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Evaluation on the Responses of Spanish Jasmine (*Jasminum grandiflorum* L.) Growth, Yield, Water and Fertilizer Use Efficiency to Drip Fertigation under Mulch condition in South India

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ABSTRACT: The efficient use of water is crucial factor which determines the crop growth and yield during crop growth periods. Drip irrigation is one among the micro irrigation methods for irrigation, a successful technique aimed to distribute water preciously to rooting zone. Modern irrigation system application has taken a greater part in irrigation techniques which gained substantial attention in developing countries. Higher significance of drip fertigation system is that it can provide optimum water with nutrient as when required by the plants on need basis. Optimization of water and nutrient levels will play a vital role in yield maximization with quality flowers in *Jasminum grandiflorum*. The utilization of water within the soil root zone is crucial to increase Water Use Efficiency by adopting mulch. Three levels of Water (5, 10 and 15 LPD) and nutrient distribution (50, 75 and 100 % RDF) through drip irrigation and fertigation with plastic mulch (50 micron) was implemented in *Jasminum grandiflorum* at Tamil Nadu Agricultural University to study the WUE and FUE. Soil moisture content and water conservation was nearer to 80 % through 15 LPD always when compared with 10 LPD (Less than 80 %) and 5 LPD (50 % soil moisture). The 'N' concentration in upper soil layer (0–15 cm) was higher than the lower bottom (15–30 cm). The Same trend was observed in 'P' concentration. 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, 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 which paved for maximum yield and other quality parameters.

Keywords: *Jasminum grandiflorum*, irrigation, nutrient distribution, root distribution, yield and post harvest life.

INTRODUCTION

Agriculture alone occupies about 80 % of ground water (Harsh, 2017). 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). Bafna *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 quitting the further extension of cultivating Jasmine and other flower crops. Drip irrigation provides the efficient rate of water with right rate exact to 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. 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). Bar-Yosef (1976) noted that only meager 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. The efficient use of water is crucial factor which determines the crop growth and yield during crop growth periods (Kader, 2019). 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 and Padmakumari, (1980); Gajare (1982) and Selvaraj (1997). 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). Drip irrigation is one among the micro irrigation methods for irrigation, a successful technique aimed to distribute water preciously to rooting zone (Nouri *et al.,* 2013).

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). Higher significance of drip fertigation system is that it can provide optimum water with nutrient as when required by the plants on need basis (Shareef *et al.,* 2019).

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). 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. Kabocha yield and brix level were significantly improved under a combination of subsurface drip irrigation and mulch (Alam and Zimmerman, 2003). 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). Cold storage of dry branches at 0.00 ± 1.11^{o}C (32 ± 2^{o}F) increased the shelf life of deciduous Holly branches. 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).

MATERIALS AND METHODS

Experimental plot. The experimental field is located at 11°02" North latitude and 76°57" East longitude at an altitude of 426.72 m above MSL. 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.

Crop and variety. It is essential to select Spanish Jasmine (*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. 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 (Annexure I).

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

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.

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 × 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 1.2 ksc in the system for irrigation.

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)

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).

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

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 root zone to the total amount applied, can be calculated by the following equation.

$E_A = X (1 - P_D)$ (2)

where,

X = depth ratio, which was taken as one.

P_D = per cent deficit

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

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

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

RESULTS AND DISCUSSION

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. 1 to 4). 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 and Padmakumari (1980); Gajare (1982); Selvaraj (1997); Chakraborty *et al.* (1998). Plant height of Dutch roses have positive response with 100 % irrigation level which was on par with 80 % irrigation level reported by Singh *et al.* (2016).

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.

