MICRO IRRIGATION

2006

by

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FOREWORD

India would need to produce additional food grains of 100 to 160 million tonnes by 2030 and 2050 AD respectively to feed its projected population of 2 billion. Expansion of area under irrigation is essential for increased food production. This can be achieved by additional development, conservation and efficient management of available water resources. Agriculture draws around 90% of total water used in India and demand for water in non – agricultural sectors like industries, urban, power etc are also there, which result 75 to 80% of water allocation for agriculture in next two decades. At the same time, the per capita avaliablity of water in India will be reduced from 2025 cum to 1500 cum by the year 2025. Hence, the major constraint in future is going to be water for irrigation.

Scientific water management involves adoption of right method of irrigation consistent with topography of field, to supply water to the crop at right time and at required quantity. Micro irrigation will enhance water use efficiency and productivity without injurious effect on soil health. Micro irrigation enables high frequency application of water in and around the root zone of plants and application of fertilizer and pesticides in an integrated manner resulting in skillful use of water and nutrients. However, many issues surfaced relating to development and popularization of micro irrigation in India. It is still needed to enhance widespread adoption of this technology particularly by small farmers.

This publication is the outcome of attempts to consolidate literature on micro irrigation. In this book, all basic aspects of micro irrigation and fertigation are covered. I am sure, the information contained in this publication entitled "Microirrigation" will be of great use to planners, engineers, researchers, students and ultimately to agricultural extension officers and farmers. I sincerely congratulate Dr. P. Suseela and Dr. V.S. Devadas who made this compilation possible.

Mannuthy
2-1-2006

K.V. Peter
Vice-Chancellor
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PREFACE

In the present era of development, all the sectors of economy are demanding larger quantities of fresh water. Thus, tremendous amount of pressure lies on agriculture sector to reduce their share of water and at the same time to enhance total production. This can be achieved only by enhancing productivity with increased water-use efficiency. However, a serious concern is being expressed in the recent years on account of less than expected performance of irrigation projects. Colossal loss of water in conveyance, distribution and field application; inefficient control and operation of irrigation and inadequate knowledge base of the farmers and field functionaries are some of the frequently identified maladies of the irrigation systems. In this context, a shift in focus is required from the development of additional irrigation resources for increasing the water use efficiency of already developed water resources.

The adoption of advanced methods of irrigation like microirrigation with improved water management will help to achieve this goal. Microirrigation is an efficient method which minimizes the conventional losses like deep percolation, run off and soil evaporation. It is providing irrigation water directly into the soil at the root zone of plants, closely to the consumptive use of plants.

The technology of microirrigation has to play a very vital role in near future; hence greater attention has to be provided to develop the skill and know-how about the system, chemicals and other equipments required by the users from time to time.

In the present compilation, we have made an attempt to compile the available information of the several aspects of microirrigation and fertigation which will provide the necessary guidance to the scientists, agricultural extension officers, engineers, planners who are engaged in irrigation and on-farm water management. This publication will also give basic information to students in Agriculture and Agricultural Engineering. In addition, the book will be valuable reference to the progressive farmers.

We feel privileged and elated to keep a record of deep sense of gratitude and heartfelt thanks to Dr. K.V. Peter, Vice Chancellor, Dr. M.K. Sheela, Director of Extension and Dr. D. Alexandar, Director of Research, Kerala Agricultural University for the help and encouragement in bringing out this bulletin. Authors express their sincere gratitude to Dr. K.P. Visalakshy, Asso. Professor, ARS, Chalakudy and Mr. Sasidharan, Kairali Marketing Associates, Chiyyaram, Thrissur for providing help in editing and compailation.

We express our profound sense of gratitude to the staff members of Agronomic Research Station, Chalakudy for their constant encouragement to bring out this publication and for providing necessary facilities.

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1. INTRODUCTION

Water is the most precious natural resource and a universal asset. Water provides life-supporting system for human beings, plants and animals. In the twentieth century, there has been phenomenal growth in the use of water. While the world population has tripled, the use of water for human purposes has multiplied six fold. Leading experts on water resources are warning that the world is fast heading towards "a water shock" which may even dwarf the oil crisis. Experts also fear that shortage of water is likely to be so acute in future that next world war may well be fought over disputes relating to sharing of water resources among various countries. Today, about 80 countries comprising 40% of world's population suffer from serious water shortages (UN, 1997). In India, even if the potential utilizable volume of water were fully tapped, nearly 45% of the cultivable area would have no irrigation.

By 2025, an additional two and a half billion people will demand more water for growing food. At the same time, farmers will face greater competition for water from growing industries. The application of surface irrigation practices has resulted not only in considerable losses of water, but also widespread salinity and water logging problems, which has affected the ecosystem adversely. Most irrigation projects have not achieved a substantial increase in agricultural production as was anticipated. In addition, the high financial and environmental costs of new dams and canals make them unlikely to contribute more than a fraction of additional usable quantity of water. Hence, judicious utilization of the available irrigation water is very essential for ensuring the food security.

Water availability in India

The Central Water Commission has reported that 75-90% of rainfall occurs during 25 to 60 days from June to September and the co-efficient of variation of annual rainfall is above 20% in most part of the country. Out of the total 400 m ha of water available, hardly 10% are used effectively (Mahendran, 2004). Due to the tremendous increase in population, the per capita water availability came down from 5300 m^3 in 1955 to 2200 m^3 in the early nineties against the world's average of 7400 m^3 and Asian average of 3240 m^3. As per the UN standards, the countries with annual per capita water availability of less than 1700 m^3 are considered as water stressed and those with less than 1000 m^3 as water scarce (Cosgrave, 2000). Another estimate states that the per capita availability of water will be reduced to 1500 m^3 by the year 2025 (Mahendran, 2004).

Hence, water is going to be the most scarce commodity. The demand for water in various fields is increasing drastically (Table.1.1) (Reddy, 1992).

Table1.1. Past, present and future demand of water in India for various purposes (mhm)

Sl.No.	Purpose	Demand in years		
		1990	2000	2025
1	Irrigation	46	63	77
2	Drinking and livestock	2.5	3.3	5.2
3	Industrial use	1.5	3.0	12.0
4	Energy	1.9	2.7	7.1
5	Others	3.3	3.0	3.7
	Total	55.2	75.0	105.0

Need for efficient irrigation

It is imperative that timely provision of irrigation water is crucial for agricultural productivity. The development of irrigation is given top priority in Indian economy as agriculture contributes to about 50% of the Gross National Product.When a reliable and suitable supply of water becomes available for agriculture, it can result in vast improvements in agricultural production and economic returns to the grower. However, owing to various reasons, not only available water for irrigation purpose has been declining rapidly but also the demand for irrigation water has been growing at a faster rate. Hence, efficient use of irrigation water is an important means for increasing the productivity. The surface irrigation methods, which is widely practiced in India leads to enormous losses of water due to seepage and evaporation. The losses also result due to poor distribution of water in farm due to inadequate land preparation and lack of farmer's knowledge in the application of water, which leads to excess applications and deep percolation. Generally, under surface irrigation methods, less than one-half of the water released only reaches the plants. In projects, which may be assumed to be planned, designed and operated properly, the efficiency ranged from 35 to 40% only. Though many technologies have been introduced to conserve the water, many of them failed to bring any impressive changes. The unscientific use of water has resulted not only wastage of water but also caused soil erosion, salination and water logging which ultimately degraded the quality of two basic natural resources – soil and water.

Therefore judicious use of water management is vital to achieve higher productivity in a sustainable manner. Good scientific water management involves adoption of right method of irrigation consistent with the topography of the field and type of soil to supply the required quantity of water to the crop at right time. Micro irrigation can be considered as an efficient irrigation method, which is economically usable, technically feasible and socially acceptable. Basically, micro irrigation systems are fairly simple technologies that maximize water use efficiency by delivering water to the plants, where and when they need it. The overall irrigation efficiency of micro irrigation is very high compared to surface irrigation methods (Table 1.2).

Table.1.2: Irrigation efficiency of three systems (Sivanappan, 1992)

Sl. No.	Details	Irrigation efficiency in percentage		
		Surface	Sprinkler	Drip
1	Conveyance	60-70	100	100
2	Application	60-70	70-80	90
3	Surface water/Moisture evaporation	30-40	30-40	15-20
	Total	30-45	40-60	75-80

Micro irrigation is the slow and regular application of water directly to the root zone of plants through a network of economically designed plastic pipes and low discharge emitters. Micro irrigation enables watering the plants at the rate of its consumptive use, thereby minimizing the losses such as deep percolation, runoff and soil evaporation. Water is supplied slowly and frequently to keep the moisture within the range desired for the plant growth. The system is also useful for fertilizer and pesticide application in an integrated manner resulting in skillful use of nutrients.

2. HISTORICAL DEVELOPMENT AND STATUS OF MICRO IRRIGATION IN INDIA

Micro irrigation was practiced in India through indigenous methods such as bamboo pipes, perforated earthenware pipes and pitcher/porous cup irrigation. In Kerala, pitcher irrigation is being practiced for coconut palm. In Meghalaya, some farmers are using bamboo micro irrigation system for irrigating betel vine, pepper and arecanut by diverting stream water on hill slopes. The discharge at the head varies from 15 to 20 lit/min., which is reduced to 10 – 30 drops at the time of application. In bamboo micro irrigation systems, long hollow bamboo pipes of varying diameters (50 – 100 mm) are used for making channels. In Maharashtra, perforated earthen pipes have been in use. Earthen pitchers (pots) and porous cups have also been used for growing vegetables in Rajasthan and Haryana. The technique is embedding of earthen cups of 500 ml capacity at the site of seedlings. The cups are filled with water at 4-5 days interval (Alam and Kumar, 2001).

In India, the present form of micro irrigation was introduced in the early seventies at the Agricultural Universities and other research institutions. However, commercial adoption took place only when government of India launched a new scheme on "Use of Plastics in Agriculture". National Committee on the Use of Plastics in Agriculture (NCPA) was set up in 1981 for the promotion of use of plastics in agriculture and allied areas. At that time, the awareness about different plasticulture applications among various categories of people including policy makers was very low. During 7th plan, NCPA had established 11 PDCs (Plastic Culture Development Centres) with State Agricultural Universities. Afterwards, five more were added. PDCs are carrying out research on plasticulture applications to find out their suitability, cost benefit analysis and also to develop package of practices. During eighties, research on micro irrigation was enlarged through DRIPNET of the ICAR and 16 PDCs (Table 2.1) established in different parts of the country. NCPA is organizing training programmes not only about the technology but also about the GOI subsidy schemes for the farmers as well as officers from the State Implementing Agencies. NCPA has also been interacting with the manufacturers for formulating the guidelines for implementing GOI Central Sponsored Scheme on Use of Plastics in Agriculture. Government of Maharashtra also contributed significantly for promoting the drip technology in Maharashtra. This enabled the growth of the drip industry in various parts of the country. Many of the drip components like laterals and emitters, which were being imported, began to be manufactured indigenously.

Table 2.1. Plasticulture Development Centres in India

Sl.No.	Name and location of PDC	Year of establishment
1	Indian Agricultural Research Institute, Delhi	1986-87
2	Andhra Pradesh Agricultural University, Hyderabad	1987-88
3	Assam Agricultural University, Jorhat, Assam	1988-89
4	Rajendra Agricultural University, Samastipur, Bihar	1995-96
5	Gujarat Agricultural University, Navsari, Gujarat	1988-89

1	2	3
6	Haryana Agricultural University, Hissar, Haryana	1995-96
7	Y.S. Parmar University of Horticulture & Forestry, Solan, H.P.	1995-96
8	University of Agricultural Sciences, Bangalore	1986-87
9	Kerala Agricultural University, Tavanur, Kerala	1995-96
10	Mahatma Phule Krishi Vidyapeeth, Rauri, Maharashtra	1986-87
11	Indira Gandhi Krishi Vishva Vidyalaya, Raipur, M.P.	1995-96
12	Orissa University of Agriculturel & Technology, Bhubaneswar	1987-88
13	Rajasthan Agricultural University, Bikaner, Rajasthan	1987-88
14	Tamil Nadu Agricultural University, Coimbatore, T.N	1985-86
15	G.B. Pant University of Agrl. & Tech. Pantnagar	1987-88
16	Indian Institute of Technology, Kharagpur, W.B	1985-86

There was a tremendous development of drip irrigation in Maharashtra after 1987. This was due to the encouragement given by the State Government and the efforts taken by the manufacturers to popularize and educate the farmers. Moreover, there was severe water scarcity problem in many parts of the state. In Nasik, farmers irrigated grape vines through drip system by purchasing tanker loads of water during the summer season. Even though installation and running cost of the system was very high, they could acquire a very high cost benefit ratio of 1:11 to 1:32 (including water saving).

In India, more than 100 Indian private companies produce and market a range of drip, micro sprinkler and sprinkler irrigation products. The names and addresses of some of the manufacturers are given in Annexure I. Many new manufacturing units, some multi-national and joint venture companies are coming up in different parts of the country.

To promote micro irrigation at farmers level, various development schemes (Use of Plastics in Agriculture, Oil Palm Development Programme and Integrated Central Development Programme on Sugarcane) under Department of Agriculture and Cooperation, Govt. of India, are being implemented in the country. Under all the above schemes, assistance to farmers were provided up to the extent of 90% of the capital cost of the system for a hectare or Rs. 25,000/ ha, whichever is less for SC/ST, small/marginal and women farmers and 70% of the cost for other categories of farmers. The details of subsidy schems implemented by the Government is given in Table 8.4. The cost of incentive is shared by central and state government. Bureau of Indian Standards (BIS) has come out with standards of various components of micro irrigation systems. This has given confidence to the financial institutions to extend credit for the same. The progress in the drip-irrigated area over the years has been substantial. The authentic figures of the area under micro irrigation in the country are not readily available. Published information show that the drip irrigated area in India was about 1500 ha in 1985, which rose to 5770 ha in 1988, 38000 ha in 1993, 71,000ha in 1994 and grown up to 2,85,000 ha in 2000-2001. In India, there was a tremendous increase in area covered under drip irrigation during 1995 to 1999 (Table 2.2). As a result, India has now emerged as a leading country in micro irrigation.

Table 2.2. Area coverage under micro irrigation in India

Year	Area (000 ha)
1992-1993	13.49
1993-1994	14.05
1994-1995	14.59
1995-1996	39.80
1996-1997	46.50
1997-1998	45.15
1998-1999	53.08
1999-2000	53.19
2000-2001	25.44
2001-2002	15.20
2002-2003	27.10
Total	347.59

The distribution of area using micro irrigation extensively in major states and upcoming states is shown in Fig.2.1. (Alam and Kumar, 2001).The important crops under micro irrigation system are coconut, grapes, banana, mango, sapota, pomegranate, sugarcane, cotton, groundnuts, vegetables, flowers etc. Crop-wise area under micro irrigation is shown in Fig.2.2. (Alam and Kumar, 2001).

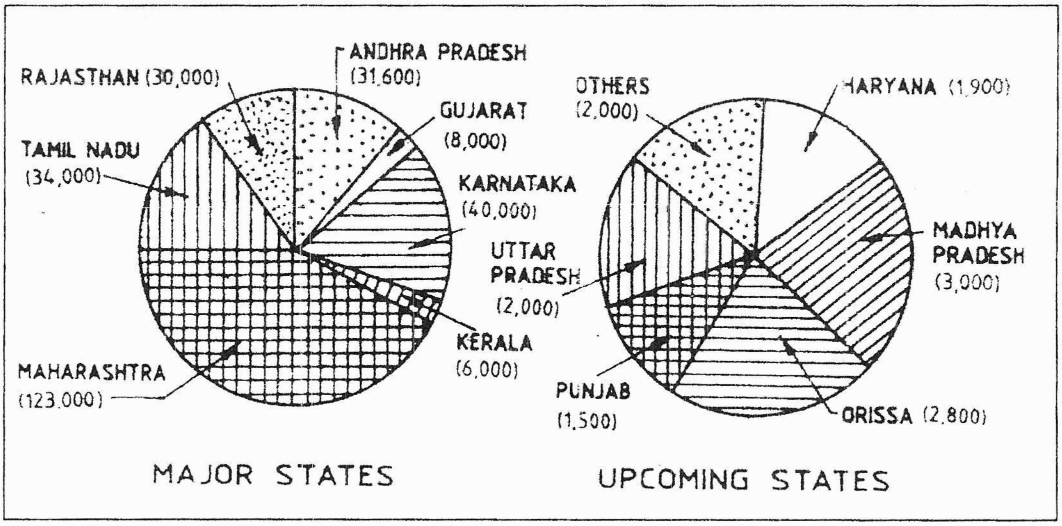


Fig.2.1 Area covered under micro irrigation (ha)

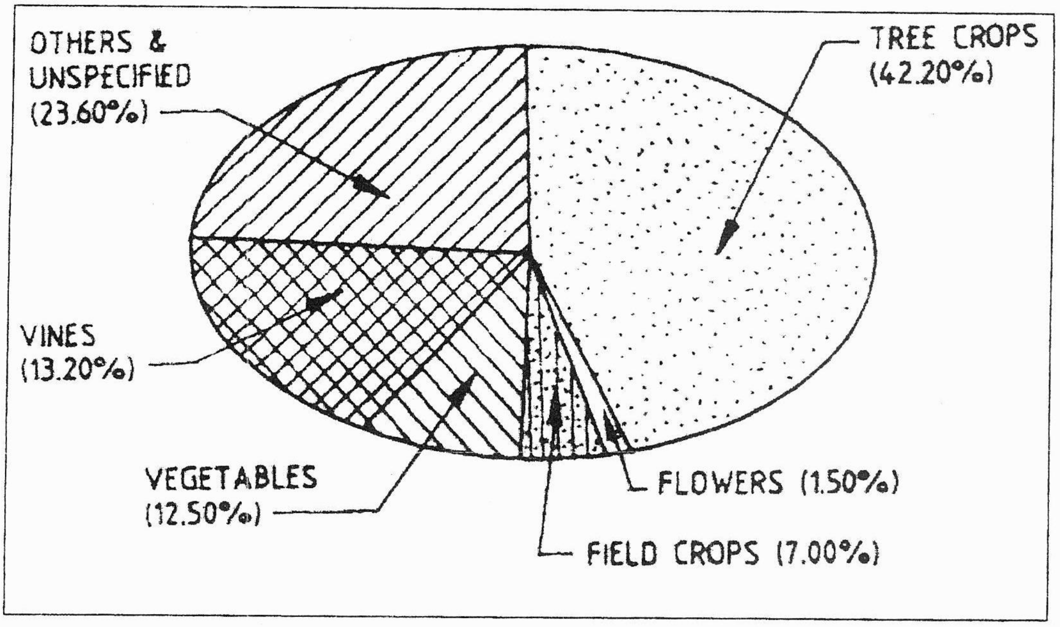


Fig. 2.2 Crop-wise coverage of micro irrigation

The area under drip irrigation in different countries is given in Table 2.3.

Table 2.3. Adoption of drip irrigation system in different countries (Rajput and Patel, 2001)

Country	Area under drip irrigation, ha (1997- 98)
United States	1,050,000
Spain	230,000
South Africa	144,000
Israel	161,000
Italy	80,000
India	285,000 (2000-01)
Egypt	104,000
France	140,000
Cyprus	25,000
China	34,000
Jordan	38,300
Others	65,753

Economic analysis of 695 beneficiary farmers and 76 non-beneficiary farmers (who installed drip system without any Government subsidy) indicated that the cost (inclusive of subsidy) was recovered in a period of less than 3 seasons in majority of cases. The benefit cost ratio was more than 2.5:1 for most of the cases (Singh, 2001).

Even though the economics of micro irrigation are well established and the technology has gained commercial acceptance, the level of technology awareness is low in the country except in some south and north western states with water scarcity conditions where micro irrigation came as a ready answer to maintain sustainable agriculture. Apart from high doses of subsidy, the coverage of micro irrigation has remained largely confined to these states. Following are the constraints experienced in bringing large areas under micro irrigation among farmers.

- High initial cost.
- Inadequate awareness about the advantage of micro irrigation.
- Sufficient availability of surface and ground water in some of the states, particularly in Northern and Eastern India.
- Inadequate facilities in getting subsidy and credit.
- Lack of manufacturers/distributors in various places for timely supply of good quality components of irrigation system.
- Lack of trained manpower.
- Clogging of emitters.
- Damage of the components of irrigation system due to rodents.
- High costs involved in spares and accessories.
- Insufficent extension and promotional activities.

Systematic studies on the economics of the technology under actual field conditions on crop/area basis and wide dissemination of findings of such studies are very essential. Moreover, greater importance has to be given to step up the technology awareness among the rural farmers.

3. SCOPE AND POTENTIAL OF MICRO IRRIGATION

Today 95% of the world's irrigation practices depends on flood and furrow methods characterized by low efficiency and high evaporation losses. Although India has largest irrigation network in the world, its irrigation efficiency has not been more than 40%. Bringing more area under irrigation will largely depend upon water use efficiency. Improper use of water may not only lead to shortage in one part but will also affect soil health and crop production. Further, the per hectare investment in irrigation has increased from Rs. 1500 during 1951-56 to more than one lakh in the 10th plan. Moreover, ground water table in many parts of the country is depleting year after year at a rate of about one metre per year. Thousands of open wells are abandoned and farmers are going for bore wells even upto a depth of 150 to 200 m for getting water (Asokaraja, 2001). The yield of the crops/ha is very less compared to the developed countries. Hence, the need of the hour is to maximize the production per unit quantity of water, for creating utmost economy in water use for agriculture.

Good scientific water management involves adoption of right method of irrigation consistent with the topography of the field to supply water to the crop at right time and required quantity. Although the land and water resources are constant, it is possible to increase the gross cultivated area by two or three times of net area by raising two to three crops in a year through judicious use of available water resources. Micro irrigation is the only solution to solve these problems in the country. Micro irrigation systems with their flexibility and efficient control of water applications, offers agronomical, agro-technical and economical advantages, which are discussed below.

(i) Water savings

The national and international studies reveal that water use efficiency in surface irrigation projects is 30 – 45% only. Since farmers are getting water at subsidized/free of cost, farmers are taking water as much as possible without knowing the ill effects of over irrigation like leaching of fertilizers, unequal distribution of water, water logging in low lying areas and land becoming saline and alkaline in due course. The effect is low yield and lands becoming unproductive after some years. It also causes environmental and health problems. In drip irrigation, loss due to conveyance, evaporation, interception, runoff and deep percolation are reduced considerably compared to other traditional irrigation systems. However, while using micro sprinklers and bubbles, when water is sprinkled over the crops, a part of water is intercepted by the foliage and evaporated later without reaching the soil. The use of micro irrigation has resulted in water savings ranging from 50 to 75 percent (depending on type of crops grown and type of emitter used) of water used in conventional surface irrigation methods. Data collected on water savings at various fields of Kerala is presented in Table 3.1.

Table 3.1. Water economy by using micro irrigation systems (Jayakumar, 1992)

Sl. No.	Crop	Quantity of water to be applied in conventional method (litres/plant/day)	Quantity of water applied in drip method (litres/plant/day)	Water economy (per cent)
1	Coconut	100	30	70
2	Rubber	20	10	50
3	Oil palm	100	30	70
4	Banana	20	10	50
5	Cardamom	20	8	60
6	Tea	4	1	75
7	Vegetables	4	1	75
8	Arecanut	40	15	62
9	Coffee	15	5	66

The results of the experiments revealed that surface irrigation methods take thousand tonnes of water to grow one tonne of grain. Whereas, sprinklers take only 400 tonnes of water to produce one tonne of grain. That is, by introducing micro irrigation system with the same amount of irrigation water, it is possible to bring 2.3 times of land under cultivation.

(ii) Energy savings

Micro irrigation has a potential for reducing pumping energy cost, since operating pressure is considerably lower than sprinkler as well as surface irrigation.

(iii) Weed and disease reduction

The limited wetted area from non-spray type of micro-irrigation inhibited the weed growth and reduced the disease incidences.

(iv) Additional land area available for crop

Under surface irrigation, about 5 to 10% of cultivable area is occupied by irrigation and drainage channels and the structures to store water for irrigation. Since micro irrigation does not require any irrigation and drainage channel, it makes available this area for cultivation.

(v) Labour saving

Labour and operational costs can be reduced by simultaneous application of water, fertilizer, herbicide and pesticide through micro irrigation system. Labour required for applying water by micro irrigation will range from one half to four manhours per acre of application. Labour saving has been found to range between 62 to 77 percent among different crops. Data collected on labour savings from the demonstration plots in Kerala during irrigation season is given in Table 3.2.

