A low cost drip irrigation system for small farmers in developing countries

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A LOW COST DRIP IRRIGATION SYSTEM FOR SMALL FARMERS IN DEVELOPING COUNTRIES[1]

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ABSTRACT: In areas where water is scarce, drip irrigation provides the most efficient way to conserve irrigation water, but its cost of $1000 an acre is prohibitive for most small farmers in developing countries. The cost was reduced by 90 percent by (1) making dripper lines moveable, so that each line reaches ten rows instead of one; (2) replacing 25-cent emitters with simple 0.70 mm holes punched by a heated needle; and (3) using $3.00 off-the-shelf 20 liter containers with cloth filters in place of expensive filter systems. This reduced the cost of a half-acre system to $50. The low cost system was field tested in the hill areas of Nepal, and in mulberry cultivation in Andhra Pradesh, India. Uniformity of flow from emitters was 73-84 percent. Small farmers reported that the low cost trickle irrigation system cut labor requirements in half, and doubled the area irrigated by the same amount of water. The low cost drip system is likely to be widely adopted by small farmers in semi-arid and hilly regions.
(KEY TERMS: economics; irrigation; water conservation; water management; drip irrigation; trickle irrigation; low cost; developing countries.)

INTRODUCTION AND BACKGROUND

Many irrigated areas in the world are running increasingly short of water (Bucks, 1995). With growing competition between farmers who need to irrigate their crops and the world's rapidly expanding cities, water saving forms of irrigation are at a premium (Postel, 1992). Drip irrigation, the most efficient form of irrigation currently available, now irrigates a little under two million hectares. This is less than one percent of global irrigated acreage. The main obstacle to its wider adoption is its high capital cost (Postel, 1996) – about $1,000 (U.S.) per acre for row crops like vegetables. This makes installation of drip systems prohibitive for the great majority of farmers in developing countries who cultivate less than five acres.

In the language of economists, existing drip irrigation technology is not "divisible," that is it cannot be divided into very small functional units. A typical small farmer in India cultivates five plots ranging in size from one fifth of an acre to a half acre. Biological technologies, like Green Revolution seeds and fertilizer, are divisible because they can be split into small affordable packets that fit tiny plots. But drip irrigation systems, like other current irrigation technologies, are difficult to customize to meet the needs of the small plots of poor farmers, and they are too expensive to be affordable.

The development of a reliable low cost drip system that fits the needs of small farmers in developing countries has long been recognized as a critical need (Hillel, 1985; Saksena, 1995; Nir, 1995). For example, Sivanappan and his colleagues tested the use of holes instead of emitters in India in the 1970s (Sivanappan and Padmakumari, 1980). To meet the need for a low cost system, International Development Enterprises, a non-profit organization specializing in small scale irrigation, has developed and field tested a simplified drip system that is divisible, and costs $250 a hectare ($50 for a one-half acre unit).

DESIGN OF LOW COST DRIP SYSTEM

The key contributors to cost for a standard drip irrigation system are: (1) the system of drip lines delivering water to each row of plants, (2) hundreds of 25-cent plastic emitters delivering water at each drip point, and (3) a filter system at the water intake point.

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For small farmers, IDE reduced the capital investment in drip lines by making them mobile. One movable drip line serves 10 rows of plants instead of one (Figure 1). Emitters are replaced by holes in the plastic emitter lines made by a 0.70 mm heated punch, the same size as an ordinary safety pin. Small farmers can then use a safety pin to manually clear any holes that become plugged. To prevent spraying at each hole, a simple baffle is fabricated from a 6 cm length of drip line split horizontally and snapped over the hole (Figure 1; Dripper Detail). The expensive filtration system of standard drip systems is replaced by an off-the-shelf, three-dollar 20-liter plastic tank placed at a height of two meters above the field, with a nylon cloth acting as a filter at the water entry point. These changes reduce the cost of a system from $2,500 to $250 per hectare. A proof-of-concept prototype system was fabricated in Nepal functioned satisfactorily and was followed by trials carried out in farmers' fields.

A LOW COST DRIP SYSTEM FOR MULBERRY CULTIVATION IN INDIA

In southern India, 350,000 hectares of mulberry produce leaves used to feed silkworms in the sericulture industry. Sixty percent of mulberry growers in India cultivate less than one and one half acres. Cocoon yield from irrigated mulberry is three times that of rainfed plants. Tests of standard drip irrigation for mulberry revealed a 40-60 percent savings in water requirements and increased leaf yield compared with flood irrigation.

