

YIELD, IRRIGATION PRODUCTION EFFICIENCY AND ECONOMIC RETURN OF BROCCOLI (*Brassica oleracea* Var. *Italica*) UNDER DIFFERENT IRRIGATION METHODS AND SCHEDULES

J. Lordwin Girish Kumar*¹ and Tayal senseba²

1. Department of Water Resources Engineering, Faculty of Engineering, Bahir Dar University, Bahir Dar, (ETHIOPIA)
2. Department of Soil, Water, Land Engineering and Management, Agricultural Institute - Deemed University, Allahabad, (INDIA)

Received September 17, 2007 Accepted April 14, 2008

ABSTRACT

Field experiment was conducted at the Irrigation Research Farm of Allahabad Agricultural Institute-Deemed University, Allahabad (India), during the winter crop growing season (November to March) of 2005-2006 on clay loam soil in order to evaluate the effect of irrigation methods and irrigation schedules on marketable yield, irrigation production efficiency and economic return of broccoli (*Brassica oleracea* Var. *Italica*). The irrigation was applied when sum of daily pan evaporation data from United States Weather Bureau (USWB) class- A-open pan reach approximately to predetermine value of 16.3 mm. Irrigation at 150 percentage of pan evaporation replenishment resulted in higher flowers weight, marketable flower yield and irrigation production efficiency and it decreased with increase in irrigation level. The drip irrigation methods resulted in slightly higher marketable yield of primary flowers and irrigation production efficiency as compared with micro sprinkler methods, whereas surface irrigation methods gave considerably lower yield of primary and secondary flowers and irrigation production efficiency. The irrigation at 150 percentage pan evaporation replenishment resulted in higher gross return, net return and benefit cost ratio. The micro sprinkler method resulted in higher gross return, net return and benefit cost ratio followed by drip and surface irrigation methods. The seasonal water applied/irrigation level and marketable yield of broccoli exhibited a strong quadratic relationship which in turn can be used for allocating limited water resource within the crop under different irrigation methods. The overall results clearly indicate that the micro irrigation system is highly economical for broccoli in this region.

Key Words : Broccoli, Irrigation production efficiency, Drip, Micro-sprinkler.

INTRODUCTION

Land and water are the basic needs of agricultural and economic development of any

country and their demands are dramatically increasing day to day. Further the per capita availability of these resources in India is much

* Author for correspondence

less compare of many other countries. Experts have accessed that water supply will be the major resource constraint to limit economic development. The potential utilizable, volume of water is estimated to be about 110 million hectare meter (MHM). Even with full exploitation of the potential nearly 40-50% of the cultivated area will remain under rain fed. Therefore it is necessary to economize the use of water for agriculture to bring more area under irrigation, reduce the cost per hectare of irrigation and increase the productivity. This can be achieved by introducing advance irrigation method like micro irrigation and sprinkler irrigation method¹.

Appropriate Irrigation scheduling is to increase irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to desire level, saves water resources and energy. Therefore, it is important to develop irrigation scheduling techniques under prevailing climatic conditions in order to utilize scare water resources effectively for crop production. Numerous studies were carried out in the past on the development and evaluation of irrigation scheduling techniques under a wide range of irrigation systems and management, soil, crop and agro climatic conditions. The meteorological based irrigation scheduling approach such as pan evaporation replenishment and cumulative pan evaporation have been used by many researches due to its simplicity, data availability and higher degree of adaptability at the farmer's level^{1,5,7}.

Surface irrigation such as furrow, check basin and border are the most common method in India. The overall efficiency of surface irrigation is considerably low (33%) and around 67% of water is wasted. The low efficiency may be accounted for in part, by convenience loss due to seepage evaporation and non beneficial use of phretophytes of water due to inadequate land preparation and lack of farmer know how in application of water with consequent with the excess application and

deep percolation. Drip irrigation is the most efficient method to determine water and nutrient to the plants, due to increasing water scarcities for irrigation, industrial as well as domestic purposes. Our farming community has no option except to adopt such as drip and micro sprinkler to meet the rising demand for foods, for human and livestock population which can be achieved by increasing the production per unit area³.

