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Pepsee systems: grassroots innovation under groundwater stress

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Abstract

Drip irrigation, in its various forms, is the dominant mode of micro-irrigation in India. The benefits of these technologies in water scarce regions have been widely studied all over the world. A review of literature on drip-irrigation technologies strongly suggests that there are significant financial, economic and social benefits in the adoption of these technologies. However, the spread of drip irrigation in the Indian context has been far below potential and expectations. In the Maikaal region of Central India, a grassroots innovation called '*Pepsee*' has become a popular choice for farmers. At less than half the cost of conventional drip systems, this innovation promises comparable returns. What is most interesting is that while government and non-government agencies have struggled to promote water-saving technologies across the country, the people in this area have adapted and adopted these technologies on their own. This paper looks at the various aspects of this grassroots innovation, its spread, adoption behavior and impacts. The authors find that while *Pepsee* and other water-saving technologies do lead to farm level improvements in water efficiency, they will not contribute to system level 'real' water saving unless a favorable policy environment encourages their adoption on a large scale.

Keywords: Grassroots innovation; Low-cost drip irrigation; Maikaal; Micro-irrigation; *Pepsee* systems; Water saving

1. Introduction

Water scarcity poses serious threats to rural livelihoods and food security. Studies done by the International Water Management Institute, Colombo (Seckler *et al.*, 1998; Seckler *et al.*, 1999) have estimated that by the year 2025, one-third of the world population will face absolute water scarcity and amongst the worst hit areas would be the semi-arid regions of Asia, the Middle East and sub-Saharan Africa which is home to some of the largest concentrations of world poverty. Precision irrigation refers to a broad range of technologies and water management practices that enable farmers to use their limited water resources in a manner that increases the productivity of water (Sally *et al.*, 2000). Drip irrigation is one such technology through which water is applied directly at the root zone of the plants to reduce conveyance and application losses in comparison with the conventional flood irrigation method.

In India, drip irrigation technologies arrived in the 1970s from developed countries like Israel and the USA, where the technology is widely used by big commercial farmers. Preliminary research studies showed that other than water saving, the yields of crops using drip irrigation are substantially higher than crops irrigated by the flood method of irrigation (Narayanamoorthy, 1996b; Narayanamoorthy, 1997b; INCID, 1994; Magar *et al.*, 1998; Kulkarni, 1987). The Government of India, realizing the potential, released around US$2500,000[1] to state governments under centrally sponsored schemes between 1982–83 and 1991–92, for the promotion of drip, sprinkler and other water-saving irrigation systems and practices (Narayanamoorthy & Deshpande, 1997, 1998).

Given the many persuasive arguments in favor of drip irrigation systems, convincing financial and economical viability and the subsidies provided by the Government of India, one would have expected large-scale adoption of drip irrigation systems by farmers. This expectation, however, has so far been belied, as the drip-irrigated area is much less than 1% of total groundwater irrigated area (Dhawan, 2000). Ever since they were first introduced, the total area under drip irrigation has expanded rather sluggishly from 1500 ha in 1985 to a little over 70,000 ha in 1992 (see Table 1; INCID, 1994; Chakravarty & Singh, 1994; Narayanamoorthy, 1997a) and rapid growth has only been seen in recent years as the area spread to 225,000 ha in 1998 (Polak & Sivanappan, 1998). This, however, is still very low compared to an estimated potential of 10.50 million ha (Sivanappan, 1994). Even with up to 90% government subsidies in some cases (Kareem, 1999), the technology has failed to attract its target consumers in some of the most water-scarce regions of the country. It is still largely seen as the 'Gentleman' farmer's technology and is popular largely among large farmers in Maharashtra, and mostly for orchids and plantation crops (see Table 2, Table 3; Kannan & Gurumurthy, 1999; Shah & Keller, 2002). Some of the reasons for the sluggish growth pointed out in some of the research papers (Narayanamoorthy 1996a, 1997c; Sivanappan 1988; Dhawan 2000) are: (1) high initial capital investment; (2) lack of credit facilities and (3) lack of information.

Table 1. Area under drip irrigation – global scenario (1991).

Country	Area (ha)
United States	606,000
Spain	160,000
Australia	147,011
South Africa	144,000
Israel	104,302
Italy	78,600
India	70,859
All other countries	474,074
TOTAL	1784,846

Source: INCID, 1994.

[1] Currency conversion rate: 1 USA dollar (US$) = 48 Indian rupees (INR).

Table 2. State-wise area under drip irrigation.

State	Area (ha)	Percentage
Maharashtra	32,924	46.46
Andhra Pradesh	11,585	16.35
Karnataka	11,412	16.11
Tamil Nadu	53,57	7.56
Gujarat	3560	5.02
Other states	6021	8.50
TOTAL	70,859	100.00

Source: Kannan & Gurumurthy, 1999.

Table 3. Crop-wise area under drip irrigation.

Crops	Area (ha)	Percentage
Orchards	32,673.40	46.11
Plantation crops	11,799.60	16.65
Nuts	2,924.30	4.13
Vegetables	1,537.00	2.17
Other crops	21,924.70	30.94
TOTAL	70,859.00	100.00

Source: Kannan & Gurumurthy, 1999.

