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YIELD, IRRIGATION PRODUCTION EFFICIENCY AND ECONOMIC RETURN OF BROCCOLI (*BRASSICA OLERACEA*. VAR. *ITALICA*) UNDER DIFFERENT IRRIGATION METHODS AND SCHEDULES

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Abstract: Field experiment was conducted at the Irrigation Research Farm of Allahabad Agricultural Institute, U.P., 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*). Irrigation was applied when the sum of daily pan evaporation data from United States Weather Bureau (USWB) class- A-open pan reach approximately to predetermined value of 16.3 mm. Irrigation at 150 percent of pan evaporation replenishment resulted in higher flower 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 percent pan evaporation replenishment resulted in higher gross return, net return and benefit cost ratio. 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.

Keywords: 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 less compared to 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 advanced irrigation method like micro-irrigation and sprinkler-irrigation method (Imtiyaz *et al.*, 2000). Appropriate Irrigation scheduling is to increase irrigation efficiencies by applying the exact amount of water needed to replenish the soil moisture to the desired level, to save water resources and energy. Therefore, it is important to develop irrigation scheduling techniques under prevailing climatic conditions in order to utilize scarce 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 researchers due to its simplicity, data availability and higher degree of adoptability at the farmer's level (Prihar *et al.*, 1974; Singh 1987; Singh and Mohan 1994; Imtiyaz *et al.*, 2000a, b, c). Surface irrigation such as furrow, check basin and border are the most common methods 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 farmers' knowhow in application of water consequent with 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 methods 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 area. Broccoli is a member of the Crucifereaceae or cole crop family and thus it is related to cabbage, cauliflower, and brussel sprouts. Broccoli is rich in vitamins and minerals. In view of this, the present study has been taken up 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, Allahabad, India (25^0 27' N, 81^0 44' E, and 98 m above sea level). During Rabi season of 2005-2006 the response of Broccoli to variable irrigation under drip, micro-sprinkler and surface (check basin) irrigation methods was studied. 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/ cm^3. The plant available soil moisture was 136.2 mm/m.

The experiment was conducted in two-factor randomized block design (irrigation schedule x irrigation method) with three replications. The area of each experimental plot was 7.5 m^2 (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 20^{th} 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 23^{rd} December, 2005, at a spacing of 50 cm between the plants and rows. The experimental field received 94.3 kg/ha P_2O_5, 62.5 kg/ha K_2O. The plot received 66 kg/ha of nitrogen at the time of transplanting, 3 weeks and 5 weeks after transplanting. The experiment consisted of three irrigation methods, viz. drip, micro-sprinkler and check-basin, and the amounts of water in different treatments were 50, 100, 150 and 200 percent pan evaporation replenishment. 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 a predetermined value of 16.3 mm (rooting depth in m x plant available water mm/m x permissible soil-moisture depletion in fraction). 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 lateral lines respectively. in the case of check-basin method, water was applied through pipe conveyance system. In micro-sprinkler system, plants were irrigated at a rate of 17 liters/h. In the case of drip-irrigation method, plants were irrigated at a rate of gap 4 liters/h. 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 asses the economic viability of different irrigation systems under variable irrigation, both fixed and operating costs were included. The total costs of production, gross return and net return under different irrigation levels were estimated under the following assumptions.

Salvage value of the components	=	0
Useful life of tube well, pump, motor & pump house	=	25 years
Useful life of drip & micro-sprinkler systems	=	3 years
Useful life of open channel conveyance systems	=	5 years
Useful life of weeding & spraying equipments	=	7 years
Interest rate	=	14%
Repair and maintenance	=	7.5%
Number of crops per year	=	2

The fixed cost 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 approach (James and Lee, 1971)

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

where

CRF = capital recovery factor

i = interest rate (fraction)

n = useful life of component (years)

Annual fixed cost/ ha = CRF x fixed cost/ha 2

$$\text{Annual fixed cost/ha/season} = \frac{\text{Annual fixed cost/ha}}{2} \quad 3$$

The operating cost which includes labor (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 the marketable yield and wholesale price of Broccoli. Subsequently, the net return for Broccoli was calculated considering the total cost of production (Fixed + Operating) and gross return.

