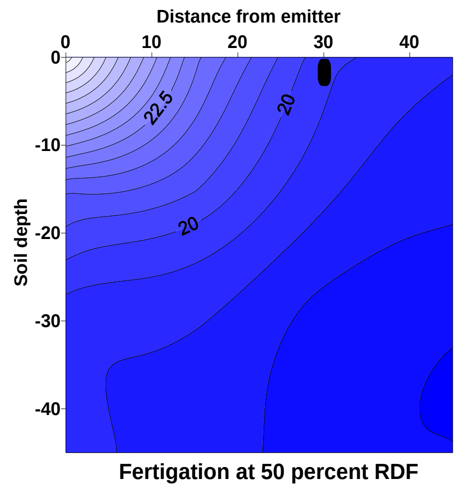
Values in contour is nitrogen content in kg per ha

Figure 10.Phosphorous dynamics under drip fertigation after second fertigation cycle

Between lateral (from dripper point)



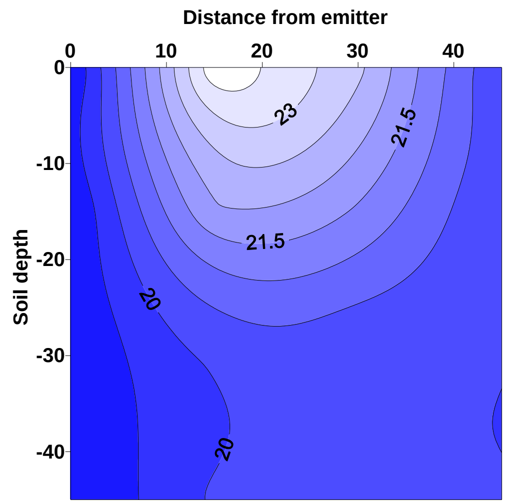
Fertigation at 75 percent RDF



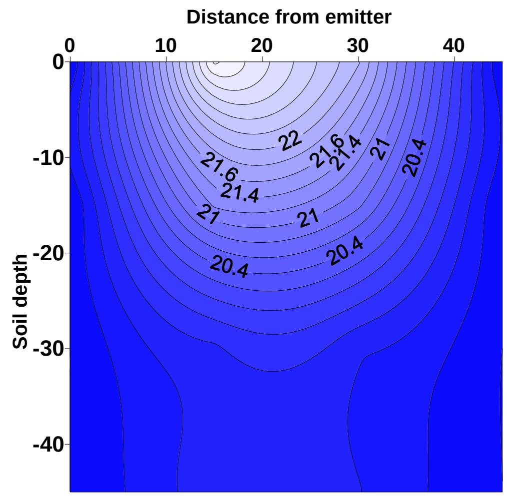
Plant

Values in contour is phosphorous content in kg per ha

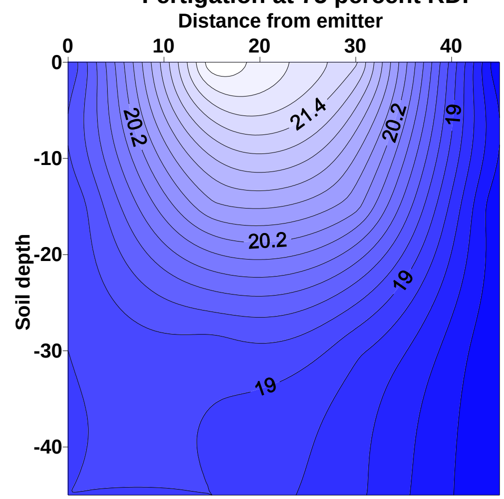
Figure 11. Phosphorous dynamics under drip fertigation after second fertigation cycle Along lateral (between dripper)



Fertigation at 100 percent RDF



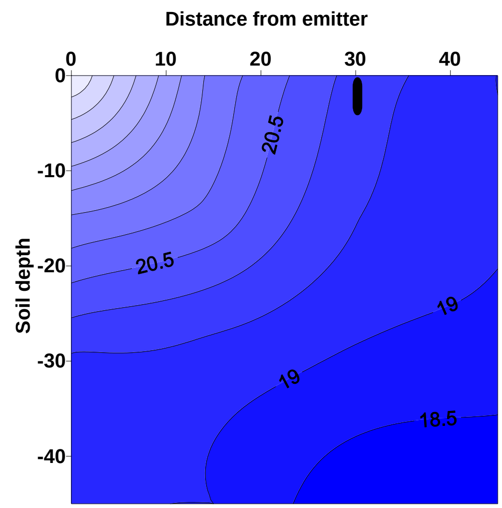
Fertigation at 75 percent RDF



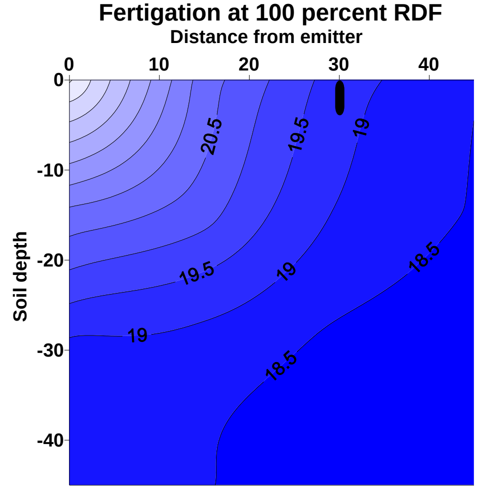
Fertigation at 50 percent RDF

Figure 12. Phosphorous dynamics under drip fertigation after final fertigation cycle

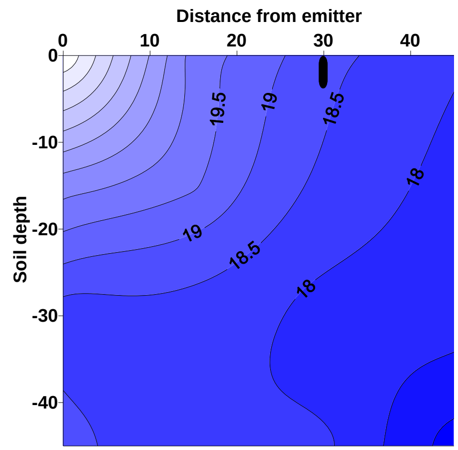
Between lateral (from dripper point)



Fertigation at 100 percent RDF



Fertigation at 75 percent RDF



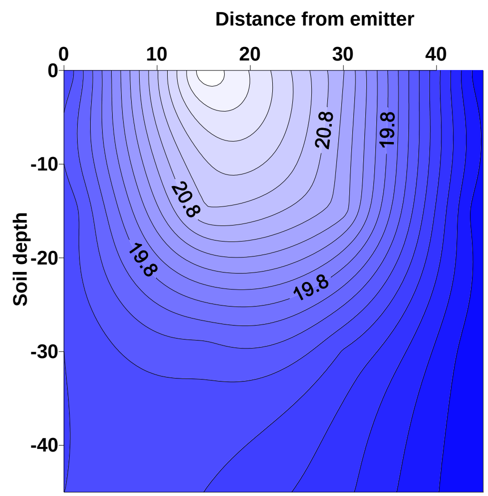
Fertigation at 50 percent RDF

Plant

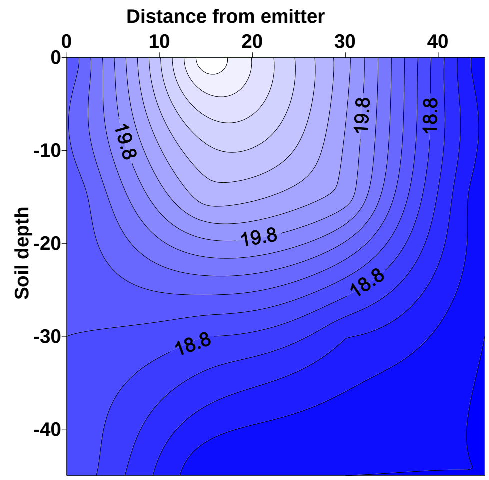
Values in contour is phosphorous content in kg per ha

