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Estimation of crop water requirement and design of drip irrigation system for guava based on the hydraulics of water movement

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Abstract
Drip irrigation is a means of increasing the efficiency of irrigation water use and reducing leaching of nutrients from the root zone. Drip irrigation is used more often for orchard crops than for field crops; primarily because the spacing between drippers and laterals is large consequently system cost per hectare is less. Soil texture is of primary importance in the design of drip irrigation and directly affects the number and placement of drippers. Hydraulics of water movement is governed by soil physical properties besides dripper discharges and operation duration of the system. Study was conducted from 1999-00 to 2005-06 to determine the arrangement of drippers in fruit plant, water requirement estimation and to study the effect of different levels of irrigation on the yield of guava. Three different irrigation levels of 60, 80 and 100% of the crop evapotranspiration (i.e. 0.6V, 0.8V and 1.0V) were applied to the crop. It was observed in sandy loam soil the drippers of higher discharges i.e. 4 and 8 LPH should be selected to wet more soil surface in a less operation time. One dripper of 4 LPH discharge was found sufficient to meet the water requirement of crop and to wet the effective roots of plant of one and two-year-old plants of guava while during 3rd and 4th year, two drippers should be placed 30 and 45 cm on either side of the lateral. From 4th year onwards, drippers of 8 LPH discharges should be placed in a loop at the vertices of equilateral triangle at a distance of 60, 75 and 90 cm during 4th, 5th and 6th year, respectively. Highest yield was obtained in treatment 1.0V and lowest in 0.6V. The yield response of guava in 1.0V (av. 16.8 t ha^{-1}) was not significantly more than 0.8V (av. 14.8 t ha^{-1}) during all the four years.

Keywords: Guava, drip design, hydraulics, dripper placement

Introduction

Drip irrigation is a means of increasing the efficiency of irrigation water use and reducing leaching of nutrients from the root zone. These two are the important objectives of irrigated agriculture, which face pressure to reduce environmental impacts and increase efficiency of irrigation water use. To achieve these goals, drip irrigation systems must be properly designed taking into consideration of lateral and dripper spacing, their arrangement with dripper discharges, irrigation scheduling and fertigation strategy should be properly made so that the rates and location of delivery of water and nutrients in the root zone are matched with the crop requirements. To fulfill the promise of drip irrigation systems for efficient delivery of water and nutrients to the root zone of crop, drip system must also take into account the actual soil properties in their design and management. If soil properties are taken into account, it is usually only a rudimentary way, such as recognizing two or three broad texture classes. Bristow *et al*. (2000) [2] used an approximate method for calculating the radial wetted perimeter distance in a plane at the source and the vertical wetted maximum depth below the dripper. Various software's have been developed to solve the various analytical equations to estimate the wetting depth and wetted surface of the different drippers. It has been clearly shown that there can be a wide range of wetting patterns in individual soils, and that the conventional notions relating average wetting behaviour to soil texture. Relating average wetting behaviour to soil texture does not hold when working with specific soils (Bristow *et al*., 2000) [2]. But in reality soil texture is an unreliable predictor of soil wetting and site-specific information on soil wetting patterns is required to design efficient drip irrigation systems. Attention is not paid to site-specific soil wetting patterns in designing and managing drip irrigation systems.

Drip irrigation system consists of drippers, either placed below the soil surface or placed on the soil surface, which discharge water at a controlled rate. Water infiltration takes place in the region directly around the dripper, which is small compared with the total soil volume of the irrigated field. As a result, three-dimensional transient infiltration occurs. This differs from more traditional techniques of flood or sprinkler irrigation, where water infiltrates through most or all of the soil surface area, and water infiltration can usually be adequately simulated by one-dimensional vertical movement. But drip irrigation systems are capable of delivering water and nutrients to the soil in small quantities at any time with no great additional economic cost. This allows maintenance of a partially wetted soil volume at optimal condition for crop growth.

Surface irrigation system known as basin irrigation is most common method of irrigation of guava. In India generally, in canal conveyance and surface irrigation methods, the overall irrigation efficiency has not been more than 40 per cent. The low efficiency may be accounted because of loss of water through seepage and evaporation. At field level losses are occurs because of poor farm distribution of water, land undulation and lack of farmers' know how about modern irrigation systems, resulting in excess application of irrigation water. The present water management practices through surface irrigation resulting in water logging and salinity in arid and semiarid part of the India. It is therefore essential to formulate an efficient, reliable and economically viable water management strategy in order to irrigate more land area with existing limited water resources.

