Research Journal of Engineering Sciences ISSN 2278 – 9472
Vol. **1(5),** 1-6, November **(2012)** *Res. J. Engineering Sci.*

Effects of Lateral Spacing and Irrigation Scheduling on Drip Irrigated Cabbage (*Brassica Oleracea*) in a Semi Arid Region of India

Himanshu S.K.[1], Kumar S.[1], Kumar D.[2] and Mokhtar A.[3]
[1]Department of Civil Engineering, Graphic Era University, Dehradun, Uttarakhand, INDIA
[2]Department of Civil Engineering, G. B. Pant Engineering College, Pauri Grahwal, INDIA
[3]TAFE, Muzaffarpur, INDIA

Available online at: www.isca.in
Received 7th October 2012, revised 12th October 2012, accepted 15th Ocotber 2012

Abstract

In order to evaluate the effect of irrigation levels (25, 75, 125, 175 and 225% of pan evaporation replenishment) and lateral spacing (0.5 and 1.0m) on marketable yield, irrigation production efficiency and economic return of cabbage under drip irrigation system and semi arid climate, a field experiment was conducted at the Irrigation Research Farm of Allahabad, India. The study was carried out during the winter crop growing season of 2009-2010 (Nov. to March) on clay loam soil. The highest mean marketable yield of cabbage (90.51 t/ha) during crop growing season was recorded when irrigation was applied at 175% of pan evaporation replenishment with 1.0m lateral spacing due to the higher mean head weight (2.26 kg). A further increase in irrigation amount resulting from 225% of pan evaporation replenishment reduces the marketable yield significantly due to significant reduction in mean head weight (2.15 kg). Irrigation at 25% of pan evaporation replenishment gave the higher irrigation production efficiency (61.59 kg/m^3) with 1.0m lateral spacing. It decreases significantly with increase in irrigation level. Minimum irrigation production efficiency was recorded with 225% of pan evaporation replenishment (13.36 kg/m^3) with 0.5m lateral spacing because it increases seasonal water applied considerably but decreases the marketable yield. Irrigation at 175% of pan evaporation replenishment and 1.0m lateral spacing resulted in higher gross return (271530 Rs/ha), net return (210972 Rs/ha) and benefit cost ratio (4.48). In spite of high initial investment, drip irrigation method is highly profitable for cabbage production with 1.0m lateral spacing.

Keywords: Drip irrigation, lateral spacing, irrigation schedule, marketable yield, pan evaporation.

Introduction

Water is the major limiting factor for crop diversification and production. Due to rapid population growth, the competition of limited water resources for domestic, industrial and agricultural needs is increasing considerably. For the ever-growing population, water for irrigation is becoming both scarce and expensive due to fast depletion of surface and sub-surface water resources, caused by erratic rainfall. Thus right amount and frequency of irrigation is vital for effective use of water resources for crop production. Improper irrigation management practices cause not only wastage of expensive and scarce water resources but also decreases crop yield, quality, water use efficiency and economic return as well as it leads to water logging and salinity which can be partly corrected by expensive drainage system.

Irrigation scheduling is a critical management input to ensure optimum soil moisture status for proper plant growth and development as well as for optimum yield, water use efficiency and economic benefits. It is defined as deciding when to irrigate and how much water to apply and is governed by various complex factors of which micro climate plays the most important role. Therefore it is essential to develop irrigation scheduling strategies under local climatic conditions to utilize scarce water resources efficiently and effectively. Numerous studies have been carried out in past elsewhere on development and evaluation of irrigation scheduling techniques under wide range of irrigation systems and management, soil, crop and climatic conditions[1, 2, 3]**.** 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. Surface irrigation such as furrow, check basin and border are the most common method in India[4]. 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[5,6].