Table 3.2. Labour saving under micro irrigation (Jayakumar, 1992)

Crop	No. of labourers/acre/year		
	Conventional irrigation	Drip irrigation	Labour saving (percent)
Coconut	80	30	62.5
Oil palm	80	30	62.5
Arecanut	120	30	75.0
Rubber	120	30	75.0
Cardamom	160	60	62.5
Coffee	160	60	62.5
Tea	160	60	62.5
Banana	160	60	62.5
Vegetables	100	30	70.0

(vi) Efficient use of nutrients and preventing the ground water contamination

Heavy irrigation and bulk application of nutrients in the conventional method causes leaching of most of the nutrients to the deeper soil layers. Many of the places are facing the problem of ground water contamination with nitrates and iron ions. In micro irrigation, since nutrients are applied along with irrigation water, the plants can utilize it more effectively. Optimum moisture content maintained in the root zone of the plants, make the nutrients in available form to the crop. Moreover, since nutrients are applied in split doses and only required amount of water is supplied, loss of nutrients due to leaching and stress due to nutrient deficiency can be avoided.

(vii) Use of poor quality water

In desert and coastal areas, more than 60% of total area has the problem of ground water salinity. Conventional irrigation with saline water caused considerable reduction in yield and deteriorated the soil health. Study revealed that daily drip irrigation provided gainful use of poor quality water. Frequent irrigation maintains the soil in the root zone in a well-aerated condition and the soil moisture content does not fluctuate between wet and dry extremes. It maintains optimum moisture content in the rooting volume and salts are pushed to the periphery of the wetting zone and below the root zone (Fig. 3.1). This reveals that micro irrigation through drip/microtube has the potential to use substandard water in our desert and coastal areas. (Care must be taken to see that water having 74 dS/m cannot be applied through micro sprinkler/ bubbler/ sprinkler as foliar salt absorption may damage the leaves). Too much drying of soil between irrigations (drop irrigation) may reverse the movement of soil water and transfer salt from the perimeter of the wetted volume back towards the emitter, which can cause damage to the plants. To avoid this type of damage, care must be taken to see that soil will not become too dry and the movement of water is always away from the emitter.

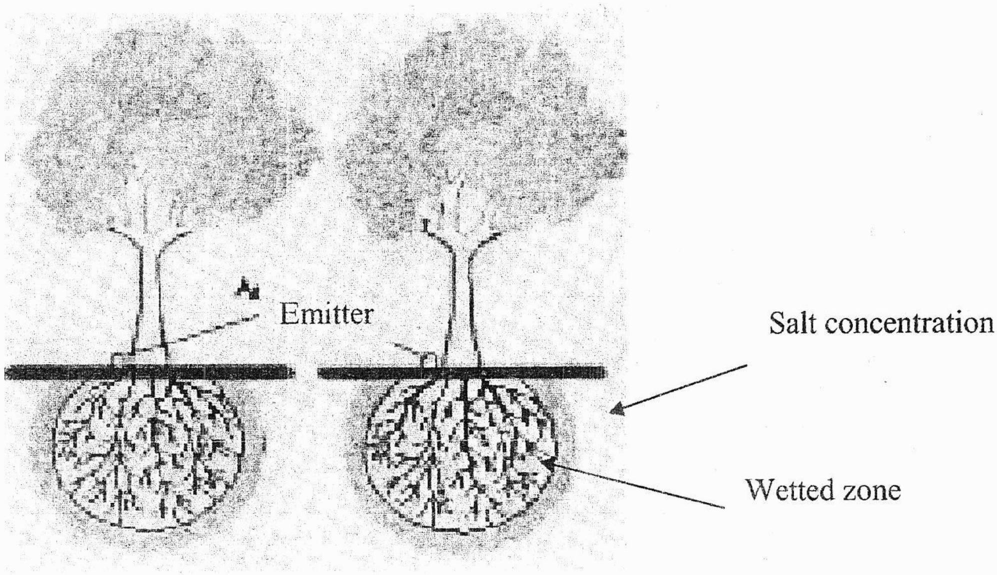


Fig.3.1.In drip irrigation with salt water, salts are pushed to the periphery of the wetting zone and below the root zone

(viii) Facilitates re-use of water

Drip irrigation also enables re-use of poor quality waters like sewage effluents after proper filtrations.

(ix) Economical production on rocky and steep land

On hilly terrain, micro-irrigation systems can operate without runoff and without much interference from the wind. The fields need not be levelled in this system. Hence in problem soils with intermixed texture & profiles and shallow soils, that cannot be graded, can effectively irrigated by micro irrigation system. Whereas in the case of surface irrigation, land levelling is a must, which may sometimes cause decrease in yield due to the removal of upper fertile soil.

(x) Yield increase

Micro irrigation offers the twin benefits of yield increase and water saving, since root zone of the crop is always kept nearer to field capacity. In surface irrigation methods, water is applied once in 5 to 15 days and hence moisture/water stress will be noticed just before irrigation. Hence, growth of the crop is affected. Moreover, regulation and control of water is not possible to give the required quantity of water at the root zone. Hence, yield in surface irrigation get depressed. In micro irrigation, water is applied daily or once in 2 or 3 days and hence there is no water or moisture stress to the crop. Since timely and precise application of water can be made in micro irrigation, moisture level in the root zone of the plants can be maintained nearer to field capacity (Fig.3.2). Hence, yield can be increased to 20 to 100% compared to the conventional methods. The result of some published data is given in tables 3.3 to 3.6.

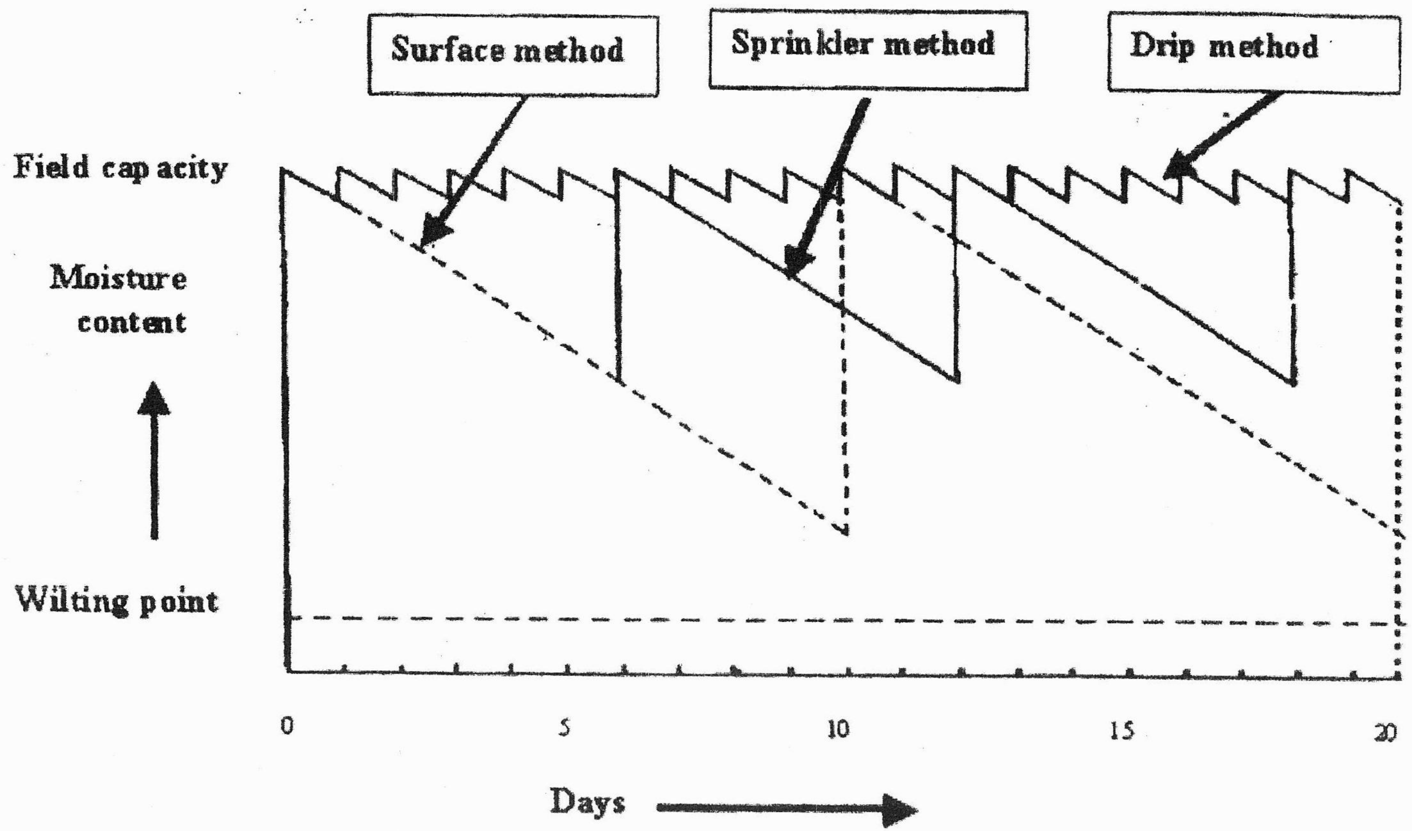


Fig.3.2. Moisture availability for crops in different irrigation methods (Sivanappan, 1990)

Table 3.3. Yield increase and water saving obtained under drip irrigation (Singh *et. al,* 1993).

Sl No.	Name of the crop	Water used in mm			Yield in t/ha		
		Control	Drip	Water saving(%)	Control	Drip	Yield increase(%)
1	Banana	1760	970	45	57.5	87.5	52
2	Grapes	532	278	48	26.4	32.5	23
3	Sweet lime	1660	640	61	100	150	50
4	Pomegranate	1440	785	45	55	109	98
5	Papaya	228	74	68	13.4	23.5	75
6	Tomato	300	184	39	32.0	48	50
7	Watermelon	330	210	36	24	45	88
8	Okcra	54	32	40	15.3	17.7	16
9	Cabbage	66	27	60	19.6	20	2
10	Chilly	110	42	62	4.2	6.1	44
11	Sweet potato	63	25	60	4.2	5.9	39
12	Beet root	86	18	79	46.0	49	7
14	Radish	46	11	77	70.0	72	2
15	Sugarcane	2150	940	56	128.0	170	33
16	Cotton	90	42	53	2.3	2.9	26

Table 3.4. Water used and yield obtained in drip and control method - Coimbatore (Sivanappan, 1990)

Sl. No.	Name of the crop	Water used in cm		Yield in kg/ha		Rainfall in cm during growing period
		Control	Drip	Control	Drip	
1	Tomato	49.80	10.76	6,187	8,872	24.18
2	Bhindhi	53.53	8.60	10,000	11,310	24.18
3	Radish	46.41	10.81	1,045	1,186	—
4	Beet root	85.76	17.73	571	867	—
5	Chilly	109.71	41.77	4,233	6,086	20.75
6	Brinjal	69.18	24.47	12,400	11,900	17.18
7	Sweet potato	63.14	25.20	4,244	5,888	12.12
8	Sugarcane	131.86	72.89	86,000	75,000	33.50

Table 3.5. Yield of coconut from the demonstration site under micro irrigation at Kannur

Months	Number of coconuts /50 trees			
	No irrigation (1985)	Micro irrigation (1986)	Micro irrigation (1987)	Micro irrigation (1988)
January	320	–	–	508
February	–	347	331	–
March	355	332	357	564
April	284	–	–	–
May	–	328	308	520
June	248	–	–	–
July	275	312	286	426
August	–	–	–	–
September	233	–	–	–
October	–	318	290	342
November	254	–	–	–
December	–	326	304	440
Total	1969	2243	2130	3185
Mean	281.3	320.4	304.3	455.0

Data based on the studies conducted by CWRDM, Kunnamangalam in Kerala

Table 3.6. Yield of arecanut from the demonstration plot under micro irrigation at Thrissur

Months	Number of arecanuts /410 trees			
	No irrigation (1985)	Micro irrigation (1986)	Micro irrigation (1987)	Micro irrigation (1988)
January	20,350	18,550	–	508
February	10,400	11,600	331	–
March	1,700	3,100	357	564
April	284	–	–	–
May	–	1000	308	520
June	–	–	–	–
July	1,200	1,500	800	1,680
August	1,500	2,000	1,400	2,250
September	2,750	1,300	4,000	3,270
October	6,300	4,550	7,500	7,810
November	10,650	8,450	11,600	10,960
December	14,600	326	304	440
Total	69,450	68,050	81,500	86,670
Mean	7,716.7	6,805.0	9,055.6	8,667.0

Data based on the studies conducted by CWRDM, Kunnamangalam in Kerala

(xi) High irrigation efficiency

High irrigation efficiency can be achieved by properly designed and well managed (use of carefully filtered water and periodical inspection of emitters to avoid clogging and non-uniform application) micro irrigation systems. Irrigation efficiencies in the range of 70 to 85% can be obtained.

(xii) Can be automated

Application of water/ fertilizers/ chemicals in micro-irrigation systems can be automated which further reduces the labour requirements and increase the efficiency of irrigation.

(a) Partial automation

Partial automation can be done through the use of volumetric valves or mechanically/ electrically timed valves. The volumetric valves can be installed at the head of each subunit or a single valve at the control head and ordinary valves at each subunit. Such valves are required to open manually to set the desired volume of discharge, but they close automatically after the preset volume of water has passed. These valves can be interconnected by hydraulic or electric control lines to operate in sequence so that, as each valve closes, the next valve opens. However, the valves must all be reset, and the first valve must be activated manually to repeat the cycle again. Mechanically timed valves must be opened manually and estimated time required to apply the desired volume of water must be set, but they close automatically after the preset time has elapsed. Electronically timed valves are powered by small batteries, come closed to provide full automation. They are designed to store a preset operating time. They can be easily activated manually by a switch or remotely through electric control wires.

(b) Full automation

Full automation can be done with a central controller operated on a time or volume basis or by various types of sensors. Centrally controlled automation is achieved by using a time or volume based control system that operates either hydraulic, electric or electronically activated valves. Hydraulic valves must be linked to the controller by hydraulic tubes and electric valves must be linked to it with wires. Electronically activated valves can either be linked to it with wires or each fitted with a radio-receiving unit activated by signals transmitted from central controller. Controllers can be set to actuate the irrigation cycle in any desirable manner. The operating time and quantity of water discharged through each valve can be easily changed at the control panel. The cycle of each irrigation can be started by a sensor, which is connected to an evaporation pan or to weather instruments.

Relevance of micro irrigation in Kerala

Kerala is a small state having an average width of 60 to 70 km and overall length of about 500 km with elevations ranging from sea level to about 2700 m above the mean sea level. With this topography, people are forced to cultivate the areas having slope even more than 100%. Soils of the state (lateritic) are having high infiltration rate (5cm/hr to 10cm/hr with rates as high as 20cm/hr in certain places) and low water holding capacity [F.C (field capacity) - as high as 30-32% and PWP (permanent wilting point)– range upto 19%] making the available soil water very little. The lateritic terrains of the state with its high drained nature coupled with 3000 mm annual rainfall has caused a considerable amount of leaching. This has resulted in the leaching of fine aluminum clay in the soil and depositing at the lower layers forming a limiting layer below with aluminium toxicity. This inhibits the root growth of plants. All these factors inhibits the efficient use of surface irrigation water.

Eventhough average annual rainfall of the state is 3000 mm, all these rains are occurring in 100 to 120 days. Most of the rains are high intensity rainfall (5 to 10 cm/hr). Moreover, because of steep topography of Kerala, it took only 24 to 48 hours for the run off to travel from the forest of Wayanad of Kerala to reach the Arabian Sea. Kerala is frequently facing severe droughts followed by acute drinking water scarcity for the last two decades. The rivers hardly contain any water during the six months in a year, only few reservoirs get filled up even in the monsoon. During summer, water level goes down to the silted up bottoms in many cases. More and more wells are getting dry in summer. The problem of ground water depletion has arisen due to the development of ground water at a faster rate than the annual replenishment of recharge. The decline of water table has resulted not only in decrease in well yield, failure of wells/tube wells, increased pumping cost and more energy consumption but also posed a big threat to the environment. All these factors caused lesser availability of water for irrigation.

The plantation crops occupy about 50% of the total cropped area of the state. Whereas, irrigated area under the plantation crops constitute less than 2% of the total irrigated area. About 60% of the national production of rubber, cardamom, coconut, arecanut, pepper etc is produced in Kerala. Unfortunately, a steep decline in the production of some of these crops was observed. At the same time, study conducted at many research stations revealed that, by providing irrigation to these crops, yield could be increased to 50 to 100%. In Kerala, there is a long dry spell from December to May. Further in Kerala, the average density of open wells is very high (250 to 260 numbers per sq. km) (Basak, 1992). Hence, in order to increase the economic standard of the farmers, it is the best choice to provide irrigation to the plantation crops by utilizing this wide network of minor irrigation potentials through the effective utilization of available water. All these factors emphasize that micro irrigation has great potential in Kerala. By introducing these advanced methods, more and more cultivated areas in the state can be brought under irrigation resulting in increased agricultural production.

Factors emphasizing the need of micro irrigation in Kerala

1. The cost of installation of micro irrigation for the important crops (plantation crops - which showed good response to irrigation) of Kerala is comparatively less as they are widely spaced.
2. Since the labour rates of Kerala are 3 to 4 times more than the adjoining states (Tamil Nadu and Karnataka), the added labour savings due to the adoption of micro irrigation over surface irrigation will act as an added incentive to the adoption of this technology.

3. The unique feature of Kerala agriculture is the open well-based homestead farms. Hence, the quality of water as regard to suspended materials is excellent. This help to reduce the clogging problem in the irrigation system.
4. Since average land holding sizes range from 0.01 to 0.025 ha, most of the farmers are wage seekers in some other trade or industry. Hence micro irrigation with less labour involvement and operated attention is easily adaptable by the literate farmers in the state.
5. The wells of coastal regions have high salt content. Conventional irrigation with saline water will cause considerable reduction in yield and deterioration of soil health. Adoption of micro irrigation, facilitates the chance of using saline water for irrigating the crops without harmful effects.
6. Since the soils of the state is characterized by high infiltration capacity, low water holding capacity and shallow top soil, adoption of micro irrigation facilitates effective utilization of water and nutrients and helps to avoid the contamination of ground water.

All these establish that there is great scope for better adoption of micro irrigation in the state. The greatest need is to make the cultivators aware of the potential of this technology and to popularize them among the farmers.

4. COMPONENTS OF MICRO IRRIGATION

Micro irrigation refers to low-pressure irrigation systems that spray, mist, sprinkle or drip water. The water discharge patterns of different systems differ because the emission devices are designed for specific applications due to agronomic or horticultural requirements. Micro irrigation components include pipes, tubes, water emitting devices, flow control equipment, installation tools, fittings and accessories. For first time users, it can be a confusing array of components and gadgets and may be difficult to select the right type of system and assemble the components suitable for irrigation needs. A brief description of various micro irrigation components may help the user for the effective utilization of water, power and money so that he can attain the maximum benefit.

Components of micro irrigation system

Arrangement of various components of micro irrigation system is shown in fig.4.1.

I. Water emission devices

The application of water in a micro irrigation system is through an emitter. The emitter is a metering device made of plastic that delivers a small but precise discharge. The quantity of water delivered from these emitters is usually expressed in litre per hour (lph). These emitters dissipate water pressure through the use of long-paths, small orifices or diaphragms. Some emitters are pressure compensating which discharge water at a constant rate over a range of pressures. Emission devices deliver water in three different modes: drip, bubbler and micro sprinkler. In drip mode, water is applied as droplets or trickles. In bubbler mode, water 'bubbles out' from the emitters. Water is sprinkled, sprayed, or misted in the micro sprinkler mode. Emitters for each of these modes are available in several discharge increments. Some emitters are adapted to apply water to closely spaced crops planted in rows. Other emitters are used to irrigate several plants at once. There are emitters that apply water to a single plant.

1) Drip irrigation

Depending on how the emitters are placed in the plastic polyethylene distribution line, the drip mode can be further delineated as a line source or a point source. The line source type emitters are placed internally in equally spaced holes or slits made along the pipe line. Water applied from the close and equally spaced holes usually runs along the line and forms a continuous wetting pattern. This wetting pattern is suited for close row crops. The point source type emitters are attached external to the lateral pipe. The installer can select the desired location to suit the planting configuration or place them at equally spaced intervals. Water applied from the point source emitter usually forms a bulb shaped wetting pattern. The point source wetting pattern is suited for widely spaced plants in orchards, vine yards and for landscape trees or shrubs.

a) Point source emitter

Point source emitters (Fig. 4.2) are installed on the outside of the distribution line. Point source emitters dissipate water pressure through a long narrow path (microtube) or a

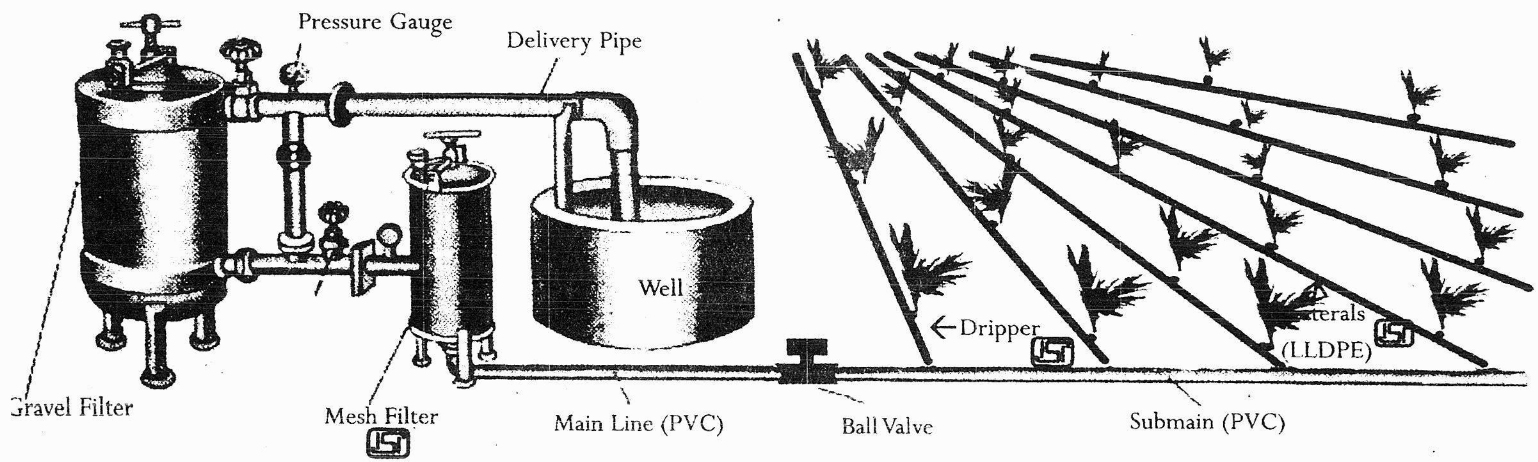


Fig. 4.1. Schematic representation of micro irrigation system

small orifice (dripper) before discharging into the air. The emitters can take a predetermined water pressure (0.5 to 1.5 atm) at its inlet and reduce it to almost zero as the water exits. Many different types of dripper designs have been developed in recent years. The efficient designs of drippers ensure a specified constant discharge, which does not vary much with pressure changes and do not block easily. Some drippers can be taken apart and manually cleaned (Fig. 4.3). The typical flow rates range from 2 to 10 lph. There is considerable water savings since water can be applied almost at the root zone and there is no need to wet the entire area. It is particularly suited for orchards and vegetable crops in soils with very low and very high infiltration rates under conditions of water scarcity and in areas where drainage of excess water is difficult.

In India, reduction in the cost of installation of drip system was facilitated by using micro tubes. Straight or curled LLDPE tube with an inner diameter ranging from 1 to 1.2 mm (Fig. 4.4) are sometimes used as emitter. The discharge from the micro-tube is directly proportional to the operating pressure and inversely proportional to its length. Micro tubes have two main advantages; they are less expensive and can be extended across rows, thereby reducing the number of laterals required. Micro tubes are less prone to clogging, which is the greatest technical problem with drip irrigation. Micro tubes are also easier to install than drippers. It facilitates the use of simple, low cost filters, and to have a lower operating pressure, which can be as low as 1m to 5 m. Normally, laterals are placed along each one to two rows and an emitter to each plant. Since laterals and emitters are the costliest component in drip irrigation per unit, significant cost savings are achieved. Technical details of micro tube is given in Annexure IV, Table A.