Figure 13. Phosphorous dynamics under drip fertigation after final fertigation cycle

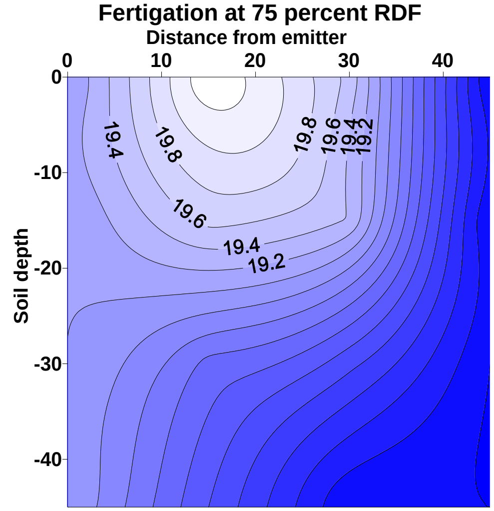
Along lateral (between dripper)



Fertigation at 100 percent RDF



Fertigation at 75 percent RDF



Fertigation at 50 percent RDF

APPENDIX – I

Weather data during the cropping period (November 2005 to August 2006)

November 2005

Date	Max.Temp ^{o}C	Min.Temp ^{o}C	RH	EVP mm	Rainfall (mm)	Sunshine (hrs)
1.	30.6	22.2	90	3.2	-	4.8
2.	30.8	21.0	94	3.7	34.5	5.2
3.	29.0	20.5	94	3.0	33.0	5.6
4.	29.0	22.2	98	3.6	18.8	2.5
5.	28.8	20.6	94	2.8	20.6	3.3
6.	28.8	20.8	98	1.5	12.0	4.1
7.	27.0	21.2	93	2.5	-	0.0
8.	28.5	22.7	89	2.6	-	3.1
9.	28.8	21.8	91	2.8	-	1.6
10.	28.0	22.1	95	2.0	-	0.5
11.	28.8	23.2	91	1.6	-	1.8
12.	29.0	22.4	96	3.0	20.0	2.7
13.	27	22.8	95	2.8	1.8	2.2
14.	28.5	21.6	86	2.2	0.5	1.1
15.	28.8	18.2	94	2.0	-	7.2
16.	30.0	20.4	94	2.8	-	9.0
17.	29.4	15.5	90	2.6	-	7.6
18.	28.8	14.l7	90	2.8	-	9.2
19.	28.9	14.4	87	3.0	-	10.2
20.	29.5	17.7	90	3.6	-	10.3
21.	29.8	21.0	88	3.4	-	8.5
22.	27.8	22.4	89	2.4	0.5	1.5
23.	25.2	22.0	94	1.4	13.0	0.0
24.	23.0	20.0	96	1.7	12.5	0
25.	22	20.2	96	1.2	28.4	0
26.	25.4	21.2	91	2.4	1.0	1.0
27.	28.0	19.8	96	3.0	-	5.5
28.	27.7	21.5	89	2.0	-	3.1
29.	28.0	18.0	94	2.2	-	5.2
30.	28.6	17.4	92	1.8	-	5.8

December 2005

Date	Max.Temp °C	Min.Temp °C	RH	EVP mm	Rainfall (mm)	Sunshine (hrs)
1.	30.5	19.6	89	2.4	-	8.4
2.	30.8	22.5	91	2.6	-	78.4
3.	31.4	22.0	93	2.0	-	3.7
4.	32.5	21.0	98	1.8	51	8.2
5.	25.6	21.6	94	1.7	2.5	0
6.	26.5	21.4	96	1.6	-	1.4
7.	28.6	17.6	90	1.8	-	8.9
8.	29.6	16.7	92	2.2	-	9.8
9.	30.2	14.8	93	2.4	-	10.2
10.	31.0	21.0	89	3.2	-	9.4
11.	26.7	21.5	96	2.4	1.8	0
12.	25.0	22.0	89	1.4	0.6	2.6
13.	28.0	21.6	96	1.6	2.8	4.2
14.	27.8	20.6	89	2.0	1.4	2.3
15.	26.8	20.9	94	3.0	-	7.2
16.	28.4	15.0	91	2.4	-	9.7
17.	29.0	14.6	93	3.0	-	7.0
18.	30.3	20.5	95	1.4	-	12.7
19.	28.6	18.5	94	3.2	-	9.6
20.	32.5	18.4	92	2.8	-	8.5
21.	32.0	18.6	92	3.0	-	7.7
22.	31.8	19.5	94	2.4	-	6.9
23.	30.8	17.6	96	2.6	-	7.9
24.	30.8	16.5	94	2.8	-	8.7
25.	29.5	20.0	91	2.4	-	3.7
26.	29.5	20.7	91	2.8	-	7.9
27.	28.5	17.2	90	2.8	-	7.2
28.	27.5	15.0	94	3.0	-	8.9
29.	28.2	18.0	91	3.2	-	4.1
30.	27.7	17.8	92	3.4	-	6.6
31.	27.7	19.0	94	3.4	-	5.5

January 2006

Date	Max.Temp ^oC	Min.Temp ^oC	RH	EVP mm	Rainfall (mm)	Sunshine (hrs)
1.	28.0	17.2	94	3.6	-	7.9
2.	28.4	18.5	88	3.8	-	9.9
3.	26.5	17.2	92	2.6	-	1.9
4.	28.0	18.2	92	2.8	-	5.3
5.	29.4	22.0	91	2.8	-	8.0
6.	29.0	22.0	91	2.6	-	2.9
7.	27.0	20.0	85	1.7	-	0.9
8.	29.8	22.5	93	3.0	-	7.3
9.	27.5	21.8	95	2.0	28.0	1.8
10.	29.8	22.0	94	2.8	28.2	6.9
11.	29.6	15.8	96	3.4	28.2	7.1
12.	29.0	17.3	94	3.5	28.2	8.2
13.	30.0	20.2	94	3.4	28.2	8.5
14.	29.5	19.0	92	3.3	28.2	6.8
15.	29.5	22.2	91	2.6	28.2	3.6
16.	29.4	22.6	93	2.8	28.2	2.3
17.	31.2	22.5	91	3.0	-	7.7
18.	30.5	21.2	89	3.4	-	6.8
19.	32.5	15.6	94	4.2	-	9.6
20.	30.5	13.0	91	4.0	-	10.3
21.	31.2	13.4	91	4.2	-	10.5
22.	31.6	13.7	89	3.8	-	10.5
23.	32.4	13.5	91	4.0	-	10.7
24.	32.5	15.0	93	4.4	-	10.3
25.	32.7	18.2	63	4.6	-	9.8
26.	29.8	19.5	85	4.8	-	9.0
27.	29.7	14.5	90	4.8	-	9.2
28.	29.2	21.0	87	5.0	-	8.7
29.	28.8	16.5	94	3.2	-	4.5
30.	29.5	14.7	89	4.0	-	9.5
31.	29.0	14.5	91	4.4	-	10.1