There is a strong notion among the farmers and sometimes within the micro-irrigation industry itself that drip is a technology suitable for big farmers. A buried strip drip system in the United States of America costs about US$ 1200 per acre (about the market value of an acre of irrigated land), will last for five to ten years and requires low-till, high herbicide agriculture (Seckler, 2003). The farmers in the Maikaal region have shaken this belief and have forced the drip irrigation industry to wake up to their demand. What is most interesting is that while most government and non-government agencies have struggled to promote water-saving technologies across the country, the people in this area have adopted and adapted these technologies on their own.

2. Genesis of the technology

In the 1990s, precision irrigation technologies penetrated into West Nimar and its adjoining districts though the intervention of International Development Enterprises (IDE) and through the informal channel of progressive farmers. IDE began its work with Maikaal Cotton Spinning Mills, an Indo-Swiss Company and bioRe (a subsidiary of Maikaal Cotton, promoting organic cotton cultivation in the Maikaal region of Madhya Pradesh). Some progressive farmers had already begun trying out the drip irrigation technology in cotton cultivation. IDE encouraged bioRe's member farmers to experiment with their micro-tube technology for drip irrigation. For various reasons, IDE moved out of the region; however, the seeds of water saving it had sown there have blossomed and borne fruit (Shah & Keller, 2002). While bioRe continues to promote micro-tube kits, they are too costly for most farmers who are unsure about the technology and are apprehensive and sometimes incapable of making the initial investments of US$150 per acre.

The recurrence of drought-like situation in the region for the last decade has worsened the problem of rapidly depleting groundwater resources and low purchasing power of farmers, compelling many farmers to look for an alternative less expensive technology which will not only enable them to take a summer crop with less water but also to increase water and land productivity. Many innovations were going on at the grassroot level to bridge the gap between technology and the cost factor. Innovations like using cycle tubes for drip irrigation and so on were carried out by farmers in some parts of Madhya Pradesh and Maharashtra. But these innovations were confined to a limited area and most of them failed to catch on, as they were not able to deliver the desired results. Around 1998–99, a new innovation called *Pepsee* came up in this area. It is not very clear how and exactly where the innovation first started but there did exist a very strong latent demand for a low-cost water-saving technology in the entire region over a long period of time.

Small candy manufacturers use light density plastics, disposable in nature, to fill ice candies, which are sold as "*Pepsee*" in the local markets. The plastic candy is transparent in nature and comes in a length of 20 cm. The candy manufacturers buy these plastics in continuous rolls and then the roll is divided into small lengths to make ice candy. The cost of the plastic rolls comes to around US$1.00 for the manufacturer and US$1.50 per kg for the farmer.

This plastic roll is today being used in place of the drip tubes and is placed directly at the root zone of the plants. The entire system is assembled locally and does not require great skill to prepare. The farmers started using the *Pepsee* system for irrigating cotton crop during the pre-monsoon season. Two years ago, a recycled-plastic version of the *Pepsee*, popularly known as Black *Pepsee*, came into the market. The farmers distinguished it from the earlier transparent product, which came to be known as White *Pepsee*. The Black *Pepsee* is cheaper and also removes the problem of algae attack that was a major problem with the earlier product. In the initial years, word of mouth was the main source of spread of the idea. As there was a strong latent need for low-cost water saving, the news about the new innovation spread among farmers like wild fire. The spread of *Pepsee* is mainly seen in the cotton growing belt on the border of Madhya Pradesh (West Nimar District) and Maharashtra (Jalgaon District). In the initial years, *Pepsee* was predominantly used only in cotton but over the years its use has spread to other crops like chilli, sugarcane and vegetables.

Pepsee systems (Figure 1) are low cost substitutes for drip irrigation systems made up of low density polythene ranging from 65–130 micrometers. In 2001, IDE India recognized the success of this grassroots innovation and came up with its own version of the *Pepsee*, aptly named "easy drip", and targeted largely at vegetable-growing farmers.

3. About the study

This study was conducted to explore the various aspects of the *Pepsee* system, its history and spread, to make a comparative technical/financial evaluation of *Pepsee* with conventional drip/micro-tube and flood irrigation techniques, to analyze the conditions and factors that lead to successful adoption of *Pepsee* systems and finally to suggest a marketing strategy for replication of the technology. The study was based on field visits, farmer surveys, and interviews with agricultural department staff, manufacturers and retailers of two districts, West Nimar and Jalgaon. These districts were selected

Fig. 1. 'White' and 'Black' *Pepsee* in use.

Table 4. Sampling plan.

Segment	Size					
	West Nimar		Jalgaon		Total	
	Planned	Actual	Planned	Actual	Planned	Actual
Pepsee adopters	30	27	30	27	60	54
Drip adopters	30	19	30	21	60	40
Non-adopters	30	30	30	33	60	63
Total	90	76	90	81	180	157

Notes: Planned – number of respondents approached with the questionnaire.
Actual – number of complete questionnaires actually used for analysis.

purposively, keeping in view the spread of *Pepsee* adopters. Cotton is the dominant crop for which *Pepsee* and micro-tubes are being used. The primary data thus collected were compiled and analyzed and a financial analysis was done with the help of four financial performance indicators for investment, i.e. net present value, internal rate of return, benefit-cost ratio and pay back period.