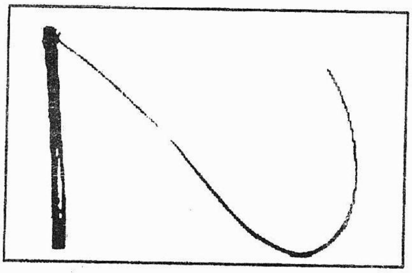


Fig. 4.4 Micro tube

b) Line source emitter

Line source emitters are suitable for closely spaced row crops in fields and gardens. Line source emitters are available in different forms.

i) Thin wall drip line (drip tape)

A thin walled drip line has internal emitters molded or glued together at set distances within a thin plastic distribution line (Fig.4.5). The emitter spacing is selected to closely fit plant spacing for most row crops. The drip line is available in a wide range of diameters, wall thickness, emitter spacing and flow rates. The flow rate is typically expressed in lit per minute (lpm) per metre length. Drip lines are either buried below the ground or laid on the surface. Burial of the drip line is preferable to avoid degradation from heat and ultraviolet rays and displacement by strong winds.

ii) Thick wall drip hose

The thick walled drip hose (Fig.4.6) is a robust variation of the thin walled drip line. The internal emitters are moulded or glued to the drip hose. It is more durable because of its considerable thickness. The diameter of the drip hose is similar to that of the thin walled drip line. Unlike the thin wall drip line, the drip hose emitter spacing is wider and it operates at a higher pressure. The emitter discharges ranges from 0.2 to 2 lph. Thick walled drip hose can be laid on the ground or under the ground.

iii) Double drip (DD) integrated dripline system

They are specially designed and built to irrigate row crops. It is a drip irrigation lateral with integrated non-pressure compensated drippers (Fig.4.7). It can be used as a subsurface drip system. A dripper of a rectangular shape is fused (integrated) into the inner wall of the drip lateral pipe. The dripper includes two different and completely individual drippers, where normally one is functioning and other is served as a spare dripper. The spare dripper can be activated as and when required by simply punching the outlet hole in the pipe above the spare dripper's outlet basin. In this way, either we can double the discharge or ensure the continuous irrigation if in case the first dripper is damaged or chocked. Water flows from the supply pipe through a filtration entry into and through the dripper's turbulent path (labyrinth) to accumulate at the outlet basin and comes out as droplets through the circular hole created in the pipe.

2) Porous pipe subsurface irrigation

Porous pipe (Fig. 4.8) is made from recycled rubber and polyethylene, which allows both air and water to pass through the pores provided in the wall at low pressure. These tiny openings are inbuilt pores, and are not mechanically made holes. Hence, there is no chance for the intrusion of roots into the pores of the pipe. Porous pipe can be considered as a continuous emitter, which produce a rectangular moisture band at the root zone. Porous pipes are directly connected to the submain using suitable connectors. Porous pipe subsurface irrigation can be defined as "application of water below the soil surface at the root zone of the plants through tiny openings provided on the wall of the pipe at a rate that allows the soil to absorb the water at its natural rate". The system can apply water, nutrients and soil additives to the root zone of the plant, which encourages deeper and more extensive root development resulting healthier and more productive plants. By using porous pipe subsurface irrigation, loss of water by evaporation, runoff, and deep percolation can be avoided; about 30 to 50 % of water can be saved compared to surface irrigation system. Porous pipe is designed to operate at low pressure, which allows for smaller and less expensive pumping systems and smaller energy demands. Moreover, compared to drip and sprinkler system, it requires less maintenance.

Porous pipe irrigation creates 60 cm to 75 cm band of moisture in most soil (ie moisture is moving 30 cm to 38 cm on either sides of the porous pipe). But, moisture movement in extremely sandy soil or compact soil could be as little as 15 cm on either side of porous pipe. Hydrodynamics of porous pipe irrigation depends on soil type and organic matter content in the soil. Hence, spacing of the porous pipe also depends on the type of the soil. Just like drip and micro sprinkler system, quality of water is important with porous pipe irrigation system. Particulate like sand, rust etc and minerals do not make much problem as in the case of drip system. But algae and bacterial slime should be filtered and treated to prevent the contamination in the porous pipe. A 250 mesh filter (61 micron) is to be installed in the porous pipe irrigation system to prevent the possibility of contamination of any part of irrigation system.

Porous pipe is designed to operate at low flow and low pressure to introduce moisture to the soil at a rate that allows the soil to absorb at its natural rate. Low flow allows porous pipe to function without the misbalancing effect of frictional loss. Studies conducted at Tamil Nadu Agricultural University found that optimum operating pressure for porous pipe in clayey soil is 0.8 to 1 kg/cm^2 (Suseela, 2003, Suseela, *et.al.*2003). This pressure can be attained even from an overhead tank. If the system is working at higher pressure, it will adversely affect the uniformity of water distribution. At higher pressure, porous pipe is expected to leak excessively close to the water source with leakage becoming progressively less toward the end of the porous pipe. This may happen due to the fact that at high flow/ high pressure in the irrigation system will increase the friction and compound the problem of uneven leakage. Moreover, at high operating pressure, water will get introduced into the soil faster than it can be absorbed. Whereas at low flow/ low pressure, there will be a static pressure zone in the porous pipe, where pressure/leakage get balanced over the length of the pipe.

Bubbler irrigation

Bubbler is relatively a new concept which is designed to operate at low pressure. Bubblers (Fig. 4.9) typically apply water on a "per plant" basis. Bubblers are very similar to the point source external emitters in shape but differ in performance. Water from the bubbler head either runs down from the emission device or spreads a few centimeters in an umbrella pattern. The bubbler emitters dissipate water pressure through a variety of diaphragm materials and deflect water through small orifices. Most bubbler emitters are marketed as pressure compensating. They are equipped with single or multiple port outlets. Bubbler heads are used in areas where deep localized watering is preferable. The typical flow rate from bubbler emitters is between 2 lph and 80 lph. Clogging in the system is avoided, as the flow rate is higher. Yet now, this system is not much popular in India.

Micro sprinkler irrigation

Micro-sprinklers are emitters commonly known as sprinklers or spray heads. They apply water above the ground as a spray, resembling rainfall. They are low volume sprinklers that operate at low pressure than conventional sprinkler systems and are less susceptible to clogging than drip emitters. There are several types of micro sprinklers (Fig. 4.10). They operate by throwing water through the air, usually in predetermined patterns. Depending on the water throw patterns, micro sprinklers are referred to as mini-sprayers, micro sprayers, jets, spinners, foggers, misters, spitters etc. The sprinkler heads are external emitters individually connected to the lateral pipe by using micro tubes, which is very small (6mm/8mm) diameter tubing. The sprinkler heads can be mounted on a support stake or connected to the lateral pipe. They are designed to dissipate pressure and discharge a small uniform spray of water to cover an area having wetting radius of 1 to 6 m..

Sprayers apply a relatively uniform depth of water to the area wetted with a low water trajectory angle. Micro sprinklers are desirable because fewer sprinkler heads are necessary to cover larger areas. The flow rates of micro sprinkler emitters vary from 20 lph to 120 lph depending on the orifice size and line pressure. Most of the micro sprinklers are designed to sprinkle water only to the root zone area as in the case of drip irrigation but not the entire ground surface as in the case of sprinkler irrigation method. This method is very much suitable for tree / orchard and crops grown on mounts (like bitter gourd, snake gourd etc) and bunds.

The depth of water applied to an area surrounding a revolving sprinkler decreases as the distance from the sprinkler increases. Thus, if micro sprinklers are used to cover the entire area of the field (to irrigate close growing vegetables, nursery, etc) for getting reasonably high degree of uniformity of application, water from adjacent sprinklers must be added. Hence micro sprinklers should be spaced along the lateral pipe at fixed positions with overlapping patterns of water distribution. Sprinklers on the entire system will distribute water in a circular pattern and depend on overlap from several micro sprinklers arranged and spaced in a grid pattern to produce relatively uniform wetting over the entire area to be irrigated. With careful selection of nozzle size, riser height, operating pressure and sprinkler spacing, water can be applied uniformly at the rate based on the intake of the soil, thus preventing runoff as well as deep percolation. Care should be taken to see that the system should apply water without causing any damage to crop and soil.

Manufacturers of micro sprinklers specify the wetted diameter for all nozzle size and operating pressure combinations for each type of sprinkler. The wetted diameters of micro sprinklers listed in manufacturer's brochures are usually based on tests, essentially no wind. Under field conditions with 0 to 5 km/hr wind, such diameters should be shortened by 10% from the listed figure to obtain the effective diameter. Effective diameter should be further reduced for winds over 5 km/hr. A reduction of 2.5% for each 1.6 km/hr over 5 km/hr is a fair estimate for usual range of wind conditions under which sprinklers are operated. Spacing of the micro sprinklers along the lateral should be made based on the wetted diameter. As a general recommendation, sprinklers should be spaced at 50 to 60% of the effective diameter of the sprinkler if micro sprinklers are used to cover the entire area of the field.

This type of irrigation is particularly suited in the case of water scarce areas with shallow rooted crops and soils with small water holding capacity and high infiltration rates.

I) KAU Micro sprinkler

In spite of numerous advantage of micro irrigation, it is yet to catch up among the farmers of developing countries due to the sophisticated design of the system components, frequent clogging of emitters apart from its prohibitive initial cost. Hence, research work was conducted at Agronomic Research Station, Kerala Agricultural University, Chalakudy for the development of an affordable, dependable, simple and farmer friendly technology, which resulted in the development of low cost micro sprinkler (Sreekumar *et. al.,* 1998)

Two sprinkler heads, suitable for various crops of Kerala, which are identical in design principle but differ in size were developed (Suseela *et.al.,* 2003) (Fig. 4.11). Micro sprinkler heads were fabricated using 8-mm and 12-mm diameter LDPE pipe cuttings of 6-cm and 8 cm length of pipe cuttings from each diameter pipes. Nozzles of equal diameter (1 mm) were provided at opposite directions of the sprinkler head at a distance of 5 mm from each ends. A hole of 4.4 mm diameter was made at the centre of the pipe cutting to insert the micro tube pin connector so that it keeps the sprinkler head in the groove of the barbed micro tube pin connector. This allows the free rotation of the sprinkler with minimum leakage. The nozzles and the central hole should be perfect round in shape, with a fine finishing. The ends of the pipe cuttings were closed by using suitable caps.

The basic principle of the KAU micro sprinkler is - moment of the couple constituted by the streams of water coming out of the nozzles in opposite directions, caused the emitter to rotate, while operation.(Fig.4.11). It is very cheap, simple in design and is almost intermediary system between the drip and sprinkler. This system was designed to operate clog free and ensuring the complete wetting of the basin area of the crop due to its rotating action. It is also useful in fertilizer application, cooling of green houses, poultry houses, cattlesheds etc. Initial investment, running cost and maintenance cost are comparatively less.

The characteristics of the two sizes of sprinkler heads suitable for various crops of Kerala are given below (Suseela, 2000). (Table 4-1)

Tabe 4.1 Charateristics of KAU micro sprinkler

Diametor	8 mm	12 mm
Length	6 mm	8 mm
Nozzle diameter	1 mm	1 mm
Pressure required for working	1 to 2 kg/cm^2	1 to 2 kg/cm^2
Discharge rate	30 – 35 liter per hour	40 – 45 liter per hour
Depth of application	4.7 mm/hr	12.5 mm/hr
Wetting diameter (when height of riser pipe = 60 cm)	250 – 300 cm	200 – 230 cm
Height of riser pipe	30 – 90 cm	30 – 90 cm
Crops suitable	Leafy vegetables, ornamental plants, lawn etc.	Vegetable crops, banana, medicinal plants, coconut etc.

II. Distribution line

The distribution line mainly constitutes main, sub-main and lateral lines.

Mainline:

Generally Rigid Poly Vinyl Chloride (PVC) or High-density polyethylene (HDPE) pipes are used as main line. These pipes convey water from source to the sub-main. Size of pipe depends on flow rate of water in the system. Usually 3.2 to 7.5 cm diameter pipes with a pressure rating of 4 to 10 kg/cm^2 are recommended for main line. In order to ensure longer life period (> 20 years), these pipes should be laid underground.

Sub-main: Rigid PVC pipes are commonly used as sub main. Recently, better quality HDPE are being used. They are available in rolls. These pipes conduct water from the main to the lateral pipes. Size of pipe depends on water requirement of the crop and size of the field. Pipes having an outer diameter of 2.5 cm to 4 cm with pressure ratings of 4 kg/cm^2 are commonly used. These pipes may be laid above the ground or underground.

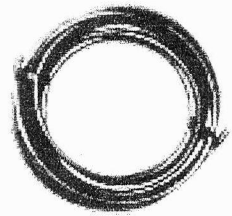


Fig. 4.12. HDPE pipe for main/sub main

Lateral pipe: Laterals are normally manufactured from LDPE. Recently, better quality LLDPE pipes (gives more protection against ultra violet rays and longer life than LDPE) are also being used as lateral lines. They are placed along the rows of the crop on which emitters are connected directly or through micro tube to provide water to the emitters. The lateral pipe size of 10 mm to 20 mm with wall thickness varying from 1 to 3 mm and a pressure rating of 4 kg/cm^2 are available. 12mm 16mm diameter pipes are most commonly used. These pipes are generally laid above ground.

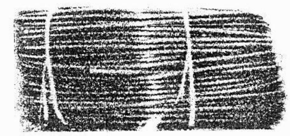


Fig. 4.13. LLDPE laterals

III. Fittings

1). Main and sub main fittings:

PVC pipes can be joined by using PVC resin, HDPE pipes can be joined by using heat butt-welding and polyethylene tubing can be connected with barbed or compression fittings. Elbows, end cap, gate valve, reducer etc are the commonly used PVC fittings, which are shown in Fig. 4.14 .

2) Lateral fittings

i) Control valve

Control valve is made of plastic which is used to close/ open the flow of water into a particular lateral line. These small, hand operated, on-off valves provide a means for shutting off flow in the lateral when repair or maintenance work is necessary. Valves suitable for varying size of the lateral pipes are available in the market (Fig. 4.15) .

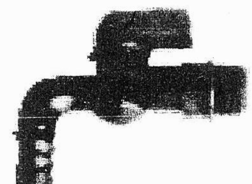


Fig. 4.15. Control valve

Tee connector

Tee connectors are used to make branch connections in lateral lines. The Tee connectors can be Equal Tee or Reducing type Tee viz. 12mm x 12mm, 16mm x 12 mm, 16mm x 16mm etc.(Fig. 4.16) .

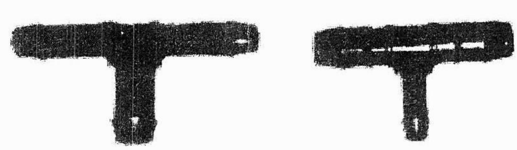


Fig. 4.16. Tee connectors

Straight connector or Joiner

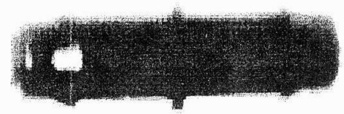
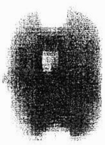


Fig. 4.17. Straight connector

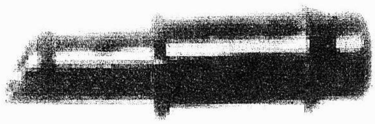
It is used to connect one lateral pipe to other. It can be equal Joiner or reducing Joiner *viz.* 12mm x 12mm, 16mm x 12 mm etc.(Fig. 4.17) .

Take-off

It is used to connect lateral pipes to the sub-main pipe. It is fixed in the wall of sub-main pipe with the help of a rubber washer called Gromate (Fig. 4.18 a) . It is available for different sizes of lateral pipes *viz.*, 12mm, 16mm. etc. Start connectors are also used to connect the lateral pipes to sub main. It consists of a strap which is wound tightly over the sub-main. (Fig. 4.18 b) .



a) Gromate



b) Start connector

Fig. 4.18. Take-off

Lateral end cap

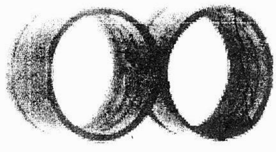


Fig. 4.19. End cap

The lateral pipes are closed at the other end with the help of plastic ring in the shape of figure of '8', or barbed end cap. The end of lateral pipes are folded tight and inserted through the rings. It is available in different sizes of pipes *viz.* 12mm, 16mm etc (Fig. 4.19) .

Stakes

Fig. 4.20. Stakes

Micro sprinklers are mounted on 12" or 18" long plastic/metal stakes and are connected to lateral pipes through extension/micro tube of 6 mm diameter (Fig. 4.20) .

Flush-out valves

Flush-out valves should be placed at the ends of main lines, manifolds and laterals, so that all portions of pipe network can be periodically flushed. This is essential for removing debris from the system after construction or repairing of broken pipelines. Flush-out valves are also useful for removing fine particles that settle out near the ends of lines during normal operation.

IV. Filters

Filtration process is very essential as natural water supply free of suspended or chemical materials is rarely available. The type of filter needed depends on the quality of water and operating pressure of the drip system. There are four types of filters namely, sand filter, screen filter, hydro-cyclone filter and disk filter. Filters are to be installed at the head of the system.

Sand filter

Sand filters (Fig. 4.21) are used as primary filters, when water for irrigation is received from river, pond, reservoir, open well etc. They are effective in removing heavy loads of light suspended impurities like sand and silt particles and algae and other organic material from the water. They are cylindrical tanks that have layers of coarse sand and fine gravel of selected sizes with a provision of valves for flushing the filter assembly in case of clogging. They are available in different sizes ranging from 500 to 900 mm diameter with an output of 15 to 50 cum respectively. In order to indicate the condition of filter, pressure gauges are to be placed at the inlet and outlet of the gravel filter. If the head loss exceeds 2 m, the filter needs cleaning. Nominal operating pressure required is 2kg/cm^2 (2 bar).

Screen filter

Screen filters (Fig.4.22) are the simplest and least expensive filters. If water contain fewer impurities, screen filter alone will be sufficient to remove the impurities. Otherwise screen filter is fitted in series with gravel filter to remove solid impurities, ie they are used as a secondary filter. Hence, they are used as primary filter when water is received from bore well and as secondary filter, when water received from river, pond, open well, reservoir etc. Screen filter consists of a single or double perforated cylinders placed in plastic or metallic container for removing the impurities. Generally 100 to 200 mesh screens are used in this type of filters. The inlet provides tangential entry of water to the casing so that heavier particles are thrown outwards and only small particles move towards the strainer at the centre. The tangential entry also helps in reducing frictional losses. It must be cleaned and inspected periodically for satisfactory operation. If head loss is higher than the permissible value, which is provided by the manufacturers, it needs cleaning. If no pressure change occurs for a long period, it indicates that the screen or seals are broken or mesh size is too large, which necessitates replacement.

Hydro-cyclone filter (Centrifugal sand separator)

If irrigation water is containing large amount of sand, hydro-cyclone type filters (Fig.4.23) are required. It is also known as 'vortex sand separator'. They depend on centrifugal force to remove and eject high-density particles from the water. The inlet provides tangential entry into the filter body so that heavier particles are thrown on the periphery of conical body of the filter and finally rolled down to under flow chamber. The collected sand and other materials may be emptied manually or by using a special flushing valve. The clean water rises up in a spiral motion to the outlet. The clamp and handle arrangement enables easy opening and cleaning of the under flow chamber. The top and bottom diameters of the cone are designed in proportion to the water flow rate from 3 to 300 m^3/hr. They do not remove organic materials, but they are effective in filtering large quantities of sand, fine gravel and other high-density materials from the water. They are produced in various sizes

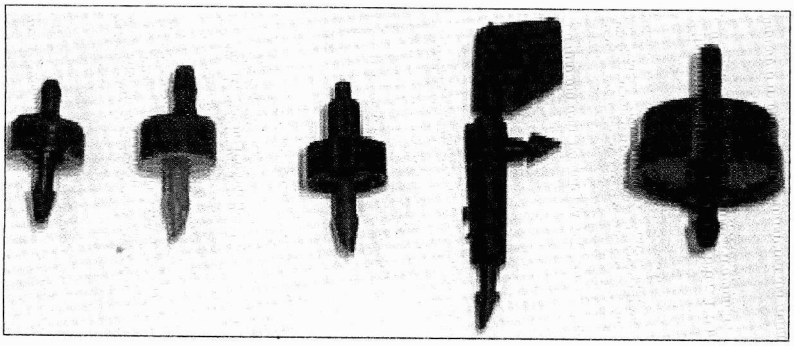


Fig. 4.2. Point source emitters of different shapes and sizes

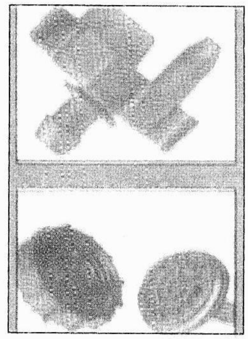


Fig. 4.3.
Manually cleanable dripper

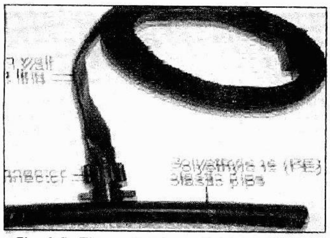


Fig. 4.5. Thin wall drip line ("drip tape") connected to sub main pipe

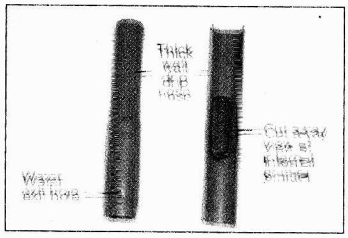


Fig.4.6. Thick wall drip hose-showing the water exit hole and the cutaway view of the internal emitter

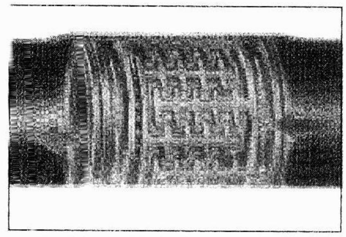


Fig. 4.7. Double drip integrated drip line

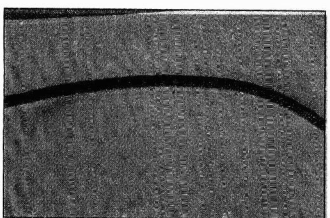


Fig. 4.8. Porous pipe

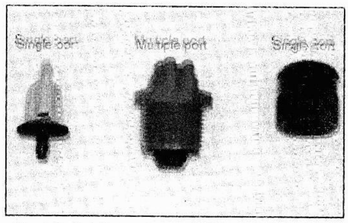


Fig. 4.9 Bubbler emitters of different shapes with single and multiport

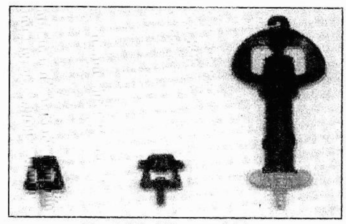


Fig 4.10. Micro sprinklers

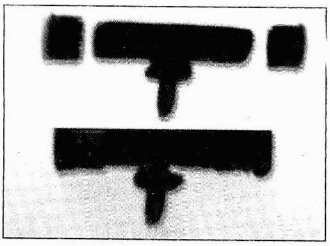


Fig. 4.11. KAU Micro sprinkler

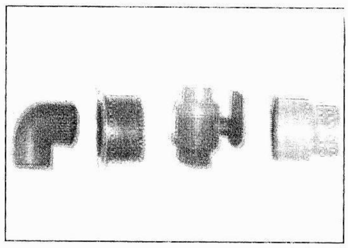


Fig. 4.14. PVC fittings

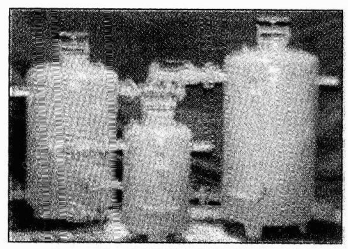


Fig. 4.21. Sand Filters

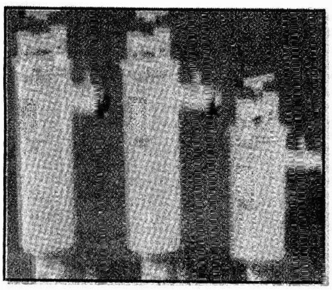


Fig. 4.22. Screen filters

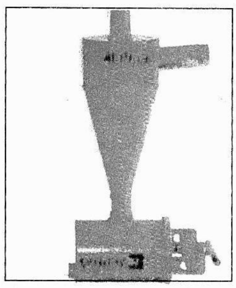


Fig. 4.23. Hydrocyclone filter

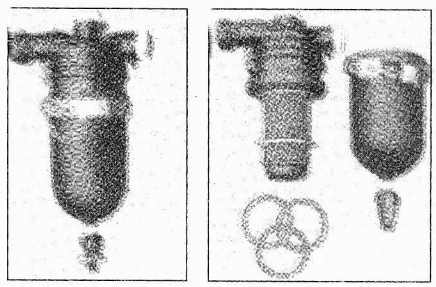


Fig 4.24. Disc filter

for different discharges. They are practically effective for primary filtration of irrigation water. Hydro-cyclones must be followed by a screen filter as a safeguard. If more sediments are present in the water, more than one filter can be installed in series.

Disk filter

Disk filters (Fig. 4.24) are very effective in filtration of organic material and algae. They facilitate high volume filtration. The filter element consists of a stack of discs, which held together by longitudinal plastic rods, capture debris. During filtration, disks are pressed together. There is an angle in the alignment of two adjacent disks, resulting in cavities of varying size. Disk filters are available in wide size range from 40 to 600 mesh. The inlet provides tangential entry for water to the casing so that heavier particles are thrown outwards and only small particles move towards the discs at the centre. The tangential entry will also help to reduce the frictional losses. The filter element is housed in a co-polymer polypropylene two parts body. Opening and closing can be done easily with the help of the clamp fitment. They are available for the flow rates from 4 to 30 m^3/hr. Back flushing of the disc filter can be carried out either manually or automatically. Back flushing can be done manually by stopping the water flow, opening the disc housing and directing a water jet to start spinning motion. In automatic back flushing, when pressure differences reaches a certain value, the flow get reversed and a drainage valve get opened.