February 2006

Date	Max.Temp °C	Min.Temp °C	RH	EVP mm	Rainfall (mm)	Sunshine (hrs)
1.	29.8	16.0	91	4.4	-	9.9
2.	29.3	17.4	90	4.0	-	8.0
3.	29.5	19.0	90	4.8	-	9.8
4.	29.0	21.5	84	4.8	-	7.5
5.	29.7	18.5	96	3.8	-	3.9
6.	32.5	16.5	94	4.8	-	9.6
7.	30.8	12.5	86	5.6	-	10.3
8.	30.8	13.5	89	5.8	-	10.4
9.	29.0	14.5	89	4.4	-	7.8
10.	31.5	18.0	94	5.0	-	8.6
11.	31.2	18.8	92	5.0	-	8.3
12.	30.7	16.5	80	6.8	-	9.7
13.	30.5	18.2	82	6.8	-	10.3
14.	30.4	11.8	86	6.2	-	10.0
15.	32.2	13.4	78	4.8	-	10.5
16.	33.0	16.2	82	4.6	-	9.8
17.	33.5	16.0	86	4.8	-	10.5
18.	33.7	18.2	87	4.6	-	10.2
19.	33.5	16.8	96	5.4	-	10.3
20.	33.5	16.7	88	5.8	-	10.6
21.	33.8	15.2	80	6.4	-	10.3
22.	33.0	15.0	85	5.6	-	10.4
23.	33.5	17.2	90	6.4	-	10.5
24.	33.6	18.5	81	6.5	-	10.6
25.	32.5	18.4	80	6.0	-	9.9
26.	33.5	18.0	83	5.2	-	8.2
27.	32.0	17.2	84	4.5	-	4.0
28.	33.8	23.2	86	4.0	-	8.9

March 2006

Date	Max.Temp °C	Min.Temp °C	RH	EVP mm	Rainfall (mm)	Sunshine (hrs)
1.	33.5	23.2	86	4.8	-	7.6
2.	34.3	22.5	89	4.6	-	9.5
3.	34.0	23.2	83	5.4	-	8.7
4.	33.2	20.4	93	OFF	82.4	7.0
5.	29.7	23.0	88	3.2	-	1.8
6.	33.5	23.4	93	4.5	-	8.6
7.	33.0	21.8	91	4.0	40.0	8.6
8.	32.5	21.7	89	4.4	-	9.6
9.	32.4	23.5	91	4.8	-	10.4
10.	31.5	20.8	95	4.4	29.0	6.2
11.	32.0	21.8	91	3.8	-	8.8
12.	32.5	21.5	91	4.8	-	10.5
13.	31.8	19.5	89	4.7	-	9.3
14.	32.6	20.5	87	5.0	-	10.4
15.	33.4	21.2	86	5.2	-	10.0
16.	33.5	21.8	91	5.5	=	9.6
17.	31.6	20.5	91	2.8	-	2.1
18.	32.7	23.6	85	3.6	-	7.9
19.	34.0	23.0	84	4.8	-	9.2
20.	33	22.1	86	5.8	-	8.5
21.	32.2	21.0	79	4.8	-	9.2
22.	34.6	20.7	91	4.6	-	9.2
23.	34.2	20.6	91	4.2	-	9.7
24.	35.7	23.2	91	4.4	-	9.5
25.	35.6	22.5	88	4.6	-	9.6
26.	35.7	23.0	95	5.0	-	9.8
27.	35.5	21.6	88	5.6	-	10.3
28.	35	21.7	88	5.8	-	10.7
29.	36.2	20.8	80	6.0	-	10.6
30.	35.2	23.4	87	6.0	-	7.1
31.	34.2	21.3	89	5.0	-	7.4

April 2006

Date	Max.Temp °C	Min.Temp °C	RH	EVP mm	Rainfall (mm)	Sunshine (hrs)
1.	35.4	21.7	89	5.4	-	8.1
2.	35.7	22.8	88	5.2	-	10.0
3.	35.0	22.5	91	5.4	-	10.1
4.	35.3	22.5	90	5.8	-	9.3
5.	34.7	22.3	88	5.5	-	9.0
6.	35.5	22.2	82	6.2	-	9.0
7.	35.5	22.8	86	6.6	-	10.2
8.	36.0	23.5	88	6.8	-	10.3
9.	35.5	23.2	91	6.5	-	10.0
10.	35.7	23.4	85	6.6	-	10.1
11.	36.0	23.4	85	6.4	-	9.4
12.	35.5	23.8	90-	6.6	-	9.5
13.	35.5	24.0	87	6.2	-	8.8
14.	36.4	23.2	90	6.0	-	9.4
15.	36.5	24.2	84	6.2	-	10.0
16.	34.0	22.8	98	5.6	-	2.8
17.	32.6	22.5	87	4.5	-	7.0
18.	33.5	22.8	90	4.7	-	8.7
19.	35.0	23.0	91	5.4	0.6	8.8
20.	34.5	22.5	95	5.4	17.4	6.7
21.	33.6	22.4	90	5.4	-	9.3
22.	33.6	22.4	90	5.4	-	9.3
23.	33.6	23.0	91	4.5	-	9.8
24.	35.2	23.4	91	6.0	-	10.4
25.	36.2	23.5	88	6.0	-	10.1
26.	35.4	23.2	91	5.6	2.2	8.2
27.	34.0	24.6	92	6.4	-	8.9
28.	35.4	23.6	79	5.6	-	9.6
29.	35	25.0	74	6.0	-	10.1
30.	34.2	22.4	93	6.8	-	7.4

May 2006

Date	Max.Temp °C	Min.Temp °C	RH	EVP mm	Rainfall (mm)	Sunshine (hrs)
1.	35.0	23.5	95	6.8	-	9.5
2.	35.0	25.0	82	7.0	-	10.2
3.	35.0	25.2	87	7.4	-	9.5
4.	35.5	25.7	87	7.6	-	8.3
5.	35.7	25.5	87	6.0	-	9.5
6.	35.0	24.0	79	5.0	-	10.2
7.	35.0	24.0	88	5.8	-	9.2
8.	35.7	24.5	90	5.6	-	8.3
9.	35.7	24.0	87	6.6	-	4.8
10.	35.5	24.0	88	7.0	-	5.1
11.	35.5	24.5	88	7.0	-	8.7
12.	36.0	25.5	78	6.8	-	7.8
13.	35.6	25.2	84	6.6	-	8.8
14.	35.0	24.6	82	5.8	-	10.2
15.	35.2	23.7	87	6.0	-	10.1
16.	35.0	24.0	85	6.6	45.8	9.6
17.	35.4	21.0	91	5.8	-	8.3
18.	31.7	22.0	91	3.4	-	4.7
19.	33.0	23.0	88	4.3	-	5.6
20.	28.5	22.0	91	2.2	-	8.7
21.	34.3	21.5	88	4.0	-	9.6
22.	34.0	23.0	85	5.8	-	3.4
23.	33.5	22.7	85	6.0	-	7.0
24.	34.5	22.6	82	6.5	-	0.3
25.	33.3	22.7	86	6.0	-	8.4
26.	32.4	24.0	76	7.2	-	9.7
27.	32.5	24.0	87	7.8	1.2	8.4
28.	28.5	22.7	77	6.0	7.4	9.6
29.	27.4	22.3	74	7.2	1.2	6.5
30.	29.0	22.7	80	7.8	7.5	7.6
31.	28.2	23	77	0.4	6.5	6.2