3.1. Survey and interview methodology

The farmer surveys conducted in the two districts covered three categories of farmers. These were:

- *Pepsee* adopters: *Pepsee* adopters are the farmers who have adopted and used *Pepsee* systems irrespective of whether or not they are or have been using other techniques.
- Drip adopters: Drip adopters are the farmers who have adopted and used conventional drip irrigation systems and/or micro-tubes but have never used *Pepsee* systems.
- Non-adopters: Non adopters are the farmers who have never used *Pepsee* or any other form of drip irrigation systems. These include both flood irrigators as well as furrow irrigators.

The sampling plan and actual number of interview schedules used for analysis is shown in Table 4. A total of 180 farmers were approached with the three sets of questionnaires developed for the three categories of farmers. A total of 157 questionnaires were included in the final analysis after some were rejected owing to incomplete data.

For the interviews with manufacturers and retailers, a checklist was used. The semi-structured interviews were conducted to understand the supply chain and the market dynamics of *Pepsee* systems. Around 10-12 retailers and manufacturers in Indore and Jalgaon were interviewed.

4. Perceived advantages and disadvantages

Pepsee systems have many potential advantages when compared with flood irrigation systems. Most of these advantages are related to the low rates of water application. It can be argued that the benefits are not unique to *Pepsee* irrigation systems but are common to drip and micro-tube irrigation systems. However, these advantages combined with the very low capital investment requirement and the low levels of technical sophistication make *Pepsee* systems unique. Compared to the micro-tubes and drip systems, benefits like water saving, reduction in weeds and savings in electricity are marginally less.

This is because unlike in micro-tubes and drips, where water is provided drop-by-drop, in the case of *Pepsee*, water flows out of the plastic pipes and more surface area under the plant is moistened than the drip. The advantage that is specific to *Pepsee* is the encouragingly low initial investment. The investment required for one acre of land under cotton (4 x 4 spacing) is as low as US$85. This is only 59% of the investment required for a similar cotton plot with micro-tubes and 22% of that for conventional drip systems.

Moreover, one of the major problems with micro-tube kits and drip systems is that some of their components, like micro-tubes and emitters, are prone to damage by rats and rodents during storage and these are very expensive to replace. In the case of *Pepsee*, this kind of risk does not exist because the system is used mostly for one season only.

Table 5 illustrates some of the advantages of *Pepsee* as perceived by cotton farmers in West Nimar and Jalgaon. Though the benefits are largely the same, there are differences in relative importance, which the farmers attribute to the different benefits. This difference in perception across the two areas for same technology is primarily because of early penetration of matching technologies like micro-tubes and drips in Maharashtra (Jalgaon). In West Nimar, technologies like micro-tubes and drip systems are relatively new and the numbers of adopters is also less. Most farmers of West Nimar look at micro-irrigation technologies only as a coping mechanism to groundwater stress. In Jalgaon, however, precision irrigation technologies have been popular for more than two decades and the farmers perceive other benefits such as higher yields, labour saving, as well.

Even with all the advantages listed above, *Pepsee* systems are not without problems. One of the major problems encountered under *Pepsee* is clogging of the holes of the plastic straw. This clogging is not caused by sand and other small particles, as in case of micro-tubes and drips, but by organic matter, bacterial slime, algae and/or chemical precipitates. The *Pepsee* straw can be used only for one year, in certain cases for two years (depending upon the size in micrometers). Since the *Pepsee* straw is very thin, after a few months it is easily burnt out by the scorching sun; high pressure of water can also tear off the straw. One of the other major problems faced by the farmers of West Nimar is that strong winds in the region blow away the *Pepsee* straw. However, farmers in West Nimar are overcoming this weakness in the system through various innovations like surrounding the straw with bricks and other local innovations. Other technical disadvantages of *Pepsee* include uneven distribution of water; the

Table 5. Perceived advantages of *Pepsee* systems in Jalgaon and West Nimar.

Advantages	Percentage of farmers who perceived this advantage	
	West Nimar	Jalgaon
Water saving	86.67	97.00
Electricity saving	73.33	83.33
Fewer weeds	70.00	83.33
Higher yield	66.67	90.00
Better quality yield	43.34	50.00
Labour saving	33.33	43.33
Better utilization of pesticide and fertilizers	33.33	20.00

Source: Primary Survey, 2002

Table 6. Perceived disadvantages of *Pepsee* systems in Jalgaon and West Nimar.

Disadvantages	Percentage of farmers who perceived this disadvantage	
	West Nimar	Jalgaon
Limited life period	87.00	93.00
High labour requirement	63.00	50.00
Fulfillment of water requirement	43.00	30.00
Low pressure	40.00	30.00
High water pressure	53.00	53.00
Control the follow	30.00	10.00
Fly away	43.00	3.00
Algae	0.00	10.00

Source: Primary Survey, 2002

problem of low pressure at tail end and high pressure at the head. Owing to high pressure at the head, the holes become bigger and more water flows out.