Broccoli is a member of the Crucifereaceae or cole crop family and thus it is related to cabbage, cauliflower, brussel sprouts. The name broccoli comes from the Italian word "brocco", meaning bunch or arm. Broccoli is rich in vitamins and minerals. It is a good source of vitamin A and C, potassium, folacium, iron, phosphorous and fibre. One ounce of broccoli has as much calcium as one ounce of milk. Broccoli also contains important photochemical such as beta-carotene, indoles and isothiocyanate that help prevent carcinogens.(www.uga.edu/vegetable/broccoli.html). The objective of this study is to examine the effect of irrigation methods and schedules on marketable yield, irrigation production efficiency, total cost and net return of broccoli.

MATERIAL AND METHODS

The field experiment was conducted at the irrigation research farm of Allahabad Agricultural Institute-Deemed University, Allahabad, India (25° 27' N, 81° 44' E, and 98 m above sea level). During Rabi season of 2005-2006 in order to study the response of broccoli to variable irrigation under drip, micro sprinkler and surface (check basin) irrigation methods. The climate in this part of the country is characterized as semi arid with cold winters and hot summers. The soil in the experimental field was clay loam (35.5% sand, 25.8% silt, and 38.6% clay). The soil moisture content at field capacity (-1/3 bar) and wilting point (-15 bar) was 19.5 and 9.1% respectively on dry weight basis. The average bulk density of the

soil was 1.3 g/cm³. The plant available soil moisture was 136.2 mm/m.

The experiment was laid out in two factor randomized block design (irrigation schedule x irrigation method) with three replications. The area of each experiment plot was 7.5 m² (3 x 2.5 m). A buffer zone spacing of 1.0 m and 0.5 m was provided between the plots and blocks. Broccoli (F1-Ashwariya) seeds were sown on 20th November, 2005, in the nursery at a depth of 0.05 m with a spacing of 10 cm between the rows. The seedlings were

transplanted on 23rd December, 2005, at a spacing of 50 cm between the plants and rows. The experimental field received 94.3 kg/ha P₂O₅ and 62.5 kg/ha K₂O. (The experimental field received 66 kg/ha of nitrogen at the time of transplanting, 3 weeks and 5 weeks after transplanting). The experiment consists of three irrigation methods viz. drip, micro sprinkler, check basin and amount of water in different treatments are 50, 100, 150 and 200 percentage pan evaporation replenishment².

Table 1. Effect of irrigation schedules and irrigation method on marketable yield, yield components and irrigation production efficiency of broccoli.

Treatments	Mean yield of primary Flower, t/ha	Mean yield Secondary Flower, t/ha	Mean total Yield (primary+ secondary) t/ha	Mean Number of primary Flower/m ²	Mean flower Weight, Kg	Mean Irrigation Production Efficiency, Kg/m ³
Irrigation Schedules (pan evaporation replenishment, %)						
50	14.32	2.22	16.54	3.82	0.37	15.04
100	20.28	3.19	23.48	3.93	0.51	10.67
150	23.44	5.50	28.94	3.98	0.58	8.77
200	21.65	3.53	25.18	3.88	0.55	5.72
CD (0.05)	0.53	0.25	0.55	0.12	0.02	0.25
Irrigation Methods						
Drip	21.65	3.95	25.60	3.92	0.55	10.94
Micro sprinkler	21.12	4.00	25.09	3.92	0.53	10.58
Surface	16.99	2.92	19.92	3.89	0.43	8.63
CD (0.05)	0.46	0.21	0.47	0.10	0.02	0.21
Interaction CD (0.05)	0.92	0.43	0.95	0.20	0.03	0.43

The daily USWB class - A open pan evaporation data for a period of 5 years (2002-

2006) were collected from the meteorological station, Lucknow. The crop was irrigated when

the sum of daily mean (5 years) of pan evaporation reached to a predetermined value of 16.3 mm (rooting depth in m x plant available water mm/n x permissible soil moisture depletion in fraction). The crop was irrigated by drip, micro sprinkler and check basin irrigation methods. Screen filter was installed to minimize dripper micro sprinkler blockage. PVC pipes of 50 mm diameter and LDPE of 12 mm diameter were used for main/ sub-main and laterals lines respectively. In case of check basin method, water was applied through pipe conveyance system. In micro sprinkler system, plants were irrigated at a rate of 17 l/hour. In case of drip irrigation method, plants were irrigated at a rate of gap 4 l/hr. The crop was harvested from 18th February to 26th March 2006, depending upon the maturity of primary and secondary flowers. The harvesting was done manually.