June 2006

Date	Max.Temp °C	Min.Temp °C	RH	EVP mm	Rainfall (mm)	Sunshine (hrs)
1.	28.5	21.7	84	2.2	14.2	1.2
2.	30.5	24.5	72	7.6	-	3.7
3.	30.6	24.2	80	7.4	-	8.6
4.	30.7	24.0	77	4.4	0.2	4.4
5.	31.2	24.2	84	6.0	-	5.8
6.	30.0	23.8	88	6.0	-	4.6
7.	29.2	22.5	87	4.0	-	0
8.	32.5	22.4	81	7.0	-	6.2
9.	32.2	21.5	87	5.4	-	7.0
10.	33.2	23.5	74	6.6	-	11.4
11.	32.4	21.0	82	7.6	-	9.0
12.	32.6	20.3	77	6.5	-	11.2
13.	33.6	21.5	82	6.2	-	11.5
14.	33.5	22.6	88	6.4	-	11.5
15.	33.4	24.2	88	5.0	3.2	7.2
16.	32.8	23.5	88	4.0	-	7.3
17.	39.0	21.7	90	4.6	-	6.5
18.	33.5	22.7	91	5.6	-	11.0
19.	34.0	24.8	51	5.5	-	9.6
20.	33.4	24.0	50	6.0	-	5.3
21.	33.0	23.4	52	4.6	-	21.0
22.	33.4	23.8	57	6.4	-	8.4
23.	33.0	22.5	48	6.4	9.6	8.9
24.	26.8	23.5	53	4.0	3.0	0.2
25.	30.2	22.5	76	4.7	7.8	4.6
26.	27.8	24.0	57	5.4	-	0.2
27.	30.8	24.6	67	5.4	-	6.2
28.	30.6	24.5	55	6.0	-	5.0
29.	29.8	24.5	62	7.2	-	0.3
30.	31.5	22.4	58	6.5	24.6	2.2

July 2006

Date	Max.Temp °C	Min.Temp °C	RH	EVP mm	Rainfall (mm)	Sunshine (hrs)
1.	29.0	25.0	69	6.0	-	2.6
2.	31.5	24.5	69	6.6	0.2	6.5
3.	30.5	24.2	72	8.6	1.0	5.0
4.	31.2	23.5	70	8.0	1.5	5.7
5.	30.0	24.0	64	7.0	2.4	3.7
6.	31.4	23.4	67	7.8	0.6	8.4
7.	31.8	24.6	70	7.9	-	10.0
8.	32.2	23.5	64	8.6	-	9.7
9.	33.0	22.0	67	8.6	-	10.8
10.	33.2	25.0	70	9.2	-	10.5
11.	31.8	23.0	64	9.0	-	8.6
12.	30.2	24.5	86	8.0	-	3.6
13.	29.6	24.0	65	8.2	-	2.9
14.	30.2	22.7	88	7.4	-	3.2
15.	30.5	25.5	74	5.8	-	1.9
16.	31.5	24.4	70	6.0	-	6.9
17.	31.7	31.7	70	7.5	-	9.5
18.	32.0	25.3	73	9.3	-	9.1
19.	31.5	23.2	76	9.7	0.2	7.8
20.	31.6	24.5	77	9.2	-	7.9
21.	32.7	25.5	67	8.5	-	10.1
22.	32.7	25.0	66	9.2	-	7.4
23.	31.3	24.5	63	8.4	-	6.2
24.	33.0	21.7	86	9.0	-	9.3
25.	32.6	21.8	89	6.5	-	9.9
26.	31.0	22.5	91	4.0	-	2.3
27.	31.5	23.2	82	4.2	0.4	2.4
28.	30.7	23.4	83	6.4	0.6	0
29.	29.5	24.2	61	7.4	-	2.8
30.	32.0	24.0	76	6.8	1.8	5.3
31.	31.2	23.7	68	7.0	-	4.4

August 2006

Date	Max.Temp ^oC	Min.Temp ^oC	RH	EVP mm	Rainfall (mm)	Sunshine (hrs)
1.	33.4	21.0	88	7.6	-	10.4
2.	32.0	21.7	89	6.6	-	5.9
3.	31.8	21.8	74	6.6	-	7.1
4.	31.6	22.4	72	6.8	-	2.7
5.	30.2	23.2	85	6.2	-	2.8
6.	30.7	23.0	74	6.4	-	6.8
7.	31.8	22.6	83	6.6	-	10.8
8.	33.0	23.6	75	8.0	-	10.8
9.	32.5	24.3	71	9.2	-	7.0
10.	31.5	22.4	86	8.0	-	4.8
11.	29.0	23.0	71	5.6	0.6	0.2
12.	29.2	23.0	75	5.2	2.2	2.4
13.	32.2	24.0	77	4.2	0.2	6.3
14.	32.0	23.0	77	7.2	3.0	9.4
15.	32.0	24.2	76	8.5	-	7.5
16.	31.5	23.7	70	9.4	-	6.6
17.	31.4	31.4	59	9.2	-	4.7
18.	31.0	24.8	73	8.2	-	9.5
19.	32.8	24.0	88	7.4	-	8.9
20.	33.2	22.6	88	6.2	-	9.2
21.	32.5	23.8	95	5.8	2.6	3.8
22.	30.8	23.0	95	4.1	0.4	3.3
23.	31.0	22.8	96	3.7	-	7.3
24.	32.0	23.2	93	4.4	-	7.7
25.	32.5	22.4	90	4.7	-	9.6
26.	33.2	21.7	77	6.4	-	11.2
27.	33.5	21.0	88	7.2	-	9.6
28.	32.7	19.4	79	8.8	-	8.7
29.	32.5	20.8	88	9.0	-	5.7
30.	32.0	20.6	89	5.6	-	8.3
31.	31.8	22.0	88	5.4	-	7.9

APPENDIX – II

Table 40.Drip system cost for *Jasminum grandiflorum* for one hectare area under paired row system

S.No.	Details	Rs/Unit	Unit	Cost
1.	Lateral (12 mm)	4.65/m	6700 m	31,155.00
2.	Drippers	2	11189 no.	22,378.00
3.	Ventury assembly	1500	1 no.	1,500.00
4.	Main and Submain (PVC 2")	33/m	285 m	9,405.00
5.	Ball valve (2")	230	2 no.	460.00
6.	Gate valve (2")	110	1 no.	110.00
7.	Flush valve	60	2 no.	120.00
8.	GTO (16 mm)	3	264 no.	792.00
9.	End stop	2	264 no.	528.00
10.	Filter 2"	2200	1 no.	2,200.00
11.	PVT 'T' (2")	40	2 no.	80.00
12.	Installation charge	1000	1 ha	1,000.00
13.	Fitting accessory	1000	1 ha	1,000.00
	Total cost			70,728.00
	(Rounded)			71,000.00

APPENDIX – III

Cost of cultivation of jasmine (*Jasminum grandiflorum*) under surface irrigation (Rs ha^{-1})

S.No	Details	Rs/Unit	Unit	Cost
1.	Seedling (3333/ha)	2/seedling	3333	6,666.00
2.	Land preparation			
	i) Manual (For rectification of bunds and channels)		20	1,600.00
	ii) Tractor (disc ploughing)	350/hr	3	1,050.00
	iii) Tractor (cultivator)	275/hr	2	550.00
	iv) Tractor (rotavater)	450/hr	3	1,350.00
	v) Tractor (rdger)	350/hr	3	1,050.00
3.	Manures (FYM)	250/t	12.5	3,125.00
4.	Recommended dose f fertilizers			
	i) 120 kg Nitrgen in the form of urea	5.00/kg	260.4	1,302.00
	ii) 240 kg P_2O_5 in the form of Super phosphate	3.50/kg	1500	5,250.00
	iii 120 kg K_2O in the form of MOP	4.60/kg	200.4	921.84
5.	Manures and fertilizer application		15	1,200.00
6.	Planting		20	1,600.00
7.	Gap fillng and pot watering		10	800.00
8.	Intercultural operation			
	i)Pruning		6	1,200.00
	ii) Rectification of irrigation channel		10	480.00
9.	Weeding			
	i) Chemical (Pendimethalin@1 l a.i/ha)	440/lit	3.3	1,452.00
	spraying			250.00
	ii)Manual (once)		25	2,000.00
10.	Irrigation			
	i) Manual		10	2,000.00
11.	Plant protection (Chemicals and application)	500/spray	8	4,000.00
12.	Harvesting (4 pickings)		48	3,840.00
13.	Transport of manures, Fertilizers and produce			1,000.00
14.	Total cost of cultivation			42,686.84