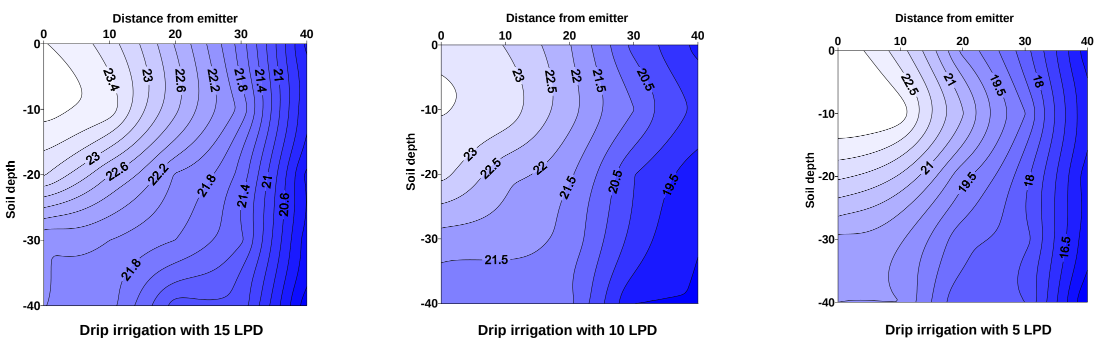


Fig. 1. Soil moisture distribution under drip irrigation after 24 hrs of drip irrigation - Between lateral (from dripper point).

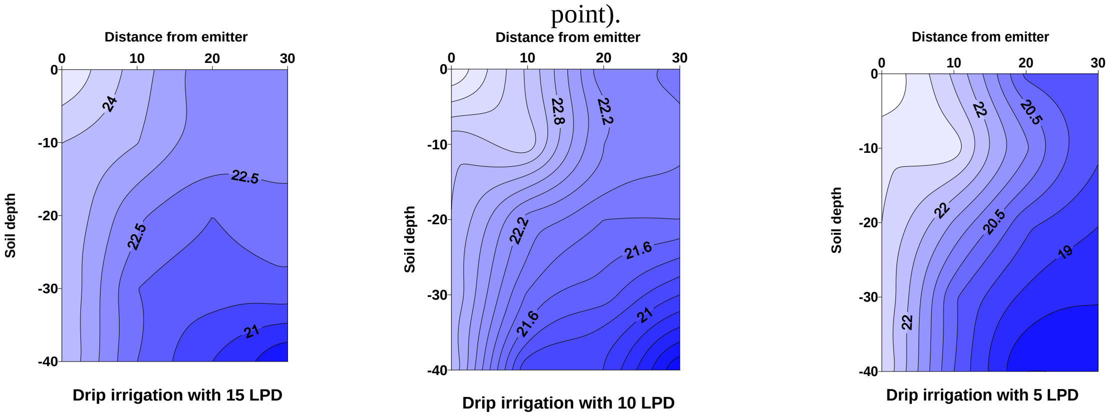


Fig. 2. Soil moisture distribution under drip irrigation after 24 hrs of drip irrigation-Along lateral (between dripper).

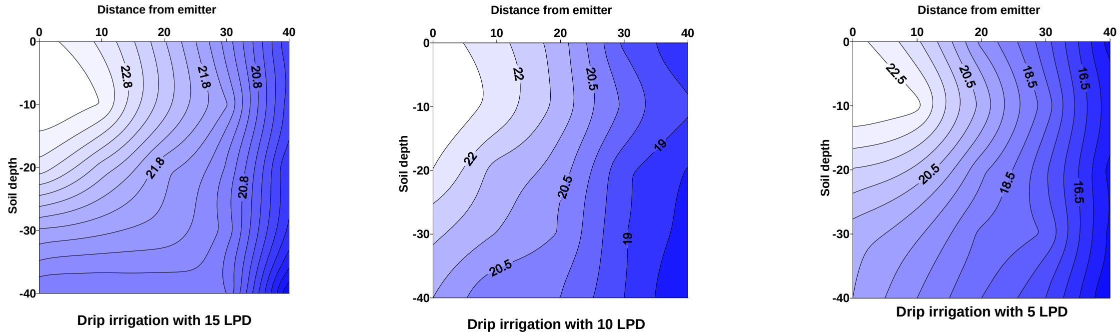
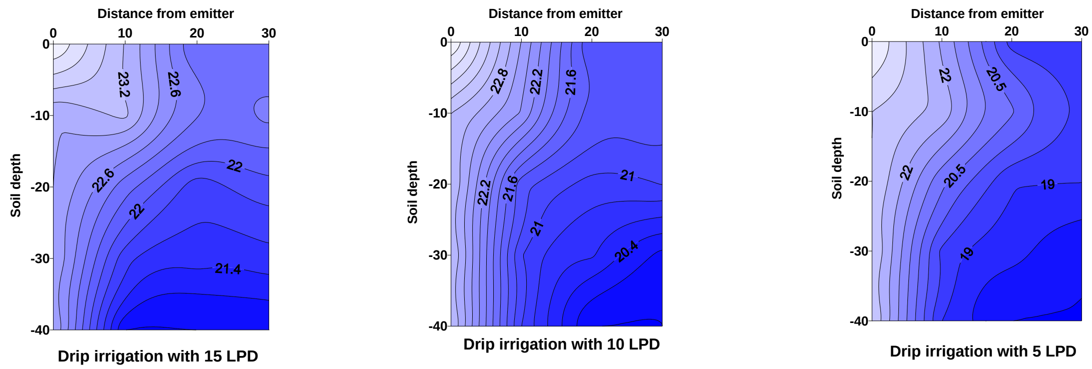