Table 6 illustrates some of the disadvantages of *Pepsee* as perceived by the farmers in West Nimar and Jalgaon. The limited life period of *Pepsee* is believed by 85 to 95% of farmers to be its biggest disadvantage. The high labour requirement and the fact that *Pepsee* cannot fulfil the water requirements of plants after a given stage are not actual disadvantages but differences in perception. In West Nimar, none of the farmers attempted to use *Pepsee* after the kharif season for two reasons: first, there is sufficient water available in the wells and second, they feel that the application of water drop-by-drop can fulfil the crop requirements only when the plant is small. There is generally perceived to be a high labour requirement by new adopters as the introduction of new technology unsettles their old system and routine of work. As the numbers of years of usage increases, they get accustomed to the new system and start seeing more of the benefits and find innovative solutions to overcome the drawbacks. This largely explains the differences between the perceptions in the two regions.

5. Reasons for adoption and non-adoption

The survey revealed the factors behind purchase decisions regarding *Pepsee* systems. The most widely perceived reason to adopt *Pepsee* (98.33% of the farmers perceive this benefit) was the fact that it led to significant water saving at the farm level (Table 7). The fact that *Pepsee* provides the benefits at less than half the price of micro-tubes and at one-fourth of the price of conventional drip systems

Table 7. Reasons for purchase of *Pepsee* systems.

Reason	Percentage of farmers
Energy saving	6.67
Higher yields	36.50
Labour saving	13.33
Water saving	98.33
Cheaper than drips	76.67

Source: Primary Survey, 2002

Table 8. Reasons for not purchasing *Pepsee* systems.

Reason	Percentage of farmers
Costly	51.67
No water	48.33
Sufficient water	21.67
Bothersome	15.00
Not easily available	5.00
Labour consuming	13.33
Flies away	13.33
No information	10.00

Source: Primary Survey, 2002

(76.67%) gives *Pepsee* a niche in the market and was a significant factor in the farmers' decision-making process. Other reasons for purchase included higher yields (36.50%), labour saving (13.33%) and energy saving (6.67%).

Surprisingly, even at these low costs, the majority (51.67%) of the non-adopters feel that the technology is too costly (Table 8). While another significant chunk of non-adopters (48.33%) complained that they did not have enough water to irrigate their fields even with the reduced water requirements in *Pepsee*. Nearly 22% of the non-adopters felt that they have sufficient water for their crops and hence do not feel the need for water saving. This is bound to change in the years to come. Fifteen percent of the non-adopters found the technology too bothersome. This can be interpreted in two ways. One, it could be that the scarcity which they face is not very great, or secondly, it could be that they face shortage of labour in their family. Around 10% of the non-adopters were either not aware of the innovation or did not have sufficient information about the technology. Another 5% complained that they had difficulties in obtaining access to the market for this technology.

6. Financial viability

Farmers' investment decisions depend primarily on subjective calculations of their incremental monetary costs and returns. Therefore, the incremental returns and costs as a result of installation of micro-tubes and *Pepsee* systems have been analyzed and compared. The benefits and costs that are non-financial and social in nature were excluded for the computation of financial performance indicators. Only labour cost was included, as a number of farmers hired labour for installation of *Pepsee* for the first time.

6.1. Investments required[2]

For cultivation of cotton (4×4 feet spacing) in one acre of land using *Pepsee* systems, the total initial investment was calculated to be US$93[3] (Table 9). This initial investment can be further reduced by

[2] The financial analysis has been done for cultivation of cotton in one acre of land. Investments do not include the cost of digging wells and installation of motor pumps as these costs are not specific to the adoption of these technologies and the farmer has to incur these costs even under flood irrigation.

[3] Initial investment in *Pepsee* includes the cost of the filter, INR 1,200, and is optional..

Table 9. Cost break-up of *Pepsee* system of irrigation.

Items	Unit	Rate/unit (US$)	Quantity required	Value (US$)	Total cost (%)
Lateral (*Pepsee* straw,16 mm)	kg	1.350	12	16.25	17.52
Filter (optional)	No.	25.000	1	25.00	26.96
Valve (2 inch)	No.	4.160	2	8.33	08.99
Grommet take-off (GTO)	No.	0.030	100	3.13	03.37
Jointer	No.	0.015	15	0.23	00.25
PVC pipe (2 inch diameter)	No.	3.330	10	33.33	35.94
Accessories (includes elbow, thread, end cap, etc.)	–		–	3.13	03.37
Cost of installation	Man days	0.830	4	3.33	03.59
Total				92.73	

Source: Primary Survey, 2002

26% as the farmer can use the technology without a filter. The main difference between the costs break-up of *Pepsee* systems and micro-tubes is the cost of micro-tube and the 12 mm lateral, which costs US$80. This cost is replaced by the *Pepsee* straw, which costs around US$16.

A look at the fixed and variable costs of *Pepsee* and micro-tubes (Table 10) indicates that variable cost is higher in case of *Pepsee* and every year a farmer needs to invest US$16.50, while in case of micro-tubes, once the initial investment has been made, the incremental investment in subsequent years is very low. *Pepsee* systems, therefore, spread the risk involved in investing in a new technology over a number of years and increase the motivation of farmers to experiment with water-saving innovations.