Fertilizer levels	Fertilizer costs	Harvesting(Labour)	Total cost
100 % RDF	7463.85	48	42,686.84
75 % RDF	5605.38	46	40,618.38
50% RDF	3736.92	44	38,549.92

APPENDIX – IV

Cost of cultivation of jasmine (*Jasminum grandiflorum*) under drip irrigation (Rs ha-1)

S.No	Details	Rs/Unit	Unit	Cost
1.	Seedling (3333/ha)	2/seedling	3333	6,666.00
2.	Land preparation			
	i) Manual (For rectification of bunds and channels)		20	1,600.00
	ii) Tractor (disc ploughing)	350/hr	3	1,050.00
	iii) Tractor (cultivator)	275/hr	2	550.00
	iv) Tractor (rotavater)	450/hr	3	1,350.00
	v) Tractor (rdger)	350/hr	3	1,050.00
3.	Manures (FYM)	250/t	12.5	3,125.00
4.	Recommended dose f fertilizers			
	i) 120 kg Nitrgen in the form of urea	5.00/kg	260.4	1,302.00
	ii) 144 kg P_2O_5 in the form of Super phosphate	3.50/kg	1500	3,150.00
	96 kg of P_2O_5 in the form of Orthophosphoric acid	45/kg	184.61	8307.36
	iii 120 kg K_2O in the form of MOP	4.60/kg	200.4	921.84
5.	Manures and fertilizer application		15	1,200.00
6.	Planting		20	1,600.00
7.	Gap fillng and pot watering		10	800.00
8.	Intercultural operation			
	i)Pruning		6	1,200.00
	ii) Rectification of irrigation channel		10	480.00
9.	Weeding			
	i) Chemical (Pendimethalin@1 l a.i/ha)	440/lit	3.3	1,452.00
	spraying			250.00
	ii)Manual (once)		25	2,000.00
10.	Irrigation			
	i) Manual(For drip fertigation once in two days on contract basis)		6	900.00
11.	Plant protection (Chemicals and application)	500/spray	8	4,000.00
12.	Harvesting (4 pickings)		48	3,840.00
13.	Transport of manures, Fertilizers and produce			1,000.00
14.	Total cost of cultivation			47,793.84

Fertilizer levels	Fertilizer costs	Harvesting (Labour)	Drip irrigation level	Harvesting (Labour)
100 % RDF	13,681.44	53	15 LPD	53
75 % RDF	10,261.08	51	10 LPD	50
50% RDF	6,840.72	49	5 LPD	47

	Drip irrigation		
	15 LPD	10 LPD	5 LPD
100 % RDF	47,793.84	47,490.00	47,290.00
75 % RDF	37,532.76	37,032.00	37,102.00
50 % RDF	40,953.12	40,600.00	40,753.00

APPENDIX – V

Irrigation date	Evaporation (mm)	Rainfall (mm)	Quantity of water applied (mm)			
			Surface irrigation	Micro irrigation levels		
				W_1	W_2	W_3
2005 Nov. 11	1.6	-				
12	3.0	20.0	50			
13	2.8	1.8				
14	2.2	0.5				
15	2.0	-		4.88	6.14	9.12
16	2.8	-				
17	2.6	-		4.88	6.14	9.12
18	2.8	-				
19	3.0	-	50	4.88	6.14	9.12
20	3.6	-				
21	3.4	-		4.88	6.14	9.12
22	2.4	0.5				
23	1.4	13.0				
24	1.7	12.5				
25	1.2	28.4				
26	2.4	1.0	50			
27	3.0	-		4.88	6.14	9.12
28	2.0	-				
29	2.2	-		4.88	6.14	9.12
30	1.8	-				

Irrigation schedule during 2005

Dec.1	2.4	-		4.88	6.14	9.12
2	2.6	-				
3	2.0	-	50	4.88	6.14	9.12
4	1.8	51				
5	1.7	2.5				
6	1.6	-				
7	1.8	-				
8	2.2	-				
9	2.4	-		4.88	6.14	9.12
10	3.2	-	50			
11	2.4	1.8		4.88	6.14	9.12
12	1.4	0.6				
13	1.6	2.8				
14	2.0	1.4				
15	3.0	-		4.88	6.14	9.12
16	2.4	-				
17	3.0	-	50	4.88	6.14	9.12
18	1.4	-				
19	3.2	-		4.88	6.14	9.12
20	2.8	-				
21	3.0	-				
22	2.4	-		4.88	6.14	9.12
23	2.6	-				
24	2.8	-	50	4.88	6.14	9.12
25	2.4	-				
26	2.8	-		4.88	6.14	9.12
27	2.8	-				
28	3.0	-				
29	3.2	-		4.88	6.14	9.12
30	3.4	-				
31	3.4	-				
Irrigation			350.00	82.96	104.38	155.04
Effective rainfall			137.8	137.8	137.8	137.8
Total			487.8	220.7	242.18	292.84

APPENDIX – VI

Irrigation schedule during 2006

2006, Jan.1	3.6	-	50	4.88	6.14	9.12
2	3.8	-				
3	2.6	-		4.88	6.14	9.12
4	2.8	-				
5	2.8	-		4.88	6.14	9.12
6	2.6	-				
7	1.7	-		4.88	6.14	9.12
8	3.0	-	50			
9	2.0	28.0				
10	2.8	28.2				
11	3.4	28.2				
12	3.5	28.2				
13	3.4	28.2				
14	3.3	28.2				
15	2.6	28.2				
16	2.8	28.2	50			
17	3.0	-				
18	3.4	-				
19	4.2	-		4.88	6.14	9.12
20	4.0	-				
21	4.2	-		4.88	6.14	9.12
22	3.8	-				
23	4.0	-	50	4.88	6.14	9.12
24	4.4	-				
25	4.6	-		4.88	6.14	9.12
26	4.8	-				
27	4.8	-		4.88	6.14	9.12
28	5.0	-				
29	3.2	-		4.88	6.14	9.12
30	4.0	-	50			
31	4.4	-		4.88	6.14	9.12

Feb.1	4.4	-				
2	4.0	-		4.88	6.14	9.12
3	4.8	-				
4	4.8	-		4.88	6.14	9.12
5	3.8	-				
6	4.8	-	50	4.88	6.14	9.12
7	5.6	-				
8	5.8	-		4.88	6.14	9.12
9	4.4	-				
10	5.0	-		4.88	6.14	9.12
11	5.0	-				
12	6.8	-		4.88	6.14	9.12
13	6.8	-	50			
14	6.2	-		4.88	6.14	9.12
15	4.8	-				
16	4.6	-		4.88	6.14	9.12
17	4.8	-				
18	4.6	-		4.88	6.14	9.12
19	5.4	-				
20	5.8	-		4.88	6.14	9.12
21	6.4	-	50			
22	5.6	-		4.88	6.14	9.12
23	6.4	-				
24	6.5	-		4.88	6.14	9.12
25	6.0	-				
26	5.2	-		4.88	6.14	9.12
27	4.5	-				
28	4.0	-	50	4.88	6.14	9.12