Guava (*Psidium guava*) is a very popular fruit and available throughout the year except during summer. Guava is the 5th most important fruit of India in area and production. It occupies an area of 0.16 million ha with annual production of 1.85 million tons. Bihar is the largest producer of guava followed by U.P. and Gujarat. Best quality guava is produced in U.P. Allahabad produce best guava in the country and in the world. Productivity of guava is 11.2 t/ha with average yield of 50 kg fruits per tree. The popular varieties of guava grown in India are Sardar, Allahabad Safeda, Lalit, Pant Prabhat, Dhareedar, Arka Mridula, Khaja (Bengal Safeda), Chittidar, Harija etc. Hybrid varieties like Arka Amulya, Safed Jam and Kohir Safeda were also developed. The usual practice is to accommodate 275 plants per ha, however, high density planting (400 to 555 plants per ha) has been found highly productive. Its nutritive value is high and is therefore considered an ideal fruit for the nutritional security. Guava can be grown successfully in tropical and subtropical regions up to 1,500 m above sea-level. An annual rainfall of about 100 cm is sufficient during rainy season (July to September). The rains during harvesting period, however, deteriorate the quality of fruits. Guava can be cultivated in variety of soils from heavy clay to very light sandy soils. Guava can tolerate a soil pH of 4.5 to 8.2.

Drip irrigation is used more often for orchard crops than for field crops, primarily because the spacing between drippers and laterals is large consequently system costs per hectare is less (Deshmukh and Sen, 2000 & 2001) [4, 5]. Soil texture is of primary importance in the design of drip irrigation and directly affects the number or placement of drippers. In sandy soil where spaces between sand grains are relatively large, gravitational forces affect water movement more than the capillary action. As a result, water moves down faster rather than laterally more than through the soil. In finer soils such as clay, capillary action is much stronger and water spreads laterally more than penetrating deeper into the soil. Dripper in sandy soil will wet an area with a diameter of about 37.5 cm, while in clay soil the same dripper will wet an area up to 60 cm in diameter. Since the same amount of water is applied through dripper in both soils, in sandy soil the vertical movement of water will be more than the clay (Dubey *et al*., 2003) [7]. An orchard plant with only 25% of its roots wetted regularly will do as well as plants with 100% wetting at 14 days irrigation intervals. This saves water by wetting only part of the root zone of plant. If drippers are placed only one side of a plant, the root system is not balanced and stability is threatened. In one experiment with drip irrigation, a larger plant was blown over in a storm because the roots of the plant had been watered on one side only (Esteban and Sammis, 2002) [8].

The dripper's arrangement at each plant should be considered carefully to provide convenient orchard care, easy dripper maintenance and adequate irrigation. Drippers should be within 30-36 cm of the trunk of young, newly transplanted plants, but should be moved away from the trunk as plants grow. An equilateral triangle arrangement contains three drippers while a loop can contains more than three drippers based on the canopy area and water requirement. Two to four drippers are installed in the lateral so that wet areas slightly overlap in a line along the plant row (Kumar *et al*., 2003) [11]. When lateral's become too long to allow for the addition of drippers without excessive friction pressure loss, a dual-lateral arrangement may be used to supply additional water as plant grow, if necessary. Formulation of water management strategy in fruit crops require long duration experimentation, therefore less efforts were made for design of system considering soil properties and estimation of crop water requirement, irrigation scheduling and effect of levels of irrigation on crop yield.

Study was conducted from 1999-00 to 2005-06 on drip irrigation system (i). to decide the arrangement of drippers on the basis of soil hydraulic properties and dripper discharge on soil wetting patterns, (ii). to estimate the water requirement of guava and (iii). to study the effect of different levels of irrigation on the yield of guava.

Materials and methods

Location and soil of experimental field plot

The experiment was conducted at the research farm of Water Technology Centre, Indian Agricultural Research Institute, New Delhi during 1999-00 to 2005-06. The soil of the experimental area was deep, well-drained sandy loam soil comprising 54.19% sand, 30.71% silt, and 14.71% clay. The bulk density of soil was 1.47 g cm^{-3}, field capacity 0.25, and saturated hydraulic conductivity 1.17 cm h^{-1} respectively.

Field having an area of 0.2 ha was heavily ploughed and pits of 1m^3 size were dug. Soil was mixed with sand and compost to refill the pits. Guava (*var. Allahabad Safeda*) was transplanted during 2nd week of August, 1999 in a square geometry at a spacing of 5m x 5m. Drip system was installed in the newly planted guava orchard. Hydro cyclone and media filters were used in the drip system for filtration. Pressure gauges were installed on both sides of the filters to provide an indication of filter clogging. Main (75 mm diameter of PVC pipe) and sub-main pipelines (63 mm diameter of PVC pipe) were installed underground while laterals were kept on the surface. For injection of fertilizers, a venturi system was installed upstream of the filter. Laterals of 16 mm diameter made of LLDPE were placed on the surface. About 4.0 m extra lateral pipes were left at the end to enable modification in layout of lateral to adjust for drippers per plant when the plants get older.