For effective operation, filters must be kept clean. Back flushing, rinsing off and replacement are standard cleaning processes depending on the type of filter. Many systems incorporate two or more filters in series to ensure adequate filtration. Keeping the filters under optimum operating condition will help to make the system run smoothly without any clogging problem.

In the case of micro sprinkler and bubbler irrigation, filter is optional. Since, discharge rate is comparatively more, the clogging susceptibility is comparatively less in this case, especially at higher operating pressure. Hence in the normal cases, filters can be avoided. But if water contain large amount of suspended impurities, it is advisable to provide a suitable filter in the irrigation system.

Pressure regulators

In ordinary micro irrigation system, a simple by-pass valve can be used to control the pressure in the system. Whereas in a large-scale design, undulating terrain and sloppy land, pressure regulators are required to decrease the higher system pressure to lower required pressure. It controls pressures only in one direction, ie, high to low.

Pump or overhead tank

Overhead tanks having a height of about 3m to 15m can be used for small areas, which require lesser water. But for larger areas and undulating topography, and where water requirement is high, pumps are recommended. Centrifugal pumps are most suitable to provide sufficient pressure for operating the micro irrigation system. They are easily adjustable to provide constant pressure.

Approximate cost of various components of micro irrigation system is given in Annexure III.

5. DESIGN AND LAYOUT OF MICRO IRRIGATION SYSTEM

Design Inputs

Micro irrigation systems are to be designed to provide high irrigation efficiency and uniform distribution of water and nutrients. The inputs required to make a good design of micro irrigation system are as follows:

1. Layout of the area.
2. Details of the water source and soil type.
3. Agronomical details (plant spacing, crop period, season, canopy, etc)
4. Climatic data (rainfall, temperature, evapo-transpiration etc).
5. Topographical details

A brief survey of the area to be irrigated is to be made to get the specific information on above inputs. By using the above information, a complete micro irrigation system can be designed.

System design starts with selection of suitable emitter depending on the type of crop, water requirement, operating time, soil type, water quality etc. Length and size of lateral and submain are to be determined from the table based on the flow rate, field size etc. Each sub main is to be considered as an individual unit with a control valve. Whole area is then divided into different sub main units and the number of sub main units operating at a time are selected based on the capacity of existing pumping/water source. Each operating section is to be decided so that discharge is more or less similar for all the sections. The mainline is then planned connecting all the sub mains by taking shortest possible route and its size is to be determined from the table based on the flow rate so that frictional head loss is within the limit and total pressure head required for the system is within an available pump/water source capacity. If new pump is to be provided, its capacity is to be worked out from the total discharge and pressure head required for the system. Depending on flow rate and water quality, suitable filtration device is to be selected. Total quantity of all the components is to be determined from the layout to prepare bill of quantity and cost estimate, which needs the following basic inputs.

1. Survey

Prepare a complete plan of the proposed area to be irrigated (including boundary details, position of source of water and pumping unit if any, types of crops, spacing of the crops and their water requirement etc).

2. Elevation

Slope of the ground surface may be judged with naked eye for small plots wherever possible and taken into consideration while designing the drip system. If the ground surface is too undulating and slope is difficult to be judged by naked eye, then levels should be taken with levelling instrument and contours drawn on the map to make proper design of the drip system.

3. Water source

Position of water source (tank, well, reservoir, pond, river, stream, existing pump, pipe line etc) should be marked on the map. Discharge capacity and flow rate of the existing water source and its height above ground level or depth from ground surface are to be noted. The details for existing pump *viz.* suction, delivery, actual discharge and head, operating time, pump HP, expected discharge and head etc. should be collected. The quality of the water is also important. The impurities present in the water (algae, sand /silt etc.) are to be known. If water analysis report is available, it should be enclosed with the survey report or if possible, farmer should try to get it analyzed from local laboratory.

If any existing source of water is not available, it is better to locate the source of water near the center of the design area. This gives least cost for main line pipe and for pumping. On sloping fields, the water source should be located uphill from the centre to better balance up and downhill pressures and also to minimize pipe sizes.

If a small part of the design area is at a higher elevation, it needs higher pressure for that particular area than the main body of the system. A booster pump can eliminate the need for supplying higher pressures at the main pumping plant to meet the pressure required for this small fraction of land. A booster pump may also be recommended where static head is so great that two pumps prove more economical than a single unit.

4. Agro-climatic details

The details of existing crops or crops to be planted should be noted viz.specific area under a particular crop, crop spacing (plant to plant distance x row to row distance), number of plants and number of rows, crop duration, expected canopy, rainfall, evapo-transpiration etc.should be taken.

5. Soil details

The soil characteristics visible to naked eye should be noted *viz.* heavy soil or light soil depending on soil texture (proportion of clay, silt and sand). If soil analysis report is available, it should be enclosed with the survey report or farmer can try to get it analyzed from local laboratory.

6. Permanent details

The details like farm house, large tree, huge rock etc. should be marked by taking angular measurements from minimum two points so that it can be plotted accurately on the survey plan.

Survey plan

From above information (1 to 6), plan of the area surveyed can be prepared on 1: 1000 scale. For smaller area, scale can be decided depending on the size of the area. Design of drip system (lay out) can be made based on this plan and then it can be used for installation purpose.

Crop Water Requirement:

The water requirement of crops (WR) is a function of surface area covered by the plant and evapotranspiration rate. Irrigation water requirement has to be calculated for each plant and thereafter for the whole plot for different season, based on the plant population. The maximum discharge required during any one of the three seasons, is to be adopted for the design purposes. The daily water requirement for fully-grown plants can be calculated as given below (Ashwanikumar, 1995):

V (lpd)= Ep x Kc x Kp x Wp x Sp, where

V = water requirement (lpd/plant)

Ep = pan evaporation (mm /day)

Kc = crop coefficient,

Kp = pan coefficient,

Wp = wetted area factor (0.3 for widely spaced crops and 0.9 for closely spaced crops)

Sp = spacing of the plant (mxm)

Net depth of irrigation water to be applied (Vn) = V - Re where,

Re = effective rainfall (mm)

The total water requirement of the field = Vn x number of plants

The crop coefficient of important crops is given in table 5.1, 5.2 & 5.3 and daily pan evaporation data for Vellanikkara, Thrissur is given in table 5.4. If specific crop coefficient values are not available, it can be assumed as one.

Table 5.1 Crop coefficients (Kc) of various crops (Varadan, 1996)

Crop	Kc
Vegetables	1.0
Groundnut	1.05
Pulses	1.0
Tapioca	0.4
Banana	0.4 - 0.85
Sugarcane	1.2
Pineapple	1.0
Arecanut	0.94
Pepper	1.0
Coconut	0.75
Coffee	0.9
Tea	1.0
Cocoa	1.0
Cardamom	1.0

Table.5.2. Crop coefficients of banana at different stages (Varadan, 1997).

	Months after planting							
Kc	1	2	3	4	5	6	7	8
	0.4	0.4	0.45	0.5	0.6	0.7	0.85	1.0

Table 5.3. Crop coefficients of selected vegetable and fruit crops (Rajput and Patel, 2001)

Crop	Crop coefficients
Beans, green	0.90
Cabbage	0.80
Corn, sweet	0.95
Onion, dry	0.90
Onion, green	0.80
Pea	0.95
Watermelon	0.85
Citrus, Kinnow	0.60
Grapes	0.70
Pecans, almonds, apricots, plums, peaches	0.75
Walnuts, apples	0.85
Melons, Peanuts, lettuce	0.95
Carrots, beans	1.00
Cotton, potato, tomato, peas	1.00
Corn, sugar - beet	1.10

Table 5.4. Normal daily pan evaporation data for Vellanikkara Thrissur

Month	Pan evaporation, mm
January	6.64
February	6.59
March	6.49
April	5.67
May	4.75
June	3.04
July	3.05
August	3.41
September	3.63
October	3.37
November	4.08
December	5.98

The values of pan evaporation for a particular area are normally available at the nearest meteorological observatory.Peak water requirement of impotant horticultural and commercial feeld crop is given in Annexure IV, Table - E.

The irrigation system is to be designed for the peak water requirement which normally occurs in high temperature and windy conditions in summer. However, daily water requirement will depend on daily rate of evapo-transpiration. It will be less during winter and more in summer. The drip system has constant discharge at the given pressure. Therefore operating time can be varied to provide required amount of water depending on the season.The objective of the overall design is to secure a system that will provide a satisfactory uniformity of distribution with minimum annual operating cost, including depreciation, power and labour cost.

Operating time / Irrigation scheduling

Operating (irrigation) time is the duration for which the irrigation system is run to provide the required amount of water to the plants. It can be calculated as following:

$$\text{Irrigation time (hrs / day)} = \frac{\text{Water requirement (liters per day)}}{\text{Application rate (liters per hour)}}$$

Example 1

Calculate irrigation time for a papaya tree with daily water requirement of 10 liters per day per plant and provided with micro tube system with discharge rate of 4 liters per hour.

$$\text{Irrigation time (hrs / day)} = \frac{10}{4} = 2.5 \text{ hrs / day}$$

Selection of emitter

Emitter is the most important part of a micro irrigation system through which water is delivered at desired rate to the plant and uniformity of water application is maintained all over the irrigated area. Therefore an emitter should match particular conditions existing at the field viz. type of crop, spacing of the plants, terrain, water requirement, water quality, operating time, pressure head etc. Some of the criteria that are to be considered for the selection of emitter are reliability against clogging, emission uniformity, easiness in installation and maintenance permissible variation of pressure head (pressure compensating in case of undulated terrain), percentage area wetted, flow rate, operating pressure and cost.

Table 5.5 shows characteristics and application of major type of emitters to different crops and recommended number and discharge of drippers for different crops in different soils is given in Annexure IV Table - F.

Table 5.5. Characteristics and application of major type of emitters

Type of emitter	Operating pressure (kg/cm^2)	Effective wetting radius(m)	Discharge range (lph)	Spacing between emitters (m x m)	Approximate cost (Rs.)	Type of crop, terrain etc
Micro-tube (Varies with length of micro tube)	0.3 to 1	0.2 to 0.5	4 to 20		0.8/m to 1.25/m	Vegetable, fruit and row crops on flat terrain.
Dripper - self /pressure compensating (Sandy to clayey soil)	0.4 to 1.2 (upto $4kg/cm^2$ discharge will be the same in case of p.c dripper)	0.3 to 0.5	2 to 8	0.6 x 0.6 to 1.0 x 1.0	2 to 5	Vegetable, fruit and row crops on undulated terrain.
Line source Thin wall/ Thick wall	1 to 1.5	0.3 to 0.5	2 to 4	0.3 to 0.6 (can be given as per requirement)	Thin wall 6 to 10 Thick wall 10 to 15	Long row crops (sugarcane vegetables, pulses etc.)
Micro Sprinkler	1 to 2.5	3 to 6	20 to 120	4x4 to 7.5x7.5	8 to 50	Vegetable, nursery
Micro Jet	1 to 2.5	1 to 2	18 to 180	1.5 x 2.5	4 to 25	Vegetable, nursery
Mini Sprinkler	1 to 3	6 to 10	300 to 900	7.5x7.5 to 12x12	60 to 200	Closely spaced crops.
Misters	1 to 4	1	18 to 40	1.4x1.4	4 to 25	Green house
Foggers (one way to four way)	2 to 4	0.5 x 1	7 to 28	0.7 x 1.5	20 to 120	Green house

Design of lateral

Some important points should be kept in mind while designing the lateral pipe. In order to obtain uniform application of water along the length of a lateral, the pipe diameter, length, and alignment must be selected so as to result in a minimum variation in discharge between individual emitters.

The desirable limit for emitter flow variation is less than 10%. For 10 % variation in discharge, approx. 20 % variation in the available head is acceptable. It is preferable to lay laterals on the contour or across prominent land slopes. If the slope of the field is more than 3 %, laterals should be used along the contours as far as possible. Running laterals down slope is often advantage, provided the slope is fairly constant and not too steep. If the average slopes of the field are less than 3 % in the direction of the lateral, it can be used at equal length on both sides of sub main pipe. Under down slope conditions, the difference in elevation between the two ends of the line results in gain in pressure head rather than a loss; therefore down slope laterals may be longer than similar laterals laid on level ground. If the ground slope along the lateral is approximately equal to the friction loss gradient, the pressure along the lateral will be nearly constant. If it is not possible to use laterals along the contours on sloping surface due to plant spacing etc., the length of laterals on downside of the sub main should be more than laterals on the upside. For higher slopes, laterals only on down-side should be used. It is important to find out how long a lateral can be used on each side of the sub main so that variation in discharge due to friction loss is within allowable limit. When the ground slopes along the lateral increases for successive setting, intermediate control valves may be required. Such valves are needed to avoid building up of excessive pressures and exceeding the pressure variation above 20%. Accordingly, allowable length of lateral can be calculated from flow equations like Hazen-Williams (using C = 150) as given below:

$$H_f = \frac{5.35\, Q^{1.852}\, L}{D^{4.871}}$$

where H_f = pressure loss due to friction (m),
Q = total discharge of lateral (lps),
L = length of lateral (m)
D = inside diameter (cm).

In most of the micro irrigation systems, LDPE/ LLDPE laterals of 12 mm and 16 mm size are used. To cover range of emitter discharge and spacing, a parameter, specific discharge rate (SDR) is used. It is actually flow per unit length of the lateral. It can be calculated as given below

$$\text{Lateral SDR(lph/m)} = \frac{\text{Emitter flow rate (lph)}}{\text{Spacing between two emitters (m)}} = \frac{\text{Discharge from lateral (lph)}}{\text{Length of lateral (m)}}$$

Table 5.6. Allowable length (m) for 12 mm and 16 mm pipe sizes at different pressure (International Development Enterprises (IDE), 2001)

Lateral SDR (lph/m)	Available pressure head											
	1m		2m		3m		5m		10m		15 m	
	12	16	12	16	12	16	12	16	12	16	12	16
1.00	30	50	35	60	40	80	70	100	100	150	120	180
2.00	25	40	30	50	35	60	50	80	60	100	70	120
4.00	20	30	25	40	30	40	35	50	40	60	50	75
6.00	12	20	15	25	20	30	25	40	30	50	35	60
10.00	08	12	12	15	15	20	18	25	20	35	25	45
15.00	06	10	07	12	08	15	10	20	15	30	18	35
20.00	04	08	05	10	06	12	08	15	10	20	15	25
25.00		04		04		08		10		15		20

Above figures are for flat land and adjustment has to be made in length of pipe depending on slope, i.e. shorter laterals for up slope and longer laterals for down slope so that total pressure variation is within the given limit.

Design of Sub main

Sub main pipe is designed in a similar way like lateral because it is also a perforated pipe like lateral and discharge in it reduces with respect to length of the pipe. Therefore, limitation of 20 % pressure variation to calculate the length can be used. Depending on flow rate, various sizes of PVC / HDPE pipes are used as sub main in micro irrigation system.

Allowable length at different pressure head and flow rates for 25 mm, 32 mm and 40 mm is given in tables below.

$$\text{Sub main SDR (lph/m)} = \frac{\text{Lateral SDR (lph/m) x Length of the lateral (m)}}{\text{Spacing between two laterals (m)}}$$

$$= \frac{\text{Total discharge from the sub main (lph)}}{\text{Length of the sub main (m)}}$$

Table 5.7. Allowable length of 25 mm, 32 mm & 40 mm pipes (m) (IDE, 2001)

Sub Main SDR (lph/m)	Available Pressure Head					
	1m	2m	3m	5m	10m	15 m
	25 mm	25 mm	25 mm	25 mm	25 mm	25 mm
10	30	40	50	60	75	90
20	20	25	40	50	60	70
40	10	15	20	30	40	50
80	04	06	10	15	20	30

Sub Main SDR (lph/m)	Available Pressure Head											
	1m		2m		3m		5m		10m		15 m	
	32 mm	40 mm	32 mm	40 mm	32 mm	40 mm	32 mm	40 mm	32 mm	40 mm	32 mm	40 mm
20	40	60	50	50	60	75	70	90	80	120	100	150
40	25	30	30	40	40	50	50	60	60	90	70	120
80	15	20	20	30	25	30	30	45	40	60	50	80
150	07	10	10	15	15	20	20	30	25	40	30	50
300		04		80		15		20		25		30

Above figures are for flat land and adjustment has to be made in length of pipe depending on slope, i.e. shorter sub main for up slope and longer sub main for down slope so that total pressure variation is within given limit.

Design of Main Line

Design of main line involves determining diameter of pipe and class/ thickness. It depends on flow rate, operating pressure and topography. As per irrigation scheduling of the sub main units, main line flow can be determined by selecting sub mains operating at a time. The main line size should be always be higher than sub main. The main line size is selected so that allowable pressure variation due to friction loss is within limit for the economic pipe sizing. Frictional head loss can be calculated using Hazen-Williams equation as given below:

$$H_f = 15.27 \left(\frac{Q^{1.852}}{D^{4.871}} \right) L$$

where H_f = pressure loss due to friction (m),
Q = total discharge in the pipe (lps),
L = length of pipe (m) & D is inside diameter (cm).

Table 5.8. Mainline sizes for different flow range and resulting frictional head loss in 10 m length of pipe (IDE, 2001)

Pipe size (outside diameter–mm)	32	40	50	63	75
Flow range (lps)	0.25 to 0.50	0.50 to 1.00	1.00 to 2.00	2.00 to 3.50	3.50 to 5.00
Friction loss (m per 10 m of pipe length)	0.10 to 0.32	0.10 to 0.30	0.11 to 0.40	0.11 to 0.32	0.13 to 0.30

Flow range (lps) of various sizes of PVC pipe, frictional losses for flow of water (in metre per 100 m length) in PVC pipes and length of straight pipe in meters giving eqiuvalent resistance to flow in pipe fittings are given in Annexure IV; Table -B, Table -C and Table -D respectively.

Selection of filter

Filtration requirement depends on size of flow path in the emitter, quality of water and flow in the main line. Screen filter can be used in case of small system and if the source of water is a well. For large system, depending on water quality, different filters or combination of filters can be used. For large flow requirements, filters can be connected in parallel using manifolds so that pressure loss across the filter is within the limit. Four types of filters are mainly available in different sizes. Selection of filtter for a particular system can be made as per table 5.9.

Table. 5.9. Selection of filters (Dasberg and Or Dani, 1999)

Causes of clogging	Contamination of water	Criteria for selection	Type of filters			
			Hydrocyclone	Sand	Disc	Screen
Soil particle size	Low	>=0.2	A	B	-	C
	High	<0.2 mm	A	B	-	C
Suspended solids	Low	<50 mg/lit	-	A	B	C
	High	>50 mg/lit	-	A	B	C
Algae, Organic matter	Low	-	-	B	A	C
	High	-	-	B	A	C
Iron and manganese	Low	<0.5mg/lit	-	B	A	A
	High	>0.5mg/lit	-	A	B	B

A – is the recommended alternative
B – is the second choice
C - is the third choice

Selection of Pump / Total Head Requirement

Head (pressure) required at the inlet of the main line or filter is given below:

Head (m) = Operating pressure (m) + Main line friction loss (m) + Fittings loss (m) + Filter loss (m) + (-) Elevation difference (m).

In case of centrifugal pump, total head requirement is as given below:

Total Head (m) = Suction head (m) + Delivery head (m) + Operating pressure (m) + Main line friction loss (m) + Fittings loss (m) + Filter loss (m) + (-) Elevation difference (m).

= Operating head of dripper (12 m) + Head lossin the lateral (2 to 3 m. maximum) + Head loss in submain (measure from table x 0.37 for 20 outlets otherwise take 0.4) + Head loss in the main (measure from table) + Head loss in the filter (5m maximum)
+ Head loss in the valve, bends etc. (10% of total above)

This total should not cross 30m which is system head in meter, because we use 2.5 kg/cm^2 pipe for drip irrigation, hence system head should be within 28m.

If head loss is greater than 30m, then increase the main line size and check total head loss. If this is more than 30m then increase submain size and check total head loss.

Horse Power Requirement

$$\text{Horse Power (HP)} = \frac{\text{Flow (lps) x Total Head (m)}}{\text{75 x Motor efficiency x Pump efficiency}}$$

Efficiency of the motor and pump differ for different model and make. Approximately motor efficiency can be taken as 80 % and pump efficiency as 75 % for mono-block pump. However, in order to procure pump from the market, required flow and total head should be mentioned to the supplier / manufacturer so that he can select suitable model.

INSTALLATION AND COMMISSIONING

Lateral pipes should be laid on the ground in straight line or along the plant rows. Emitters are to be fixed on the lateral. They are placed at equal spacing so that plants get uniform amount of water. Stakes are used in case of micro-tube and micro-sprinklers to place them properly. In the case of micro sprinkler/bubbler irrigation, laterals should be located at right angles to the prevailing wind direction where possible. Under high temperature, low relative humidity and extremely windy conditions, there will be poor uniformity and excessive evaporation loss. Hence, for better performance, it is better to operate the micro sprinkler/ bubbler irrigation system during early morning or night. Care should be taken to see that dirt, sand etc. does not enter into pipes while making connections. Back washing of the filters are to be done. Before operating the system, end caps at the end of laterals / sub main are to be released so that if there is dirt in the pipes, it is washed away and air is also driven out. Open the control valve and let the water flow freely through the pipes for some time (flush the system). Then close the end caps and ensure that water is coming out from each emitter. Check the pressures on the gauges installed at the inlet and outlet of the filter. If excess pressure is observed at the filter, open the by-pass valve slowly till the desired pressure is obtained. Check the working of air release valve at the sub main. At the desired pressure, measure the discharge at different points and ensure all emitters are working properly.

Micro sprinklers should be kept erect, ie., their risers should be perpendicular to the ground surface. All nozzles should permit free flow of water and sprinklers should be turning uniformly.

6. FERTIGATION

Efficient crop production requires efficient utilization of soil water and soil fertility. In order to make the nutrients available to the plant, it should be present in the vicinity of plant root. Placement of fertilizers in the correct zone of moisture availability is important to maximize fertilizer efficiency. Micro irrigation offers an opportunity for precise application of soluble fertilizers and other nutrients to the soil at appropriate time in the desired concentration. In this technique, since nutrients and water are applied at the same time in the zone of highest root concentration, it help to improve the efficiency of fertilization, to save labour and also to reduce pollution of ground water due to the split up of the nutrients (especially nitrogen) during the growth stages of the crop. Hence, if application of fertilizers or any other chemicals are done through micro irrigation system, development of root system will be extensive.

Any chemical added through micro irrigation system must meet the following criteria.

1. They must avoid corrosion of GI pipe, softening of plastic pipe and tubing and clogging of any component of the system.
2. They must be safe for field use
3. They should increase the crop yield
4. They should be soluble in water
5. They should not react adversely to salts or other chemicals in the irrigation water.
6. It must contain needed elements in a form available to plants.

Care should be taken to distribute the fertilizers uniformly throughout the field. In order to achieve uniform distribution, it requires efficient mixing, uniform water application and knowledge of the flow characteristics of water and fertilizers in the distribution lines. The chemicals should be completely soluble to avoid clogging. If more than one chemical is used for preparing concentrated stock solution for subsequent injection into the distribution lines, the chemicals must not react with each other to form a precipitate.

Advantages of fertigation

1. Ensures a regular flow of water as well as nutrients resulting in increased growth rates for higher yields.
2. Offers greater versatility in the timing of the nutrient application to meet specific crop demands.
3. Improves availability of nutrients and their uptake by the roots.
4. Safer application method, which eliminates the danger of burning the plant root system.
5. Offers simpler and more convenient application than soil application of fertilizer, thus, saving time, labour, equipment and energy.
6. Improves fertilizer use efficiency.
7. Reduction of soil compaction and mechanical damage to the crops.
8. Potential reduction of environmental contamination.

Fertilizer injection

Fertilizers can be injected into the micro irrigation systems by selecting appropriate equipment. It is better to provide two injection points, one before and one after the filter. This arrangement can be used to bypass the filter if filtering is not required, and thus avoid corrosion damage to the valves, filters and filter screen/ sand media of the sand filters. The discharge line from the fertilizer tank should have equipped with an in-line filter or screen. The intake or suction side of the injector should also be equipped with filter or strainer.

Fertilizer injection through drip and micro tube should not begin until all lines are filled with water and the emitters are running. It is preferable for chemical injection to begin one hour after the system has been operating and the injection should cease one hour before the system is to be turned off. Applying fertilizer into partially filled system will result in poor fertilizer distribution. The calibration of the instruments should be checked frequently.