Mar.1	4.8	-				
2	4.6	-		4.88	6.14	9.12
3	5.4	-				
4	OFF	82.4				
5	3.2	-				
6	4.5	-				
7	4.0	40.0				
8	4.4	-	50			
9	4.8	-				
10	4.4	29.0				
11	3.8	-				
12	4.8	-				
13	4.7	-				
14	5.0	-				
15	5.2	-	50	4.88	6.14	9.12
16	5.5	=				
17	2.8	-		4.88	6.14	9.12
18	3.6	-				
19	4.8	-		4.88	6.14	9.12
20	5.8	-				
21	4.8	-		4.88	6.14	9.12
22	4.6	-				
23	4.2	-	50	4.88	6.14	9.12
24	4.4	-				
25	4.6	-				
26	5.0	-		4.88	6.14	9.12
27	5.6	-				
28	5.8	-		4.88	6.14	9.12
29	6.0	-				
30	6.0	-	50	4.88	6.14	9.12
31	5.0	-				

April.1	5.4	-				
2	5.2	-		4.88	6.14	9.12
3	5.4	-				
4	5.8	-		4.88	6.14	9.12
5	5.5	-				
6	6.2	-		4.88	6.14	9.12
7	6.6	-	50			
8	6.8	-		4.88	6.14	9.12
9	6.5	-				
10	6.6	-		4.88	6.14	9.12
11	6.4	-				
12	6.6	-		4.88	6.14	9.12
13	6.2	-				
14	6.0	-	50	4.88	6.14	9.12
15	6.2	-				
16	5.6	-		4.88	6.14	9.12
17	4.5	-				
18	4.7	-		4.88	6.14	9.12
19	5.4	0.6				
20	5.4	17.4				
21	5.4	-				
22	5.4	-	50			
23	4.5	-		4.88	6.14	9.12
24	6.0	-				
25	6.0	-		4.88	6.14	9.12
26	5.6	2.2				
27	6.4	-				
28	5.6	-		4.88	6.14	9.12
29	6.0	-	50			
30	6.8	-		4.88	6.14	9.12

May 1	6.8	-				
2	7.0	-		4.88	6.14	9.12
3	7.4	-				
4	7.6	-		4.88	6.14	9.12
5	6.0	-				
6	5.0	-		4.88	6.14	9.12
7	5.8	-	50			
8	5.6	-		4.88	6.14	9.12
9	6.6	-				
10	7.0	-		4.88	6.14	9.12
11	7.0	-				
12	6.8	-		4.88	6.14	9.12
13	6.6	-				
14	5.8	-	50	4.88	6.14	9.12
15	6.0	-				
16	6.6	45.8				
17	5.8	-				
18	3.4	-				
19	4.3	-				
20	2.2	-				
21	4.0	-				
22	5.8	-	50	4.88	6.14	9.12
23	6.0	-				
24	6.5	-		4.88	6.14	9.12
25	6.0	-				
26	7.2	-		4.88	6.14	9.12
27	7.8	1.2				
28	6.0	7.4				
29	7.2	1.2	50			
30	7.8	7.5				
31	0.4	6.5				

June 1	2.2	14.2				
2	7.6	-				
3	7.4	-				
4	4.4	0.2		4.88	6.14	9.12
5	6.0	-				
6	6.0	-	50	4.88	6.14	9.12
7	4.0	-				
8	7.0	-		4.88	6.14	9.12
9	5.4	-				
10	6.6	-		4.88	6.14	9.12
11	7.6	-				
12	6.5	-		4.88	6.14	9.12
13	6.2	-	50			
14	6.4	-		4.88	6.14	9.12
15	5.0	3.2				
16	4.0	-				
17	4.6	-		4.88	6.14	9.12
18	5.6	-				
19	5.5	-		4.88	6.14	9.12
20	6.0	-				
21	4.6	-	50	4.88	6.14	9.12
22	6.4	-				
23	6.4	9.6				
24	4.0	3.0				
25	4.7	7.8				
26	5.4	-				
27	5.4	-		4.88	6.14	9.12
28	6.0	-	50			
29	7.2	-		4.88	6.14	9.12
30	6.5	24.6				

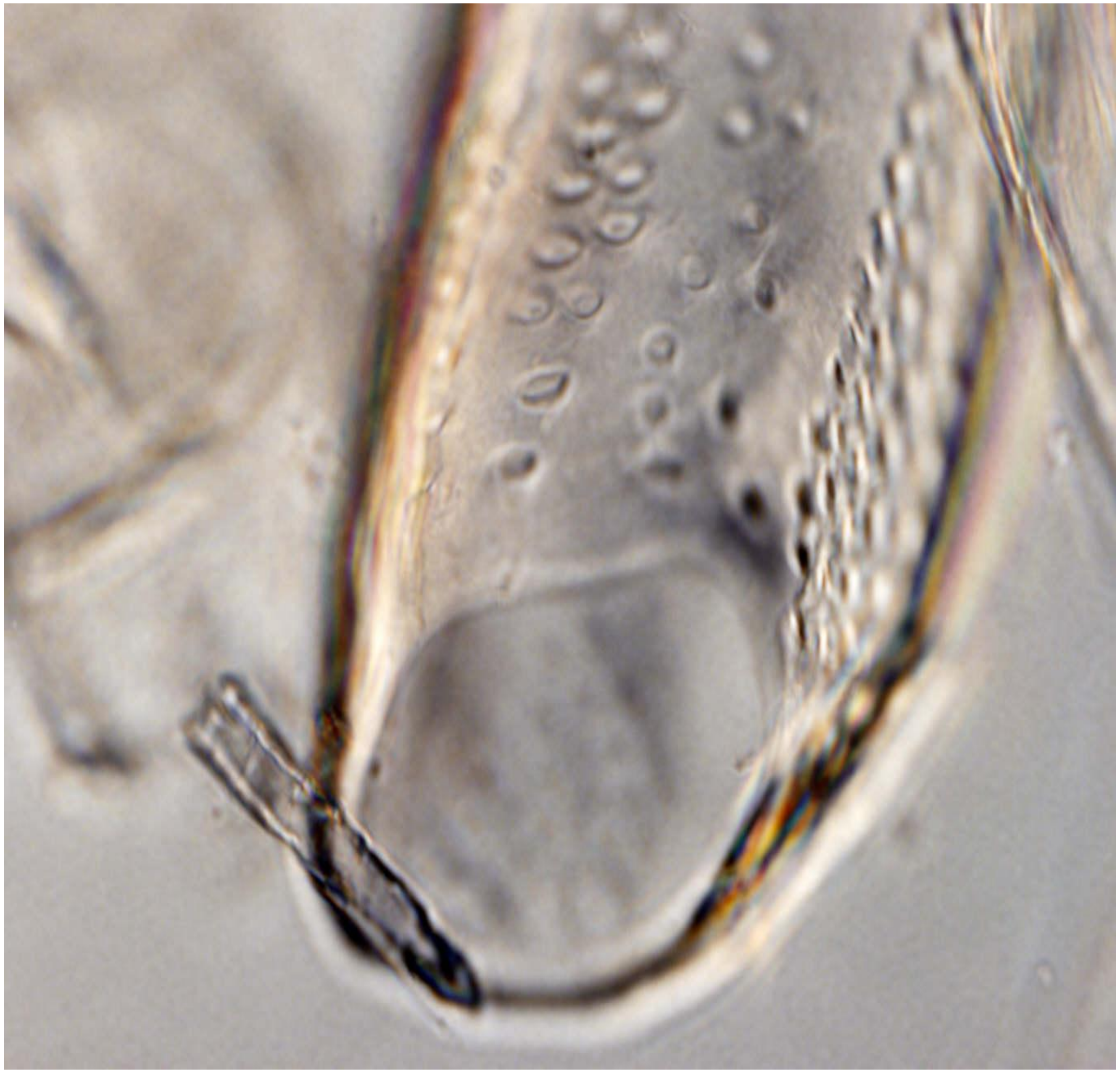
July 1	6.0	-				
2	6.6	0.2				
3	8.6	1.0		4.88	6.14	9.12
4	8.0	1.5				
5	7.0	2.4		4.88	6.14	9.12
6	7.8	0.6	50			
7	7.9	-		4.88	6.14	9.12
8	8.6	-				
9	8.6	-		4.88	6.14	9.12
10	9.2	-				
11	9.0	-		4.88	6.14	9.12
12	8.0	-				
13	8.2	-	50	4.88	6.14	9.12
14	7.4	-				
15	5.8	-		4.88	6.14	9.12
16	6.0	-				
17	7.5	-		4.88	6.14	9.12
18	9.3	-				
19	9.7	0.2		4.88	6.14	9.12
20	9.2	-				
21	8.5	-	50	4.88	6.14	9.12
22	9.2	-				
23	8.4	-		4.88	6.14	9.12
24	9.0	-				
25	6.5	-		4.88	6.14	9.12
26	4.0	-				
27	4.2	0.4		4.88	6.14	9.12
28	6.4	0.6	50			
29	7.4	-		4.88	6.14	9.12
30	6.8	1.8				
31	7.0	-		4.88	6.14	9.12

