6. DISCUSSION

6.1 CROP YIELD

Crop yield is a function of the soil water availability during different crop developmental phases under adequate availability of other inputs. As expected productivity of all the crops studied viz., fruit crops (mango, sweet orange, banana, pomegranate & papaya), vegetables (chillies, brinjal & tomato) and field crop sugarcane was higher with respect to the farmers adopting drip irrigation in comparison to non adopted farmers (Conventional method of irrigation).

The increase of yield in different crops viz., mango was 59.7%, sweet orange 39.8% banana 38.6%, pomegranate 20.8%, papaya 40.2%, chillies 33.3%, brinjal 25.6%, tomato 28.95% and sugarcane 58.1%. This improvement in yield could be attributed to optimal soil water plant relations associated with drip method of irrigation. Under drip irrigation the soil water content in a portion of the plant root zone remains fairly constant because irrigation water is applied slowly and frequently on daily basis as per the crop water requirement. As the frequency of irrigation increases, the time-average soil water potential increases and is restricted to a narrow range, hence eliminating low average soil water content and high water fluctuations, which typically result from additional flood & sprinkler irrigation methods, as factors affecting plant growth and yield. This increase in soil water potential (or decrease in the soil water suction) at very frequent or continuous
water application is a consequence of both high average matric potential and low solute concentration in soil solution resulting from the fact that the salinity of soil solution approaches that of the irrigation water. (Ayers et al., 1943 and Wadliegh et al., 1951) suggested that matric and osmotic potentials are additive in their effect on plant growth. Furthermore, frequent irrigation will cause frequent leaching of excess salts to the periphery of the root zone, maintaining a high osmotic potential. There is evidence to support the view that crop yield of many crops is increased by maintaining the soil water regime at high-time average of soil water potential in the effective root zone (Clough et al., 1990). Potential yield increases by adoption of drip over conventional irrigation systems were reported in India under different agro-climatic zone viz., 52% in banana, 45% in chillies, 23% in grapes, 50% in sweet orange, 45% in pomegranate, 33% in sugarcane, 50% in tomatoes and 88% in watermelon (INCID, 1994). Likewise several researches in India observed significant yield increase by adoption of drip over conventional irrigation methods in several crops viz., banana -14.5 to 52%, (Hedge & Srinivas, 1990); cauliflower 24.3 to 72.2%, (Raman et al., 2001); grapes – 23.1% (INCID, 1994); mango – 86.5% (Singh et al., 1998); pomegranate – 36% and 37% (Firake and Kumbhan, 2002; & Prasad et al., 2003); sugarcane – 13% and 25% (Sivanappan, 1998; Mahendran et al., 2002). The general increase in the total soil water potential with irrigation frequency suggests that the crop yield may be highly increased by very high irrigation frequency.
The maintenance of continuously high soil water potential, while minimizing fluctuations in soil water content during the irrigation cycle, is an important and advantageous feature of drip irrigation (Bresler, 1977) if the yield response curve is convex and the effects of fluctuating soil water contents behave in a manner similar to the theory of Zaslavsky and Mokadi (1966) and Zaslavsky (1972). Other discussions (Hillel, 1980; Childs and Hanks, 1975; Rawlins and Raats, 1975) also imply that the best irrigation policy is to apply water as frequently as possible. This is assuming that no problems of aeration (Dasberg and Steinhardt, 1974), plant disease (Hanson and Patterson, 1974), or restricted plant rooting (Willoughby and Cockroft, 1974) will occur with high frequency irrigation.

Whereas under the irrigation cycle under traditional irrigation methods viz., furrow, flood or overhead sprinkler consists of a short period of infiltration followed by a long period of redistribution, evaporation and extraction of water by growing plants starting from field capacity moisture content down towards permanent wilting point. During this transition in the soil moisture, it becomes increasingly difficult for the crop plants to extract water with every passing day since progressive decrease in soil-water content increases soil water tension and therefore the water use rate by the crop decreases at greater tensions. This reduction in water use is accompanied by decrease in plant water content affecting the crop growth & development of the plants resulting in reduced crop yields.
Ideally to achieve maximum yields the soil moisture level should be slightly below the field capacity. Thus the drip irrigation system with its controlled application of water makes possible the task of maintaining the soil moisture regime close to field capacity and results in marked increase in crop yields. The more favourable growing conditions made possible by drip irrigation were also shown to bring the crops into maturity earlier than traditional irrigation methods. Weed infestation is also reduced under drip irrigation significantly in non wetted areas thus markedly reducing the competition for growth resources viz, light, water, nutrients etc., as evident under conventional method of irrigation. Also filtration of irrigation water for drip irrigation may result in delivery of fewer weed seeds to the field in comparison to other irrigation methods. Recent herbigation techniques using selective and contact herbicide further emerged the grower to improve the efficiency of production systems.