Hydraulic study of drip system

Field experiments to study the hydraulics were conducted in bare soil before transplantation of guava orchard to monitor the wetting pattern at the soil surface as well as that of the soil profile in all the three arrangements. Drippers of 2, 4 and 8 LPH discharges were selected for the study. The following three arrangements of drippers were made for hydraulic study.

1. Drippers were installed in the lateral pipe at a spacing of 5 meter (Fig. 1).
2. Two drippers were installed in the lateral pipe through micro tube. Spacing between 2, 4 and 8 LPH drippers were kept at 60, 90, 120, 180, 240, 300 and 360 cm. Drippers were placed in a way that line joining the two drippers made a right angle with lateral (Fig. 1).
3. Three drippers were arranged in circular loop. Drippers were placed at the vertices of the equilateral triangle with a spacing of 90, 120, 150 and 180 cm for the dripper of 2, 4 and 8 LPH (Fig. 1).

Drip system was operated for 1, 2, 3 and 4 h and wetted surface and wetted depth were measured by cutting the soil profile and moisture distribution were also monitored in all the three arrangements.

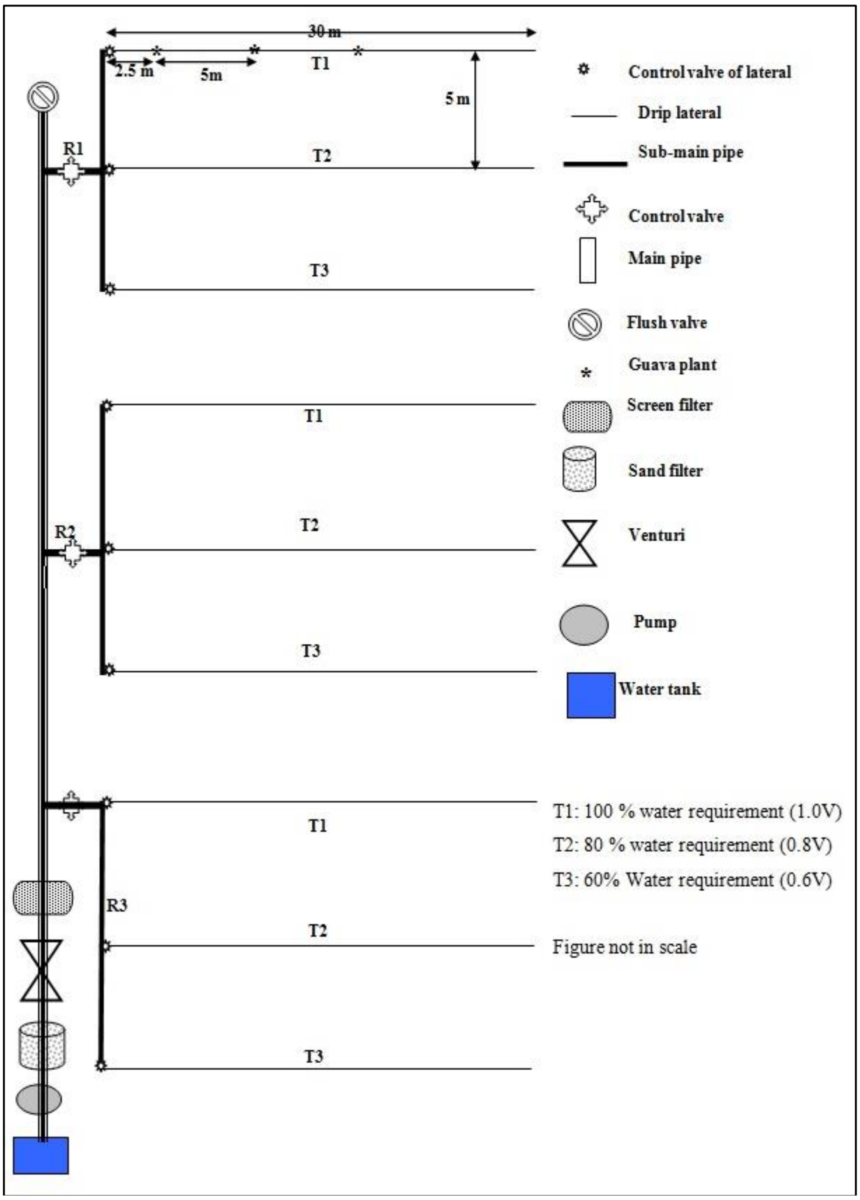


Fig 1: Layout of guava orchard

Estimation of water requirement

Daily crop evapo-transpiration (ET_0) and other weather data were collected from the weather station installed in the IARI premises located about 2 km away from the guava orchard. The monthly values of ET_0 during different years i.e. from 1999-00 to 2005-06 in are plotted in Fig. 2. The irrigation frequency was maintained weekly during each year of study. The crop coefficient varies from 0.61 to 0.81 depending on the crop development (Teixeira *et al*., 2003) [17].