The meteorological approach of scheduling irrigation is relating the evapotranspiration from crop to evaporation from an open pan, as it is well known that the rate of evapotranspiration is related to open pan evaporation. The meteorological approach such as pan evaporation replenishment, cumulative pan evaporation and ratio between irrigation water and cumulative pan evaporation play very important role in scheduling[7]. In spite of some limitations, evaporation from USWB class-A open pan is the most common and simplest approach for scheduling of irrigation[8]. The daily weather data can be used to estimate reference evapotranspiration using the Penman equation. It was observed that both grain and dry matter yield increased significantly with the increase in water application rates[9].

Surface irrigation is the most common method for field, vegetable and fruit crop in India. The overall efficiency of surface irrigation method is considerably low as compared to modern irrigation method such as drip, micro-jet/micro sprinkler and over head sprinkler. Drip irrigation method with its ability to apply small but frequent water application has been found superior In terms of water economy yield, quality and water use efficiency[10,11]. It also makes possible the application of fertilizers and other chemical along with water application to match the plants requirements at various growth stages. The drip irrigation system impedes the growth of weeds as it wets only a fraction of the soil surface. This explicates the preponderance of drip irrigation system overall other irrigation methods of irrigation, however, its adoption by the farmers of the region has largely been limited owing to its high cost of installation and lack of information of irrigation scheduling techniques even though the government subsidy is available on its purchase.

Efficient use of water by irrigation system is becoming increasingly important particularly in arid and semi-arid regions. The drip irrigation systems with its ability to apply small but frequent irrigation have numerous advantageous over other methods in terms of water economy, yield and quality[12]. Water application efficiency in the drip irrigation is higher than other methods of irrigation[13].

Material and Methods

The field experiment was be conducted at Allahabad (25° 27'N, latitude 81° 44'E longitude, 98m above mean sea level) during the winter crop growing period (Nov. to march 2009-2010.) in order to examine the effect of variable irrigation and lateral spacing on yield, irrigation production efficiency and economic return of cabbage. The climate in this part of country has been classified as semi-arid with cold winter and hot summer. The soil of the experimental field was fertile clay loam, (35.5% sand, 25.8% silt and 38.6% clay) with average bulk density of 1.31 g/cm^3.

The experiment was laid out in a two factor complete randomized block design with three replications. It comprised of 10 treatments with five irrigation levels (25, 75, 125, 175 and 225% of pan evaporation replenishment) and two lateral spacing (0.5m and 1.0m). The area of each experimental plot will be 9 m^2 (3m×3m). Before sowing the seeds of cabbage, soil was prepared by mixing 70% of field soil and 30% compost. Cabbage (Prithvi F1 hybrid) seed was sown on 1st November 2009 in the nursery at a depth of 5cm with a spacing of 10cm between the rows. The seed bed was irrigated regularly and covered with dry straw of 6cm thickness and treated with Gamaxene in order to facilitate good emergence. The seedlings were transplanted on 3rd December 2009 at a spacing of 0.5m × 0.5m. A buffer zone spacing of 0.5m was provided between the plots. Prior to transplanting, 72 kg/ha N, 21kg/ha P_2O_5 and 90 kg/ha K_2O were applied to the experimental field of cabbage.

The daily mean evaporation data from USWB class A open pan for a period of 5 years were collected from meteorological station, SHIATS, Allahabad. The crop was irrigated when the sum of the daily mean (5 years) of pan evaporation reached approximately to the predetermined value of 16.3mm (rooting depth in mm × plant available soil moisture in mm/m × readily available soil moisture in fraction). The drip irrigation system was designed and installed to meet the objectives of research work. PVC pipes of 50mm and polyethylene pipes (LDPE) of 12mm were used for main/sub-main and lateral lines respectively. Plants were watered by 3 l/hr online drippers. Each experimental plot was connected by control valve in order to deliver the desired amount of water. In order to assess the economic viability of drip irrigation system under variable irrigation and lateral spacing, both fixed and operating cost are included. Total cost of production, gross return and net return under different irrigation levels will be estimated on the following assumptions.