IDE installed a low cost drip irrigation system on one half an acre of mulberry at a Andhra Pradesh State Sericulture Research Farm near Hyderabad (International Development Enterprises, 1995). A standard drip system was installed adjacent to compare the two systems. The climate at the test site is semi-arid and water is supplied by a submersible pump in a 230 foot tubewell.

Initial observations indicated that mulberry plants irrigated by the low cost drip system demonstrated a less uniform growth rate than plants irrigated with the standard drip system. Holes in the drip line produced by a hand-held punch were not sufficiently uniform, producing differences in drip rates and mulberry plant growth rates. The manual punch method was replaced by a lever operated bench machine using a 0.70 mm punch heated by a soldering machine. This produced an acceptable standard of uniformity of drip holes. The low cost system required two man hours a day more than the traditional system to move the drip lines and keep the emitter holes clear.

IDE and Swiss Development Co-operation (SDC) are now collaborating on a three-year initiative to further refine the application of low cost drip irrigation to mulberry cultivation and broadly disseminate it to small mulberry farmers in Andhra Pradesh, Karnataka, and Tamil Nadu. We estimate sufficient market demand for the low cost drip system in Southern India to irrigate 75,000 hectares of mulberry.

A LOW COST DRIP SYSTEM FOR VEGETABLE PRODUCTION IN HILL AREAS IN NEPAL

The middle hills of Nepal are governed by a monsoon climate. While there is more than adequate moisture during the rainy season from June to September, there is inadequate rainfall for most crops during the rest of the year. There are, however, large numbers of rivers, streams, and springs which flow throughout the year. These sources can be tapped to irrigate winter dry season crops. With drip irrigation, water sources previously considered too small for irrigation can now be utilized. Water from existing sources like canals can be extended to irrigate twice as much land as is possible under flooding.

The first of these systems was installed on one half an acre of vegetables at an agricultural Research Station outside Kathmandu. Tests were run on uniformity of flow from the drip holes, head losses in the drip lines, and uniformity of flow from one terrace to the next. Uniformity of dripper flow within terraces was found to be 84 percent within terraces, and 73 percent across all terraces varying in head from 2-4 meters. This was judged to be adequate (Table 1). It was also found that lateral length could go up to 75 meters without significant head losses.

The variations in pressure produced by hill terraces at differing elevations was addressed by designing and testing a series of push-on plastic orifices which the farmer could insert at the head of lateral lines at lower elevations to reduce pressure (Figure 1; Orifice Detail). Each pressure reducing orifice was made in a different color so a farmer could pick blue for an elevation difference of 2 meters, red for 4 meters, and so on. With this change, the system was ready for on-farm field tests.

Ten systems were installed over a period of two months on small farms in hill areas west of Kathmandu. Farmers with some experience in vegetable production, farming small plots of land, with access to a small source of water were selected. The results of these trials were extremely encouraging. All the