Howell et al. (1981) reviewed over 50 research reports on crop response to drip irrigation, published over the last few decades. Where drip irrigation was compared with either no irrigation or other water application methods. Yields were equal or better in all cases regardless of difficulties in making adequate comparison among the different irrigation methods and management practices, the potentiality found to adjust for improved crop yield in different crops by using an irrigation method such as drip that is capable of frequent delivery of water to the soil. However, optimization of soil water regime for maximum production depends upon proper drip irrigation
scheduling (Frequency and quantity of irrigation) and water placement with the drip irrigation method.

6.2 WATER PRODUCTIVITY

Water use for different crops where farmers adopted drip method of irrigation was significantly less as compared to water use by crops under conventional furrow & basin methods of irrigation. The water savings in crops for the farmers adopting drip irrigation amounted to 242.33% in mango, 204.59% in sweet orange, 183% in banana, 148% in pomegranate, 190.32% in papaya, 175.9% in chillies, 173.66% in brinjal, 154.98% in tomato and 245.3% in sugarcane over conventional methods of irrigation.

There is a general agreement in the literature that irrigation water requirements under drip irrigation are less than the traditional furrow, basin & overhead sprinkler irrigation systems. The savings of course depend on the crop, soil, environmental conditions and the attainable on farm irrigation efficiency. Much of the water saving can be achieved by restricting the water application to the extent of the most efficient root zone (Dasberg and Steinhardt, 1974). Primary reasons assessed for water savings include irrigation of a smaller portion of soil volume, decreased surface evaporation, reduced irrigation runoff from the field (the dry soil between rows could also store more precipitation) and controlled de-percolation losses below the crop root zone (Aljibury, 1974; Davis, 1975; Shoji, 1977). It is possible to compare field application efficiencies of surface, sprinkler
and drip irrigation using the definition according to the ratio between water at the field inlet and water needed to maintain the soil water level above a minimum requirement for the crop. Wu & Gitlin (1981) concluded that an application efficiency of 90% could easily be achieved for drip irrigation as compared to 60 – 80% for sprinkler and 50 – 60% for surface irrigation. This calculation assumes that variation in the emitter flow does not exceed 20%, which is a very conservative estimate according to Soloman (1977). The manufacturing variation of many of the modern emitters has coefficients of variation less than 5%, resulting in a uniformity coefficient of more than 96%.

Direct evaporation from the soil surface (Dan, 1974) and water uptake by weeds (Lemon, 1956) can be reduced by not wetting the entire soil surface (partial wetting of the root zone) between rows or trees, especially on young trees or row crops before the closure of the canopy. Black (1971) tested the effect on water use of young apple trees when varying proportions of the root system were supplied with an “optimum” water regime. They found that when the fraction of the wetted root system was decreased from 1.0 to 0.25, the relative transpiration reduced from 1.0 to only 0.75. Their results also suggested that wetting substantially less than the total root system daily would produce at least as good a regime for plant water supply as would wetting the entire root system with a 14-day interval between irrigations.
Sprinkler irrigation is subject to the water loss by wind drift, increases evaporation or poor application uniformity especially with strong winds (Seginer, 1969). On steep hills and/or under strong wind conditions, furrow and sprinkler irrigation methods are very inefficient with respect to water saving (Seginer, 1969). Under these conditions the use of drip irrigation prevents water loss beyond the border of the irrigated field by wind convection or runoff in contour cultivation on steep hills (Seginer, 1969). The development of surface crust and destruction of soil structure (Lemon, 1956) can be avoided, where as water infiltration into the soil permeability and for low permeability or crusted soils can be improved by using low application rate drip systems. Deep percolation losses can be controlled (Rawlins, 1973) especially on sandy soils (Roth et al., 1974). The water use per unit amount of yield produced serves as a good indicator of efficiency of water use in comparison to drip irrigated and conventionally irrigated crops (Non drip). Our results revealed that the field water use efficiency under drip irrigated crops was significantly higher and varied from 60 to 79%.

From the forgoing fact it is emerged clearly that adoption of drip irrigation not only reduces seasonal irrigation water depth but also substantially reduces the quantum of water required to produce 1-kg of crop yield when compared to other methods of irrigation. Potential water savings in different crops viz., banana (45%), chillies (63%), grapes (48%), sweet orange (61%), pomegranate (45%), sugarcane
(56%), tomato (31%) and watermelon (36%) by adoption of drip were reported in India (INCID, 1994).