In order to assess the economic viability of different irrigation system under variable irrigation, both fixed and operating costs were included. The total cost of production, gross return and net return under different irrigation levels were estimated under following assumptions.

- Salvage value of the components = 0
- Useful life of tube well, pump, motor and pump house = 25 years
- Useful life of drip and micro sprinkler systems = 8 years
- Useful life of open channel conveyance systems = 5 years
- Useful life of weeding and spraying equipments = 7 years
- Interest rate = 14%
- Repair and maintenance = 7.5%
- Number of crops per year = 2

The fixed cost which includes tube-well, pump, motor, pump house and irrigation systems. PVC pipe for main and sub main and LDPE pipes for lateral, filter, fertilizer tank, pressure gauge, water meter, drippers, spraying

and weeding equipments and other accessories were calculated. The annual fixed cost for irrigation system was calculated by the following approach⁴.

$$CRF = \frac{i(1+i)^n}{(1+i)^n - 1} \dots\dots 1$$

where

- CRF = capital recovery factor
- i = interest rate (fraction)
- n = useful life of component (years)

$$\text{Annual fixed cost/ ha} = CRF \times \text{fixed cost/ha} \dots\dots 2$$

$$\begin{aligned} \text{Annual fixed cost/ha/season} = \\ \frac{\text{Annual fixed cost / ha}}{2} \dots\dots 3 \end{aligned}$$

The operating cost which includes labour (system installation, fertilizer and chemical application and harvesting etc.), land preparation, seed, fertilizer, chemicals (insecticides and pesticides), water pumping (electricity) and repair and maintenance (tube-well, pump, motor, pump house, irrigation system and pipe conveyance system etc.) was estimated. The gross return for different irrigation methods and schedules was calculated taking into consideration of marketable yield and wholesale price of broccoli. Subsequently, the net return for broccoli was calculated considering total cost of production (Fixed + Operating) and gross return.

$$\begin{aligned} \text{Net return (US\$/ha)} = \text{Gross return (US\$/ha)} \\ - \text{Total cost of production (US\$/ha)} \dots\dots 4 \end{aligned}$$

The benefit cost ratio (B/C) under different irrigation methods and schedules was calculated as follows :

$$B/C = \frac{\text{Gross return (US\$/ha)}}{\text{Total cost of production (US\$/ha)}} \dots\dots 5$$

RESULTS AND DISCUSSION

Yield, yield component and irrigation production efficiency

Yield, yield component and irrigation production efficiency of broccoli as influence by different irrigation methods and schedules are presented in **Table 1**. Irrigation level significantly influences the mean flower weight and marketable yield of primary and secondary flower but it does not influence the number of flower per square meter. The mean marketable yield of primary flower for different irrigation schedules ranges from 14.32 to 23.44 tonnes/ha. The higher mean marketable yield of primary flower (23.44 tonnes/ha) was obtained when irrigation during crop growing season was applied at 150 percentage of pan evaporation replenishment. A further increase in irrigation level resulting from 200 percentage of pan evaporation replenishment reduce the marketable yield of primary flower (21.65 tonnes/ha) significantly due to significant reduction in number of primary flower /m² and mean flower weight. The marketable yield of secondary flower ranges from 2.22 to 5.50 tonnes/ha. The marketable yield of secondary flowers (5.50 tonnes/ha) was higher when irrigation during crop growing season was applied at 150 percentage of pan evaporation replenishment. A further irrigation level significantly reduce the marketable yield of secondary flowers (3.53 tonnes/ha). The irrigation level had marked effect on irrigation production efficiency of broccoli. The irrigation production efficiency of broccoli ranges from 5.72 to 15.04 kg/m³. The significant higher irrigation production efficiency 15.04 kg/m³ was recorded with irrigation at 150 percentage of pan evaporation replenishment because reduction in marketable yield was less as compared with seasonal water applied. The minimum irrigation production efficiency (5.72 kg/ha) was recorded when irrigation during crop growing season was applied at 200 percentage of pan evaporation replenishment

yield (**Table 1**). The mean marketable yield of primary flowers was significantly higher for drip irrigation method followed by micro sprinkler and surface irrigation methods. Drip, micro sprinkler methods resulted in significantly higher irrigation production efficiency (10.94 kg/m³). The surface irrigation method resulted in minimum irrigation production efficiency (8.63 kg/m³) due to considerably low marketable yield of primary and secondary flower (**Table 1**).