The actual evapo-transpiration (ET_0) was estimated by multiplying reference evapo-transpiration with crop coefficient (ET_c = ET_0 x K_C) for different months based on crop growth stages. The water requirement is estimated by using Equation 1.

$$WR \rightleftarrows = \left(\frac{K_c \times ET_0 \times A \times C_c}{\eta}\right) - R_{eff.} \quad (1)$$

For guava orchard, the area (A) in Equation 1 is the area of a circle with a diameter equal to the diameter of the plant canopy, calculated by using Equation 2.

$$A = \left(\frac{\pi d^2}{4}\right) \quad (2)$$

Where,
WR = Daily water requirement, litre day^{-1} $plant^{-1}$
A = Plant canopy area, m^2
d = Diameter of plant canopy, m
ET_0 = Evapotranspiration, mm day^{-1}

η = System efficiency (in fraction)
K_c = Crop coefficient
Cc= Canopy coefficient (taken as 0.8)
$R_{eff.}$ = Effective rainfall, mm day^{-1}

Crop coefficients varied from 0.61 to 0.65 during 1999-00 to 2001-02 and 0.65 to 0.81 during 2002-03 to 2005-06. Effective rainfalls in different months were considered equal to 70% of total rainfall in that particular month. Plant canopy increases with growth of plant. Canopy radius varies from 15, 30, 60, 90, 120, 150 and 180 cm during 1999-00 to 2005-06. Net water requirement per day per plant was estimated by subtracting the effective rainfall from water requirement.

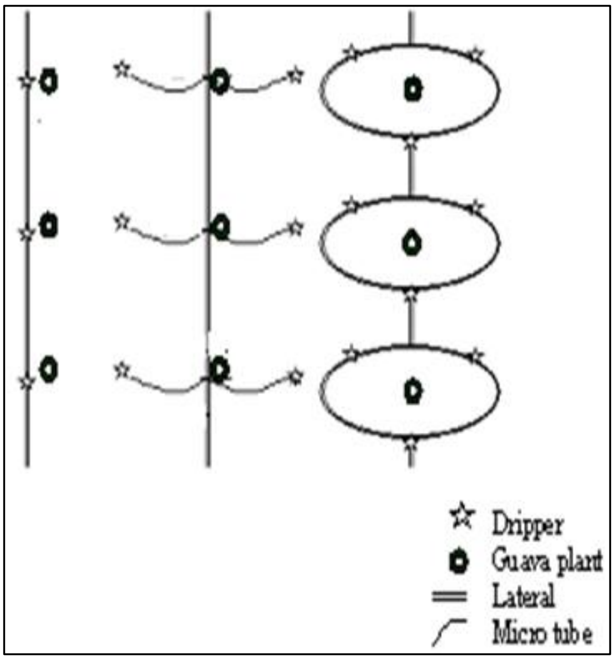


Fig 2: Arrangement of drippers

Three different irrigation levels of 60, 80 and 100% of the crop evapo-transpiration (ETc) (i.e. 0.6V, 0.8V and 1.0V) were applied to the crop. One lateral line was provided for each row of guava plants, in all treatments. Each treatment is having three replications following the RBD. The operation duration of drip system was worked out for different levels of irrigation. The duration of irrigation to each treatment were controlled with the help of control valves.

Fertilizer management

Guava is heavy feeders of nutrients and needs regular application of fertilizers. Fertilizers were applied through fertigation in three split doses therefore nutrients may be available along the periphery of the root zone (Singh *et al*., 2003). Amount of fertilizer applied was shown in Fig. 3.