6.3 FERTILIZER USE EFFICIENCY

Drip irrigation offers considerable flexibility in fertilization (application of fertilizers in the form of solution along with irrigation water called fertigation, which is a benefit unique to the system (Lindsey and New, 1974; Isobe, 1974; Bar Yosef, 1977). Thus the present study also disclosed that the farmers adopting fertigation technique in comparison to broadcast soil application or band placement had higher fertilizer use efficiency indices. The fertilizer use efficiency for different crops amounted to 94.6% in mango, 42.39% in sweet orange, 48.3% in banana, 27.6% in pomegranate, 46.87% in papaya, 47.8% in chillies, 57.1% in brinjal, 74.2% in tomato and 110% in sugarcane over conventional soil fertilization.

Several researchers (Bester et al., 1974; Marsh et al., 1975; Shani, 1974) have cited various reasons for the increased efficiency of fertilization: a) decreased quantity of applied fertilizer, because fertilizer is applied only to the crop root zone in the absolvable available form. b) Improved timing of fertilization according to crop developmental phases, because the more frequent application (daily or weekly) make it possible to match plant nutrient consumption requirement at various growth stages. c) Improved distribution of fertilizers with minimum leaching beyond the root zone or runoff. However, the fertilizer mixtures must be completely soluble in water,
with out leaving any residues in the dispensers and should not cause clogging of emitters. There is no problem usually with N & K compounds (Miller et al., 1976). P is usually added in soluble forms as Ortho Phosphate, as mono ammonium poly phosphate, and phosphoric acid (Rauschkolb et al., 1976). Micro elements may be added in chelate form. Further the drip system is well suited to the application of herbicides and soil-borne diseases and pests, since localized application in the wetted area results in the chemicals being more effective at lower concentrations.

Potential savings in fertilizer due to fertigation over conventional soil application either by broadcast or band placement were reported by several workers (Dasberg et al., 1983, 1988; Legaz et al., 1983; Aiva & Mozaffari, 1995; Christensen et al., 1991; Lahar & Kalmar, 1998; Awada et al., 1979; Bar yosef & sagiv, 1982; Phene et al., 1982, 1986, 1990) in different crops viz., banana (20%), onion (40%), sugarcane (50%), cotton (30%), potato (40%), tomato (40%), castor (60%), lady’s finger (40%) and broccoli (40%).

6.4 ENERGY SAVING

It is well known that owing to rapid energisation of pump sets and wide spread cultivation of water-intensive crops, consumption of electricity by the agricultural sector has increased enormously in India since independence. On an average, pump sets used to lift water from wells consume about 70% of the total electricity used in agriculture (Sharma, 1994). Though the increased consumption of
electricity indicates better growth in agriculture, many researchers argue that electricity is not used efficiently in agriculture for various reasons. These days, with the energy supply becoming more limited and expensive, an optimal irrigation method should also rely on a relatively low operational pressure. Thus, it may be an important feature of drip irrigation method as long as energy losses in the “Control Head Unit System” are not too large (Bresler, 1978). Therefore adopting drip irrigation is more advantageous in achieving more energy efficiency.

In the present study, farmers adopting drip irrigation method registered energy saving to the tune of 684 kWh/ha/year in mango, 697 kWh/ha/year in sweet orange, 1532 kWh/ha/year in banana, 806 kWh/ha/year in pomegranate, 1307 kWh/ha/year in papaya, 592 kWh/ha/year in chillies, 557 kWh/ha/year in brinjal, 564 kWh/ha/year in tomato and 1020 kWh/ha/year in sugarcane over conventional irrigation methods viz., furrow and basin.

It is well documented that drip irrigation has a potential for reducing pumping energy requirement since operating pressures are considerably lower compared to other types of pressurized irrigation systems. However, the real energy conservation under drip irrigation comes from reduction in the amount of water pumped because of higher on farm irrigation application efficiency (Davis, 1975; Shoji, 1977). Narayananmoorthy (2004) indicated that drip irrigated farmers operate pump sets for a less number of hours and therefore consumption of electricity is quite less.
Since the savings of electricity through drip irrigation is higher and thereby reduces the total electricity bill. The overall electricity consumption under drip system is lower and results in the lower electricity bill, accordingly the cost of cultivation comes down.