Economic return

The total cost of production, gross return, net return and benefit cost ratio of broccoli in relation to irrigation methods and schedules are presented in **Table 2**. The total cost of production increased slightly with an increasing irrigation level due to increase in pumping cost induced by variation in season water application. The total cost of production for drip, micro sprinkler, surface irrigation methods varied from 2025.54 to 2119.83, 1511.00 to 1605.28 and 1305.88 to 1400.09 US\$/ha respectively. The cost of production in drip irrigation was considerably higher compared with micro sprinkler irrigation mainly due to variation in irrigation system cost. The gross return under different irrigation schedules from drip, micro sprinkler and surface irrigation methods ranged from 5125.71 to 9120.00, 4776.19 to 8983.80 and 4279.04 to 6705.71 US\$/ha respectively. The gross return increased considerably with the increase in irrigation level. The maximum gross return was obtained when irrigation during crop growing season was applied at 150 percentage of pan evaporation replenishment. Further increase in irrigation level resulting from 200 percentage pan evaporation replenishment decreased the gross return due to reduction in marketable yield. The drip and micro sprinkler irrigation gave similar gross return but surface irrigation gave considerably low gross return due to lower marketable yield. The maximum net return for drip (7030.26 US\$/ha), micro sprinkler (7409.95 US\$/ha) and surface (5337.04 US\$/ha),

Table 2. Economic return of broccoli under different irrigation schedules and irrigation methods.

Treatments (Pan evaporation Replenishment, %)	Total cost of production (US\$/ha)			Gross return (US\$/ha)			Net return (US\$/ha)			Benefit cost ratio		
	Drip	Micro sprinkler	Surface	Drip	Micro sprinkler	Surface	Drip	Micro sprinkler	Surface	Drip	Micro sprinkler	Surface
50	2025.54	1511.00	1305.88	5125.71	4776.19	4279.04	3100.16	3265.19	2973.23	2.53	3.16	3.27
100	2056.97	1542.42	1337.23	7343.80	7219.04	5564.76	5286.71	5700.42	4227.52	3.57	4.68	4.16
150	2088.40	1573.85	1368.67	9120.00	8983.80	6705.71	7030.26	7409.95	5337.04	4.36	5.70	4.89
200	2119.83	1605.28	1400.09	7674.28	7697.14	6217.14	5554.45	6091.85	4817.04	3.62	4.79	4.44

irrigation methods were obtained when irrigation during crop growing season was applied 150% of pan evaporation replenishment. A further increase in irrigation level resulting from 200% pan evaporation replenishment reduce a net return considerably due to reduction in gross return. The micro sprinkler irrigation methods gave higher net return as compared to drip irrigation because of lower system cost. The benefit cost ratio for drip, micro sprinkler and surface irrigation methods are ranges from 2.53 to 4.36, 3.16 to 5.70 and 3.27 to 4.89 respectively. The benefit cost ratio increase with an increase in irrigation level. Irrigation at 200% of pan evaporation replenishment reduced the benefit cost ratio considerably because it reduced the gross return but increased the total cost production.

Water supply and yield

The relationship between seasonal water applied and marketable yield of broccoli for drip, micro sprinkler and surface irrigation methods are presented in **Fig. 1**. In spite of some variation, the seasonal water applied

and marketable yield of broccoli for drip ($R^2 = 0.9527$), micro sprinkler ($R^2 = 0.9698$) and surface ($R^2 = 0.9669$) irrigation methods exhibited strong quadratic relationship. The marketable yield of broccoli increased with increase in seasonal water applied upto 310 mm for drip, micro sprinkler and surface irrigation methods respectively and thereafter yield tended to declined (**Fig.1**).