Fig. 3. Soil moisture distribution under drip irrigation after 48 hrs of drip irrigation - Between lateral (from dripper point).



Values in contour are moisture content (%)

Fig. 4. Soil moisture distribution under drip irrigation after 48 hrs of drip irrigation - Along lateral (between dripper).

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. 5 to 8). 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).

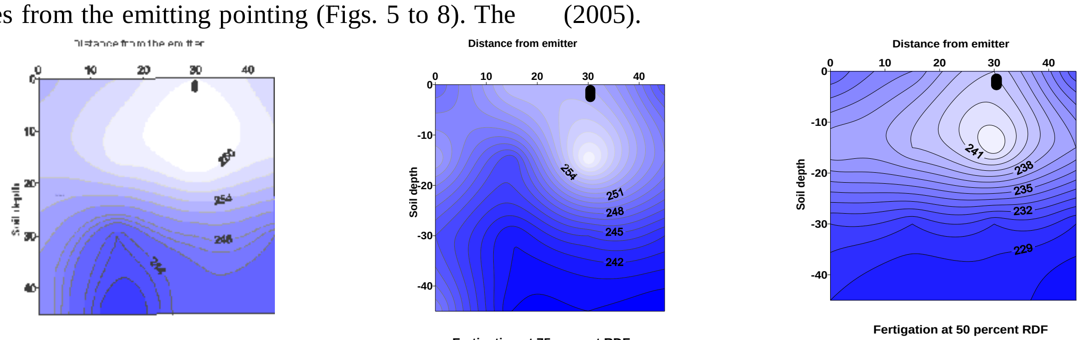


Fig. 5. Nitrogen dynamics under drip fertigation after second fertigation cycle Between lateral (from dripper point).

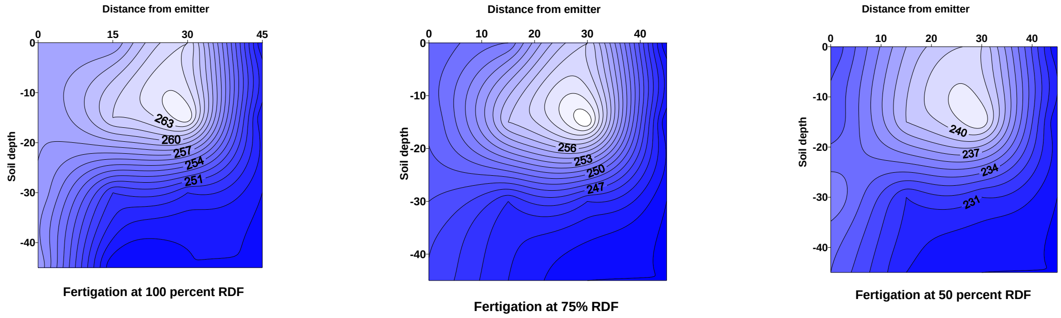


Fig. 6. Nitrogen dynamics under drip fertigation after second fertigation cycle along lateral (between dripper).