Potential savings in energy due to adoption of drip system over conventional irrigation systems were reported by Narayanamoorthy, (1996, 1997 and 2001) in different crops viz., banana (29.16%), sugarcane (44.43%), and grapes (37.28%).

6.5 ECONOMIC ANALYSIS

To gauge the economic viability of drip investment in fruit, vegetables, and field crops cultivation, the Net Present Value, Internal Rate of Return, Cash Flow, Break even point for Price & Yield and pay back period were computed using a discounted cash flow technique.

6.5.1 Cost of Cultivation

As mentioned earlier, although the importance of drip irrigation method in increasing crop yields and water savings has been proved based on data from Research Stations, however wider economic analysis using field level data has not been documented. As fruit, vegetable and field crops like sugarcane are categorized under water intensive crops it is desirable to assess and understand the impact of drip irrigation technology on cost of cultivation and economic indices. In the present study the cost of cultivation of crops viz., mango, banana, pomegranate, sweet orange, brinjal, chillies and tomato under drip method of irrigation was found to be less when compared
to the crops that are cultivated under surface method of irrigation like the furrow and basin irrigation. Cost reduction was generally realized specially due to labour intensive operations like weeding, irrigation scheduling, fertilizer dose & scheduling and plant protection. Similar observations were made by Narayanamoorthy (1996 & 1997).

The weed infestation in farmer’s fields adopting drip irrigation was considerably low owing to partial wetting of the soil contrary to the conventional surface methods of irrigation wherein the entire cropped field surface was wetted. This enabled remarkable savings in weed control operations for crops using drip irrigation (Roth et al., 1974). Since water was applied mostly under the shaded area of trees or vegetables less cultivation was required than other irrigation methods. Also filtration of irrigation water for drip irrigation resulted in delivery of fewer seeds of weeds to the field, in comparison with surface irrigation method.

Irrigation scheduling also offered significant savings in the cost of cultivation through drip irrigation. First the requirement of labour is less for scheduling operations to crops during its base period. Second since water saving is substantial under drip method of irrigation it significantly reduced the working hours of pump set, which inturn reduces the cost of electricity.

The operation wise cost of cultivation of the sampled farmers in the present study was presented in table 5.2,3,8,11,14,17, 20,23 & 26 clearly revealed that cost reduction was high in operation like
weeding, irrigation scheduling, plant protection, fertilizer dose and scheduling, as expected. The total cost reduction amounted to 8.17% in mango, 27.82% in sweet orange, 7.06% in banana, 8.73% in pomegranate, 2.86% in brinjal, 16.57% in tomato, 3.80% in chillies due to drip method of irrigation when compared to surface basin or furrow method of irrigation. Further the sampled farmers opined that application of fertilizers via irrigation system by fertigation, the amount of fertilizers were reduced significantly when compared to the conventional application method like basal soil application and top dressing in splits, which are commonly followed under conventional surface furrow/basin method of irrigation.

6.5.2 Benefit Cost Analysis

Though drip irrigated crops registered significantly higher profits than the crops cultivated under conventional surface furrow/basin irrigation, it can not be treated as the effective profit (real) profit with respect to the crop cultivated using drip system because it does not account for the capital cost of the drip system, its depreciation and interest accrued on the fixed capital while calculating the reference profit of crops. The life period of drip system is one of the important variables which determines the per ha., profit of a given crop. The magnitude of fixed capital for installing the drip system also varies by crop species. Wide spaced crops like mango, sweet orange, pomegranate, require relatively low fixed capital as compared to narrow spaced annual vegetable crops (tomato, brinjal, chillies) and biennial crops like sugarcane, banana, papaya etc.,
which need higher fixed capital. In the present study, the fixed capital for drip system varied from Rs. 22000/- per ha to Rs. 35000/- per ha for widely spaced crops like mango, sweet orange, pomegranate, whereas the fixed capital varied from Rs. 71000/- per ha to Rs. 83000/- per ha for narrow spaced annual crops (sugarcane) & biennial crops like banana and papaya.

Besides the crop type, size of the fixed capital requirement is also sensitive to the quality of the material used for the system, type of water source, (open well, bore well) and associated water quality as well as the distance between well and field. However in the APMI Project prior to the commissioning of the scheme, through a series of negotiations with the MI suppliers a uniform quality standards and pricing policy were determined and implemented. Moreover, since it is a capital intensive technology, the huge initial investment needed for installing the drip system remains the main deterrent for the widespread adoption of drip irrigation technology. To what extent this discouragement effect is real and to what extent such effect can be counter balanced by Government subsidies are important policy issues requiring empirical answers. Therefore in order to determine the economic viability of drip investment in the context of the crops studied viz., fruit crops (mango, banana, papaya, pomegranate and sweet orange), vegetable crops (tomato, brinjal, chillies) and field crops (sugarcane), an attempt has been made to compute the Net Present Value (NPV), pay back period, internal rate of return and break even point for price & yield, by utilizing the cash flow technique. Since the
NPV is the difference between the sum of the present value of the benefits and the costs for a given life period of the drip system and it collates the total benefits with the total costs covering items like capital and depreciation costs of the system. In terms of NPV criterion, the investment on drip system can be treated as economically viable if the present value of benefits is greater than the present value of costs.