All four indicators (Table 11) reveal that investments in micro-tubes and *Pepsee* systems are financially viable and sound. The analysis also indicates that investments in micro-tubes are better than in *Pepsee*! Moreover, our primary data also indicates that benefits in terms of yields and water saving are also marginally higher in micro-tubes and conventional drip systems compared to *Pepsee* systems. Then, it is important to investigate why farmers have taken to *Pepsee* and have not adopted drips and micro-tubes?

The fast growing adoption rate of *Pepsee* corroborates the findings of other research work. The initial investment for *Pepsee* systems is 41% less than the same for micro-tubes and 78% less than the same

Table 10. Fixed and variable costs.

Heads	*Pepsee* (US$)	Micro-tubes (US$)
Fixed cost	72.92	154.69
Operations and maintenance cost[a]	3.33	2.50
Other variable costs	16.48	1.22
Total	92.73	158.41

Source: Primary Survey, 2002

[a] Amount may vary over years and across farmers.

Table 11. Financial indicators of *Pepsee* and micro-tube irrigation system[a].

	Cost level	*Pepsee*	Micro-tubes
Internal rate of return (%)	A	45.00	40.00
	B	38.00	39.00
	C	18.00	28.00
Net present value (US$)	A	114.85	188.69
	B	91.47	183.15
	C	20.07	102.68
Benefit cost ratio	A	1.51	1.82
	B	1.41	1.80
	C	1.10	1.43
Payback period		2.37	2.23

Source: Primary Survey, 2002

[a] Assumptions:

- The life span of *Pepsee* and micro-tubes' hardware (other than the *Pepsee* straw) is sometimes more than 10 years, but using conservative estimates for the purpose of financial calculations, we have taken 7 years.
- In order to minimize uncertainty, while calculating financial indicators, an inflation rate of 6% and a discount rate of 12% have been assumed.

for conventional drip systems. Since initial investment is low, the basic finance requirements are also reduced considerably. The third major reason – lack of information in terms of low level of awareness and inadequate knowledge about application, utility, methods of operation and maintenance, etc. – also holds as under these conditions, few farmers are likely to take the risk of a one-shot investment of US$158 per acre. However, the success of *Pepsee* systems indicates that the farmers are willing to experiment with innovations, if not constrained by financial limitations. The farmers' risk is spread across many years and in case they want to shift to micro-tubes or conventional drips in the future, they just need to make additional investments on laterals and micro-tubes. No *Pepsee* hardware will go waste!

7. Impact of adoption

Pepsee systems make pre-monsoon sowing possible. The provision of irrigation, made possible through the use of *Pepsee*, leads to a higher germination rate and lower incidence of pest attack. The impact of *Pepsee* on average cotton yields can be seen in Table 12. *Pepsee* systems also improve the chances for the farmers to take rabi (winter) crops. This is indicated by the fact that 30 of the 32 rabi cultivators in West Nimar and 28 of the 32 rabi cultivators in Jalgaon were *Pepsee* adopters. The early

Table 12. Average cotton yields per acre.

Category	Average cotton yield (kg/acre)	
	West Nimar	Jalgaon
Pepsee adopters	7.40	8.10
Drip adopters	7.62	9.60
Non adopters	3.60	5.02

Source: Primary Survey, 2002

Table 13. Difference in pumping between *Pepsee* adopters and flood irrigators.

Method of irrigation	Number of irrigations	Hours of irrigation/acre	Total hours of pumping
Pepsee	18	0.42	7.50
Flood	3	5.00	15.00

Source: Primary Survey, 2002

sowing of the kharif (monsoon) cotton crop also allows farmers to take rabi crops. Farmers also believe that there is a significant improvement in the quality of the harvest through the use of precision irrigation. This is due to the fact that each individual plant receives the correct quantity of water at regular intervals unlike in flood irrigation where farmers tend to over-irrigate or under-irrigate depending on the availability of water and power and not based on crop requirements.

One of the most frequently asked questions by groundwater managers and scientists is weather the adoption of *Pepsee* and other water-saving technologies can help alleviate the problem of groundwater depletion? To answer this, we compared the pumping behavior of a *Pepsee* adopter and a flood irrigator. Table 13 shows the difference in pumping behavior between the two.

There is a *notional* saving of 50% in terms of water used. Therefore, adoption of *Pepsee* does lead to more efficient utilization of water. However, the question of the impact on the depleting groundwater table is a tricky one. Adoption of *Pepsee* has in fact led to greater pumping of water in some cases, as it has helped farmers to undertake a summer crop of cotton which was not possible before the emergence of this innovation. Also, on average, there has been an increase in area under irrigation as a result of adoption of *Pepsee* of 2.20 acres per farmer. Farmers who could not irrigate at all without this innovation (and were thus not pumping any groundwater) are now able to use the limited amounts available for irrigation. The use of *Pepsee* is restricted largely to the pre-monsoon season. Post-monsoon, when there is sufficient water in the wells, farmers revert back to flood irrigation. Thus *Pepsee* adoption leads to more efficient utilization of water but not effective and sustainable management of groundwater resources.