Water supply and economic return

The relationship between seasonal water applied and gross return of broccoli under drip, micro sprinkler and surface irrigation methods are presented in (**Fig. 2**). The seasonal water applied and gross return of broccoli under drip ($R^2 = 0.9528$), micro sprinkler ($R^2 = 0.9697$) and surface ($R^2 = 0.9668$) irrigation method exhibited strong quadratic relationship. The gross return increased with an increase in seasonal water applied upto 335 mm for drip, micro sprinkler and surface irrigation methods respectively and thereafter, gross return tended to decline (**Fig. 2**).

The relationship between seasonal water

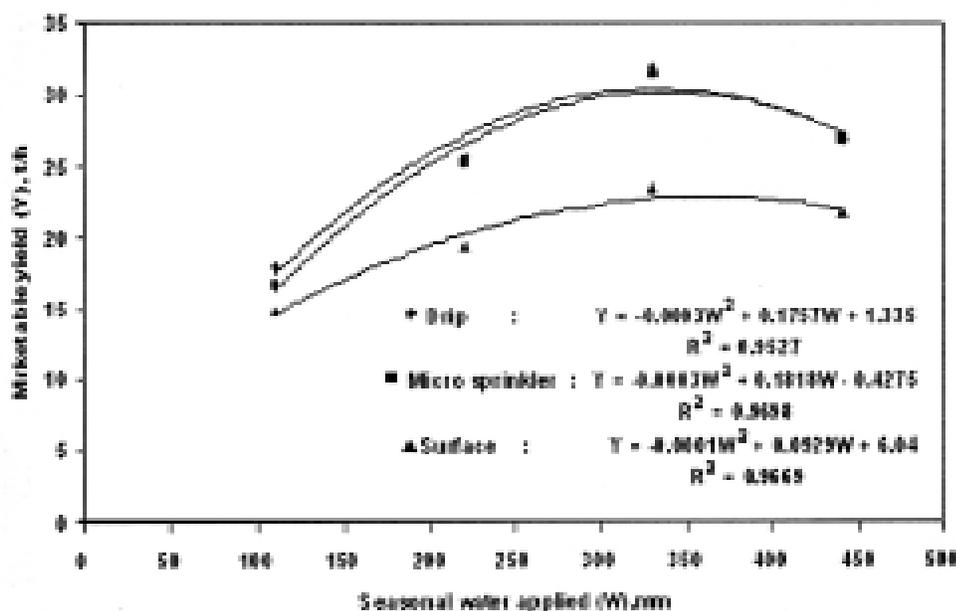


Fig. 1 : Relationship between Seasonal Water Applied (W) and marketable yield (Y) of broccoli for different irrigation methods

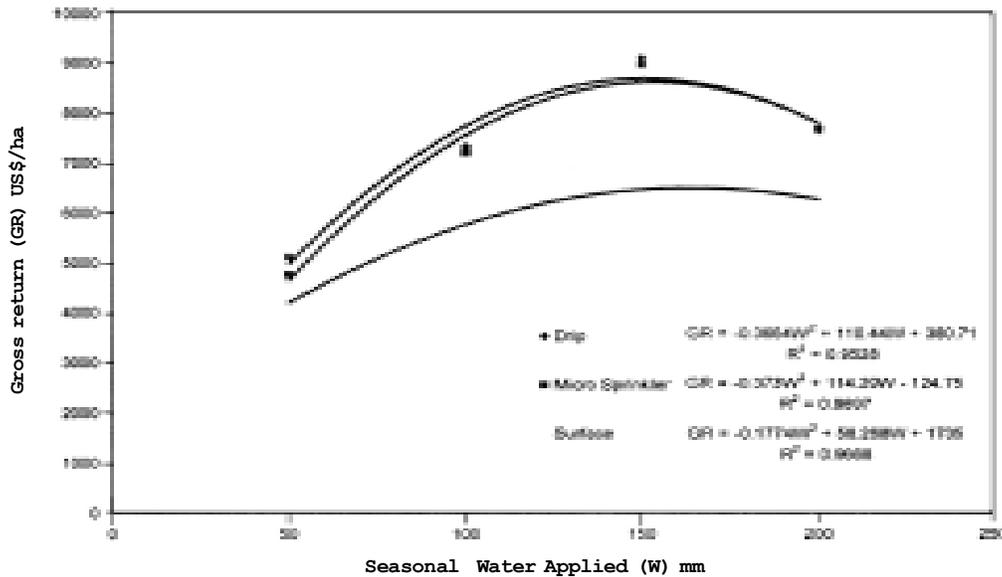


Fig. 2 : Relationship between Seasonal Water Applied (W) and Gross Return (GR) of broccoli for different irrigation methods