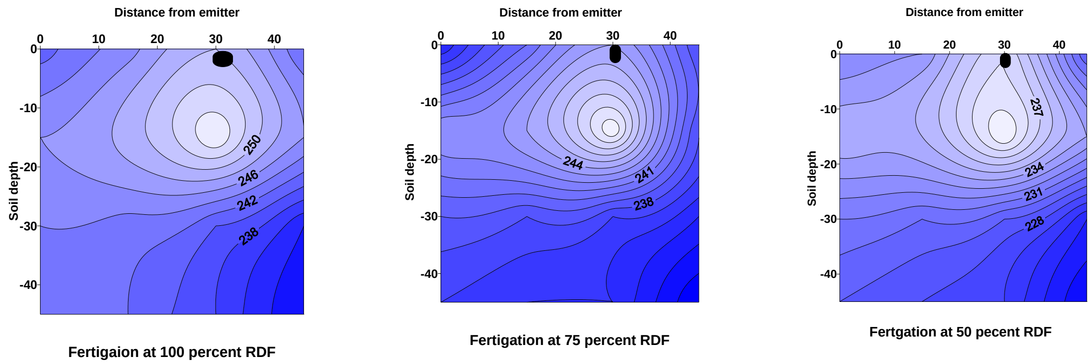
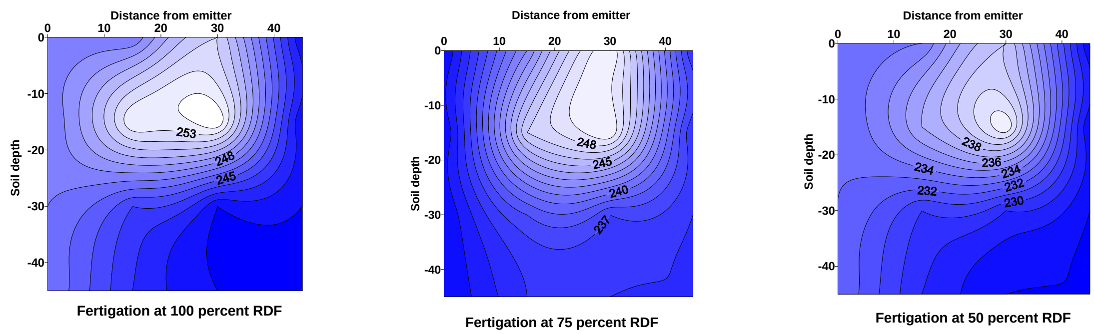


Fig. 7. Nitrogen dynamics under drip fertigation after final fertigation cycle between lateral (from dripper point).



Values in contour is nitrogen content in kg per ha

Fig. 8. Nitrogen dynamics under drip fertigation after final fertigation cycle Along lateral (between dripper).

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. 9 to 12). 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.

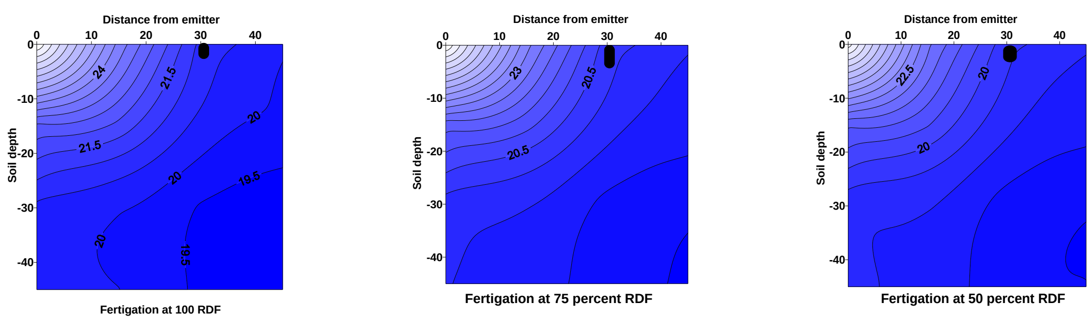


Fig. 9. Phosphorous dynamics under drip fertigation after second fertigation cycle -Between lateral (from dripper point).