The technologies enable poor farmers to bring larger areas under irrigation through improved farm-level water efficiencies but unless the higher efficiencies are achieved system-wide and all through the cropping season, they will not make a significant impact on the overall groundwater withdrawal.

8. The market

Apart from the survey of farmers, discussions with a number of retailers and manufacturers were also held in both West Nimar and Jalgaon. The purpose of these discussions was to understand the market dynamics and the supply chain of the innovation.

The market for *Pepsee* is totally demand driven and is growing fast as more and more retailers are getting into the business of selling *Pepsee* to cater for the increasing demand from the farmers. Till now, however, no manufacturer or seller is really pushing *Pepsee* as its share in their total business is only around one to 3% and the demand is seasonal in nature. Figure 2 identifies six different chains currently in operation in West Nimar and Jalgaon.

The supply chains in West Nimar and Jalgaon are different from each other. In West Nimar, the agriculture implements retailer has not assumed a significant role in the supply of *Pepsee* and hence the

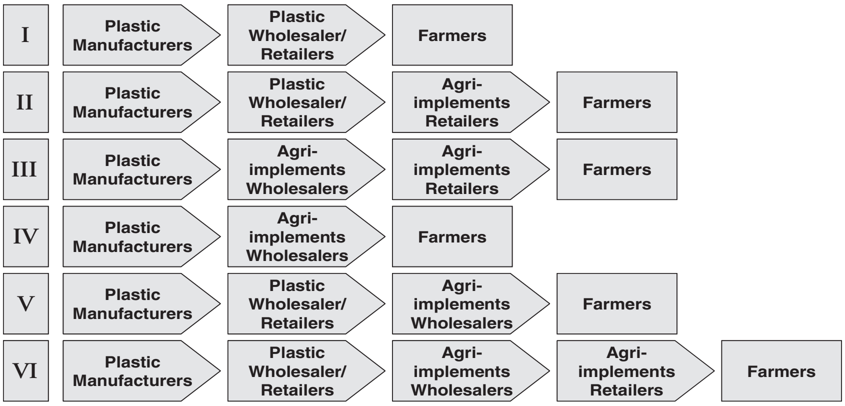

Fig. 2. Different supply chains of *Pepsee* systems.

prominent models are I and II, given in Figure 2. The plastic wholesale market is situated in Indore, which is around 100 km from the Maikaal region. The retailers take the orders from the farmers and deliver to farmers within two days. The transaction between retailers and plastic sellers in Indore is via the telephone and the plastic seller delivers it to the shop. The transportation cost is approximately US$0.125 per 30 kg box.

The small retailers in the villages get *Pepsee* directly from Indore and sell in the villages. They charge around US$1.50 per kg for the straw. The accessibility of farmers to the wholesale market is a problem in West Nimar and this has created problems for the farmers in terms of price discrimination and the variable quality of the product. Also, the range of products available to the users is limited. Models I and IV are more prominent in Jalgaon. There is a greater accessibility for farmers to the wholesale market and the farmers have greater choice in terms of thickness and quality. There is no specific brand for *Pepsee* as such in West Nimar but in Jalgaon the market is more developed and there are a number of brands that are adaptations of *Pepsee*. Black *Pepsee*, which is the thicker version of *Pepsee* and is made of recycled plastic, is also available in Jalgaon.

9. Promoting micro-irrigation in India

The greatest concentrations of poverty in the world are found in rural South Asia. The majority of poor farmers in this region lack access to appropriate and affordable irrigation. *Pepsee* systems offer an enormous opportunity to expose the poor to the benefits of appropriate drip irrigation technologies under conditions of groundwater stress.

Micro irrigation technologies have been around in India for more than 25 years and several studies have highlighted the advantages of adopting these technologies. However, the technologies have failed to capture the kind of market share that would have been expected given the numerous advantages and significantly positive financial returns. Shah and Keller (2002) highlight two distinct aspects of low-cost micro-irrigation in India and Nepal: (1) Poverty focus, in terms of enhancing income and quality of output for poor farmers; and (2) market development, in terms of ensuring the survival of distressed agrarian economies facing both water and energy crises. *Pepsee* systems have not only helped farmers

Table 14. Overview of *Pepsee* systems.

Strengths	Weaknesses
Low cost	Limited life period and delicate
Low initial investment	High labor requirement
Risk spread over number of years	High replacement cost of *Pepsee*
Skill requirement is less	Cannot withstand high pressure of flow
Shift to micro-tube and drip feasible	Unequal distribution of water
Fewer transportation and storage problems	
Opportunities	**Threats**
Scope for improvement	Non-standardization in product
Latent demand for water saving	Non-performance of early adopters
Involvement of agencies for replication	Decreasing price of micro-tube and drip
Manufacturing process available everywhere	Environmental problems with polythene
Shift from flat to metered electricity billing	

in the Maikaal region in ensuring the sustainability of irrigated agriculture under worsening conditions of groundwater stress, but have also expanded the potential market of micro-irrigation technologies through significant cuts in the investments required for adoption.

The grassroots innovation offers a very high potential for promoting water-saving technologies among the poor. What is required at this stage is a concerted effort to disseminate the success achieved by the farmers in West Nimar and Jalgaon to poor farmers around the country. Table 14 gives an overview of the strengths and weaknesses of and opportunities and threats for *Pepsee* systems.