Net return (US$/ha) = Gross return – Total cost of production 4

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

$$B/C = \frac{\text{Gross return}}{\text{Total cost of production}} \quad 5$$

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 flowers but it does not influence the number of flowers per square meter. The mean marketable yield of primary flowers for different irrigation schedules ranges from 14.32 to 23.44 tonnes/ha. The higher mean marketable yield of primary flowers (23.44 tonnes/ha) was obtained when irrigation during crop growing season was applied at 150 percent of pan evaporation replenishment. A further increase in irrigation level resulting from 200 percent of pan evaporation replenishment reduced the marketable yield of primary flowers (21.65 tones/ha) significantly due to significant reduction in number of primary flowers/m^2 and mean flower weight. The marketable yield of secondary flowers ranges from 2.22 to 5.50 tones/ha. The marketable yield of secondary flowers (5.50 tones /ha) was higher when irrigation during crop growing season was applied at 150 percent of pan evaporation replenishment. A further increase in irrigation level significantly reduced the marketable yield of secondary flowers (3.53 tones/ha).

The irrigation level had marked effect on irrigation production efficiency of Broccoli, which ranges from 5.72 to 15.04 kg/m^3. The significant higher irrigation production efficiency 15.04 kg/m^3 was recorded with irrigation at 150 percent of pan evaporation replenishment, because reduction in marketable yield was less as compared to seasonal water applied. Minimum irrigation production efficiency (5.72 kg/ha) was recorded when irrigation during crop-growing season was applied at 200 percent 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 and micro-sprinkler methods resulted in significantly higher irrigation production efficiency (10.94 kg/m^3). The surface-irrigation method resulted in minimum irrigation production efficiency (8.63 kg/m^3) due to considerably low marketable yield of primary and secondary flowers (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 seasonal 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.

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 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 USD/ha respectively. The gross return increased considerably with the increase in irrigation level. Maximum gross return was obtained when irrigation during crop-growing season was applied at 150 percent of pan evaporation replenishment. Further increase in irrigation level resulting from 200 percent pan evaporation replenishment decreased the gross return due to reduction in marketable yield. Drip and micro-sprinkler irrigations gave similar gross return but surface-irrigation gave considerably low gross return due to lower marketable yield. Maximum net return for drip- (7030.26 USD/ha), micro-sprinkler (7409.95 USD/ha) and surface- (5337.04 USD/ha), irrigation methods was obtained when irrigation during crop-growing season was applied at 150 percent of pan evaporation replenishment. A further increase in irrigation level resulting from 200 percent pan evaporation replenishment reduced the net return considerably due to reduction in gross return. Micro-sprinkler irrigation method gave higher net return compared to drip-irrigation because of lower system cost. The benefit-cost ratio for drip, micro-sprinkler and surface-irrigation methods ranged from 2.53 to 4.36, 3.16 to 5.70 and 3.27 to 4.89 respectively. The benefit-cost ratio increased with an increase in irrigation level. Irrigation at 200 percent of pan evaporation replenishment reduced the benefit-cost ratio considerably, because it reduced th 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 Figure 1. Despite 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 up to 310 mm for drip, micro-sprinkler and surface-irrigation methods respectively, and thereafter the yield tended to decline (Fig.1).