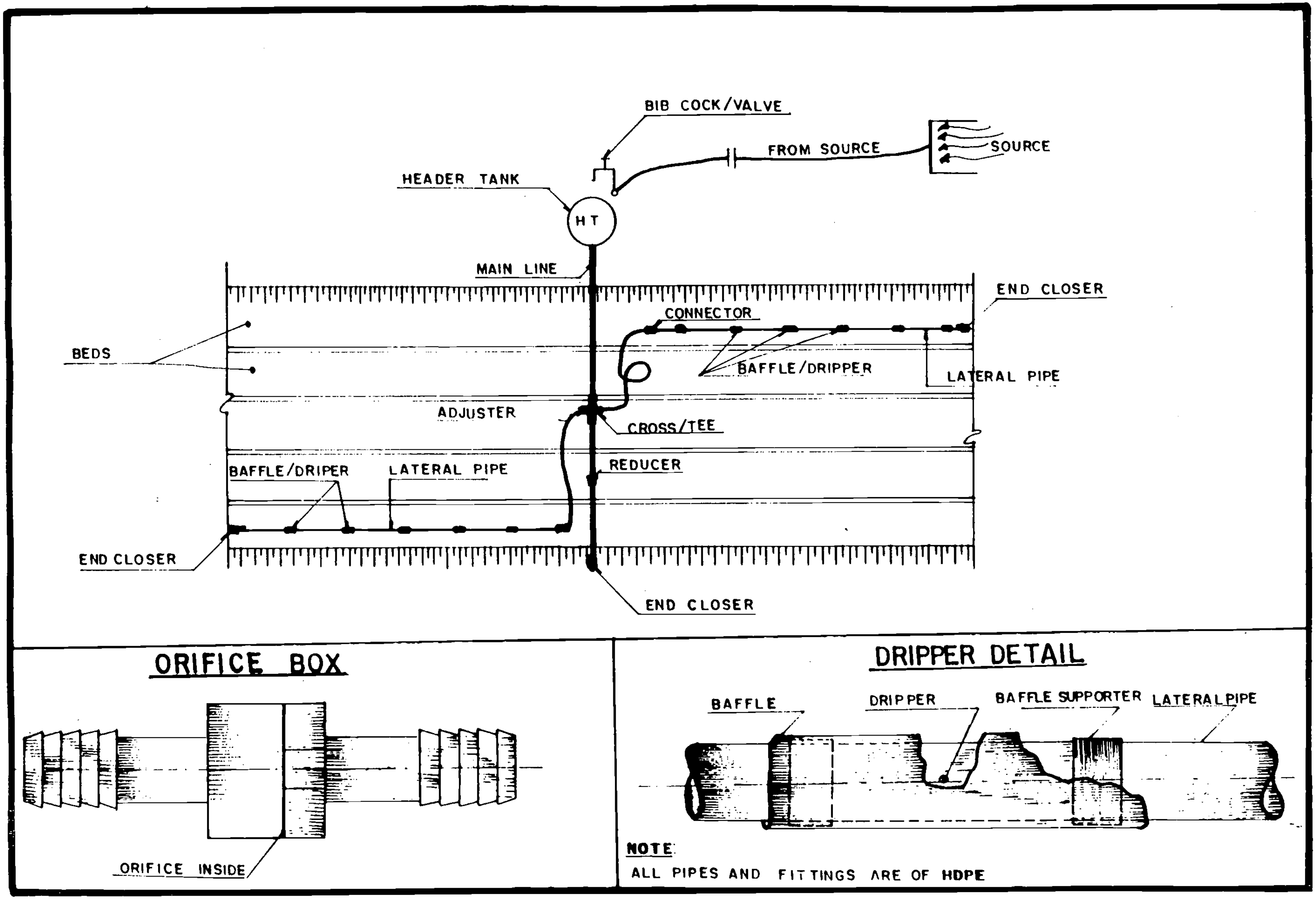

Figure 1. Typical Layout Plan of Low Cost Drip Irrigation System.

farmers were able to readily handle and adapt to the management of the system. Farmers who had been watering by hand found a tremendous saving of time and labor. One farmer, who used the system to irrigate fruit trees on a steep slope, found that he could now irrigate 20 trees at a time instead of walking up and down the slope each time he moved the hose from one tree to another. Another farmer who previously used flood irrigation noted a significant decrease in soil compaction.

All farmers at least doubled their irrigated area as a result of introducing the drip system, and some increased irrigated area by as much as four times. At the same time, they reported that the labor requirements for irrigation were cut in half. An investment of $50 in the drip system increased annual income by $50-$170. Participating NGOs reported a waiting list to purchase 100 additional systems by neighbors of two demonstration farmers. IDE and its partners are now implementing local manufacture and grass roots dissemination of the low cost drip system to small farmers in the hill areas of Gorkha and Tanahun.

UNIFORMITY OF EMITTER FLOW

While numerous field studies have verified the superior performance of drip irrigation systems in economizing water use (Chandia *et al.*, 1995), evaluations of its capacity to apply water uniformly have produced mixed results (Hansen *et al.*, 1995). For example, 11 out of 19 drip systems evaluated in Florida had emission uniformity less than 90 percent, compared with only 12 out of 57 microsprinkler systems. (Yurgalevitch *et al.*, 1995). The Bureau of Indian Standards (BIA) has set a standard of no more than 5 percent variation for class A emitters. Manufacturers in India, like those in other countries, have great difficulty in meeting this standard (Chauhan, 1995). The American Society of Agricultural Engineers (ASAE) has recently specified standards as "excellent" for coefficient of variation for emitters of less than 5 percent, and "average" for variation from 11 to 15 percent.