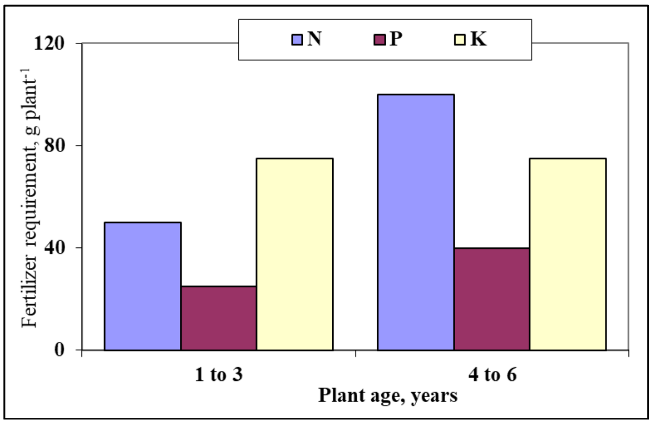


Fig 3: Fertilizer requirement

Results and discussions

Soil moisture movement

Soil moisture movement under a point source of water application depends on the soil type, dripper discharge and the operation duration of the drip system. Rate of horizontal as well as vertical advance of soil moisture keeps decreasing with time. Advance of the wetting soil surface was monitored with time and space under different arrangement of dripper systems. Increasing operation time from 1 h to 4 h resulted into larger wetted surface in all drippers having 2, 4 and 8 LPH discharge and wetting surface varied from 27 to 50.2, 35 to 70.2 and from 52 to 95.5 cm, respectively (Table 1). Higher dripper discharge attained the maximum wetted surface in lesser duration of operation of the system (Fig. 4). However, it may be observed that wetting depth did not stabilize and kept increasing with increasing dripper discharge and operation time.

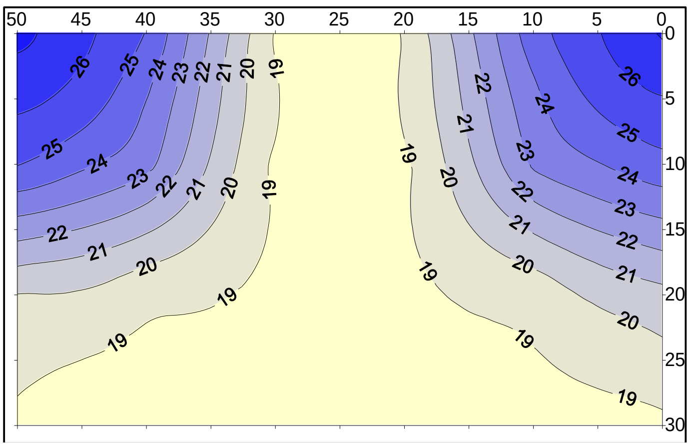
a) 2 LPH Dripper **b)** 4 LPH Dripper **c)** 8 LPH Dripper

Fig 4: Wetting of soil surface after 1 h duration of drip system

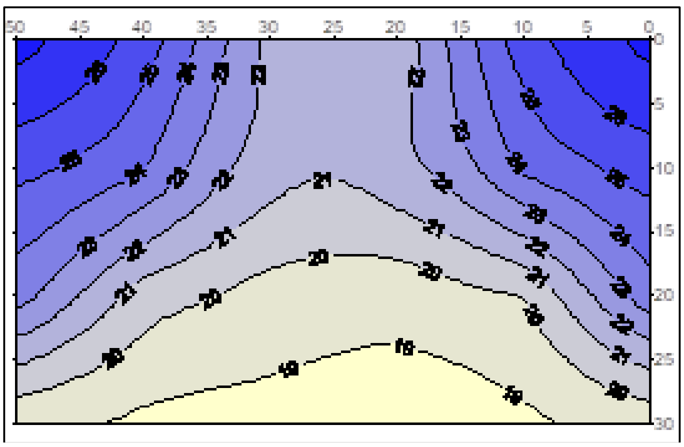
Table 1: Weather parameters recorded during the experimentation period (2000 to 2006)