Salvage value of the component = 0, Useful life of tube well, pump, motor and pump house = 25 years, Useful life of drip irrigation system = 10 years, useful life of weeding and spraying equipments = 7 years, interest rate = 12.5%, repair and maintenance = 2.5%, no. of crops / year = 2.

The fixed cost including water development (tube well, pump, motor, pump- house and other accessories) and irrigation systems, Poly vinyl chloride (PVC) and Low density polyethylene pipes (LDPP) for main, sub-main and laterals, filters, fertilizer unit, pressure gauges, control valves, water meter, drippers and other accessories will be calculated for different irrigation levels and lateral spacing as:

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

Where, CRF = capital recovery factor, i = internet rate (fraction), n = useful life of the component (years).

$$\text{Annual fixed cost/ha} = \text{CRF x fixed cost /ha} \tag{2}$$

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

The operating cost including labour (system installation, irrigation, planting, weeding, cultivation, fertilizer and chemical application and harvesting etc. land preparation, fertilizer and chemical, water pumping and repair and maintenance (tube-well, pump, electric motor, pump-house, irrigation systems etc.)

will be estimated. The gross return will be calculated taking into consideration the marketable yield and current whole sale price of cabbage. Subsequently, the net return for cabbage will be calculated considering total cost of production (fixed and operating costs) and gross return.

Results and Discussion

Marketable yield and irrigation production efficiency of cabbage: Marketable cabbage yield and irrigation production efficiency as influenced by irrigation levels (pan evaporation replenishment) and lateral spacing are presented on table no.1 for1m lateral spacing (LS_2) and 0.5 lateral spacing (LS_1) respectively.

In (LS_2) systems irrigation levels significantly influenced the mean cabbage weight as we could see that mean cabbage weight was increasing with an increase in irrigation level from 1.04 at 25% up to 2.15 at 225% of pan evaporation replenishment. However there was a fall in mean cabbage weight at 225% of pan evaporation replenishment. Mean number of heads per m^2 was influenced by irrigation levels as we could see that mean number of heads was increasing with an increase in irrigation levels from 25% to 175% of pan evaporation replenishment. But 225% of pan evaporation replenishment there was decrease in mean number of heads per m^2. The marketable cabbage yield range from 41.89/ha to 90.51t/ha with 1m lateral spacing. The highest marketable cabbage yield which was 90.51t/ha was observed when irrigation was performed at175% pan evaporation replenishment. And the lower cabbage yield which was 41.89t/ha was observed when irrigation was performed at 25% of pan evaporation replenishment. Irrigation production efficiency ranged from 61.59 at 25% to 14.09 at 225% of pan evaporation replenishment.

In (LS_1) systems irrigation levels influenced the mean cabbage weight as we could see that mean cabbage weight was increasing with an increase in irrigation level from 0.76 at 25% up to 2.04 at 225% of pan evaporation replenishment mean number of heads per m^2 was influenced by irrigation levels as we could see that mean number of heads was increasing with an increase in irrigation levels from 25% to 175% of pan evaporation replenishment. But at 225% of pan evaporation replenishment there was decrease in mean number of heads per m^2. The marketable cabbage yield ranged from 30.79t/ha to 84.65t/ha. The highest marketable cabbage yield which is 84.65t/ha was at 175% irrigation level and the lowest cabbage yield which is 30.79t/ha was obtained when irrigation was performed at 25% of pan evaporation replenishment. Irrigation production efficiency ranged from 45.27 at 25% of pan evaporation replenishment to 13.36 at 225% of pan evaporation replenishment.

Economic return: The total cost of production, gross return, net return and benefit cost ratio for cabbage under different irrigation levels and lateral spacing are presented on table no.2 for 1.0m (LS_2) and 0.5m (LS_1) lateral spacing.