Tests of uniformity in the IDE low cost drip systems found a 12 to 29 percentage variation from hole to hole at heads varying from two to four meters (Table 1).

A number of studies of standard drip systems have found that clogging of drippers and variations in line pressure make significant contributions to emitter variance. For example, an evaluation of standard drip systems installed in the Indian state of Maharastra found emission uniformity of less than 50 percent in installations in steep or hilly areas, particularly if the system used an inappropriate pumpset and contour mapping was not used (Holsambre, 1995).

The IDE low cost system uses simple color-coded pressure reducers (Figure 1) which can be installed by the farmer to equalize pressure for lower terraces in hilly areas. The dripper holes are designed to be the same diameter as that of a standard safety pin and farmers are taught to regularly check drip lines and clear any holes that may have become plugged. The simplicity of clearing plugged holes make it possible to reduce the investment in filter systems. We anticipate the ease of clearing plugged holes combined with the use of color coded push-on pressure regulators will provide long term advantages in emitter discharge uniformity, but this can only be determined by more extended field tests.

GLOBAL APPLICATION

Modern surface microirrigation emerged from Israel in the 1960s, and now irrigates close to two million hectares. Lowering its capital cost from $2500 to $250 a hectare will likely at least double its global adoption, and the adoption curve for low cost trickle systems will favor small farmers. In addition to mulberry and vegetable crops, the low cost system will prove attractive for small farmer cultivation of herbs, horticultural crops, cotton, and sugar cane. It will be especially applicable in areas where irrigation water has high value, such as semi-arid areas in India and Sub-Saharan Africa. It is appropriate for small farms in hill regions such as Himalayan hill areas, and in semi-arid regions like Sub-Saharan Africa. It will be especially useful for canal systems producing insufficient water to cover irrigable land in the canal distribution area (Sawleshwarker, 1995).

DISCUSSION AND CONCLUSIONS

The Green Revolution has tripled the global harvest of cereals in the past thirty years, yet serious obstacles block the access of small farmers to high yielding seeds and fertilizers. While biological agricultural technologies are divisible and for the most part neutral with respect to farm size, mechanical technologies are for the most part not divisible and their distribution strongly favors large farmers (Hayami *et al.*, 1985) The lack of divisibility in irrigation technology is the most important barrier to increasing the harvest of small farmers.

The recent development and mass marketing of affordable and efficient human and animal powered

TABLE 1. Dripper Discharge Calculations.

Hole Specification: 0.70 mm diameter and 75 cm apart (made with heated punch).
Lateral Specification: HDPE pipe with 16 mm and 13.6 mm outer and inner diameter, respectively.