Though the sampled farmers have received subsidy for installing drip system in all the crops through APMIP, we have computed economic indices by excluding subsidy in the total fixed capital cost of drip system.

Results of the economic analysis clearly show that the adoption of drip technology is economically viable for all the crops. The NPV under drip irrigation system, for different crops was Rs. 227445/- in mango, Rs.104554/- in banana, Rs.454715/- in papaya, Rs.328053/- in pomegranate and Rs.337879/- in sweet orange, Rs.151075/- in tomato, Rs.31,448/- in brinjal, Rs.63712/- in chillies, Rs.48942/- in sugarcane. The NPV showed that farmers recovered the entire capital cost of the drip system from the income within seven years in mango, one year in banana, one year in papaya, three years in pomegranate and, five years in sweet orange, and in one year each in tomato, brinjal, chillies, and sugarcane, even without any subsidy from the APMIP operated by the Government. The findings of NPV & pay back period for different crops for the sampled farmers clearly discards the common misapprehension that the capital cost recovery of drip investment takes more time. More importantly, in the present
study, the farmer recovered the capital cost within a year in annual vegetable crops (tomato, brinjal, chillies), and biennial crops (banana, papaya, sugarcane). Thus the role of discount rate as a device to capture the time preference of the farmers seems to be of considerably lesser importance than one might think further, the IRR was relatively higher for drip irrigated fruit crops than conventional surface basin irrigation as well as the customer cost of capital (i.e., interest rate of 10%) indicating the profitability of adoption of drip in these crops.

The break even point for yield unit and price in all crop sampled was lower due to adoption of drip irrigation in comparison to conventional surface furrow/basin irrigation. The profitability was achieved above Rs. 55.50 /ton in mango, 48.73/ton in banana, 62.45 /ton in papaya, 54.51 /ton in pomegranate and 69.45/ton in sweet orange, 69.63/ton in tomato, 29.71 /ton in brinjal, 44.92/ton in chillies, 19.77/ton in sugarcane. Likewise break even point for yield quantity revealed that the profitability was achieved at lower yield levels plugged each year by adoption of drip irrigation in all the crops as compared to conventional surface furrow/basin irrigation. The profitability was achieved above Rs. 4672.86/ton in mango, Rs. 2050.69/ton in banana, Rs. 1689.96/ton in papaya, Rs. 5914.08 /ton in pomegranate and Rs. 2505.26/ton in sweet orange, Rs. 5716.66 /ton in tomato, Rs. 9984.31/ton in brinjal, Rs. 14319.52/ton in chillies, and Rs. 882.55 /ton in sugarcane.
6.6 **SOIL SALINITY AND NITRATE LEVEL**

The larger volume of water in case of conventional surface irrigation methods, disburse extra nitrate nitrogen leaching and enhance nitrate leaching (Watts and Martin, 1981). The salinity profiles in the crop root zone depth for different crops revealed lower nitrate concentration under surface drip irrigation method in comparison to conventional surface irrigation methods.

6.7 **NO$_3$ CONTAMINATION OF GROUND WATER**

Nitrates are soluble and mobile in soil and move with the leaching water. Thus frequent drip irrigation & fertigation of crops in precise quantities resulted in less migration of nitrates to deeper layers in comparison to conventional (non-drip) irrigation at longer intervals with more depth of water. The results further demonstrated that the NO$_3$-N concentrations exceeded the threshold limit (i.e. 10 mg/l set by EPA) in certain crops under conventional irrigation method but remained below the threshold limit under drip irrigation in deeper soil layers. (Badr and Abou E l, 2007) Measured NO$_3$-N concentrations in ground water samples from well water source located in cropped fields practicing drip irrigation & fertigation had lower NO$_3$-N concentrations (2.08 ppm to 4.82 ppm) in comparison to practicing conventional (non-drip) irrigation(10.81 ppm to 11.03 ppm) . Similar observations were made by Mirjat *et al.* (2008).