While applying the fertilizer through the micro sprinkler/ bubbler system, the application should start only after operating the system long enough to wet the soil and plant foliage. The fertilizer is then injected through the system in a solution of 1 kg of fertilizer to about 30 kg of water and timed in such a way so as to complete the injection in about 30 minutes. After the application of fertilizer, the system should work for sufficient time so as to flush it from any toxic effects of the fertilizer solution.

The frequency of fertigation depends on the design of system, irrigation scheduling, soil type, type of crop and farmer's interest. Fertilizers can be injected into the irrigation system once in a day/ once in two days or even once in a week. In order to have a uniform of nutrients throughout the fertigation zone, 25 to 30 minutes of fertilizer injection is recommended. Too much water will leach plant nutrients below the root zone and will saturate the soil resulting damage to the roots of plants. Hence, care must be taken to limit duration of fertilizer injection time.

Nitrogen fertilization

Since nitrogen being the one of the major plant nutrients for optimum crop production, it is most often applied in drip irrigation system. Nitrogen injection will not significantly increase the clogging problems. It is usually applied through the system as anhydrous ammonia, aqua ammonia, ammonium phosphate, urea, ammonium nitrate etc. Urea and urea-ammonium nitrate mixtures are highly soluble and usually does not cause large pH shifts.

Water quality must be considered when N is applied through a drip irrigation system, eventhough it causes fewer problems than other nutrients. The injection of anhydrous ammonia or aqua ammonia into irrigation water will bring about an increase in PH that may be conductive to the precipitation of calcium, magnesium and phosphorus or the formation of complex magnesium ammonium phosphates, which are insoluble. This can be a serious problem if bicarbonate is present in the irrigation water. Nitrogen injected in the form of ammonium phosphate can cause serious clogging of irrigation system if calcium and magnesium are present in the irrigation water.

Phosphorus fertilization

Generally, injection of phosphatic fertilizer through drip system has not been recommended since most phosphatic fertilizers react and cause chemical or physical precipitation problems leading to clogging of the system. But with low pH water, if phosphorus is applied in the form of phosphoric acid, which is soluble in water, does not produce any clogging problem. However, it is *common practice to apply the phosphate fertilizer separately at seeding/planting time.*

Phosphate based fertilizers should not be mixed with calcium based fertilizers. Magnesium is compatible with phosphates only at low concentrations and low pH.

Potassium fertilization

No adverse chemical reaction is expected with common potassic fertilizers. It can be applied as *potassium sulphate, potassium chloride and potassium nitrate.* These potassium sources are soluble and have few precipitation problems. However, reduced solubility and/ or fertilizer incompatibility is possible when different fertilizer types are mixed. An example is a mixture of calcium nitrate and potassium sulphate, which will yield insoluble calcium sulphate.

High performance and high cost fertilizers

These fertilizers use Nitrate as resource of Nitrogen, Phosphate as the source of Phosphorus and Potassium Nitrate as a source of K and N. These are chloride free fertilizers. Eventhough these fertilizers are 5 to 6 times costlier than the conventional water-soluble fertilizers, they are found cost effective for high value crops like grapes, strawberry and crops grown in greenhouses. The manufacturing plants for such fertilizers require large capital investment and require large production capacities. Therefore we may have to continue to import such fertilizers. Hence these fertilizers are being imported into India by the grape growers and greenhouse growers.

The details of fertilizer which can or cannot be mixed is shown in table 6.1 and the solubility of defferent fertilizers is shown in table 6.2.

Table 6.1. Compatablility chart: Fertilizer which can or cannot be mixed

	$(NH_4)_2SO_4$	Ca (NO_3)	$NaNO_3$	KNO_3	K_2SO_4	$MgSO_4$
Ammonium sulphate		No	Yes	Yes	Yes	Yes
Calcium nitrate	No		Yes	Yes	No	No
Sodium nitrate	Yes	Yes		Yes	Yes	yes
Potassium nitrate	Yes	Yes	Yes		Yes	Yes
Potassium sulphate	Yes	No	Yes	Yes		Yes
Magnesium sulphate	Yes	No	Yes	Yes	Yes	
Potassium carbonate	Yes	Yes	Yes	Yes	Yes	Yes
Ammonium phosphate	Yes	No	Yes	Yes	Yes	Yes

Table. 6.2. Fertilizer solubilities of conventional fertilizer (at 20 °C) (Ashwani Kumar, 2001)

Fertilizer	Solubility (g/l of water)
Potassium chloride	340
Ammonium sulphate	750
Urea	1060
Potassium sulphate	110
Potassium nitrate	320
Monoammonium phosphate	370
Magnesium sulphate	250

Calculation of fertilizer application

Step – I Amount of fertilizer per application

A fertilizer application F (kg/ha) can be applied through the drip system during N (nos) application to an area of A (ha). The amount of fertilizer to be applied P (kg per application) can be calculated as :

$P = (F \times A) / N$

Step – II Amount of fertilizer compound per application

The ratio of N, P and K in fertilizer compounds varies with different fertilizer compounds. If the nitrogen content of a given fertilizer is X % , the actual amount of fertilizer T (kg of compound per application) to be applied per application is

$T = (F \times 100) / X$

Work example:

If a total 120 kg of N, 60 kg of P and 60 kg of K, area of 1 hectare during 30 application, the amount of fertilizer to be applied during each application, P (kg / application) :

I part 30 kg : 30 kg : 30 kg in 10 application
N P K

Compound fertilizer have N, P & K percentage in the ratio of 8:8:8

So P = (30x1) /10 & N = (1x30)/10 & K = (30x1) /10

= 3kg/ application of N, 3kg/ application of P & 3kg/ application of K

The amount of fertilizer compound to be applied per application T,

= (3 x 100) /8 = 37.5 kg/ application

So 375 kg of fertilizer in 10 application

II part 90kg : 30kg : 30kg in 20 application
N P K

Compound fertilizer (liquid) having N, P & K percentage in the ratio of 15:5:5

So (90 x 1) / 20 of N, kg/application

= 4.5 kg/application

The amount of fertilizer compound to be applied per application T,

= (4.5 x 100) /15

= 30 kg/ application

So 600 kg of liquid fertilizer (15:5:5) in 20 application

Methods of fertigation

Pressure differential (By-pass tank)

The fertilizer tank (Fig.6.1 & 6.2) is connected to the main line by means of a by-pass pipeline. The pressure differential tank system is based on the principle of a pressure differential created by regulating the main system valve. This allows certain quantity of flow to by-pass through the fertilizer tank. The difference in pressure forces the water to enter through a by-pass pipe into a pressure tank which contains the fertilizer, and to go out again, carrying a varying amount of dissolved fertilizer. The rate of flow through the by pass is determined by the pressure head difference between the entrance and exit (usually 1 to 5 m).

Advantages

* Very simple to operate
* Initial and maintenance cost is comparatively less.
* Easy to change fertilizers
* Both dry formulations (which is fully soluble in water) and liquid fertilizers can be used.
* No electricity or fuel is needed.
* Hydraulic head loss is low.

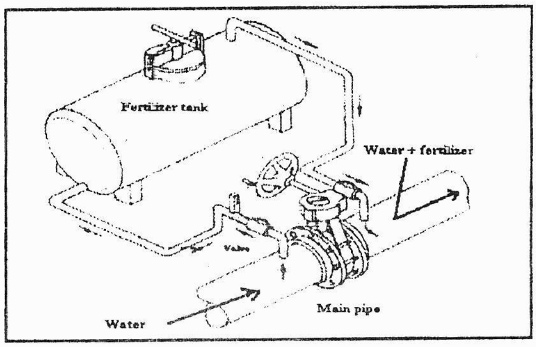


Fig. 6.2. Fertilizer tank connected to the main pipe

Disadvantages

* Concentration of solution decreases as fertilizer dissolves
* Accurate of application is not possible
* Causes pressure loss in main irrigation line or needed to use a booster pump
* Limited capacity
* Not suitable for automation

(ii) Venturi system

Venturi (Fig.6.3 & 6.4) consists of a converging section, throat and a diverging section. When water is passed through the venturi, due to increase in velocity, a velocity head is created. This will create a suction effect. Then liquid fertilizer enters into the irrigation system through a tube from the fertilizer tank. By regulating the valves fitted on either sides, desired pressure difference between the gauges can be obtained. This enables the flow of fertilizer into the system. The injection rate is depending on the pressure difference created.

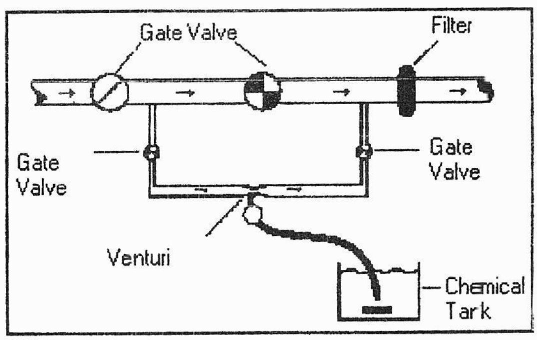


Fig.6.4. Venturi connected to the main pipe

Advantages:

Simplicity

Affordability

Good control over the fertilizer concentration in the irrigation water is possible

Disadvantages:

* Fertilizer intake rate is controlled by manual adjustment of valves
* Reduced system flow rate and high pressure loss (about one third of the total operating pressure)
* Increased time of operation
* Since the rate of injection is very sensitive to pressure and rate of flow in the system, precise regulation of flow is very difficult.

(ii) Fertilizer Injector Pump

In direct injection pump, pumps of piston type or diaphragm type are used (Fig.6.5 & 6.6). It gives fixed quantity of fertilizer in the water through irrigation. These pumps are operated by the system pressure only. Fertilizer pump draws the fertilizer solution from the fertilizer tank and injects it under pressure into the irrigation system. The pumping rate and concentration of stock solution can be adjusted to attain the desired level of fertilizer application.

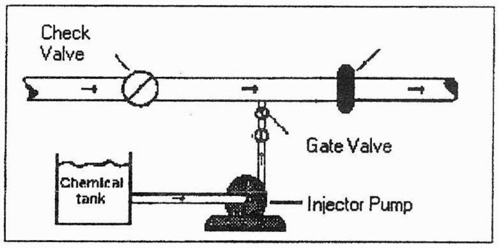


Fig.6.6. Fertilizer Injector Pump connected to the main pipe

Advantages:

* Doesn't affect the system flow rate
* High uniformity of application

Disadvantages:

* Complex in operation for low concentration application
* Increased running cost.

Non-Electric Proportional Liquid Dispenser (NEPLD) (Fig.6.7)

It consists of a Hydraulic Piston Pump. It can operates without the electricity. Water pressure is used as the power source. It is compatible for flow rates from 500 lit/hour to 20,000 lit/hour. It can withstand the pressure up to 10 bar. Dispenser pump is activated by the water. The concentrate is mixed inside the dispenser and water pressure forces down the solution. Dose of concentrate is proportional to volume of water flows.

Advantages

* Uniform and timely application
* Reduced application costs
* Improved management
* Reduced exposure to chemicals
* Reduced environmental contamination

A chart showing the comparative evaluation of various fertigation methods is shown in fig. 6.8.

Computer controlled fertilizer applicator (Fig.6.9)

Equipped with precise and efficient venturi injector. It has the capacity to control 60 individual valves separately with 4 periods per day.

7. MAINTENANCE OF MICRO IRRIGATION SYSTEM

The success and efficiency of micro irrigation depends on timely and proper maintenance. The most important problem associated with micro irrigation especially in drip system is clogging. In the irrigation system, clogging can occur at any place, namely, emitters, distribution lines and filters. This is caused due to the presence of some unwanted physical, chemical and biological materials present in the water source. (Table 7.1).

Problems

1) ***Physical:*** The physical causes include the mineral particles of sand, silt, clay and other water borne debris that are too large to pass through the small openings of the emitters and filters. Silt and sand particle may aggregate and can coat filters, inner walls of emitters and distribution line. Clogging may also occur due to broken pipes and root intrusion.
2) ***Chemical:*** If the irrigation water contain large amount of soluble salts, it may precipitate inside the emitters as water evaporate from the emitter. Precipitation of carbonates and iron oxides and precipitates from the chemical injection of fertilizers or other chemicals are significant causes of emitter clogging. Mixed liquid fertilizers can be used as long as conditions favouring solubility are maintained. In order to identify the most soluble compounds, an irrigation water analysis is to be performed.
3) ***Biological***: The microorganisms like algae and bacteria present in the water are large enough to clog the emitters completely. Some bacteria can oxidize iron and manganese present in the water, which may cause clogging problem in the system. The weeds, fungi, fish, frogs, ants, spiders, flies and oils present in the source of water may cause clogging in the emitters. Generally, visual inspection can identify these organisms. Microscopic examination is necessary for proper identification of bacterial and algal problems.

Table.7.1.Extend of clogging on the basis of quality of irrigation water (Dasberg & Or Dani, 1999)

Quality of water	Clogging hazard		
	Slight clogging	Moderate clogging	Severe clogging
Physical			
Suspended solids (ppm)	< 50	50 – 100	> 100
Chemical			
pH	< 7.0	7.0 –8.0	> 8.0
Dissolved solids (ppm)	< 500	500 – 2000	> 2000
Manganese (ppm)	< 0.1	0.1 – 1.5	> 1.5
Iron (ppm)	< 0.1	0.1 – 1.5	> 1.5
Calcium & Magnesium (ppm)	< 20	20 – 50	> 50
Hydrogen sulphfide (ppm)	< 0.5	0.5 – 2.0	> 1.5
Biological			
Bacterial population (no./ ml)	< 10000	10000 - 50000	> 50000

Remedy

Many clogging problems are specific to given set of conditions. Hence, procedures for correcting clogging problems are to be considered according to the type of problem.

Physical: In addition to provide an adequate filter in the system, regular flushing of the lines and emitters is desirable. Routine flushing of pipelines (at a flushing velocity > 0.6 m/sec) will help to prevent emitter clogging due to gradual accumulation of particles, which are too small to be filtered, but, settle out or flocculate at the ends of the pipelines. Application of dispersing agents like sodium hexa meta phosphate through the drip irrigation system will prevent the flocculation of silt and colloidal clays and allow them to pass easily through the emitters and hence, help to prevent the clogging problem.

Chemical: Most of the chemical clogging can be solved by acid treatment. The injection of acid into drip irrigation system is primarily carried out to lower the pH of the irrigation water and hence to prevent the precipitation of salts. In the case of mild clogging, acid treatment is performed till a pH of 4 is observed and the system should shut down for 24 hours. Next day, the system should be flushed by opening the flush valve and lateral ends. The amount of acid required to lower the pH is determined by trail and error with a small volume of water. If there is severe clogging, emitters must be soaked in one percent acid solution. Commonly used acids are sulphuric acid and hydrochloric acid. Since acid will corrode the metal pipes, fittings and containers, care must be taken to rinse all such parts after contact with acid.

Biological: When bacterial slime or algae clog the emitters, the standard treatment is the injection of a biocide followed by thorough flushing to clear the system of organic matter.

Chlorine injection

The most common chemical injected into the micro irrigation system is chlorine because it is very effective and cost efficient biocide.

Following points are important for the success of the treatment:

- Chlorine may be injected as continuous or intermittent treatment. Either type of injection is effective
- It is very important to treat the system regularly to prevent blockage.
- Frequency of treatment depends on the level of contaminants in the water.
- System should be chlorinated at the time of shut down and prior to use in the next season.
- Chlorine should be injected upstream from the filters to remove any un-dissolved or precipitated material and to prevent algae and other organisms from plugging the filtration surfaces or pores.
- Chlorine activity increases exponentially with decreasing pH with optimal values between 5.5 and 6.

Continuous treatment

When the plugging potentials are high, chlorine is injected continuously at a level sufficient, i.e., 1 to 2 ppm to maintain the residue free chlorine at the end of the system

Intermittent treatment

The quantity of chlorine depends on the amount of organic matter present. Since chlorine is injected for killing micro-organism, larger amount is injected at the starting point to maintain the required level at the end of lateral. It consists of injecting chlorine at an interval of 4 to 10 days so that 8 to 20 ppm pulse of free residual chlorine should be injected over a period of 30 to 60 minutes at the end of an irrigation event so that all lines contain chlorine when shut off. Chlorine injection at the end of irrigation is a good practice. If no organic matter is built up, this period can be extended.

Super chlorination

When a system is partially or completely blocked with organic material, it is possible to clean the system by super chlorination ie., injecting chlorine at a rate of 500 ppm for a time sufficient to ensure even distribution throughout the laterals. Care should be taken to see that a thorough flushing of distribution line should be done after the treatment.

Common chlorine sources

- Calcium hypochlorite
- Sodium hypochlorite

Calcium hypochlorite

It is available commercially in a dry form as a powder or as granules and also known as "Bleaching Powder" and contains 65% of freely available chlorine. The bleaching powder is dissolved in water and this solution is injected into the system for about 30 minutes. Then the system is shut off for 24 hours. After 24 hours the lateral ends and flush valves are opened to flush out the water with impurities. Bleaching powder can be directly added into the water source at a rate of 2 mg / litre or through ventury assembly.

Sodium Hypochlorite

Liquid Form - Sodium Hypochlorite (NaOCl)

It is available in liquid form with free chlorine of 5 -10 %. It readily decomposes at high concentration and is affected by light and heat.

Amount of chlorine to be injected:

$$IR = \frac{Q x C x 0.006}{S}$$

Where IR = Chlorine injection rate (gallons/hour)

Q = System Flow Rate (gpm)

C = Desired Chlorine Concentration (ppm)

S = Strength of NaOCl Solution (percent)

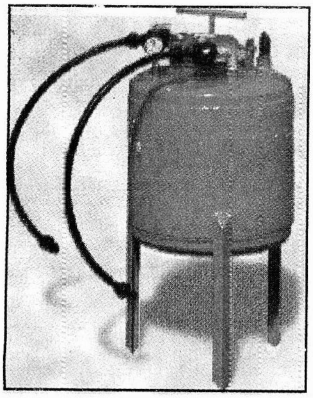


Fig. 6.1 Fertilizer tank

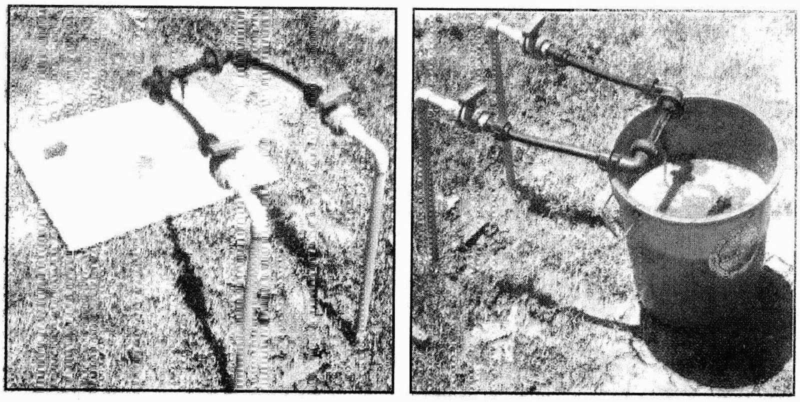
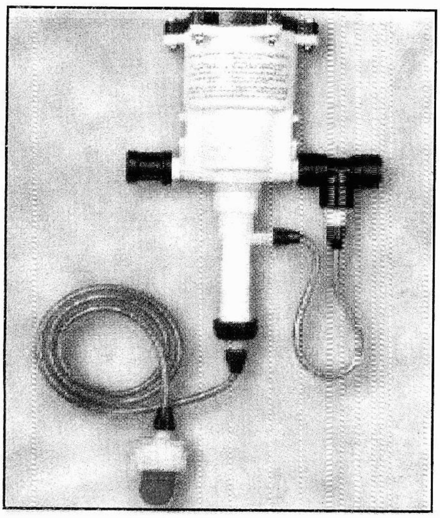


Fig. 6.3. Venturi and its connection to the main pipe



6.6. Fertilizer injector

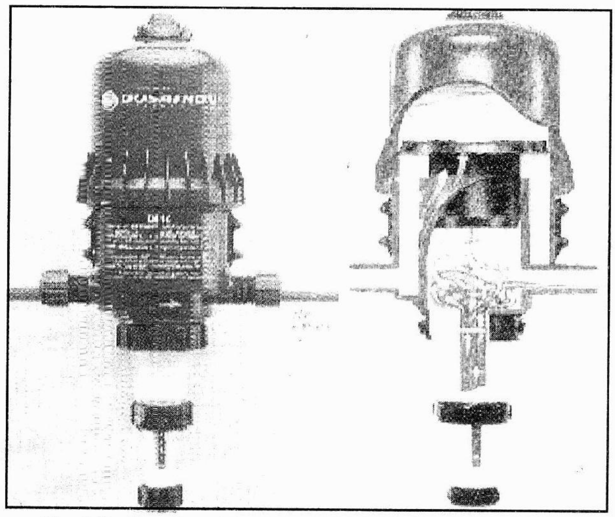


Fig. 6.7. Non-Electric Proportional Liquid Dispenser (NEPLD)

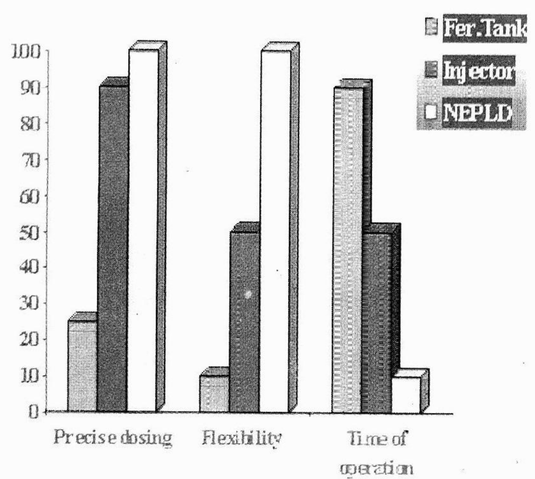


Fig. 6.8. Comparative evaluation of fertigation methods

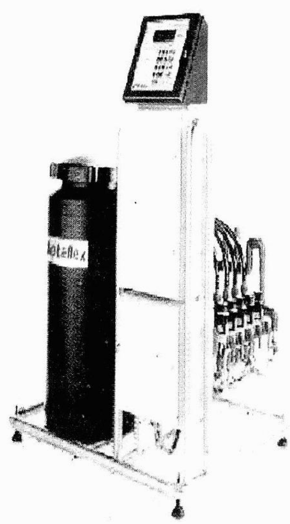


Fig. 6.9. Computer controlled Fertilizer applicator

Solid Form - Calcium Hypochlorite ($Ca(OCl)_2$)

Calcium hypochlorite is normally dissolved in water to form a solution, which is then injected into the system. Calcium hypochlorite is 65 % chlorine (hypochlorite) by weight. Therefore, a one percent chlorine solution would require the addition of 8.34/0.65 = 12.8 pounds of calcium hypochlorite per hundred gallons of water. Using this fact, a stock solution of the desired strength may be mixed and used in the same manner as sodium hypochlorite solutions.

Maintenance of various parts of the system

Ideally maintenance of the system should start at the time of system is installed. Thereafter, frequent maintenance and repair of the system is essential for its successful functioning. By observing the following steps, the system can be kept free of clogging problems.

General maintenance

- Check the discharge, wetting zone and functioning of the emitting device, leakage of pipes, valves and fittings
- Check the placement of the emitters. If the placement is disturbed, put them to the proper location
- Check for leakages through filter gaskets in the lids, flushing valves, fittings etc

Filters

Filters are the heart of the micro irrigation system. In order to function the system properly, all the filters must be kept clean. Back flushing with automatic or manual control valves will keep both sand and some screen filters clean. Backwashing allow the backwater to come out through the lid (Fig.7.1). Stir the sand in the filter bed upto filter candle without damaging them. Whatever dirt is accumulated deep inside the sand bed, will get free and goes out with the water through the lid. Seventy five percent part of sand filter should be filled with sand. If the sand level is low, it should be filled with sand up to the required level (Fig. 7.2.). Sand filter should be opened and cleaned once in a week.

Other screen filters are to be cleaned by removing the screen from its housing and rinsing off the accumulated dirt materials. Rubber seals are to be taken out and it should be cleaned from both the sides (Fig.7.3). Care should be taken while replacing the rubber seals; otherwise, they might get cut. Filters equipped with removable cartridges require only simple replacement.

The drop in pressure indicated by the pressure gauges on either side of the filter should be less than 2 m. Filter cleaning should be performed so as to maintain the operating pressure of the system within 10 to 15% of the design pressure.

Submain and lateral flushing

Sometimes, silt escapes through the filters and settles in submains and laterals. Similarly, algae and bacteria lead to the formation of slimes/pastes in the submains and laterals. In order to remove these silts and slimes, submain should be flushed by opening the flush valves (Fig.7.4). The lateral lines are to be flushed by removing the end caps. This will help to remove the traces of accumulated salts. Flushing should be stopped once the water going out is clean.