In system with 1m lateral spacing (LS_2)gross return increased with an increase in irrigation levels from Rs. 125670/ha at 25% of pan evaporation replenishment to Rs. 271530/ha at 175% of pan evaporation replenishment. But there was a fall in gross return at 225% of pan evaporation replenishment. Total cost of production also increased with an increase in irrigation levels from Rs.55968/ha at 25% of pan evaporation replenishment to Rs. 62088/ha at 225% of pan evaporation replenishment. Net return also increased with an increase in irrigation levels from Rs. 69702/ha at 25% of pan evaporation replenishment and Rs. 210972/ha at 175% of pan evaporation replenishment (figure-2).

In system with 0.5m lateral spacing (LS_1) gross return increased with an increase in irrigation levels from Rs. 92370/ha at 25% to Rs. 253950/ha at 175% of pan evaporation replenishment while there was a decrease in gross return with an increase in irrigation levels at 225% of pan evaporation replenishment. Total cost of production also increased accordingly as irrigation levels increased from Rs. 65607/ha at 25% pan evaporation to Rs. 71727/ha at 225% of pan evaporation replenishment. Net return increased accordingly up to 175% of pan evaporation replenishment and thereafter at 225% of pan evaporation replenishment. Net return increased accordingly up to 175% of pan evaporation replenishment and thereafter at 225% of pan evaporation replenishment there was a decrease in net return due to increase in total cost of production. Generally the net return for 1m lateral spacing is higher than that of 0.5m lateral spacing.

Benefit cost ratio also for 1.0m lateral spacing showed quadratic increase from 2.24 at 25% of pan evaporation replenishment to 4.48 at 175% of pan evaporation replenishment. But a fall in both benefit cost ratio and net return was observed when water was applied at 225% of pan evaporation replenishment.

The benefit cost ratio for 0.5m lateral spacing increased sharply from 1.40 at 25% to 3.61 at 175% of pan evaporation replenishment due to increase in marketable yield but further increase in irrigation levels at 225% of pan evaporation replenishment led to increase in cost of production and decrease in gross return thus there was a decrease in benefit cost ratio.

Water supply and marketable yield: The relationship between seasonal water applied and marketable yield of cabbage for two lateral spacing are presented in figure-1. The seasonal water applied ranged from 68 to 612mm, whereas, marketable yield for 0.5m and 1.0m lateral spacing ranged from 30.79 to 84.65t/ha and 41.89 to 90.51t/ha respectively. The seasonal water applied and marketable yield of cabbage for 0.5m and 1.0m lateral spacing exhibited strong quadratic relationship (figure-1). The marketable yield of cabbage increased with an increase in seasonal water applied from 68 up to 476mm for both lateral spacing, thereafter the marketable yield tended to decline. The result revealed that higher seasonal water application did not increase evapotranspiration as well as marketable yield but it increased deep percolation. The decline in marketable yield at at 612mm seasonal water applied resulted from nutrient leaching through deep percolation and the poor aeration.

The relationship between marketable yield and pan evaporation replenishment of cabbage for 0.5m and 1.0m lateral spacing are presented in table 1. The pan evaporation replenishment ranged from 25% to 225% whereas marketable yield of cabbage ranged from 30.79 to 84.65t/ha and 41.89 to 90.51t/ha for 0.5m and 1.0m lateral spacing respectively. The marketable yield and pan evaporation replenishment for 0.5m and 1.0m lateral spacing exhibited quadratic relationship.

Water supply and economic return: The relationship between seasonal water applied and gross return of cabbage for the two lateral spacing are presented in table 2 and they showed strong quadratic relationship (figure-3). The seasonal water applied from 68 to 612 mm, whereas gross return for 0.5m and 1m lateral spacing ranged from Rs. 92370/ha to Rs. 253950/ha and Rs. 125670/ha to Rs. 271530/ha respectively. The gross return of cabbage increased with an increase in seasonal water applied up to 476mm for both 1m and 0.5m lateral spacing and thereafter gross return tended to decline.