The limited growth of micro-irrigation technologies in India so far can, to a large extent, be explained by the apparent gap between what has been marketed and where the demand lies. Over the years, government as well as non-government agencies have been promoting micro-irrigation as a "new concept in agriculture" through a "package solution" with the following salient features: (1) water saving; (2) good pay back period and internal rate of return; (3) customized and highly sophisticated technology; (4) higher yields and better quality of output; and (5) labour saving. The farmers, on the other hand, have different priorities and concerns. They demand solutions and technologies that would provide them with: (1) assured returns; (2) lower costs; (3) simple technology; (4) generic applicability; and (5) higher and better yields with fewer pumping hours. Clearly, there is an urgent need to bridge this demand–supply gap.

10. Conclusions and lessons for policy makers

The success of *Pepsee* systems marks the "next" phase of growth in the micro-irrigation industry. The farmers in Maikaal have shown the way to bridging the apparent demand–supply gap. There are significant lessons for policy makers and promoters of water-saving technologies from the Maikaal experience. These can broadly be listed as below.

10.1. Inputs versus capital investments

There is a need to view water-saving technologies as recurring but much lower input costs rather than capital investments that offer returns over the next eight to ten years. If the small farmers are to be targeted, policy makers must understand that they would be hesitant in making huge capital investments in new technologies unless they are very sure of their results. Even when they are convinced about the returns, they might not be in a position to incur the huge capital costs owing to poor access to good quality credit options.

10.2. Demystification of technology

There is a need to transfer the technology into the hands of the users. Some of the most successful experiments are done, not by scientists in the labs, but by farmers in their backyards and fields. Unless the farmers feel totally comfortable and competent in handling the technology intended for them, there is little chance that even 60–70% subsidies would bring the desirable results.

10.3. Building in modularity

Pepsee systems are not complete substitutes for highly sophisticated drip technologies. Even our financial calculations and survey results indicate that the returns offered by micro-tubes and drip kits are higher that those offered by *Pepsee*. However, if *Pepsee* systems are viewed as a “stepping stone” to adoption of a higher degree of sophistication and higher cost technologies and if these technologies are designed in such a way that the transition is made simple and modular, the results can be very positive. Six of the eight farmers who discontinued the use of *Pepsee* after one to two years shifted to IDE’s micro-tubes. Thus, there are indications that as the farmers are convinced about the results, become familiar with the technology and possibly also improve their financial status in the process, they will shift to the more efficient technologies being marketed today.

10.4. Operating strategies

In 2001, IDE started working on their own improved version of *Pepsee*, aptly named “Easy Drip”. This is a very encouraging sign, as the presence of a professional agency would definitely help the innovation to spread to new areas. Since the technology is in the nascent stage, there is a need to focus on three things: (1) product quality – both in terms of consistency and standardization as well in terms of longevity of the product; (2) ensuring easy availability through a reliable channel; and (3) creating demonstrations of success in the target group.

10.5. Where to promote

While promoting micro-irrigation, it is imperative that the nexus between energy and irrigation be kept in mind. Micro-irrigation technologies have tended to become popular where between water and energy, water is scarcer. In Maikaal also, people have responded positively to water-saving technologies as they did not have enough water to run their pumps for the available hours of electricity supply. If, on the other hand, the power supply were the critical resource, people would prefer to run their pumps for every hour that electricity is supplied. Ignoring this critical nexus could lead to undesirable gaps in policy tools and results. A detailed discussion of the different aspects of this nexus is available in numerous studies done by the IWMI-Tata Water Policy Program group (Shah *et al*., 2003; Kumar 2002; Kishore & Verma 2002; Kishore *et al*., 2002) among others.

10.6. Water saving?

Does micro-irrigation really save water? From what has been observed in Maikaal, adoption of these technologies does lead to improved water efficiency at the individual farm level. However, unless the technologies are adopted on a large scale, the impact would not be significant at the basin or sub-basin level. Can pre-monsoon adoption of *Pepsee* lead to basin-level water saving in the long run? Our contention is that as farmers begin to experience (and perceive) the entire range of benefits offered by micro-irrigation (higher yields, better quality of output, etc), they would use these technologies throughout the cropping season, and in the long run *Pepsee* and other water-saving systems would become a routine farming practice rather than a short-run water-stress coping mechanism. It is only then that these technologies would lead to basin-level water saving. Now, it is for the policy makers to use this opportunity and promote this transition by providing an enabling policy environment.

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References

Chakravarty, S. & Singh, L. B. (1994). Water economy through drip irrigation. *Proceedings of the 20th WEDC Conference*. Colombo, Sri Lanka. http://www.lboro.ac.uk/departments/cv/wedc/papers/20/sessiong/chakrava.pdf

Dhawan, B. D. (2000). Drip irrigation: evaluating returns. *Economic and Political Weekly*, October 14, 3775–3780.

INCID. (1994). *Drip irrigation in India*. Indian National Committee on Irrigation and Drainage, New Delhi.

Kannan, S. & Gurumurthy, S. (1999). Drip irrigation and water management. *Yojana*, February, 15–16.