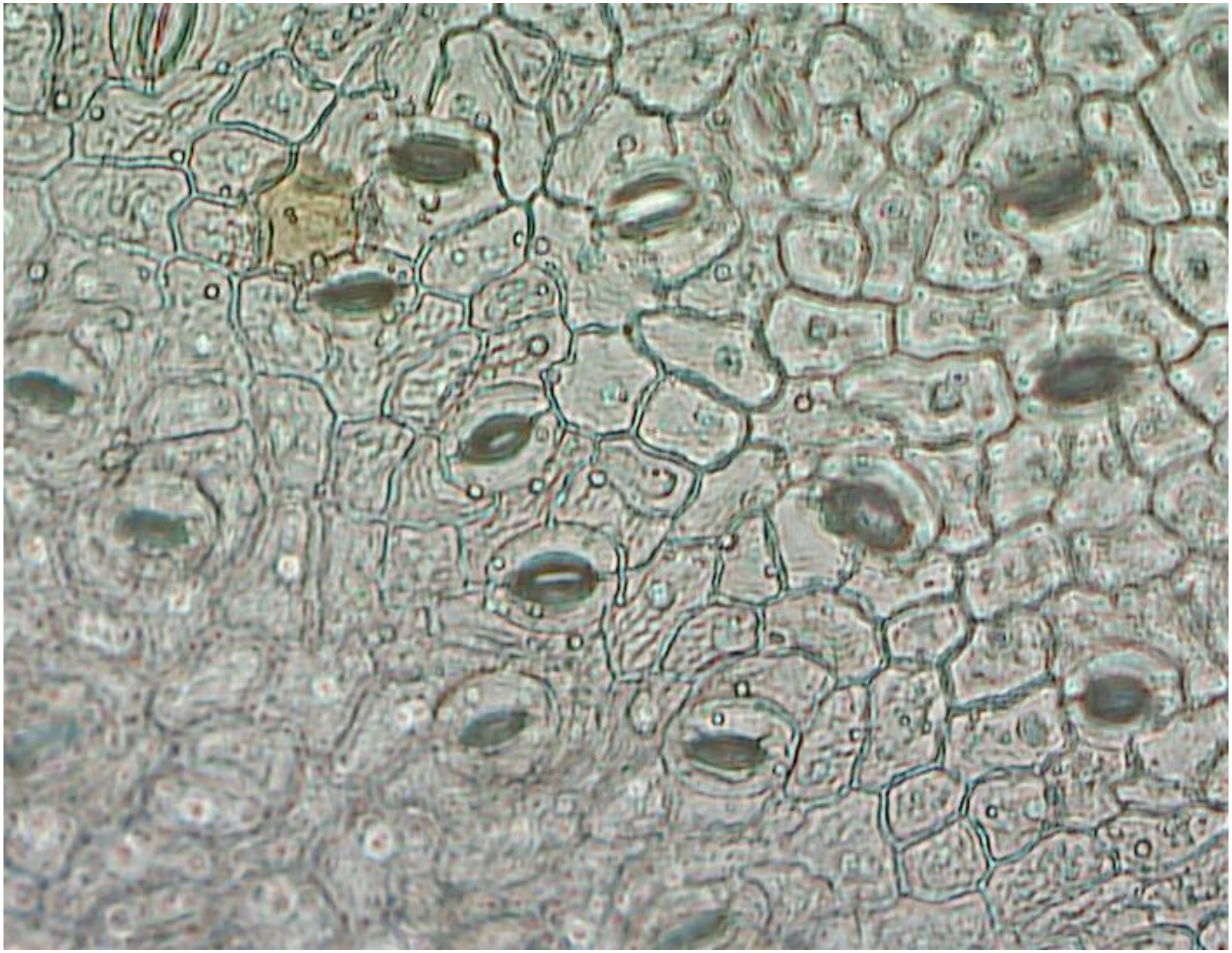
August 1	7.6	-				
2	6.6	-		4.88	6.14	9.12
3	6.6	-				
4	6.8	-		4.88	6.14	9.12
5	6.2	-	50			
6	6.4	-		4.88	6.14	9.12
7	6.6	-				
8	8.0	-		4.88	6.14	9.12
9	9.2	-				
10	8.0	-		4.88	6.14	9.12
11	5.6	0.6				
12	5.2	2.2	50	4.88	6.14	9.12
13	4.2	0.2				
14	7.2	3.0		4.88	6.14	9.12
15	8.5	-				
16	9.4	-		4.88	6.14	9.12
17	9.2	-				
18	8.2	-		4.88	6.14	9.12
19	7.4	-				
20	6.2	-	50	4.88	6.14	9.12
21	5.8	2.6				
22	4.1	0.4		4.88	6.14	9.12
23	3.7	-				
24	4.4	-		4.88	6.14	9.12
25	4.7	-				
26	6.4	-		4.88	6.14	9.12
27	7.2	-	50			
28	8.8	-		4.88	6.14	9.12
29	9.0	-				
30	5.6	-		4.88	6.14	9.12
31	5.4	-				
Irrigation			1650	473.36	595.58	884.64
Effective rainfall			546.9	546.9	546.9	546.9
Total			2196.9	1020.26	1142.48	1431.54