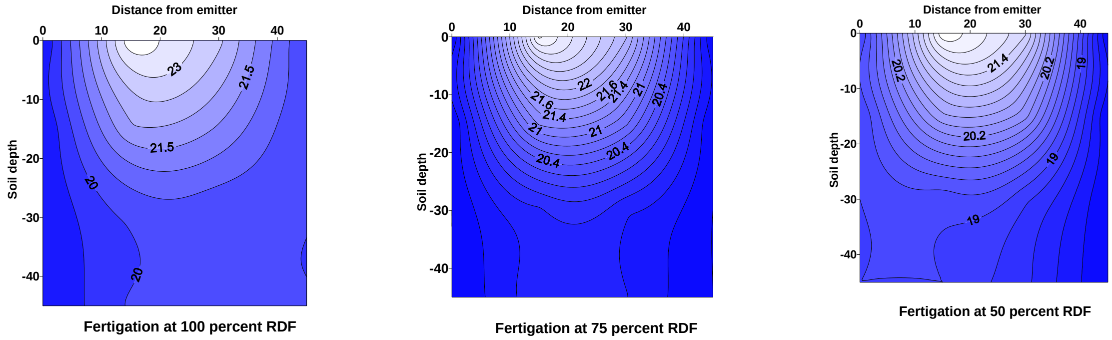


Fig. 10. Phosphorous dynamics under drip fertigation after second fertigation cycle - Along lateral (between dripper).

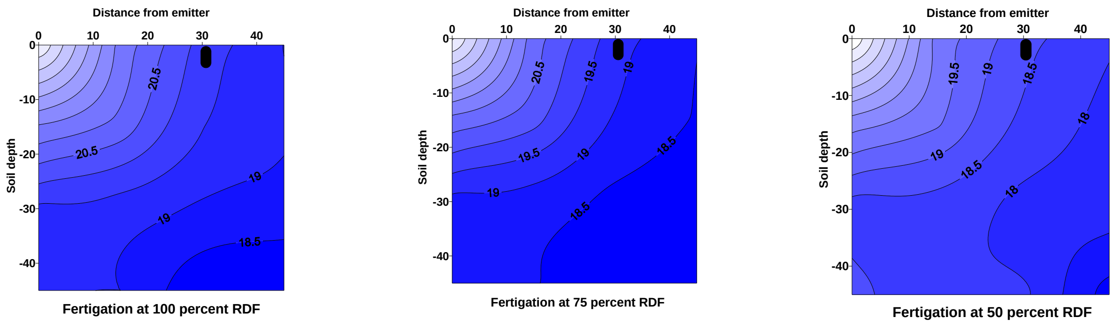
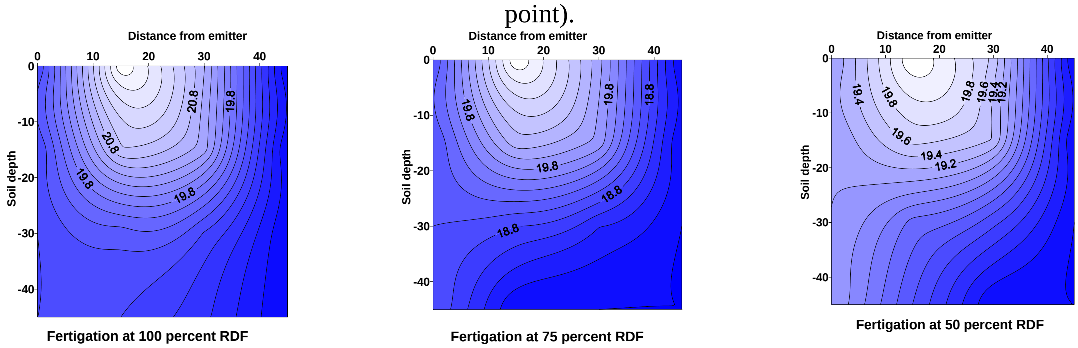


Fig. 11. Phosphorous dynamics under drip fertigation after final fertigation cycle Between lateral (from dripper point).



Values in contour is phosphorous content in kg per ha

Fig. 12. Phosphorous dynamics under drip fertigation after final fertigation cycle along lateral (between dripper).