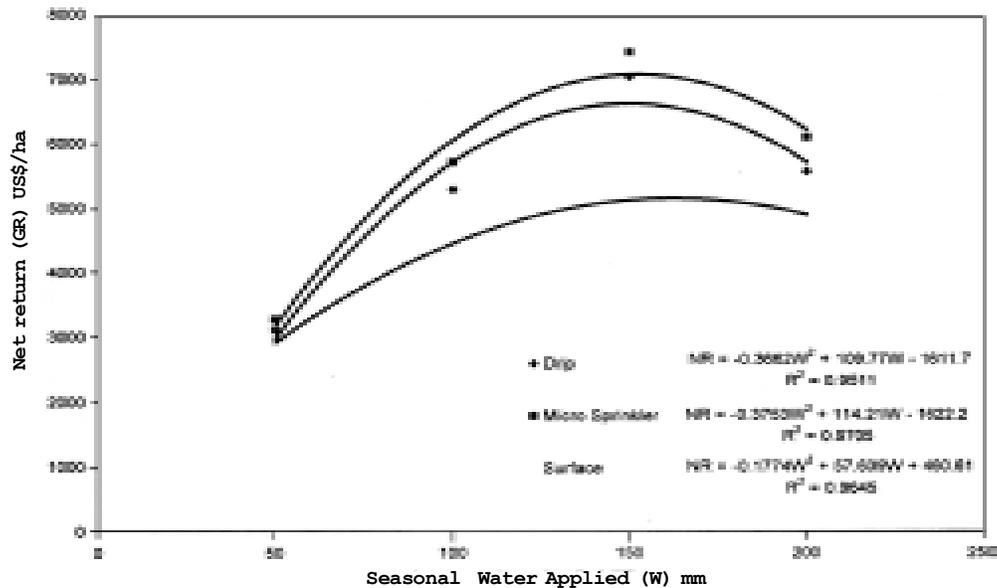


Fig. 3 : Relationship between Seasonal Water Applied (W) and Net Return (NR) of broccoli for different irrigation methods

applied and net return of broccoli under drip, micro sprinkler and surface irrigation methods are illustrated in Fig. 3. The seasonal water

applied and net return of broccoli under drip ($R^2 = 0.9511$), micro sprinkler ($R^2 = 0.9705$) and surface ($R^2 = 0.9645$) irrigation methods

exhibited strong quadratic relationship. The broccoli attained the maximum net return at 360 mm of seasonal water applied application for drip, micro sprinkler and surface irrigation methods respectively and thereafter, the net return tended decline (**Fig. 3**).

The relationship between seasonal water applied and benefit cost ratio of broccoli under drip, micro sprinkler and surface irrigation methods are illustrated in Figure 4. The seasonal water applied and benefit cost ratio of broccoli under drip ($R^2 = 0.9518$), micro sprinkler ($R^2 = 0.9692$) and surface ($R^2 = 0.9628$) irrigation methods exhibited strong quadratic relationship. The broccoli attained the maximum benefit cost ratio at 340 mm of seasonal water application for drip, micro sprinkler and surface irrigation methods respectively and thereafter, benefit cost ratio tended to decline (**Fig. 4**).

marketable yield of primary and secondary flowers of broccoli but irrigation production efficiency was higher when crop was irrigated at 150% of pan evaporation replenishment. Drip irrigation methods result in highest marketable yield and irrigation production efficiency followed by micro sprinkler irrigation methods.