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
	Mean temperature, ^{0}C											
2000	13.4	14.6	21.1	29.4	33.5	31.4	29.3	29.6	28.8	26.3	20.7	14.9
2001	12.3	16.8	21.4	27.4	31.9	30.0	30.2	30.2	29.3	26.2	20.2	15.4
2002	13.3	15.9	22.3	29.6	33.1	32.9	34.5	30.2	27.4	25.6	20.1	15.7
2003	11.0	15.7	21.0	28.8	31.8	34.5	29.4	29.5	28.3	24.4	19.0	14.6
2004	12.4	16.7	24.1	29.5	32.4	31.5	33.0	29.5	29.5	24.5	19.8	15.1
2005	12.8	15.5	22.7	27.6	31.2	33.8	29.9	31.1	28.7	24.5	19.3	12.8
2006	13.9	20.6	20.0	28.4	32.3	31.6	30.5	30.0	28.4	25.8	20.5	15.3
	Mean relative humidity %											
Year	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
2000	75.1	71.3	53.1	33.1	40.3	62.2	79.7	77.5	70.2	63.5	64.4	63.8
2001	74.5	60.1	51.0	40.2	45.4	69.8	77.4	72.4	62.9	65.3	61.2	71.3
2002	74.7	65.4	50.8	31.3	34.2	52.5	46.1	72.7	76.1	65.8	65.5	68.7
2003	82.2	83.9	58.5	41.6	40.1	52.8	79.1	78.6	75.1	57.0	56.4	75.7
2004	78.7	64.4	52.4	46.8	47.3	58.2	61.6	80.1	62.0	70.1	62.6	69.6
2005	71.9	67.1	60.2	38.8	45.2	51.2	77.4	66.9	75.9	64.6	63.5	67.2
2006	64.1	60.6	56.9	29.6	45.1	40.4	73.3	70.4	71.9	61.2	65.1	66.3
	Wind speed											
Year	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
2000	1.7	1.5	1.6	1.7	2.8	2.2	1.6	1.4	1.3	0.7	0.9	1.0
2001	1.5	1.5	1.3	1.6	2.2	1.4	1.5	1.9	1.4	0.8	0.7	1.1
2002	1.3	1.5	1.8	1.8	2.1	2.0	2.9	1.4	1.2	0.8	0.7	0.9
2003	2.1	3.6	3.9	3.3	4.2	4.7	3.4	1.8	1.5	0.8	1.2	2.1
2004	2.0	3.4	3.4	3.8	6.0	4.9	6.2	4.6	4.3	2.0	1.8	3.2
2005	4.2	4.8	2.8	3.9	3.6	5.4	3.0	6.1	5.1	2.2	2.1	1.2
2006	1.3	1.2	1.5	1.4	1.9	1.7	1.2	1.7	1.2	1.0	0.7	0.8
	Monthly rainfall, mm											
Year	**Jan.**	**Feb.**	**March**	**April**	**May**	**June**	**July**	**Aug.**	**Sept.**	**Oct.**	**Nov.**	**Dec.**
2000	14.7	49.8	6.4	0.8	14.7	92.2	284.7	216.4	25.4	0.0	8.6	4.6
2001	17.3	9.6	5.1	13.7	57.2	152.9	132.6	108.5	73.7	9.7	1.0	0.8
2002	6.9	14.0	4.1	1.5	80.5	42.4	15.0	84.8	161.3	4.3	0.3	3.6
2003	41.6	28.4	24.6	0.0	7.4	31.5	578.6	148.0	44.5	0.0	0.0	21.3
2004	14.1	0.0	0.0	19.6	24.8	89.8	7.2	290.0	5.4	80.6	0.0	0.0
2005	2.0	32.2	13.0	4.8	1.6	46.6	181.2	107.2	215.6	0.0	0.0	0.0
2006	4.8	0.3	32.3	3.1	81.8	77.5	267.7	108.5	83.8	1.8	2.3	2.5

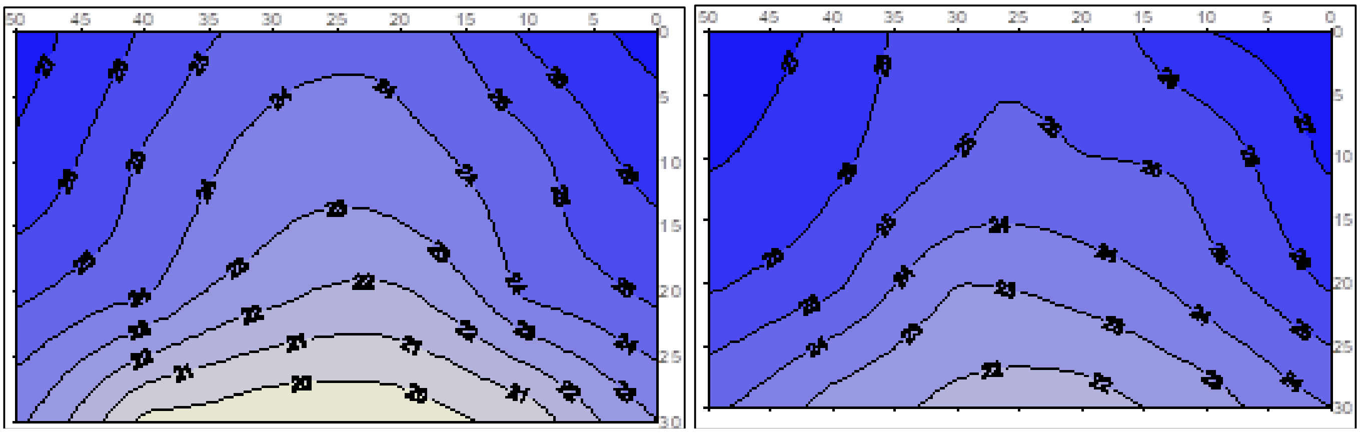
Wetting pattern at the soil surface under a two drippers system appeared exactly as it would be under two different drippers till the two wetting fronts joined each other at the soil surface (data not shown here). Two drippers of 2 LPH discharges were kept at a spacing of 50 cm resulted in wetting of soil surface and depth of 50.2 cm and 45.9 cm, respectively when system was operated for 4 h. Wetting fronts of 2 LPH dripper discharge merged at the soil surface after 4h operation duration of system (Fig. 5). When two drippers of 4 LPH and 8 LPH discharges were kept at spacing of 50 cm wetting surfaces of both the drippers merged after 3 h and 2 h operation of the drip system, respectively. Three sections were cut along the median of the equilateral triangle when three drippers were placed in a loop. In case of drippers of 4 LPH discharges placed at the vertices of the equilateral triangle of each of 90 cm side, the front meets after 3 h duration of drip system. When drippers of 8 LPH discharges were placed in a loop at the vertices of triangle at a distance of 90 cm, the wetted surface merged with each other after 4 h duration of drip system.