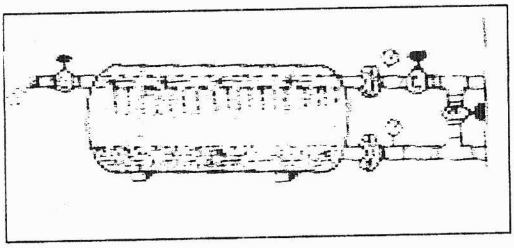


Fig.7. 1 Backwashing of sand filter

Fig. 7.2. Replacement of sand in sand filter

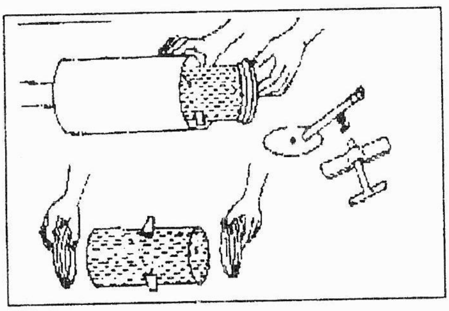


Fig. 7.4. Cleaning the screen filter

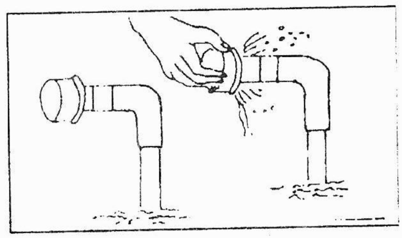


Fig. 7.4. Flushing main and submain

8. ECONOMICS OF MICRO IRRIGATION AND DEVELOPMENT SCHEMS

The techno-economic feasibility of any new technology is essential for its adoption by the public. All over the country, scientists have studied the economics of micro irrigation system by utilizing the research data as well as farm level information. The studies revealed that the technology has commercial acceptance and in most of the crops the cost benefit ratio is in the range of 1: 2.5. Hence, the initial investment is justifiable on the basis of the long-term benefits acquired by way of increased area under irrigation and higher production.

In spite of enormous cost of installation of micro irrigation system, the economic study conducted by Sivanappan (1993) for various crops reveals that the pay back period varies from 6 months to 24 months and the benefit cost ratio is 2 to 5 (Table 8.1).

Table. 8.1.Cost benefits and pay back period of micro irrigation for various crops

Crop	Crop spacing mxm	Drip irrigation cost (Rs)	Pay back period (year)	Benefit cost ratio
Banana	1.8x1.8	47,500	1	3.00
Grapes	3.03x1.8	44,000	<1	3.28
Pomegranate	4.3x4.3	30,000	<1	5.16
Ber	4.5x4.5	30,000	1	4.56
Tomato	0.9/0.6x0.6 paired row	30,000	1 season	1.09
Papaya	1.81x1.81	40,000	1	4.09
Cotton	1.5/0.9x0.6 paired row	47,500	$1\frac{1}{2}$	1.83
Sugarcane	1.0/0.6x0.1 paired row	47,500	1	3.45

The study conducted by INCID (1994) revealed that the cost benefit ratio of various crops excluding grapes is found to range from 1.31 to 2.6 (excluding water saving). (Table.8.2.)

Table.8.2. Benefit- cost ratio for various crops by using drip irrigation system

Sl. No	Kind of Crop	Spacing in m x m	Cost of the system per acre in Rs	Benefit cost ratio	
				Excluding water saving	Including water saving
1	Coconut	7.62x7.62	4,475	1.41	5.14
2	i. grapes	3.04x3.04	7,700	13.35	32.32
	ii. grapes	2.44x2.44	9,340	11.50	27.08
3	Banana	1.52x1.52	13,670	1.52	3.02
4	Orange	4.57x4.57	8,040	2.60	11.05
5	Acid lemon/ citrus species	4.57x4.57	8,040	1.76	6.01
6	Pomegranate	3.04x3.04	7,700	1.31	4.04
7	Mango	7.62x7.62	4,475	1.35	8.0
8	Papaya	2.13x2.13	9,500	1.54	4.01
9	Sugarcane	Between biwall 1.83	12,750	1.31	2.78
10	Vegetables	Between biwall 1.83	12,750	1.35	3.09

Note: Adapted from the table. 6.3. of INCID (1994)

The investment needed/ha of coverage under micro irrigation depending upon the crop for which it is designed. Since laterals and emitters are the costliest component in drip irrigation, cost of micro irrigation system is enhanced with decrease in spacing between the plants.

Table. 8.3. Approximate cost of drip irrigation system under different plant spacings (based on the costs of 2005)

Plant spacing, m x m	Cost of drip system, Rs./ha
12 x 12	25,300
10 x 10	27,800
8 x 8	32,900
6 x 6	40,500
4 x 4	48,300
2 x 2	63,300
1 x 1	78,400

The cost of installation of micro sprinkler irrigation system designed to cover the entire area (installed at a spacing of 4m x 4m to 5m x 5m) will come around 44,500/ha.

Analysis of all the information obtained from the various farmer's field enlighten the following points:

1. The level of awareness is the important factor for the contribution toward the adoption of drip irrigation technology by the farmers.
2. The studies conducted among the farming communities who were actively (personally) involved in all the farming operations revealed that the productivity of crops, savings of water and profits are significantly higher compared to the control group.
3. Drip irrigation was economically viable even for the farmers who have operated one-hectare holdings and they could recover the cost of installation of irrigation system in the very first year when they could get subsidy for acquiring the system.
4. The farmers who installed drip irrigation systems on their own were obviously more careful in the operation and maintenance of the systems and put them to better use.
5. Eventhough subsidy is not a perquisite to enhance the economic – viability to drip investment, it is still needed to enhance the widespread adoption of this technology, particularly by smaller farmers.
6. There are some failures observed which caused mainly due to defects in the design, poor quality of material used to produce the system, carelessness of the farmers in maintaining the system and very poor quality of water used for irrigation.
7. Micro irrigation helped to reduce the unemployment problem of educated youth and also helped to earn foreign exchange by way of exportable surplus flowers, vegetables and fruits.

Considering the advantages of drip irrigation, Government of India has decided to promote drip irrigation in all the States and Union Territories of the country. In 1991, Govt. of India announced a subsidy scheme in a few selected states. Farmers showed very good response to this subsidy scheme and hence during VIII plan (1992-1997), Govt. of India announced a massive subsidy scheme of Rs. 250 crores. During IX plan, an outlay of Rs. 375 crores was announced. The details of subsidy given in different years are given in table. 8.4.

In order to ensure uniformity in the sanction of subsidy throughout the country, the following standardized procedure has been followed:

a) Farmers are required to submit applications to Agriculture/ Horticulture Department (ADO/HDO) or any other authority designated for the purpose. through village level workers (VLW)
b) After scrutiny of the applications, ADO/HDO or any other designated authority has to issue eligibility certificates for availing subsidy along with a list of approved drip /micro irrigation system manufacturers to the farmers
c) Farmer obtained proforma invoice from one of the approved manufacturers and submit to ADO/HDO and also indicates whether the balance amount extending subsidies will be met from his own resources or borrowed from the Bank.
d) After scrutinizing the design, water and soil test reports, quotations, ADO shall submit the document with his recommendation to the District Agriculture Development Officer (DAO) / equivalent authority.

If beneficiary pays his own contribution

- DAO conveys final approval to the farmer with a copy to the system manufacturer.
- There upon, the manufacturer installs the system.
- Farmer pays his own share to the manufacturer.
- Farmer informs ADO of the installation.
- ADO verifies and submits satisfactory installation of the system to the DAO.
- The subsidy amount will be released by DAO to the manufacturer through the farmer.
- The State Government will ensure that the payment is released within a month from the date of installation.

If beneficiary takes loan

- The DAO conveys sanction of subsidy by the State Government along with the farmer's intention to avail loan to the bank and system manufacturer with a copy to the farmer.
- The system manufacturer installs system on the field.
- The performance of the system will be verified by the farmer, bank and the State Government official.
- Farmer and the State Government official approves the system and request bank to make payment to the manufacturer on their behalf.

- Bank pays loan and subsidy amount to the system manufacturer within a month which will meet the total cost of the system.
- Bank debits to the State Government account and farmer's account to the extent of subsidy and loan respectively.

e) In order to have control on the quality of materials, all the State Governments have to identify the manufacturers in their own states who are registered under the State Government. Care must be taken to ensure the guarantee period, after sales service etc. The State Government is required to ensure that only those suppliers who are manufacturing the laterals and emitters are registered. These manufacturers, however can appoint distributors for supply of material on their behalf. These manufacturers should have obtained BIS mark for various components. The imported material having international standards like ISO should be permitted only if it matches certain physical standards as per BIS specifications. If a new technology is imported, its performance should be evaluated in the field by the recognized testing laboratories before the system is approved for subsidy.

The subsidy cost includes expenses towards mains, sub-mains, laterals, drippers, micro tubes, connectors, filters, and control head

Future strategies to be made for the promotion of micro irrigation

- The DRIPMA and Ministry of Agriculture should plan an intensive programme to popularize the micro irrigation systems.
- There should be a separate department entrusted with the responsibility for popularizing the system in the State. Care should be taken to avoid multiplicity of the agencies
- .A group of master trainers are to be generated by giving proper training through the state agricultural universities and state departments
- Intensive training should be provided to the State Government officers, Bank officials, other officers involved in promoting the micro irrigation and to the field staffs involved in the implementation of micro irrigation.
- Studies should be made to solve the clogging problems, fertigation studies, crop geometry experiments, water requirements of various crops under micro irrigation in different soil and climatic conditions, moisture distribution pattern and effective spacing of emitters and measures to improve the overall efficiency of micro irrigation systems.
- Studies should also be carried out to explore the feasibility of micro irrigation in the wastelands and salt effected soils. Steps are to be taken to evolve package of practices to use saline and brackish water through micro irrigation systems.
- Research has to be made to identify/develop the rodent repellent materials for the laterals of the system.
- The overall cost of micro irrigation system is governed by the crop geometry and system design. Hence, optimization of crop geometry and desigsn of the system is very essential to reduce the cost of the micro irrigation system.

- The cost of the system should be brought down; otherwise, the subsidy component can be increased to all the farmers. Subsidy at least @ of 50% is to be continued to all the farmers at least for 5 years for enhancing the widespread adoption of this technology.
- The main policy should be so as to encourage and to motivate all categories of farmers, since the critical issue is saving of water and augmentation of productivity.
- Specific financial provision should be given in the credit plan of each bank for providing credit assistance to the farmers who opt micro irrigation systems. Timely financial assistance to the farmers is crucial. Hence, steps must be taken to remove the hurdles in speedy delivery of finance.
- The research institutions should integrate their activities with R&D units of the manufacturing companies. Higher priority should be given to the adaptive research, rather than to basic research.
- Quality control of all the components and equipments as per BIS is to be ensured. The code of practice has also to be made for the installation of the irrigation system. Manufacturers who are manufacturing BIS products should be encouraged for registration.
- It is advisable that manufacturing companies should establish operation and maintenance staff cum research and development cells in their organizations.
- Manufacturers should open service centers within the easy reach of farmers and they should provide adequate spare parts and attend the repair and maintenance problems of farmers so that the farmers could get the system back to operation with the least possible delay. This is very essential for the success of micro irrigation systems and to infuse confidence in the farmers
- The repair and maintenance facilities should be made available at no extra cost to the farmers at least for the initial 1-year period after installation of the system.
- The annual area of coverage under drip irrigation in the country need to be enhanced to at least 50,000 ha
- Efforts would be needed to ensure the balanced development of drip irrigation in all parts of the country.
- The implementation of Government schemes should be made simpler and transparent so that more and more manufacturers get attracted for the scheme and may create a competitive market.

The successful implementation of any project necessitates active participation of farmers and social will power. The political will power is also important for motivating the implementing agencies and society. Apart from the basic knowledge and research findings, strong organizational and management setup is necessary for the implementation of the micro irrigation schemes.

Table. Details of subsidy scheme

Year	Issued by	State category	Available for	Subsidy	Contribution by		Limit		Remarks
					Central	State	Area (ha)	Amount (Rs.)	
1990-91	Coconut Dev. Board*		Micro irrigation system+ pump set + reservoir	33%					
1991-92	Agrl. Dept		Micro irrigation system + pump set+ reservoir	50%			0.4 1.0 2.0 3.0 4.0	15,000/- 26,500/- 43,000/- 59,500/- 60,000/-	
1992-93	Agrl. Dept		Micro irrigation system	50%			0.4 1.0 2.0 3.0 4.0	15,000/- 26,500/- 43,000/- 59,500/- 60,000/-	
1994-95	Agrl. Dept		Micro irrigation system	50%	90%	10%	1.0	15,000/-	
1995-96	Agrl. Dept	A - Maharashtra	Micro irrigation system	50%	90%	10%	1.0	15,000/-	
		B - AP/TN/Kar/ Ker/Guj		50%	90%	10%	1.0	17250/-	
		C - Rest of States		50%	90%	10%	1.0	18750/-	
*1996-97	Agrl. Dept	A - Maharashtra	Micro irrigation system	90%	90%	10%	1.0	25,000/-	For SF, MF, SC, ST & WF
				70%	90%	10%	1.0	25000/-	For other farmers
		B - AP/TN/Kar/ Ker/Guj		90%	90%	10%	1.0	28750	For SF, MF, SC, ST & WF

				70%	90%	10%	1.0	28750	For other farmers
		C – Rest of States		90%	90%	10%	1.0	31250	For SF, MF, SC, ST & WF
				70%	90%	10%	1.0	31250	For other farmers
*1997-98	Agrl. Dept	A - Maharashtra	Micro irrigation system	90%	90%	10%	1.0	25,000/-	For SF, MF, SC, ST & WF
				70%	90%	10%	1.0	25000/-	For other farmers
		B - AP/TN/Kar/ Ker/Guj		90%	90%	10%	1.0	28750	For SF, MF, SC, ST & WF
				70%	90%	10%	1.0	28750	For other farmers
		C – Rest of States		90%	90%	10%	1.0	31250	For SF, MF, SC, ST & WF
				70%	90%	10%	1.0	31250	For other farmers
*1998-99	Agrl. Dept	A - Maharashtra	Micro irrigation system	90%	90%	10%	1.0	25,000/-	For SF, MF, SC, ST & WF
				70%	90%	10%	1.0	25000/-	For other farmers
		B - AP/TN/Kar/ Ker/Guj		90%	90%	10%	1.0	28750	For SF, MF, SC, ST & WF
				70%	90%	10%	1.0	28750	For other farmers
		C – Rest of States		90%	90%	10%	1.0	31250	For SF, MF, SC, ST & WF
				70%	90%	10%	1.0	31250	For other farmers
*1999-2000	Agrl. Dept	A - Maharashtra	Micro irrigation system	90%	90%	10%	1.0	25,000/-	For SF, MF, SC, ST & WF
				70%	90%	10%	1.0	25000/-	For other farmers
		B - AP/TN/Kar/ Ker/Guj		90%	90%	10%	1.0	28750	For SF, MF, SC, ST & WF
				70%	90%	10%	1.0	28750	For other farmers

		C – Rest of States		90%	90%	10%	1.0	31250	For SF, MF, SC, ST & WF
				70%	90%	10%	1.0	31250	For other farmers
*2000-01	Agrl. Dept	A - Maharashtra	Micro irrigation system	50%	90%	10%	1.0	22,500	For SF, MF, SC, ST & WF
				35%	90%	10%	1.0	16,000	For other farmers
		B - AP/TN/Kar/ Ker/Guj		50%	90%	10%	1.0	25875	For SF, MF, SC, ST & WF
				35%	90%	10%	1.0	18400	For other farmers
		C – Rest of States		50%	90%	10%	1.0	28125	For SF, MF, SC, ST & WF
				35%	90%	10%	1.0	20000	For other farmers
			Sprinkler irrigation system	50%	75%	25%	1.0	15,000	For SF, MF, SC, ST & WF
				33%	75%	25%	1.0	10,000	For other farmers
2001-02	Agrl. Dept	A - Maharashtra	Micro irrigation system	50%	90%	10%	1.0	22,500	For SF, MF, SC, ST & WF
				35%	90%	10%	1.0	16,000	For other farmers
		B - AP/TN/Kar/ Ker/Guj		50%	90%	10%	1.0	25875	For SF, MF, SC, ST & WF
				35%	90%	10%	1.0	18400	For other farmers
		C – Rest of States		50%	90%	10%	1.0	28125	For SF, MF, SC, ST & WF
				35%	90%	10%	1.0	20000	For other farmers
			Sprinkler irrigation system	50%	75%	25%	1.0	15,000	For SF, MF, SC, ST & WF
				33%	75%	25%	1.0	10,000	For other farmers
2002-03	Agrl. Dept	A - Maharashtra	Micro irrigation system	50%	90%	10%	1.0	22,500	For SF, MF, SC, ST & WF
				35%	90%	10%	1.0	16,000	For other farmers

		B - AP/TN/Kar/ Ker/Guj		50%	90%	10%	1.0	25875	For SF, MF, SC, ST & WF
				35%	90%	10%	1.0	18400	For other farmers
		C – Rest of States		50%	90%	10%	1.0	28125	For SF, MF, SC, ST & WF
				35%	90%	10%	1.0	20000	For other farmers
			Sprinkler irrigation system	50%	75%	25%	1.0	15,000	For SF, MF, SC, ST & WF
				33%	75%	25%	1.0	10,000	For other farmers
2003-04		All farmers	Micro irrigation system	25%			1.0	11250	The combined area for drip and sprinkler should not be more than 4 ha/ beneficiary
		All farmers	Sprinkler irrigation system	25%			1.0	7500	The combined area for drip and sprinkler should not be more than 4 ha/ beneficiary
2004-05		All farmers	Micro irrigation system	25%			1.0	11250	The combined area for drip and sprinkler should not be more than 4 ha/ beneficiary
		All farmers	Sprinkler irrigation system	25%			1.0	7500	The combined area for drip and sprinkler should not be more than 4 ha/ beneficiary

*A minimum of 25% of sanction amount is to be utilized for the benefit of SC/ST, 25% for Small & marginal farmers and 10% for woman farmers

SF - Small farmers, MF - marginal farmers, WF - woman farmers; AP – Andhra Pradesh, TN – Tamil Nadu, Ker – Kerala, Kar – Karnataka, Gug -Gujarath

Note : Subsidy worked out at Fixed cost + Optional items + variable cost. Subsidy is eligible for the area admissible as per land ceiling act of the state.

9. DETAILS OF VARIOUS MICRO IRRIGATION PRODUCTS IN THE MARKET

Particulars	Name of manufacturer	Specification	Application
I. Double Jet Micro Sprinkler I. Double jet sprinkler 920 & 940	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* Wetting diameter - upto16m * Overlapping spacing - up to 10m x 10m * Operating pressure 2.2 – 2.9 atm. at the sprinkler * Available flow rate (at 2 atm.) : 180, 200, 240, 300 lit/hr * Insect protected, Integral nozzle filter	For overlapping irrigation in :- field crops, seedling, flowers, vegetables, nurseries, hot houses, landscape gardening, for cooling & frost protection systems, for large trees, banana plantations etc.
II. POP-UP Sprinkler POP 940	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd., 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email :export@eindor.com	* Wetting diameter : 14 m * Operating pressure : 2.2-3.0 atm. at the sprinkler * Raises 10 cm. to 30 cm.	* Parks and home gardens to keep the sprinkler assembly out of view * Banana plantations etc.
Maxi-Paw	Nagarjuna Palma India Ltd, Plot No. P10/1, Industrial Development Area, Nacharam, Hyderabad-500076 Ph: 040-7150004/7150141		* Lawns, ground cover & shrubs, turf grass etc.
III. Single jet sprinkler 961 single jet sprinkler	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	*Wetting diameter : upto 12.5m *Overlapping spacing : upto 7m x 7m * Operating pressure: 2.0 - 2.5 at the sprinkler atm * Available flow :120, 160 lit/hr rates (at 2 atm) *Simple compact structure, insect protected, integral nozzle filter	For overlapping irrigation in :- Field crops, flowers , vegetables, nurseries , hot houses, landscape gardening, for large trees, etc

Particulars	Name of manufacturer	Specification	Application
IV. Part circle Sprinkler Part circle sprinkler model 961-P	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* Adjustable arc : 90^0 to 270^0 * Wetting radius – 7 m * Operating pressure: 2.0 - 2.5 at the sprinkler atm * Available flow : 120lit/hr rate (at 2 atm.) * Simple compact structure, insect protected, integral nozzle filter	* For edges of an area irrigated with 360" sprinklers in open fields and in hot houses * Home & landscape gardening * Wide strip irrigation (by setting sprinklers at 8mx8m on both sides of strip)
DANMODULAR group micro sprinklers & microjets *Spreaders* *Swivels*	DAN sprinklers irrigation equipment , Kibbutz dan , 12245 Israel Ph : 972-6-6953811 E-mail : sales@dansprink.co.il	* Its basic component, the bridge, can accommodate all types of nozzles, spreaders & swivels, allowing a wide range of flow rates, distribution patterns and wetted diameters * Can be fitted with anti-mist devise Available spreaders: 90^0, 180^0, strip spreader, close range spreader, flat spreader & 12 jet spreader * Operating pr.-1.5 to 2 bar * Flow rate : 30 to 200 lit/hr * Wetting dia : 0.9 to 6 m Available swivels: small, Anti-ant, one sided, big, upside down * Operating pr. – 1.5 to 2 bar * Flow rate : 30 to 300 lit/hr * Wetting dia : 4.5 to 10 m	* Innumerable combinations make this sprinkler a highly versatile emitter, adaptable to orchards, garden crops & green houses
Nagarjuna Micro sprayer	Nagarjuna Palma India Ltd, Plot No. P10/1, Industrial Development Area, Nacharam, Hyderabad-500076 Ph : 040-7150004/ 7150141	* Available in 90^0, 180^0, 210^0, 300^0, 360^0 and rectangle with different discharge and throw range	* Suitable for home gardens, landscape gardens, horticultural crops like banana, coconut, cocoa etc.

Particulars	Name of manufacturer	Specification	Application
III. Mini sprinkler Series 86X mini compact super mini sprinkler	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	*Compact firm structure *Uniform water distribution *Self flushing during irrigation *Extra strong propulsion *With different nozzle sizes to provide discharge rates from 20 l/hr to 160l/hr *Max. wetting dia at 2 atm : 3.8m to 9 m	Vegetables, landscape gardening, for large trees, banana plantations etc
Model 861 mini compact	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* Wetting diameter : 5.6m to 9m * Working pressures: 1.4 -2.2 atm. * For overlapping irrigation, spacings : upto 5m x 5 m in areas protected from wind.	* Mature trees, one emitter per tree or per two trees. * Hot houses , seedling & germination * Landscape gardening * Cooling & frost protection systems. * Used also for upside down irrigation
Model 862 & 862R mini compact	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	*Wetting diameter :0.5m to 7m *RJC- Removable Jet Converter (in model 862R) *Working pressures 1.0 atm. to 2.0 atm	*Trees with small or medium root zone *862R for young plants up to mature tree (by removing the RJC) *Landscape & home gardening.
Model 863& 863R mini compact	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* Special model for very low flow rate of 20 lit/hr with a 0.9 mm nozzle. * NFR, RJC (in model 863R) * Recommended working pressures 1.5 atm. -3.0 atm * Wetting diameter: 0.5m – 3.8m (at 2.0 atm)	* For young trees or trees with small or medium root zone where very low flow rate is needed. * 863R for young plants up to 2-3 years old or mature trees with small root zone, (by removing the RJC) * Landscape & home gardening.