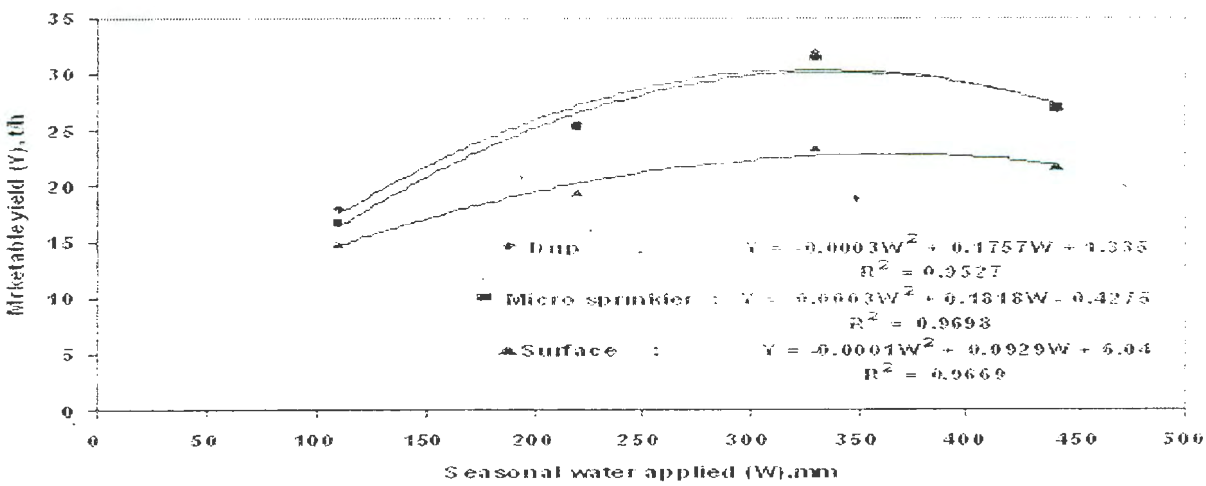

Fig.1 Relationship between sesonal water applied (W) and marketable yield (Y) of broccoli for different irrigation methods

Water supply and economic return

The relationship between seasonal water applied and gross return of Broccoli under the three irrigation methods is presented in Figure 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 methods exhibited strong quadratic relationship. The gross return increased with an increase in seasonal water applied up to 335 mm for drip, micro-sprinkler and surface-irrigation methods respectively, and thereafter gross return tended to decline (Fig. 2).

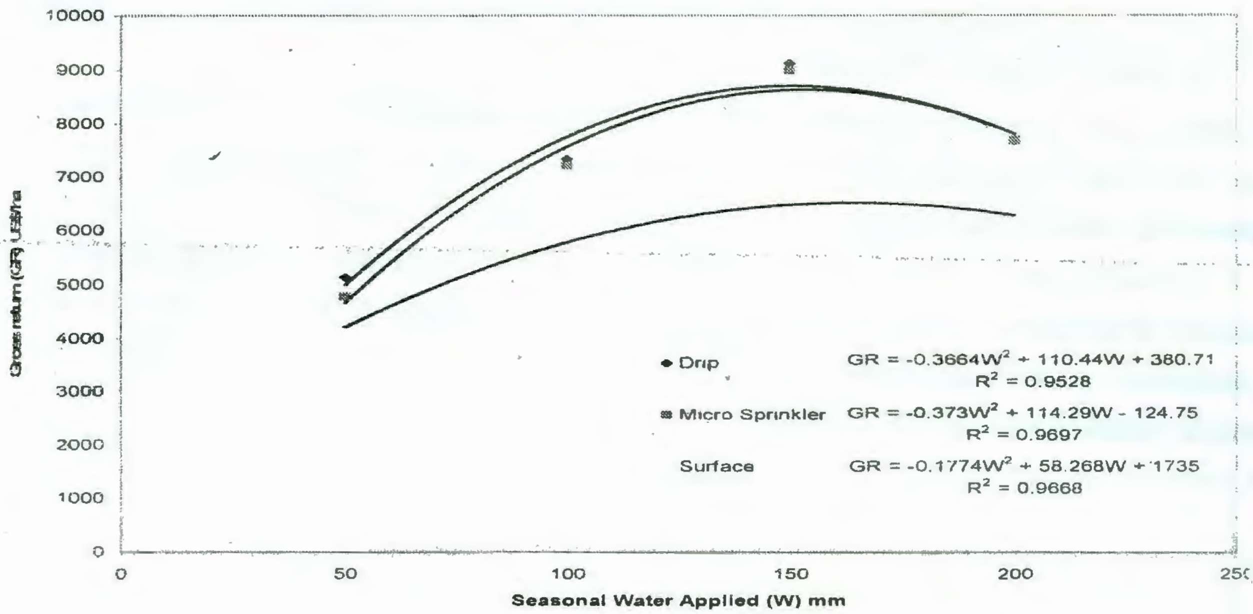

Figure 2: Relationship between Seasonal Water Applied (W) and Gross Return (GR) of Broccoli for different irrigation methods