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. 13 and 14).This falls in line with the findings of Singh *et al.* (2002) in mandarine orange.

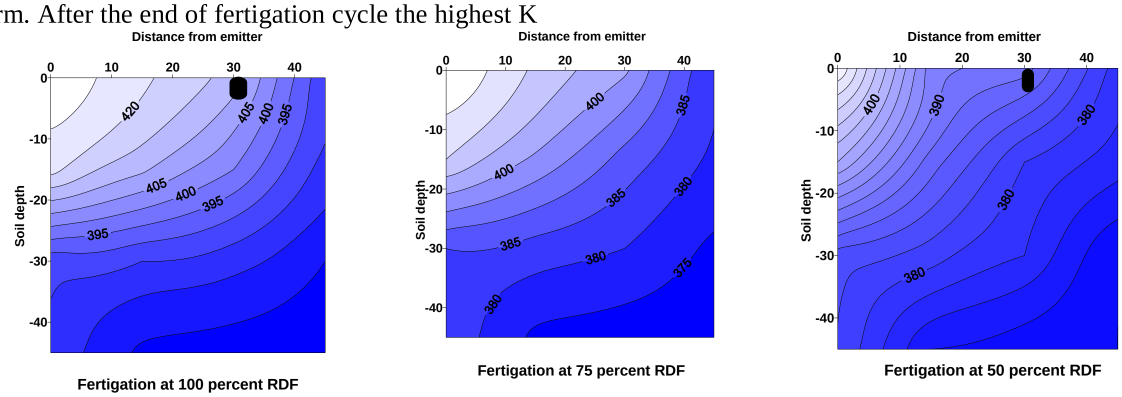
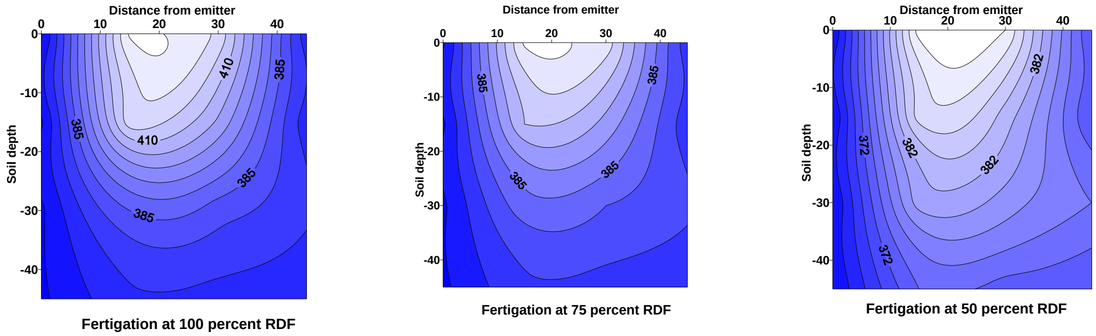


Fig. 13. Potassium mobility under drip fertigation after final fertigation cycle between lateral (From dripper point).



Values in contour is potassium content in kg per ha

Fig. 14. Potassium mobility under drip fertigation after final fertigation cycle Along lateral (Between dripper).

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); Bieleski and Rao (1986).

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); 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.

Table 1: 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 2: 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

	Season I							
	W	F	M	WxF	WxM	FxM	FxW	MxW
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*

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).

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.

Table 3: 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: 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

	Season I							
	W	F	M	WxF	WxM	FxM	FxW	MxW
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							
	W	F	M	WxF	WxM	FxM	FxW	MxW
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							
	W	F	M	WxF	WxM	FxM	FxW	MxW
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							
	W	F	M	WxF	WxM	FxM	FxW	MxW
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*

Water Use Efficiency. The details of irrigation water applied, for surface irrigation and drip irrigation treatments are depicted in Table 7. 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); 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); 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.

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 5 and 6. 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.

Table 5: 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 × M	1.583	3.313

Table 6: 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 7: 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

Annexure I: A. 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

B. 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 :

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

CONCLUSION

The peak quantity of K was observed in the 0–15 cm depth of emitter, 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 which paved for maximum yield and other quality parameters.

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