Particulars	Name of manufacturer	Specification	Application
Model 866 mini compact	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	*For upside down irrigation *Excellent uniform water distribution at upside down position in overlapping irrigation *Wetting diameter: 6.6m to 8.6m *Working pressures :2. to 2.2 atm.. *Overlapping spacing: 5m x 5 m *Can be connected to non drip valve	*For overhead irrigation in : Seedling, nurseries, hot houses, germination, cooling and micro climate systems, cooling chicken coops & animal houses.
Model 831 Mini Sprinklers (insect protected)	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* Wetting dia : .7 to 10.4 m * Spacing for overlapping irrigation: 6m x 6 m * Operating pressure: in single emitter irrigation 1.0 -2.0 atm. * Operating pressure: In overlapping irrigation : 2.0 – 2.5 atm * Insect protected, Single jet swivel	* Large trees, one emitter per tree or between two trees * For overlapping irrigation in: hot houses, nurseries, flowers, vegetables etc * For cooling & frost protection systems * Park and home gardens
Model 841 Mini Sprinklers (insect protected)	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* wetting diameter: 4.9m upto 8m * operating pressure: 1– 2.5 atm * Uniform water distri bution, Single jet swivel, Insect pro tected	* Orchards, citrus, kiwi, mango, etc * For irrigation systems of low and regular operating pressures * Park and home gardens
Model 850 Part Circle Mini Sprinkler (insect protected)	Ein Dor Modern Irrigation Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* Dynamic operation, fine drops without mist *Uniform water distribution * IP – shuts off after operation * Wetting radius : 3.0m to 3.5 m * Operating pressure: 1.4 –2 atm * Flow rates:50 lit/hr, 70 lit/hr, 90 lit/hr	* Landscape & home gardening. * Trees, on both sides of the tree to avoid wetting the trunk * Edge of an area irrigated with mini sprinklers * Strip irrigation

Particulars	Name of manufacturer	Specification	Application
Model 800 mini sprinkler	Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com Ein Dor Modern Irrigation	* Wetting diameter : 5.0 m to10.5m * Strong propulsion * Operating pressure : 2 atm. for single emitter irrigation	* Large trees with wide root zone, or one emitter per two trees. * Cooling & frost protection systems
Model 801 mini sprinkler	Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* Single emitter irrigation operating pressure : 1.4 atm. * Overlapping irrigation operating pressure : 2 atm * Spacing up to 5m x 5m * Trunk protector to avoid wetting the tree	* Large trees with wide root zone, or one emitter per two trees. * Cooling & frost protection systems * Overlapping irrigation
Model 803 mini sprinkler	Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* Wetting diameter: 6.9m to10.2m * Overlapping spacings in upside down position 5x5m * Operating pressure: 2–2.5atm.	* Overhead irrigation in: - Hot houses, nurseries, seedling, germination - Cooling in micro climate systems
Ball Driven Mini Sprinkler	DAN sprinklers irrigation equipment, Kibbutz dan, 12245 Israel Ph : 972-6-6953811 E-mail : sales@dansprink.co.il	* Compact, sturdy * Ensures safe operation * Nozzles sizes : 3mm to 4.2mm * Low or high trajectory nozzles * Flow rate : 335 lit/hr & 445 lit/hr * Wetting dia : 18m to 20m * Operating pressure range : 2.5 – 4.0 bar for unregulated sprinklers, 3.0 – 5.0 bar for regulated sprinklers * Spacing : 8m to 12m	* Vegetables, green houses, orchards and banana plantations
Sprayer 806 Sprayer	Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* Fine droplets - with a small amount of mist * Wetting diameter: 2.6m to 5.4m * Static operation	

Particulars	Name of manufacturer	Specification	Application
806 Sprayer	Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	*Irrigates a very small area : 0.6m upto 1m *Static operation	
Agridor Series 44XX	Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* Irrigates with fine drops without mist * Operating pressure: 1.5 – 3.5 atm. (22-35 psi) * Color coded nozzles for flow rates from 20 lit/hr up to 90 lit/hr	* For irrigation of trees, narrow beds, strips, sector areas, potted plants, vines, bushes, small plants * For landscape and home gardening
Model 4460	Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131 Ph: 972-3-6482231 Email : export@eindor.com	Irrigates full circle in a wetting diameter upto 4.0m	
Model 4461 Equipment, Ein	Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	Irrigates 320^0 area in a wetting diameter up to 4 m, maintains a dry area around the trunk of the tree. Includes LDE minimizing dripping caused by water hitting the bridge.	
Model 4462	Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	Irrigates full circle with a wetting diameter from 2.4m to 3.3m	
Model 4463	,,	Irrigates full circle with a very small wetting diameter from 0.7m to 0.9m	
Model 4452	,,	Irrigates 180"sector area with wetting radius from 1.8m to 2.4m	
Model 4454	,,	Irrigates 90"sector area with wetting radius from 2.2m to 2.9m	

Particulars	Name of manufacturer	Specification	Application
Model 4442 Twin Sprayer	,,	Irrigates two small elliptical areas on both sides of the sprayer - enabling irrigation of two plants/vines with one sprayer Available flow rate - 10 lit/hr per each irrigated side	Can be spaced in overlapping achieving uniform water distribution in narrow strip Suitable for upright or upside down assembly
Model 4444 Ellipse/ Strip Sprayer	,,	Model 4444 – 40 lit/hr irrigates a narrow strip. Model 4444 – 70 lit/hr to 90 l/h irrigates an elliptical area up to 5.0 x 2.8 m.	
The 700 Dynamic Sprayer	,,	* Uniform water distribution with fine droplets; * Vibrating needle effects self cleaning * Wetting diameter 3m to 5.5m * Operation at upside down position reduces the wetting diameter	* Trees with medium root zone * Home gardens & parks
41 xx series Agridor jet sprayer - 4168 12 Jets Sprayer	,,	* Integral nozzle filter * Large wetting diameter	Trees, orchards, parks, home gardens etc where a large wetting diameter with a static sprayer is required.
Pot Sprayer	,,	* Nozzle flow reducer * Several models of sprayers with different water distribution patterns can be used in the system.	* Potted plants planted * Young plants * As a better substitute to drippers * For specific systems of very low flow rates
Fogger DAN Fogger 7800	Dan sprinklers irrigation equipment, Kibbutz dan, 12245 Israel Ph : 972-6-6953811 E-mail : sales@dansprink.co.il	* All components are made of high quality plastics * Very fine mist * Provided with leakage pretension device stops drainage * The fogger is not dripping during operation * Working pressure - 4.0 bars. * Ave. droplet size-100 µm * Recommended density : - one fogger to 1m² – 1.5 m² for cooling - one fogger to 0.3m² – 0.4 m² for propagation	Green houses, mist chambers

Particulars	Name of manufacturer	Specification	Application
F.L.F Fogger Low Flow	Plastro International Plastro Gvat, Kibbutz Gvat M.P. Ha'amakim 30050 Israel. Ph : 972-6-6549444 E-mail: export@plastro.com	* Flow rates : 4.5 lph – green vortex insert, grey nozzle cap * 10 lph- red vortex insert, black nozzle cap * Operation pressure range: 3.0 – 6.0 bar * Average droplet size: 70 micron * High pressure anti leak valve * Sealing pressure: 2.0 bar * Opening pressure: 3.0 bar * Very fine spray, no dropping * when system turned off or pressure drops	Green houses, mist chambers
MISTER a. Green 3600x 8 spinner b. Down spray mister	EPC Irrigation Ltd. , Corporate office & works: B- 20 MIDC, NASHIK- 422 010 Ph : 382152, 383241, 383242 Regd. Office: 401, Kakad Chambers, Dr. Annie Besant Road, Worli, Bombay - 400 018	Throw range (radius) - 1.22 m Discharge - 45.4 lph Operating pressure - 14 m Throw range (radius)- 0.61 m Discharge - 45.4 lph Operating pressure - 14 m	* Green house misting * Landscape Irrigation
809 Mister	Equipment, Ein Dor Ltd. 3 Ha'arad St., POB. 13129, Tel- Aviv Israel, 61131. Ph: 972-3-6482231 Email : export@eindor.com	* Provides mist in very thin droplets, apr. 0.2mm at 3 atm. * The size of the droplets become smaller when raising the operating pressure * Can be connected to Non Drip device	* Hot houses, rooting, seedling, germination systems * To maintain steady humidity * To reduce high temperature and create proper micro-climate conditions
Agridor mister 4191 & 4190	,, ,,	* Firm construction & static operation * mist in very tiny droplets : (apr. 0.15 mm at 3 atm. operating pressure) * Working pressure: 1.5 – 5atm * with Integral nozzle filter * low dripping emitter	* Maintains steady humidity * Reduces high temperature and creates proper micro climatic conditions * For hot houses irrigation seedling, germination and rooting * For cooling systems in hot houses, chicken coops, animal houses etc

Particulars	Name of manufacturer	Specification	Application
Integral Drip line	Nagarjuna Palma India Ltd, Plot No. P10/1, Industrial Development Area, Nacharam, Hyderabad-500076 Ph : 040-7150004/ 7150141	* Discharge rates available: 2 lph & 4 lph * Dripper spacing : 15cm, to 150 cm * Clog resistant, two outlets for every dripper, anti-corrosive, resistant to fertilizers & chemicals, easy installation	* Suitable for sugarcane, cotton, banana, vine yards, vegetables, strawberries, medicinal & aromatic plants, floriculture, green house
Doubledrip integrated dripline EPCDoubledrip	EPC Irrigation Ltd., Corporate Office & Works : B-20, MIDC, AMBAD, Nashik – 422 010. Ph : 382152, 383241, 383242	* Outside dia : 16 mm * Wall thickness : 0.7/0.9 * Operating Pr. : 1 kg/cm^2 * Max. Operating Pr. : 3kg/cm^2. * Flow rate of both drippers at operating pr. : 4 lph * Spacing between dripper : 30/40/50/60/75/100 cm (std supply is with 60 cm spacing) * Meters per reel : 600 m	* Well suited to grapes, orchards, citrus, vegetables, corn, cotton, banana, greenhouses
Flipper Dan Flipper	Dan sprinklers irrigation equipment, Kibbutz dan, 12245 Israel Ph : 972-6-6953811 E-mail : sales@dansprink.co.il	* Spreads water in very long and narrow strip * 70% water saving compared to 4mm/hr overhead system * Big droplet size minimizes the cooling effect while starting * Safe operation under freezing conditions * Filtration requirement: 120mesh/140 microns * Low flow rates-30-35 lit/hr * Operating pressure:1.5-2 bar * Pathways stay dry, reduces water logging, allows machinery movement soon after operation	* Effective, economical and ecological frost protection method * Covers vines rows without wasting water at the intercoms Suitable for Dan Micro sprinklers
Leakage Prevention Device Low pressure Dan L.P.D.	Dan sprinklers irrigation equipment, Kibbutz dan, 12245 Israel Ph : 972-6-6953811 E-mail : sales@dansprink.co.il	Rubber valve- closes the outlet to the emitter *Below the threshold pr., valve closes and keeps the system filled with water * Minimal operating pressure: - for opening : 20 m - For closure : 7 m * Pressure loss (for flow rate 100 to 220 lit/hr) : 0 to 1.5 m	

Particulars	Name of manufacturer	Specification	Application
High pressure Dan L.P.D.		* Minimal operating pressure: - for opening : 40 m - For closure : 22 m * Pressure loss (for flow rate 60 to 120 lit/hr) : 0 to 1 m	Suitable for Dan foggers
Filters Nagarjuna Screen filter (as per IS: 12785/1989)	Nagarjuna Palma India Ltd, Plot No. P10/1, Industrial Development Area, Nacharam, Hyderabad-500076 Ph : 040-7150004/ 7150141	Available in sizes 2", 2.5", & 3" with filtering capacity 10, 20, 30, 40 cum/hr Mesh size : 120 & 150 screen size Efficiency : upto 90% depending on water source	* Useful for water sources like bore well, open well * Can be used with gravel filter as secondary filter if irrigation water contains suspended solid particles, algae, trash etc.
Nagarjuna Disc filter	Nagarjuna Palma India Ltd, Plot No. P10/1, Industrial Development Area, Nacharam, Hyderabad-500076 Ph : 040-7150004/ 7150141	* Available in 2" with 25 cum/hr filtering capacity * Easy to open & clean * Plastic body with plastic discs , resistant to chemicals, acids etc. * Better filtration quality	* Useful for water sources like bore well, open well * Can be used with gravel filter as secondary filter if irrigation water contains suspended solid particles, algae, trash etc.
Nagarjuna Sand/ gravel filter (IS 14606-1998)	Nagarjuna Palma India Ltd, Plot No. P10/1, Industrial Development Area, Nacharam, Hyderabad-500076 Ph : 040-7150004/ 7150141	* Vertical model * Available in sizes 2", 2.5" & 3" with filtering * Capacity 10, 20, 30 & 40 cum/hr * Filtering media : 1 mm to 5 mm * Effective filtration equivalent to 80 mesh * Provision for back flushing * Operating pressure : 2 bar * Clean pressure drop : 2 bar	* Effective against trash, algae, suspended solid particles * Useful for water sources like open well, reservoir, river with trash, algae, suspended solid particles
Non electric proportional dispenser	DOSATRON International, Rue Pascal- BP 6 – 33370 TRESSES (Bordeaux), France Ph :33 (0)5579711 11		Fertigation in micro irrigation system

Particulars	Flow rate (m^3/hr)	Pressure (bar)	Dosage (%)
D1 150	10 to 2.5	0.3 to 6	1 to 5
D1 16	10 to 2.5	0.3 to 6	0.2 to 1.6
D1 210	10 to 2.5	0.5 to 4	2 to 10
D 8 R	500 to 8	0.15 to 8	0.2 to 2
D 8 R 150	500 to 8	0.15 to 8	1 to 5
D 20 S	1 to 20	0.12 to 10	0.2 to 2
D 30 S turbo	5 to 30	1 to 8	0.2 5 to 1.25
D 60 S bi-turbo	10 to 60	0.5 to 8- 0.	1 to 0.65

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ANNEXURE I

Manufacturers of Micro Irrigation System

1. Agritools, 1 -2-33/5, Gaganmahal Road, Domalguda, Hyderabad- 500029, Andra Pradesh; Grams: AGRITOOLS:
2. Agro Engineering Co. 6-6-37-4 Kavadiguda, Adjacent lane to Petrol Pump, Secunderabad- 500003 , Andra Pradesh , Phones: 833339, 884177.
3. Agroplast , 14 Belladapet, Tiptur- 572201 Karnataka. Phone 08134 2653.
4. Ajanta Plastic Industries, 31/A, Co-op. Industrial Estate, MIDC , Ahmednagar- 431005, Maharashtra.
5. Alpha plastic Industries, L- 2326/3 &4 GIDC , 3rd phase , Vapi- 396191 Gujarat.
   Bombay office: 46, Nagdevi Street, Bombay- 400003 Maharashtra. Phones: 3423179 & 3424017
   Ahmedabad office: 2, Kumar Complex, Kadia Kul, Ahmedabad- 380001 Gujarat. Phone: 334005
6. Anil Kumar & Co., opp. Pathik Ashram , Ist Floor, Bhavnagar- 364001. Gujarat.
7. Ashok India Agro products, Post Box No.66 , C-5/2 New MIDC Area , Ajanta Road, jalgaon- 425003 Maharashtra , Phones 3991, 6137, 5183, 6930; Grams: CAKPRODUCT:
8. Batliboi $ Co . ltd. ; 3- A , Surya Towers, Sardar Patel road, Secunderabad- 500003, Andra Pradesh: Phone: 841701, Telex : 0425- 6242, fax: 91- 842 841700
9. Bhoruka Aluminium Limited, No.1, K.R.S. road, Metagalli, Mysore-570016. Tel: 511116, 511066: Gram: EXTRUSION Telex: 0846- 347 Fax No: 0821- 513067. Corporate : 26/1, Lavelle Road, Bangalore- 560001. Telex: 0845- 8511 BLS IN.
10. Coimbatore Irrigation Equipment and Consultancy Services, Kungarupalayam, P.O. Kangayam TK, Udhiyur 638703, Erode RMS , Tamil Nadu.
11. Desert Gold India Irrigation Limited, Agro Products and Products Hi- Tech System Design of Irrigation Project, 157, Aarey road, Goregaon (West), Bombay- 400062, Maharashtra, Phones: 8720478, 8722033. Fax: 91-22- 8724367, Telex : 011- 70056 VPI IN.
12. Drip India, Lasalgaon, Tal. Niphad, Nasik, Maharashtra ..
13. ELGI Equipments Ltd., India House, Trichy Road, Coimbatore- 641018, Tamil Nadu ; Phone: 210155; grams: HYDRAULICS; Telex: 0855- 222 ELGI IN
14. EPC Irrigation Limited., B- 20 MIDC, Ambad, Nashik- 422010 Maharashtra , Phones: 23241, 23242 & 22152. Telex: 0752- 363 EPCN IN. Fax: 91- 0253- 22975 EPC IND. Branches at: Ahmedabad, Aurangabad, Bombay, Bhubaneshwar, Coimbatore, Hubli, Hyderabad, Jaipur and Sangil.
15. Flow Tech Power, 137 London Mission School St., Papanaickenpalayam, Coimbatore- 641047, Tamil Nadu.
16. Greenthumb Engineers Pvt. Ltd., 103 Pavanbhumi, Somalwada, Wardha Road, Nagpur 440025, Maharashtra , Phones: 2819.
17. Irrigation Engineering Company, 5-5-44/45, Ground Floor, 5-5-97 Ist Floor, 5-5-42, 2nd Floor, Ranigunj, Hill Street, Secunderabad- 500003, Andra Pradesh, Phones: 75749, 77548: Fax: 0842- 842477: Telex: 0425- 8484 PCO IN ; Grams: IEC DRIP.
18. Rungta Irrigation Systems Limited, B-7 , Electronic Complex , Kushaiguda, Hyderabad- 500 712, Andra Pradesh, Phones: 623909/ 623974, Fax: 040- 622776.
19. Jain Irrigation Systems Limited, Jain plastic park P.O. Box.72, N.H. no.6, Bambhori, Jalgaon425001, Maharashtra.

20. Jiven Irrigation Equipments, 503 Shivganga Chambers, 656/1, Budhwar Peth, Near Prabhat Cinema, Pune, . Maharashtra.
21. Jyothi Marketing and Products Ltd., Agri Products Division, B-3/15 BIDC, Gorwa, Vadodara-390016; Phones: 320448, 320561; Telex: 0175- 215 JMP IN Grams: SERVEJYOTHI
22. Kalpataru Irrigation Systems Ltd., 917/190 A Sivajinagar , P.O. Road, Pune- 411004 Maharashtra , Phones: 52195; Fax: 212- 52894; Gram: KICONS; Telex: 145-226.
23. Kaveri Drip Irrigation Systems, Plot no. 23/A, Phase III, I.D.A Jeedimetia, Hyderabad, Andra Pradesh; Phone: 263007, Grams: OCTYL
24. Kisan Irrigation Equipments, 1696, Vijayashree Buildings, Trichy road, Ramanathapuram, Coimbatore- 641045. Tamil Nadu.
25. Maya Agencies, 2078, Ushama, 10th Lane, Rajarampuri, Kolhapur, Maharashtra.
26. New Bharat Minerals and Chem., 10 B Haresh Chambers , 313/319 Samuel Street, Bombay-400030.
27. Parimal Irrigation Engineering, Arvind 1244, Sadashiv Peth, Near Sivaji Mandi, Pune- 411030; Maharashtra.
28. Polyene General Industries Pvt. Ltd., P. O. Box 3208, Regd. Office & Factory A-11 & A-1, Industrial Estate, Guindy, Madras-600032 Tamil Nadu; Phone: 2342306, 2342307, 2343025; Telex: 041- 26093 POND: Fax: 044- 2341470: Grams: POGENIND
29. Polytube Plastics, 175 Shri Samrath Industrial Estate, Pimpalgaon Baswant-422209, Dist. Nashik, Maharashtra: Ph: (02553) 50340, 50350, Grams: BORASTES. Telex: 0752-276 B Fax IN, Fax: 02553-50106. Regional Office:

    Madras Polytube Plastics, Pragati Irrigation, 13th , 3rd Floor ,Armenian Street, Madras- 600001 TAMIL NADU.

    Cochin: Sterling Farm Research & Services Pvt. Ltd., Post Box No. 2344, Sterling House, 35/1865- Valanjabalam, Cochin - 682016.
30. Premier Irrigation Equipment Ltd., 17/I-C Alipore Road, Calcutta- 700027, West Bengal: Phone: 4795155, 4797455 & 4799530: Grams: PREQUI ; Telex: 021- 8033 PIEC IN . Fax: 91-33-4797626.
31. Raindrop Equipments (India) Ltd.,A-7, MIDC Area, Amravati- 444605 Maharashtra.. Phone:4969; Grams: RAINDROP
32. Sprinkler and Drip Irrigation Equipments, Fakhri Manzil Near Pawar Bungalow Amrai, Baramati 413102, Pune, Maharashtra.. Phone:24441
33. Sathish Agricultural Enterprises, 12-3-8 Main Road, Patti- veeranpatti- 624211, Anna Dist. Tamil Nadu.
34. Spento Plastics, 'Zamavaz' , HK Marg, Dahanu – Road, Thane- 401602, Maharashtra.. Phone:2306.
35. Sujay Irrigation System, 497, Ist 'G' Cross, 18th Main, 3rd Stage, 4th Block, Basavareshvaranagar, Bangalore- 560079, Karnataka.
36. Santharaj & Sons, 122 Nanjappa Block, Govipuram Post, Bangalore- 560019, Karnataka.
37. Southern Agro Industries, 161 Greams Road, Post Box 7412, Madras 600006.
38. Shivaji Engineering & M/ Cco., 7-A, Murarji Peth Sholapur- 413001 Maharashtra.
39. Telecom Wires & Cables ; MS Ramaiah Industrial Estate, Gokula, Bangalore- 560054, Karnataka.
40. Watman Irrigation Systems Pvt. Ltd., Kinkhede Layout, Opp Hislop College, Civil Lines, Nagpur - 440001, Maharashtra.

41. Wavin India Limited, Irrigation System Division, 706 Rohit House, 3 Tolstoy Marg, New Delhi-110001; Gram: INDWAVIN ; Telex: 031- 4235.

42. Krishi Irrigation Ltd. C-184, 2nd stage, Peenya Industrial estate, Bangalore-560058, Karnataka. Ph. 8360498, 8362152

43. M/S Irrigation Products International Pvt Ltd., 18-A, kalashetra road, C/26, Fort indraprastha, Thiruvanniyur, Chennai-600041, Tamilnadu. Ph. 044- 24914043, 24483414

44. M/S. A.R.Agritech, Srivari complex, M.B.menon Road, Jose Junction, kochi-16, Ernakulam. Ph. 0484- 2362129

45. M/S AGS Irrigation, 11& 12 Ekangipuram, Main street, Ayanavaram, Chennai-600023, Tamilnadu. Ph: 044- 26449636, 26449174

46. Manikya Plastickam Pvt. Ltd, Plot No.5, belavadi industrial area, Mysore-570018, Karnataka. Ph: 91-821-402248

47. Sterling irrigation Ltd. , Anupam Plaza Ii, Block-51, Sanjay Place, Agra- 282002, Delhi. Ph: 2153750, 2153537

48. Rainbow Irrigation Ltd., Shed no.3, laxmi Venkateshwara, Industrial Estate, ,Bangalore-560058, Karnataka.

SOME OF AUTHORISED DEALERS OF MICRO IRRIGATION IN KERALA

I. Jain irrigation system Limited, Jain plastic park P.O. Box.72, N.H. no.6, Bambhori, Jalgaon 425001, Maharashtra. Ph: 0257-250011/22 , Fax: 0257-251111/22, E- Mail : jisl@jains Com.

   1. M/s. A.R.Agritech, Srivari complex, M.B.menon Road, Jose Junction, Kochi-16, Ernakulam. Ph. 0484- 2362129
   2. M/s. Divine Distributors, Vichitra commercial complex, Kannur. Ph. 0497- 2707703
   3. M/s. Mekkattukulam Brothers, Railway station road, Thrissur. Ph. 0487- 2424871
   4. M/s. Eco Farms, Velloorkunnam, Muvattupuzha-686673, Kottayam. Ph. 0484-2522757
   5. M/s. Kumar Agencies /Eakay Brothers, Sekahar Jyothi, G.B Road, Palakkad-678001. Ph: 0491-2533178
   6. M/s. Patani Equipments, Nilambur road, Melakom,Manjeri-676121, Malappuram. Ph: 0483-2765572
   7. M/s. Patani Enterprises, Main Road, Kalpetta-673121, Wyanad. Ph: 0493-202486

II M/s. EPC Industries Ltd, Aathira, Chiyyaram, Thrissur-680026, Kerala. Ph: 0487-421146, Fax: 91-22-5706638 (Mumbai)

   1. M/s. Vikas agro service, Ram Nagar road, Kottachery, Kanhangad, Kasaragode-671315. Ph. 04997-202350
   2. M/s. Wayanad Engineers, Main road, Kalpetta, Wayanad-673121. Ph. 04936-202660
   3. M/s. Kairali Marketing Associates, Aathira, Chiyyaram, Thrissur-680026. Ph. 0487-2250011
   4. M/s. Krishikendra, Chiravakku, Thaliparamba, Kannur-670141. Ph: 04982-204570
   5. M/s. Calicut engineering company, Kallai Road, Kozhikode-673002. Ph: 0493-2301942
   6. M/s. Hindustan Enterprises, Palace road, Nilambur, Malappuram-679329. Ph: 04931-220681
   7. M/s.General Marketing Federation, MC Road, Koothattukulam, Kottayam. Ph: 0485-2252401.
   8. M/s. Geo Agencies,Railway station road, Thiruvalla-689101, Alapuzha. Ph: 0469-2601364
   9. M/s. New India Machine Tools, Balaramapuram, Thiruvananthapuram-695501. Ph: 0471-2401369

III M/s. Flow tech power. Flowtech Towers, 81, New scheme road, Papanaickenpalayam, Coimbatore- 641037, Tamil Nadu. Ph: 221 5551, Email : Flow tech power@vsnl.net

1. M/s. Sreerangom groups, P.B.no. 24, Karunagappally, Kollam-690518
2. M/s. M.B.M Industries, Kurichy, Kottayam-686549
3. M/s. Hi-Tech Irrigation, East Kaloor, Thodupuzha, Idukki

IV Rungta Irrigation Ltd. 74/2A , Srigandhanagar, Hegganhalli, Peenya IInd Stage, Vishwaneedam, Bangalore- 560091, Karnataka. Ph: 6382008, 6362029

1. M/s. Anu Agencies, Chimpukad, Kuthanur-678721, Palakkad.
2. M/s. Raidco & its branches in Kerala, SPCA Road, Kannur-670002
3. M/s. Haritha Agri Services, Perumpilavu, Thrissur-630519
4. M/s. calicut Engineering Company, Near Municipal Stand, Mananthawady, Wayanad
5. M/s. G&S Electrical Services, Market Junction, Kattappana, Idukki-685508
6. M/s. Sushanth Traders, Main road, Payyannur- 670307, Kannur.