Discharge 2 LPS placed at 50 cm for 1 Hr



2 LPH discharge placed at 50 cm for 2 Hr



2 LPH discharge placed at 50 cm for 3 Hr | 2 LPH discharge placed at 50 cm for 4 Hr

Fig 5: Soil moisture distribution under 2 LPH dripper discharge

Table 2: Wetted surface and depth in a single dripper system

Operation duration,	Wetted surface, cm			Wetted depth, cm		
	Dripper discharge, LPH			Dripper discharge, LPH		
	2.0	4.0	8.0	2.0	4.0	8.0
1	24.8	32.0	45.0	21.4	24.7	44.3
2	36.5	45.5	65.0	32.1	36.0	50.4
3	41.0	58.0	70.2	40.1	47.5	75.6
4	48.2	60.5	85.5	45.2	51.4	90.8

It was observed from the various experiments conducted to study the movement of water at the soil surface and at soil depth in a sandy loam soil, drippers of higher discharges i.e. 4 and 8 LPH should be selected to wet more soil surface in a less operation time. Since unit cost of 2, 4 and 8 LPH drippers is same, therefore in orchards having larger canopy size, the drippers of higher discharge should be placed in a loop. In guava orchard, for one and two year old plants, one dripper of 4 LPH discharge is sufficient to meet the water requirement of crop and to wet the effective roots of plant while during 3rd and 4th year, two drippers should be placed at a distance of 60 cm and 90 cm with each other in the right angle with lateral pipe. From the 4th year onwards, drippers of 8 LPH discharges should be placed in a loop at the vertices of equilateral triangle at a distance of 60, 75 and 90 cm. The diameter of loop may be increased from 60 cm to 90 cm as canopy of the plants will increase.

Maximum concentration of feeding roots is available up to 25 cm soil depth, therefore top soil should be rich to provide enough nutrients and water for accelerating new growth which bears fruits (Chadha, 2001) [3]. The longer operation durations of drip system tends to lead to percolation losses as the moisture advances more in vertical direction. It is important in guava crop to apply water and nutrients in a manner so that maximum percentage of plant canopy area gets wetted (Patil and Patil, 1997) [12].

Effect of irrigation levels on guava yield

The water requirement of crop depends on the actual crop evapo-transpiration. Non-parametric test (Friedman's test) was applied to test the difference in water requirement at any particular month during different years. Guava plants were transplanted during July, 1999 and started giving fruits from 2002-03. The Friedman's test was first applied during non-fruiting period (1999 to 2002) and then to fruiting periods (2002-03 to 2005-06). Difference in water requirement in any particular month in different years is not significant during both periods ($\alpha =$ 1, 5 and 10%). The net water requirement of guava varies from 0.3 to 1.3, 0.6 to 4.1, 1.3 to 6.7, 3.3 to 16.6, 1.6 to 29.3, 6.7 to 61.1 and 15.3 to 78.7 litre day^{-1} plant^{-1} for 1999-00, 2000-01, 2001-02, 2002-03, 2003-04 and 2004-05, 2005-06, respectively. Net water requirement at different days of the growing season for the year 1999-00, 2000-01, 2001-02, 2002-03, 2004-05 and 2005-06 are shown in Fig. 6.