Finally the overall result clearly suggest that in order to obtain higher marketable flowers yield, irrigation production efficiency and net return of broccoli during winter growing season (Nov. to Mar.), the crop should be irrigated at 150% of pan evaporation replenishment with drip, or micro sprinkler irrigation methods. Furthermore, the irrigation management approach using USWD class A open pan evaporation data is the most common, simple and can be easily adopted for fruits, field and

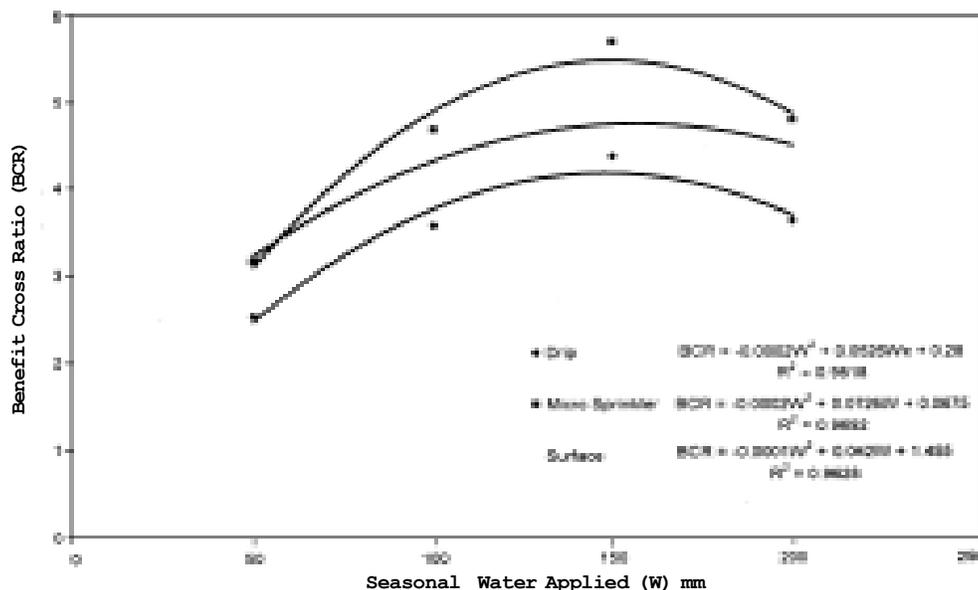


Fig. 4: Relationship between Seasonal Water Applied (W) and Benefit Cost Ratio (BCR) of broccoli for different irrigation methods

CONCLUSION

The experiments result shows that irrigation at 150% of pan evaporation replenishment gave a significantly higher

vegetable crops. In spite of the high initial cost the micro irrigation system for carrot production in this region is highly profitable. The clogging of drippers and sprinklers are the major

concern, but it can be maintained by using appropriate filters chemicals and flushing out mains, sub mains and lateral lines regularly.

REFERENCES

1. Imtiyaz M., Mgadla N.P., Manase S.K., Chendo K. and Mothobi E.O.. Yield and economic return of vegetable crops under variable irrigation. *Irrig. Sci.* **19**, 87-93, (2000a).
2. Imtiyaz M., Mgadla N.P., Chepete B. and Manase S.K., Response of six vegetable crops to irrigation schedules. *Agric. Water Manage* **45**, 331-342, (2000b).
3. Imtiyaz M., Mgadla N.P. and Manase S.K., Response of green mealies to water levels under sprinkler and drip irrigation. *Proc. of International Agricultural Engineering Conference*, Asian Institute of Technology, Bangkok, 343-350, (2000e).
4. James L.D. and Lee R.R., Economic of water resources planning. *M.C-Graw Hill, New Delhi*, **20**, (1971).
5. Prihar S.S., Gajri P.R. and Narang R.S. Scheduling of irrigation to wheat using pan evaporation, *Indian J. Agric. Sci.*, **44**, 567-571, (1974).
6. Singh B.P., Effect of irrigation on the growth and yield of okra, *Hort. Science* **22(5)**, 870-880, (1987).
7. Singh P.N. and Mohan S.C., Water use and yield response of sugarcane under different irrigation schedules and nitrogen levels in sub tropical region. *Agric. Water Manage*, **26**, 253-264, (1994).



DECLARATION BY THE AUTHOR(S)

I/We
 declare that the manuscript (Full Length Research Paper/Short communication/Review paper) entitled

 submitted to the “**Journal of Environmental Research And Development**”, have not been published and have not been submitted for publishing elsewhere, besides manuscript is my/our original work. Moreover, I/we assure to put my/our best efforts for the upliftment of environment.

Date :

Signature of Author(s)

Place :

Name(s) in Full