V Krishi Irrigation (Pvt). Ltd , C-184, 2nd stage, Peenya Industrial Estate, Bangalore-560058, Karnataka. Ph. 8360498, 8362152, Fax : 080 - 8362054

1. M/s. The Raidco Ltd. & its branches in Kerala, SPCA Road, PB No. 407, Kannur-670002
2. M/s. Haritha agri services, Perumpilavu, Karikkad Thrissur-630519
3. M/s. Theivannai Amman & Co., No.7 , New Scheme Road, Pollachi, Palakkad.
4. M/s. Thomarakkattil Hardwares, High School Road, Thiruvambady- 673603, Kozhikkode.
5. M/s. G.S Electricals, Market Junction, Kattappana, Idukki- 685508.
6. M/s. Sani Point, T.D.East, Sannidhi road, Ernakulam-682035.
7. M/s. Agrotech Agencies, Nedumgolam, Paravoor, Kollam.

VI. M/s. Irrigation Products International Pvt Ltd, 18-A, Kalakshetra road. C/26, Fort Indraprastha, Thiruvanniyur, Chennai-600041, Tamilnadu. Ph. 044- 24914043, 24483414

1. M/s. Hitech Agro Agencies, Govindapuram, Chittoor, Palakkad- 678507

VII. M/S Agroplast, S.K.P Temple Road, Tiptur- 572201,Tumkur, Karnataka. Phone 08134 452653

1. M/s. Raidco Ltd. & its branches in Kerala, SPCA Road, Kannur-670002
2. M/s. Shankar Traders, Nayak's road, Kasaragode-670121
3. M/s. KAIC Ltd. & its branches in Kerala, Kissan Jyothi, Fort, TVM-23
4. M/s. General Agencies, Temple Road, Kaduthuruthy-686604, Kottayam.
5. M/s. Anaswara Agencies, Q.S Road , Kollam.

VIII ELGI Ultra Industries Ltd., India Home, Trichy Road, Coimbatore- 641018, Tamil Nadu

1. M/s. Agri agro, Kozhalmannam, 16 KMS Building, Palakkad-678702
2. M/s. KAIC & its branches in Kerala, Kissan Jyothi, Fort, TVM- 695033. Ph. 0471- 2471343
3. M/s. Power Flow, 18, TC Road, Thellicherry, Kannur-670104. Ph: 0490- 2341754.
4. M/s. Karipallil Agencies, Ayroor South, Pathanamthitta-689611. Ph:0473 2530255

IX. Sujay Irrigation (Pvt). Ltd., No.86,Main Road, Petechannappa Industrial Estate, Kamakshipalya, Bangalore-560079, Karnataka

1. M/s. KAIC Ltd. & its branches in Kerala, Kissan Jyothi, Fort, TVM- 695033. Ph. 0471- 2471343
2. M/s. Raidco Ltd. & its branches in Kerala, SPCA Road, Kannur-670002
3. M/s. J.K Traders, Nooranad, Alappuzha
4. M/s. Krishnarajan & Sons, Main Road, Ramanattukara, Kozhikode-673633
5. M/s. General Agencies, Temple Road, Kaduthuruthy-686604, Kottayam
6. M/s. A.K Brothers, M.G road , Kasaragode.
7. M/s. General Agencies, Kottakal, Malappuram.

X. M/s. AGS Irrigation, 11& 12 Ekangipuram, Main street, Ayanavaram, Chennai-600023, Tamilnadu. Ph: 044- 26449636, 26449174

1. M/s. Pee Yes Associates, Kannattumukk, Thycaud, TVM.
2. M/s. Hi-Tech Irrigation, Anakkara, Vandenmedu, Idukki.

XI. Netafim Irrigation (Pvt.) Ltd, Ist Floor, 297, CST road, Vidyanagari, Kalina, Mumbai- 400098, Maharashtra. Ph: 02667- 264601/04

1. M/s. Mas Enterprises Ltd.,Vandenmedu, Idukki-685551. Ph: 0486 277077
2. M/s. Raino Irrigation Company, Parolickal, Kottayam- 686562. Ph: 0481 2790702

XII. M/S Alpha Irritech (P) Ltd .Alpha House, Plot .No.11, Srikumaran Nagar, Kolathur, Chennai- 600099, Tamilnadu. Ph: 0091 -44- 26511818

1. M/s. Raidco Ltd. & its branches in Kerala, SPCA Road, Kannur-670002
2. M/s. Archana Enterprises, Mananthavadi, Wayanad. Ph: 0493 540982
3. M/s. General Agencies, Temple Road, Kaduthuruthy-686604, Kottayam
4. M/s. Anu Agencies, Chimpukad, Kuthanur-678721, Palakkad
5. M/s. Sheeba paints, Hospital junction, Kundara, Kollam-691501.
6. M/s. Krishi Agencies, Mavoor road, Chaverambalam, Kozhikode- 673017.

XIII. Premier Irrigation Equipment Ltd, 271, Mysore road, Bangalore-560026, Karnataka. Ph: 6745844,6749662

1. M/s. Madhu Enterprises, Main Road, Kalpetta, Wayanad-673121.
2. M/s. Mas Enterprises, Vandenmedu, Idukki-685551
3. M/s. Krishna Rajan & Sons, Calicut Road, Ramanattukara, Kozhikode- 673633.
4. M/s. Agri Agro Irrigation systems, N.H. Junction, Koyalmannam, Palakkad- 679702.
5. M/s. Spinner Marketing, Athani- 680771, Thrissur.

XIV. Bharuka Irrigation Systems, No. 427, E, Heebal Industrial Area, Mysore- 570016, Karnataka. Ph: 0821- 2513876, 2510351; Fax : 91-0821-2512846; Email : bislmys@oth.net

1. M/s. Patani Enterprises, Mysore Road, Kalpetta, Wayanad – 673 124
2. M/s. Wyanad Engineering Agencies, Mananthawady, Wayanad
3. M/s. Palani Equipments, Manjeri, Malappuram.
4. M/s. KAIC Limited and it branches in Kerala, Fort, Thiruvananthapuram.

XV. Manikya Plastickam (Pvt) Limited, Flat No.5, Belavadi Industrial Area, Kunoor Road, Mysore – 570018, Karnataka. Ph : 91-821-402248, Email : manikya@vsnl.com

1. M/s. Jyothis electricals Industries, NH Road, Pangappara. Thriruvananthapuram – 695531.
2. M/s. Oopoothil Agricultural Services, MDC Centre, Kottayam – 686001.
3. M/s. Granpa Marketing Corporation, Sulthan Bathery, Waynad – 673592.
4. M/s. Raidco Ltd. and all its branches in Kerala, SPCA Road, Kannur.

XVI. M/s. Sterling irrigation Limited, Anupam Plaza II, Block – 51, Sanjay Palace, Agra – 282002, Delhi. Ph: 2153750, 2153537. Fax: 0562 – 2153449..

1. M/s. Beema Brothers, Calicut Road, Peruthalmanna, Malappuram.
2. M/s. Continental Traders & Agencies, Menathottam Chambers, Pattom, Thiruvananthapuram.
3. M/s. C.P.M Tools & Hardware, Pulimmodu Jn., Kottayam.
4. M/s. Kappens Saniware, Market Road, Pala, Kottayam.

5. M/s. Pattani Enterprises, Main Road, Kalpetta, Waynad.
6. M/s. Popular Mill Stores, Banerji Road, Ernakulam.
7. M/s. Popular Mill Stores, C.H. Cross Road, East Nadakkavu, Kozhikkode
8. M/s. Popular Mill Stores, Pattalam Road, Thrissur..
9. M/s. Sunil Steels, Podiyadi, Thiruvalla, Alappuzha.
10. M/s. Sushanth Traders, Main Road, Payyanur, Kannur.
11. M/s. Vikram Pump Set Services, Main Road, Kanhangad, Kasargod.
12. M/s. Bharat Agro Sales & Service, Nullipady, M.C. Road, Kasargod.
13. M/s. Menachery Traders, power Palace, Surya Complex, Palakkad.
14. M/s. Taurus Utilities, Park Junction, Kanjamkulam, Alappuzha.
15. M/s. Subramania Industries, Aryasala, Thiruvananthapuram.
16. M/s. Chennoth Sanitary Wares, Cherthala, Alappuzha.
17. M/s. General Marketing Federation, M. G. Road, Koothattukulam, Kottayam.
18. M/s. Best Engg. Company, Poozhithala, Mahe, Main Road, Kozhikode.

XVII. Rainbow Irrigation Ltd., Shed No. 3, Laxmi Venkateshwara Industrial Estate, 8th Main, Pennya IInd Stage, Bangalore – 560058, Karnataka. Ph: 080 – 8363710.
Email: ritttd@vsnl.com.

1. M/s. Calicut Engg. Company, Municipal Bus Stand, Mananthavady, Waynad.
2. M/s. Kalyan Traders, Kalpetta North, Waynad.
3. M/s. Rohini Sales & Services, Sulthan Bathery, Waynad.
4. M/s. Haritha Irrigation Equippments, Kumily Road, Kattapana, Idukki.
5. M/s. Jasmrik Spices (P) ltd., Kaloor, Kochi. Ernakulam.
6. M/s. Mas Enterprises, Vandenmedu, Idukki.

XVIII. M/s. Chaitra irrigations, KSSIDC 'B' Shed, KEB Office, Bellur Cross, Mysore, Tunkur Road, Nagamangala, Mandya, Karnataka. Ph: 08234 – 487664. Fax: 487388.

1. M/s. Winning Irrigation Systems, Kozlinsamborgi, pollachi, Main Road, Palakkad.
2. M/s. Staragencies, Kollengode, Palakkad.

XIX. M/s. Nargarjuna Palma India Ltd., L - Block, No. 227 A, First main Road, 21st street, Anna Nagar East, Chennai – 600102. Ph: 044 – 6632284.

1. M/s. Vaigai Agro Enterprises, Nellimedu, Meenachipuram, Chittoor, Palakad – 678533.
2. M/s. IAC Agro inputs, Kozhinjapara, Chittoor, Palakkad – 678533
3. M/s. Bharath irrigation, Civil Station road, Fort Maithanam, palakkad.

XX. M/s. National Organic Chemical Industries Ltd., Plastic Products Division, B 3 – Shreyas Apt., No. 3, Balakrishna Road, Mylapore. Chennai – 600004. Ph: 24985933, Fax: 24983945;.
Email: nocil@md4vsnl.com

1. M/s. Kalarickal Agencies (P) Ltd., Kalarickal bazaar, Kottayam – 686001. Ph: 0481 – 2560284.

XXI. M/s. Sudal Industries Ltd., No. 68, Industrial Area, Yeshwanthapur, Bangalore – 560022, Karnataka. Ph: 3371121, fax: 3372385.

1. M/s. Archana Enterprises, Main Road, Kalpetta – 673121, Waynad.
2. M/s. Kerala Engg. Agencies, B. Street, Mananthavady – 670645, Waynad.

ANNEXURE II

Area covered under drip irrigation in India as on March, 2004 (Sarma, 2005)

State	Area (ha)
Andhra Pradesh	39,500
Assam	200
Gujarat	10,000
Haryana	3,000
Karnataka	50,000
Kerala	7,500
Madhya Pradesh	3,800
Maharashtra	2,00,000
Orissa	3,000
Punjab	2,000
Rajasthan	35,000
Tamil Nadu	42,500
Uttar Pradesh	2,500
West Bengal	200
Others	2,000
Total	4,02,000

ANNEXURE III

Approximate cost of various components of micro irrigation

Sl. No.	Particulars	Specification	Amount (Rs.)
1	2	3	4
1.	Gravel filter B3	upto 15,000 lit/hr	13,160
	B5	upto 25,000 lit/hr	16,900
	B9	upto 45, 000 lit/hr	27,250
2.	Screen filter (metal)	upto 10,000 lit/hr	1965
		upto 15,000 lit/hr	2915
		upto 25,000 lit/hr	3725
		upto 45,000 lit/hr	4325
3.	Disc filter (2.5" size)	upto 25,000 lit/hr	7106
	(3" size)	upto 45,000 lit/hr	12483
4.	Hydraulic pressure pump		7000
5.	Venturi		1400
6.	Fertilizer tank		7750
7.	Gromate	16 mm	4.50
		12 mm	3.50
8.	Integrated drip line start connecter (Provided with compression ring & reducing start)		8.00
9.	End cap	16 mm	3.35
		12 mm	2.70

1	2	3	4
10.	Tap	16 mm	4.50
		12 mm	3.50
11.	Plug		0.70
12.	Drip Tee	16 mm	5.40
		12 mm	3.90
13.	Dripper (0.4 to 1 kg/cm^2)	4 & 8 lph	2.90
14.	Automatic self flushing dripper (High pressure compensating & flushing)		4.50
15.	Joiner/straight connecter	16 mm	4.50
		12 mm	2.55
16.	Lateral pipe –LLDPE (4kg/cm^2)		
	(Class I 1.3 mm thick)	16 mm	7.90
	(Class II 1.5 mm thick)	16 mm	8.50
	(Class I 1.3 mm thick)	12 mm	5.60
	(Class II 1.5 mm thick)	12 mm	6.00
	Main & sub main		
	PVC (4 kg/cm^2)	75 mm	65.85
	PVC (6 kg/cm^2)	75 mm	95.60
	PVC (4 kg/cm^2)	63 mm	46.50
	PVC (6 kg/cm^2)	63 mm	68.00
	PVC (6 kg/cm^2)	50 mm	40.25
	PVC (6 kg/cm^2)	40 mm	28.50
	PVC (10 kg/cm^2)	32 mm	26.50
	HDPE (4 kg/cm^2)	75 mm	119.50
	HDPE (3.2 kg/cm^2)	75 mm	101.30
	HDPE (2.5 kg/cm^2)	75 mm	83.00
	HDPE (4 kg/cm^2)	63 mm	88.80
	HDPE (3.2 kg/cm^2)	63 mm	72.80
	HDPE (6 kg/cm^2)	50 mm	79.40
	HDPE (4 kg/cm^2)	50 mm	56.70
	HDPE (6 kg/cm^2)	40 mm	52.00

ANNEXURE IV

Table A. Technical details of micro tube.

Length of micro tube (ft)	Operating pressure (m)				
	3	4	5	6	7
	Discharge (lph)				
1.00	7.63	9.20	10.64	11.97	13.24
1.25	6.69	8.06	9.32	10.50	11.60
1.50	6.00	7.24	8.37	9.43	10.42
2.00	5.07	6.11	7.06	7.95	8.79
2.25	4.75	5.73	6.62	6.46	0.24
2.50	4.45	5.36	6.20	6.98	7.72
2.75	4.22	5.09	5.89	6.63	7.33
3.00	4.00	4.82	5.58	6.28	6.94
3.25	3.80	4.59	5.31	5.97	6.60
3.50	3.65	4.41	5.10	5.74	6.34
3.75	3.50	4.22	4.88	5.50	6.08
4.00	3.38	4.08	4.71	5.31	5.07

The design tolerance of micro tube is 2m, at discharge variation of 20%

Table B. Technical details of PVC pipe

Pipe size		Flow range
mm	Inch	(lps)
20	0.5	0.07 – 0.13
25	0.75	0.13 – 0.25
32	1	0.25 – 0. 50
40	1.25	0.50 – 1.0
50	1.5	1.0 –1.8
63	2	1.8-3.0
75	2.5	3.0-5.0
90	3	5.0-8.0
110	4	8.0-15.0
140	5	15.0-20.0
160	6	20.0-30.0
180	7	30.0-40.0
200	8	40.0-50.0
225	9	50.0-60.0
250	10	60.0-70.0

Table C. Frictional losses for flow of water (in meters per 100 m pipe length) in smooth pipes (C= 140)

Discharge lps	Bore diameter (mm)									
	20	25	32	40	50	65	80	100	125	150
0.5	16.4	5.5	1.66	0.56						
1.0		10.0	6.0	2.0	0.68					
1.5			12.7	4.3	1.45	0.4				
2.0			16.0	7.3	2.50	0.68	0.25			
3.0				15.5	5.2	1.45	0.53			
4.0				26.4	8.9	2.5	0.90	0.3		
5.0					13.4	3.8	1.36	0.46		
6.					18.8	5.2	1.90	0.64	0.22	
7.0						6.9	2.50	0.84	0.29	
8.0						8.9	3.20	1.10	0.37	0.15
9.0						11.1	4.0	1.36	0.46	0.19
10.0						13.4	4.9	1.66	0.55	0.32

Table D. Length of straight pipe in meters giving equivalent resistance to flow in pipe fittings.

Sl. No.	Pipe size (mm)	Equivalent length in m				
		Elbow	Bend	Tee	Sluice valve	Foot/reflux valve
		Ks = 0.7	Ks = 0.12	Ks = 0.4	Ks = 0.4	Ks = 3.5
1	25	0.536	0.396	0.704	0.077	2.04
2	40	0.997	0.569	1.31	0.142	3.05
3	50	1.296	0.741	1.704	0.185	3.96
4	65	1.814	1.037	2.384	0.259	5.18
5	80	2.241	1.281	2.946	0.320	6.10
6	100	2.959	1.691	3.889	0.422	8.23
7	125	4.037	2.307	5.306	0.576	10.0
8	150	5.125	2.928	6.735	0.732	12.0

Table E. Peak water requirement of horticultural and commercial field crops (Guled, et.al, 1997)

Sl. No.	Crops	Plant population (per ha)	Water requirement lit/plant/day	M³/ha/day
1	Coconut	156	29-50	5-8
2	Sapota	156	37-57	6-9
3	Mango	69	55-94	4-7
4	Guava	400	8-13	3-5
5	Lime	494	10-17	5-8
6	Sweet Orange	278	17-29	5-8
7	Tamarind	100	55-94	6-9
8	Pomegranate	494	8-13	4-6
9	Ber	278	8-13	2-4
10	Fig	667	13-22	9-15
11	Banana	3,086	17-29	53-90
12	Grapes	3,086	14-24	43-74
13	Papaya	3,086	10-17	31-53
14	Cashewnut	156	40-68	6-11
15	Cocoa	1,111	12-20	13-22
16	Oil palm	124	29-50	4-6
17	Coffee	3,086	14-24	43-74
18	Mulberry	55,556	4-6	41-67
	Vegetable crops			
19	Cabbage	74,074	6-9	62-93
20	Onion	175,439	6-9	63-95
21	Peas (fresh)	333,333	6-11	60-110
22	Pepper (fresh)	29,630	6-10	60-101
23	Watermelon	3,704	8-14	30-52
24	Carrot	434,783	6-10	156-260
25	Tomato	22,222	7-11	70-110
26	Potato	100,000	6-11	60-110
	Commercial Crops			
27	Cotton	6,944	7-12	70-120
28	Groundnut	333,333	6-10	60-100
29	Sugarcane	37,037	7-12	78-133
30	Tobacco	18,519	3-6	30-60

Table F. Recommended number and discharge of drippers for different crops in different soils

Sl. No.	Crop	Spacing (ft x ft)	No. of dripper/ plant and discharge (lph)	Soil type	Peak water requirement (lit/day/plant)
1	2	3	4	5	6
1	Grapes	6 x 4	1 x 4	Light & medium	20-32
		8 x 6	2 x 4	Light & medium	
		8 x 8	2 x 4	Heavy	
		10 x 10	2 x 4	Heavy	

1	2	3	4	5	6
2	Pomegranate	10 x 10 12 x 12 15 x 15	2 x 4 2 x 4 3 x 4	Light & medium Light & medium Heavy	50-60
3	Guava	15 x 15 18 x 18	3 x 8 4 x 8	Light Medium	70-80
4	Sapota & Mango	25 x 25 30 x 30	4 x 8 4 x 8	Light & medium Heavy	150-200
5	Coconut	25 x 25 30 x 30	4 x 4 4 x 4	Light & medium Heavy	70-80
6	Lemon, Sweet Orange, Mandarine, orange	16x 16 18 x 18	4 x 8 4 x 8	Light & medium Heavy	80-120
7	Fig	10 x 10 15 x 15	2 x 4 3 x 4	Light & medium Heavy	50-60
8	Ber, Custard apple	10 x 10 25 x 25	2 x 8 3 x 8	Light & medium Heavy	50-60
9	Cashewnut	20 x 20 25 x 25	4 x 8 4 x 8	Light & medium Heavy	80-120
10	Banana	5 x 5 6x 4	1 x 4 1 x 4	Light Medium	16-20
11	Papaya	6x 6 7x 7	1 x 4 1 x 4	Medium Heavy	16-20
12	Tamarind, Amla	25 x 25 30 x 30	4 x 8 4 x 8	Light & medium Heavy	150-160

ANNEXURE V

Modification of crop geometry and its effect on B:C ratio of various crops irrigated through micro irrigation at different locations in India

Crop	Locations	Yield (tones/ha) under		B: C ratio with subsidy		B: C ratio without subsidy	
		Normal planting	Paired row planting	Normal planting	Paired row planting	Normal planting	Paired row planting
1	2	3		4		5	
Banana	Bhavanisagar	7.4	71.0	2.68	3.41	2.18	2.77
	Rahuri	69.0	65.0*	2.27	3.57	1.82	2.86
	Parbhani	73.0	73.0	2.43	3.67	1.98	2.89
Brinjal	Navsari	24.8	22.7	4.57	5.69	3.74	4.66
	Parbhani	27.3	24.3	4.04	5.98	3.28	4.86
Cotton	Rahuri	2.4	2.2	3.30	4.29	2.73	3.54
	Akola	2.8	3.0	3.21	4.57	2.55	3.63
	Parbhani	2.1	1.9	2.81	3.17	2.27	2.56
	Sriganganagar	2.3	2.4	2.57	3.07	2.05	2.46
Green chilli	Belvatgi	3.8	3.2	4.31	4.94	3.53	4.05
	Bhavanisagar	4.3	4.2	4.16	5.34	3.44	4.41
Goundnut	Madurai	1.8	1.7	2.47	3.19	2.01	2.59
	Rahuri	2.0	1.9	2.87	3.24	2.37	2.68
	Belvatgi	1.4	1.3	2.16	2.93	1.74	2.36

1	2	3		4		5	
Sugarcane	Sivganga	98.0	110.0	3.13	3.69	2.46	2.90
	Bhavanisagar	95.0	96.0	2.87	3.12	2.35	2.57
	Rahuri	112.0	147.0	3.21	3.58	2.53	2.82
	Navsari	89.0	93.0	2.64	2.89	2.11	2.31
Tomato	Rahuri	32.6	28.9	4.36	5.39	3.46	4.28
	Navsari	26.7	27.2	3.98	4.87	3.21	3.93
Average	–	37.2	39.0	3.20	4.03	2.59	3.26

* Triangular geometry
Source : AICRP (Water Management), Annual Report 1998-99, 2000-03, 2003-04, 2004-05)

GLOSSARY

Abbreviation	*Description*
<	Less than
>	Greater than
°C	Degree Celsius
ADO	Agriculture Development Officer
BIS	Bureau of Indian Standards
cc	Cubic centimeter
cm	Centimeter
DAO	District Agriculture Development Officer
Ep	Pan evaporation
et al	And others
FAO	Food and Agriculture Organization
ft	Feet
gm	Gram (s)
GOI	Government of India
gpm	Gallon per minute
ha	Hectare (s)
HDO	Horticulture Development Officer
HDPE	High density polyethylene
hp	Horse power
hr	Hour
inch	Inches
Int	International
K	Potassium
kg	Kilogram (s)
LDPE	Low density polyethylene
lit	Litre (s)
LLDPE	Linear low density polyethylene
lps	Litre (s) per second
m	Meter
m.ha	Million hector
m^3	Cubic meter
mg	Milligram
min	Minute (s)
mm	Millimeter
N	Nitrogen
P	Phosphorus
PE	Polyethylene
ppm	Parts per million
PVC	Polyvinyl chloride
sec	Second (s)
sq.m	Square meter