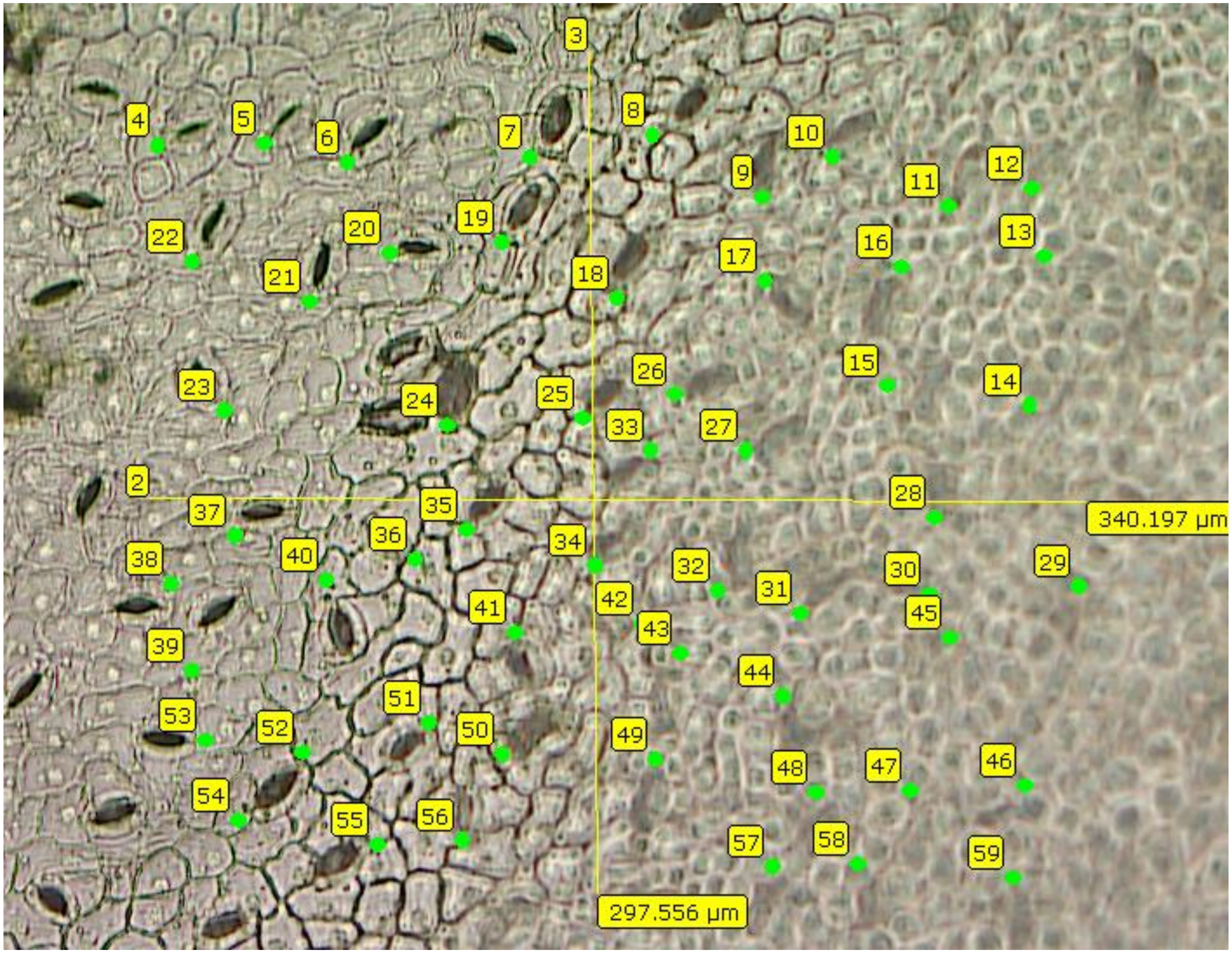
ABSTRACT

K.S.Vijay Selvaraj, 2007. Standardization of irrigation and fertigation techniques in jsmine (*Jasminum grandiflorum*) var CO.2 (Dr.M.Jawaharlal).

Field experiments were conducted at the Botanic Gardens, TNAU, Coimbatore to evaluate the performance of drip fertigation on growth, yield and water use in jasmine (November 2005-August 2006). Subsequently greenhouse experiments for water use efficiency and identification of aquaporin genes in jasmine were conducted (August 2006-September2007) at The Hebrew University of Jerusalem, Israel. Field experiments were under split plot design with irrigation regimes in main plots *viz.*, W_1-Drip irrigation with 5 litres of water per day (LPD), W_2-Drip irrigation with 10 LPD , W_3- Drip irrigation with 15 LPD and fertilizer level in sub plots viz., F_1-50 percent of recommended dose of fertilizers(RDF), F_2- 75 per cent RDF, F_3- 100% RDF and sub plots with black polyethylene mulch as M_1 and without mulch as M_0 with three replications. Jasmine (*Jasminum grandiflorum*) var CO 2 was used as the test variety. Entire nitrogen application was spread over a period of 45 to 120 days after pruning with its maximum share during the peak vegetative phase. 60 percent of phosphorous was applied as basal in the beginning and the rest was applied through fertigation. The application of potassium nutrient was scheduled right from 75 to 130 Days after planting (coinciding with flowering phase). All the plant growth characters like plant height, number of primary and secondary branches, number and length of primary and secondary roots, 100 flowers weight, length of flower stalk, flower diameter, concrete recovery were found to be highest by the application of 10 litres of water per day with 75% recommended dose of fertilizers under black polyethylene mulch of 50 micron thickness of all the treatments. Whereas the flower yield per plant and hectare was highest by 15 litres of water per day with 100 % recommended dose of fertilizers under mulch. Flowers with normal packing and storage at 5o C recorded maximum shelf life of 4.2 days. Highest moisture and nutrient content was recorded by application of 15 litres of water with 100 % recommended dose of fertilizers under mulch. Through the experiments conducted at Israel, jasmine required water of 10.1 litres per day pre plant. Studies n DNA quantification indicated that, *Jasminum grandiflorum* had a band width upto 100 bp (base pairs). Treatments with 15 litres of water per day, 100 per cent RDF with black polyethylene mulch showed the highest BCR of 3.70.The MBCR values for 15 and 10 LPD with 100 per cent RDF under mulch gave almost similar value indicating the comparable nature in the production of MBCR.







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35
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340.197 µm
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59
297.556 µm

Plate 1. *Jasminum grandiflorum* plants under drip irrigation, fertigation and mulch

Plate 2. *Jasminum grandiflorum* plants under surface irrigation

Plate 3. Performance of *Jasminum grandiflorum* var CO.2 plants under control and fertigation

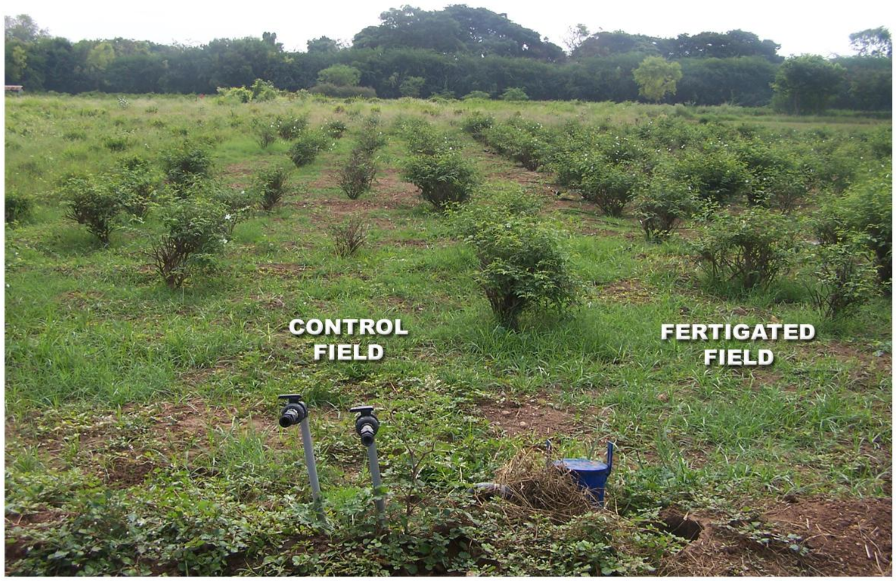

Plate 4. Fertigation through venturi system

Plate 5. *Jasminum grandiflorum* flowers under normal packing

Plate 6. *Jasminum grandiflorum* flowers under vacuum packing

Plate 7. *Jasminum grandiflorum* flowers under 5^{0}C and room temperature storage

Plate 8. *Jasminum grandiflorum* plants on load cells weighing lysimeter

Plate 9. *Jasminum grandiflorum* plants on load cells weighing lysimeter with PAN

Wetting Pattern

Plate 10. Diameter and depth of wetting (4 LPH dripper)

Plate 11. Diameter and depth of wetting (8 LPH dripper)

Plate 12. Diameter and depth of wetting (12 LPH dripper)