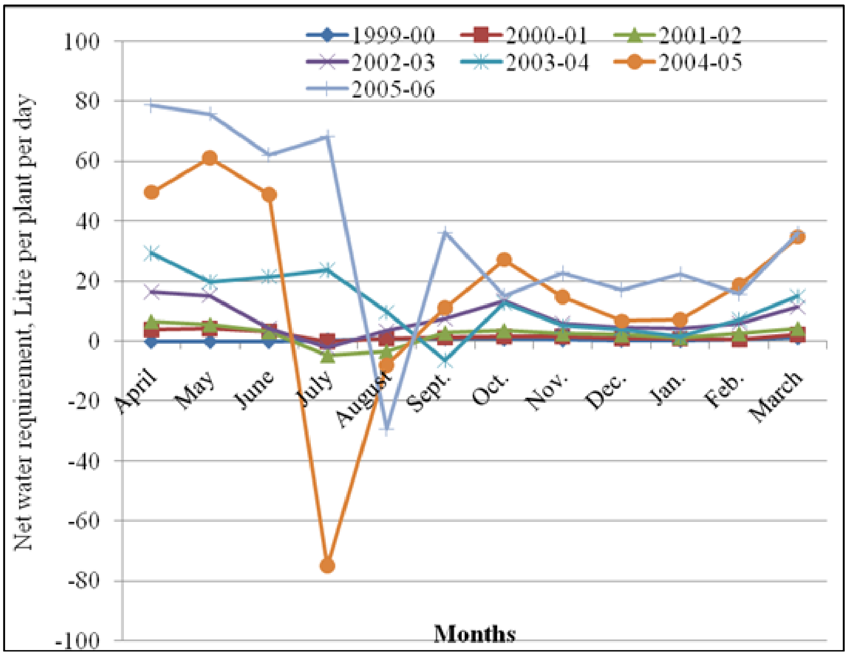


Fig 6: Net water requirement of guava in different months

Sandy loam soil needs frequent irrigation with less amount of water per irrigation. Guavas are deep-rooted crop but its most active roots remains at 25.0 cm soil depth (Chadha, 2001) [3]. Soil water content just below the dripper was more throughout the year at about field capacity (~ 25.6%) i.e. 25.2, 25.3 and 25.1% for treatments 1.0V, 0.8V and 0.6V, respectively. With successive irrigation event, the water moves from upper profile to lower profile. Constant soil moisture near surface is important for good crop growth and maximum percentage of plant canopy should be wetted during the irrigation (Patil and Patil, 1998, & 2001) [13, 14].

During 2001-02, good yields were observed in all treatments. Amount of irrigation has significantly effect on guava yield (Friedman's test at $\alpha = 5\%$). Highest yield was obtained in treatment 1.0V and lowest in case of 0.6V in all the years of fruiting (Fig. 7).

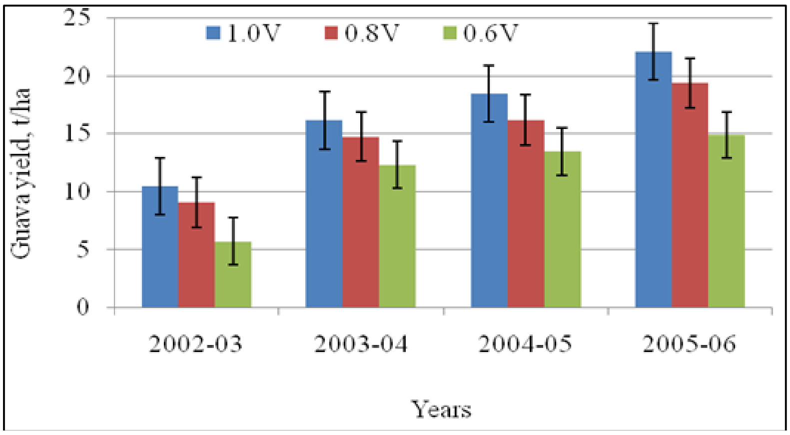


Fig 7: Guava yield as affected by levels of irrigation

However, in 2002-03, lesser yields were recorded in all treatments because of less growth of plants. By applying 40.0% less amount of irrigation water, there was reduction in yield of 44.8%. Whereas in case of 0.8V, guava yield reduced by 14.5%. The yield response of guava in 1.0V (av. 16.8 t ha^{-1}) was not significantly more than 0.8V (av. 14.8 t ha^{-1}) during all the four years. Guava is a hardy plant but 100% irrigation water application has considerable influence on yield over two other irrigation levels, that is, 0.8V and 0.6V.

Conclusions

Nutrients and salts tend to concentrate at the edges of the wetted soil area. It is necessary to locate more than one dripper per plant in a way so that wet areas overlap at the plant trunk to prevent harmful accumulations of salt and excess amount of nutrients at or near the trunk. Looping pattern of drippers' arrangement was found good for old guava plants. The loop can be formed around the trunk based on the plant growth and water requirement. The net water requirement of guava varies from 0.3 to 1.3, 0.6 to 4.1, 1.3 to 6.7, 3.3 to 16.6, 1.6 to 29.3, 6.7 to 61.1 and 15.3 to 78.7 litre day^{-1} $plant^{-1}$ for 1999-00, 2000-01, 2001-02, 2002-03, 2003-04, 2004-05 and 2005-06, respectively. The yield response of guava in 1.0V (av. 16.8 t ha^{-1}) was not significantly more than 0.8V (av. 14.8 t ha^{-1}) during all the four years.

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