Kareem, A. A. (1999). Micro-irrigation: Need of the 21st century for conserving water resources. In: *ICID*, *17th Congress on Irrigation and Drainage*. Granada, Spain.

Kishore, A. & Verma S. (2002). What determines pumping behaviour of tube-well owners: marginal cost or opportunity cost? *IWMI-Tata Water Policy Research Highlight, No. 6*. IWMI-Tata Water Policy Program, Anand.

Kishore, A., Sharma, A. & Scott, C. (2002). Power supply to agriculture: reassessing the options. *IWMI-Tata Water Policy Research Highlight, No. 7*. IWMI-Tata Water Policy Program, Anand.

Kulkarni, S. Y. (1987). Sprinkler and drip irrigation system. *Sinchan*, **6**(3), October, 56–61.

Kumar, D. M. (2002). Micro management of groundwater in North Gujarat. *IWMI-Tata Water Policy Research Highlight, No. 5*. IWMI-Tata Water Policy Program, Anand.

Magar, S. S., Firke, N. N. & Kadam, J. R. (1988). Importance of drip irrigation. *Sinchan*, **7**(2), October, 61–62.

Narayanamoorthy, A. (1996a). Impact of drip irrigation on consumption of water and electricity. *The Asian Economic Review*, **38**(3), December, 350–364.

Narayanamoorthy, A. (1996b). *Evaluating Drip Irrigation System in Maharashtra*. Mimeograph Series No. 42, Agro-Economic Research Centre, Gokhale Institute of Politics and Economics, Pune, Maharashtra, March, pp. viii+114.

Narayanamoorthy, A. (1997a). Economic viability of drip irrigation: an empirical analysis from Maharashtra. *Indian Journal of Agricultural Economics*, **52**(4), October–December.

Narayanamoorthy, A. (1997b). Drip irrigation: a viable option for future irrigation development. *Productivity*, **38**(3), October–December, 504–511.

Narayanamoorthy, A. (1997c). Beneficial impact of drip irrigation: a study based on western India. *Water Resources Journal*, **195**, 17–25.

Narayanamoorthy, A. & Deshpande, R. S. (1997). Efficient water management through drip irrigation: some evidences from Western India. In: *ICID, The Tenth Afro–Asian Regional Conference Proceedings: Water and Land Resources Development and Management for Sustainable Use*, Denpasar, Bali, Indonesia, 19–24 July.

Narayanamoorthy, A. & Deshpande, R. S. (1998). *Economics of Drip Irrigation: A Comparative Study of Maharashtra and Tamil Nadu*. Mimeograph Series No. 47, Agro-Economic Research Centre, Gokhale Institute of Politics and Economics, Pune, Maharashtra.

Polak, P. & Sivanappan, R. K. (1998). The potential contribution of low cost drip irrigation to the improvement of irrigation productivity in India. *India – Water Resources Management Sector Review, Report on the Irrigation Sector*. The World Bank in Cooperation with the Ministry of Water Resources, Government of India.

Sally, H., Sakthivadivel, R. & Molden, D. (2000). More crop per drop: considerations for precision irrigation in a basin context. Paper presented at the *6th International Micro-Irrigation Congress, "Micro-irrigation Technology for Developing Agriculture"*, Capetown, South Africa, 22–27 October 2000, 10pp.

Seckler, D. (2003). Personal communication.

Seckler, D., Amarasinghe, U., Molden, D., de Silva, R. & Barker, R. (1998). *World Water Demand and Supply, 1990 to 2025: Scenarios and issues*. Research Report 19. Colombo, Sri Lanka. International Water Management Institute (IWMI).

Seckler, D., Baker, R. & Amarasinghe, U. A. (1999). Water scarcity in the twenty-first century. *International Journal of Water Resources Development* (Special Double Issue: Research from the International Water Management Institute (IWMI)), **15** (1/2), 29–42.

Shah, T. & Keller, J. (2002). Micro-irrigation and the poor: A marketing challenge in smallholder irrigation development. In: Sally, H. & Abernethy, C. L. (Eds.), *Private Irrigation in Sub-Saharan Africa: Regional Seminar on Private Sector Participation and Irrigation Expansion in Sub-Saharan Africa*, Accra, Ghana, 22–26 October 2001. Colombo, Sri Lanka: IWMI; FAO; ACP-EU Technical Centre for Agricultural and Rural Cooperation, pp.165–183.

Shah, T., Scott, C., Kishore A. & Sharma A. (2003). *Energy–Irrigation Nexus in South Asia: Improving Groundwater Conservation and Power Sector Viability*. Research Report 70. International Water Management Institute, Colombo, Sri Lanka.

Sivanappan, R. K. (1988). Use of plastics in drip irrigation. *Moving Technology*, **3**(4), August, 7–9.

Sivanappan, R. K. (1994). Prospects of micro-irrigation in India. *Irrigation and Drainage Systems*, No. 8, 49–58.

Verma, S. (2003). More crop per drop: Can micro-irrigation help alleviate groundwater depletion? *Proceedings of the 3rd World Water Forum*, *"Groundwater governance in Asia: The challenge of taming a colossal anarchy"*, Kyoto, Japan, 16–23 March 2003.