Expt. Site: Agro-Farm Kathmandu, Nepal
Date: February 1995

	Dripper Discharge Calculations											
	Lateral No. 1			**Lateral No. 2**			**Lateral No. 3**			**Lateral No. 4**		
Drip Hole No.	**H = 2 m**	**H = 3 m**	**H = 4 m**	**H = 2 m**	**H = 3 m**	**H = 4 m**	**H = 2 m**	**H = 3 m**	**H = 4 m**	**H = 2 m**	**H = 3 m**	**H = 4 m**
1	6.30	8.40	10.15	6.00	7.44	10.15	6.30	8.88	11.35	5.25	6.60	8.95
2	6.00	7.92	9.69	6.90	8.16	12.00	5.55	8.16	10.15	5.40	7.20	8.58
3	7.05	8.40	11.08	4.80	8.16	10.15	7.65	10.20	12.92	6.15	8.16	10.15
4	6.00	7.80	8.95	5.70	8.40	7.85	6.30	8.88	11.54	5.85	768	9.97
5	6.00	7.68	8.86	7.50	9.72	11.54	6.75	8.88	11.82	6.00	7.80	9.78
6	7.65	10.08	12.46	6.75	10.20	9.69	6.30	8.40	9.23	6.45	8.40	10.62
7	7.20	9.96	12.46	7.50	8.52	9.88	7.05	9.12	12.00	6.45	8.40	10.62
8	6.00	7.68	9.05	6.30	9.00	11.82	6.75	9.00	10.15	7.50	10.44	12.92
9	6.00	7.80	9.23	5.25	6.00	8.58	8.25	11.28	14.31	5.40	7.32	9.23
10	6.75	8.04	10.15	5.40	8.16	9.23	6.60	9.00	11.82	8.55	11.64	13.85
11	6.90	8.64	11.08	6.75	8.40	9.05	6.60	8.88	12.46	6.00	8.16	10.43
12	6.15	7.68	9.23	4.95	6.00	8.12	7.65	10.20	12.92	7.65	10.44	12.92
13	5.85	7.44	8.86	5.10	7.80	8.12	7.05	9.60	12.92	6.60	8.88	11.26
14	6.75	9.00	8.31	6.90	9.00	11.623	6.75	7.08	10.25	7.95	10.68	13.85
15	4.20	8.76	10.34	7.20	9.48	11.82	5.10	8.28	11.08	6.45	8.64	11.08
16	7.95	10.20	12.92	6.30	9.60	9.97	5.25	5.64	6.92	6.60	8.88	11.82
17	7.80	10.80	13.02	5.70	8.04	9.78	5.10	6.96	7.38	7.95	11.04	13.85
18	5.70	7.56	9.32	4.80	6.60	10.25	5.55	7.44	9.05	6.75	9.00	12.00
19	6.75	8.64	10.62	6.00	8.04	8.95	5.85	7.80	10.15	7.05	9.84	12.92
20	6.45	8.40	10.43	7.50	9.60	10.25	4.50	6.48	7.94	7.20	9.84	13.11
21	6.75	8.52	11.08	7.50	9.84	12.18	4.05	5.64	8.31	7.20	10.08	13.02
22	6.00	7.32	9.23	5.85	8.16	9.51	5.40	7.56	7.38	7.05	9.96	12.92
23	6.45	8.16	12.00	6.30	10.20	11.08	6.00	8.16	9.23	7.05	10.08	12.74
24	5.55	10.56	6.65	6.00	8.64	12.00	6.75	9.36	4.34	4.50	6.24	15.69
25	7.80	8.52	12.92	4.95	8.16	9.05	4.05	5.76	12.00	3.90	5.52	13.85
Mean Flow	**6.48**	**8.56**	**10.32**	**6.16**	**8.45**	**10.11**	**6.13**	**8.27**	**10.30**	**6.52**	**8.84**	**11.85**
Standard Deviation	**0.84**	**1.01**	**1.64**	**0.91**	**1.15**	**1.34**	**1.09**	**1.45**	**2.35**	**1.09**	**1.57**	**1.85**
Flow Variation (percent)	**13**	**12**	**16**	**15**	**14**	**13**	**18**	**18**	**23**	**17**	**18**	**16**

TOTALS	**All H=2m**	**All H=3m**	**All H=4m**	**All Lat #1**	**All Lat #2**	**All Lat #3**	**All Lat #4**	**All Lats**
Mean Flow	**6.32**	**8.53**	**10.64**	**8.45**	**8.24**	**8.23**	**9.07**	**8.50**
Standard Deviation	**0.99**	**1.31**	**1.94**	**1.98**	**1.98**	**2.41**	**2.67**	**2.29**
Flow Variation (percent)	**16**	**15**	**18**	**23**	**24**	**29**	**29**	**27**

small scale irrigation devices is beginning to reverse this trend. The installation of one million manually powered Treadle Pumps in Bangladesh has provided divisible waterlifting technology irrigating three-quarters of an acre of vegetables at an installed price of $35 (Polak, 1996). An animal powered tubewell pump that irrigates three acres of vegetables at a cost of $125 will further expand small farmer access to affordable divisible irrigation devices (International Development Enterprises, 1996). In the case of the low cost drip irrigation system, farmers who are very poor can optimize divisibility and reduce the capital cost of the system further by using only one drip line and moving it more frequently. They can use the income generated by the system to add more drip lines in subsequent growing seasons.

In areas with a high concentration of small farmer operations and a scarcity of water, the low cost drip system will provide access to water saving irrigation technology which is affordable on a small scale and divisible. The low cost drip system is likely to be particularly applicable to areas of the world where both water and crops have relatively high value, and where the high capital cost of existing drip irrigation technology constitutes a significant barrier to its adoption.

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