The relationship between seasonal water applied and net return of Broccoli under the three irrigation methods is illustrated in Figure 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 under drip, micro-sprinkler and surface-irrigation methods respectively, and thereafter the net return tended to decline (Fig. 3).

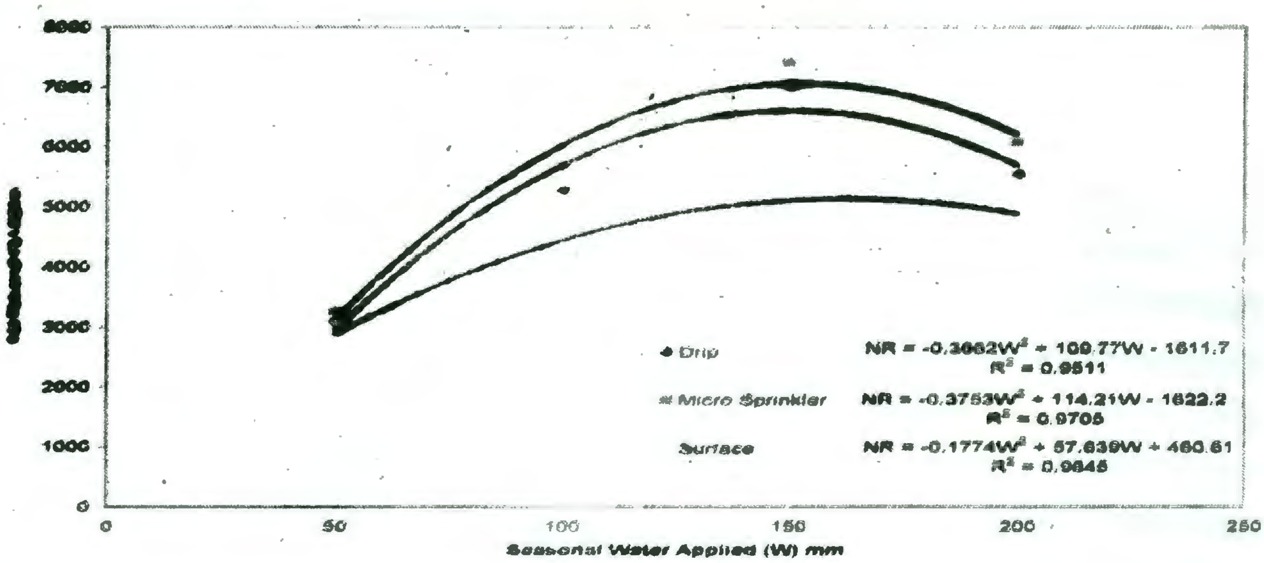

Figure 3: Relationship between Seasonal Water Applied (W) and Net Return (NR) of Broccoli for different irrigation methods

The relationship between seasonal water applied and benefit-cost ratio of Broccoli under the three irrigation methods is illustrated in Fig. 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. 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 the benefit-cost ratio tended to decline (Fig. 4).

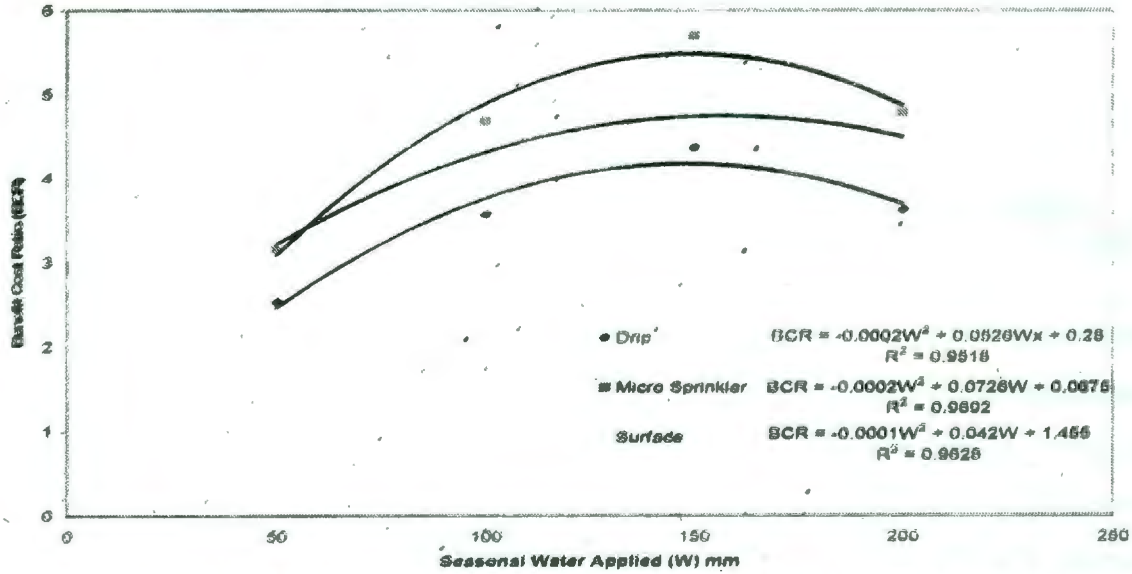

Figure 4: Relationship between Seasonal Water Applied (W) and Benefit Cost Ratio (BCR) of broccoli for different irrigation methods

Conclusions

The results show that irrigation at 150 percent of pan evaporation replenishment gave a significantly higher marketable yield of primary and secondary flowers of Broccoli but irrigation production efficiency was higher when crop was irrigated at 150 percent of pan evaporation replenishment. Drip-irrigation method results in highest marketable yield and irrigation production efficiency, followed by micro-sprinkler irrigation method.

The results also clearly suggest that in order to obtain higher marketable flower-yield, irrigation production efficiency and net return of Broccoli during winter growing season (November to March), the crop should be irrigated at 150 percent of pan evaporation replenishment with drip or micro-sprinkler irrigation method. Furthermore, the irrigation management-approach using USWB class A open-pan evaporation data is the most common and simple, which can be easily adopted for fruit, field and vegetable crops. In spite of the high initial cost, the micro-irrigation system for Broccoli production in this region is highly profitable. The clogging of drippers and sprinklers is the major concern, but it can be maintained by using appropriate filters, chemicals and flushing out main, sub-main and lateral lines regularly

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

References

Imtiyaz, M., Mgadla, N.P., Manase, S.K., Chendo, K. and Mothobi E.O. (2000a). Yield and economic return of vegetable crops under variable irrigation. *Irrig. Sci. 19:87-93.*

Imtiyaz, M., Mgadla, N.P., Chepete, B. and Manase, S.K. (2000b). Response of six vegetable crops to irrigation schedules. *Agric. Water Manage 45:331-342.*

Imtiyaz, M., Mgadla, N.P. and Manase, S.K. (2000c). Response of green mealies to water levels under sprinkler and drip irrigation. *Proc. of International Agricultural Engineering Conference*, Asian Institute of Technology, Bangkok, pp. 343-350.

James L.D. and R.R. Lee. (1971). *Economic of water resources planning.* M.C-Graw Hill, New Delhi, pp. 20.

Prihar S.S., Gajri, P.R. and Narang, R.S. (1974). Scheduling of irrigation to wheat using pan evaporation. *Indian J. Agric. Sci.* 44:567-571.

Singh, B.P. (1987). Effect of irrigation on the growth and yield of Okra. *Hort. Science* 22: 870-880.

Singh, P.N. and Mohan, S.C. (1994). Water use and yield response of sugarcane under different irrigation schedules and nitrogen levels in sub tropical region. *Agric. Water Manage.* 26:253-264.