The relationship between pan evaporation replenishment and gross return of cabbage for two lateral spacing are presented in table 2. The pan evaporation replenishment and gross return showed strong quadratic relationship for 0.5m and 1m lateral spacing. The gross return increased with increased pan evaporation replenishment up to 175% for 0.5m and 1m lateral spacing respectively and thereafter, it tended to decline.

The relationship between seasonal water applied and net return of cabbage are presented in table 2. The seasonal water applied ranged from 68 to 612mm, whereas net return for 0.5m and 1.0m lateral spacing ranged from Rs. 26763/ha and Rs.183753/ha and Rs. 69702/ha to Rs. 210972/ha respectively. The seasonal water applied and net return showed strong quadratic relationship for 0.5m and 1.0m lateral spacing (figure-3). The net return of cabbage increase with an increased in seasonal water applied up to 476mm for both 0.5m and 1.0m lateral spacing and thereafter it tended to decline. The relationship between pan evaporation replenishment and net return of cabbage for two lateral spacing are presented in table 2. The pan evaporation and net return showed strong quadratic relationship for 0.5m and 1.0m lateral spacing. The net return increased with increased pan evaporation replenishment up to 175% for both 0.5m and 1.0m lateral spacing respectively and thereafter, it tended to decline. Ratio of cabbage increased with an increased in seasonal water applied up to 476mm for both 0.5m and 1.0m lateral spacing and thereafter it tended to decline.

The relationship between seasonal water applied and benefit cost ratio of cabbage for two lateral spacing are presented in table 2. The seasonal water applied ranged from 68mm to 612mm, whereas benefit cost ratio for 0.5m and 1.0m lateral spacing ranged from 1.40 to 3.67 and 2.24 to 9.97 respectively. The seasonal water applied and benefit cost ratio exhibited strong quadratic relationship as shown in figure-4. The benefit cost ratio increased with an increase in pan evaporation replenishment up to 175% for both 0.5m and 1.0m lateral spacing respectively and thereafter, it tended to decline.

The relationship between pan evaporation replenishment and benefit cost ratio of cabbage for two lateral spacing are presented in table 2. The pan evaporation replenishment and benefit cost ratio exhibited strong quadratic relationship. The benefit cost ratio increased with an increase in pan evaporation replenishment up to 175% for both 0.5m and 1.0m lateral spacing respectively and thereafter, it tended to decline.

Table-1
Effect of irrigation schedules and lateral spacing on marketable yield and irrigation production efficiency of cabbage

Treatment (PER)	Mean cabbage yield (t/ha)	Irrigation production efficiency (kg/m^3)	Mean head weight (kg)	Marketable head/m^2
0.25LS$_1$	30.79	45.28	0.76	3.46
0.75LS$_1$	52.24	25.60	1.30	3.57
1.25LS$_1$	69.49	20.43	1.73	3.68
1.75LS$_1$	84.65	17.78	2.11	3.89
2.25LS$_1$	81.79	13.36	2.04	3.41
LSD (5%)	0.91	0.66	0.078	NS
lateral spacing (m)				
0.5	63.79	24.48	1.53	3.38
1.0	72.08	30.14	2.16	4.07
Interaction LSD (5%)	1.32	0.86	0.13	0.17

Table-2
Effect of irrigation levels and lateral spacing on fixed cost, operating cost and total cost of production of cabbage

Pan evaporation replenishent (%)	0.5m lateral spacing (LS_1) for every row				1m lateral spacing (LS_2) for every row			
	Fixed cost Rs/ha	Operating cost Rs/ha	Total cost of production Rs/ha	Benefit cost ratio (B/C)	Fixed cost Rs/ha	Operating cost Rs/ha	Total cost of production Rs/ha	Benefit cost ratio (B/C)
25	23651	41956	65607	1.40	14247	41721	55968	2.24
75	23651	43486	67137	2.33	14247	43251	57498	3.28
125	23651	45016	68667	3.03	14247	44781	59028	4.00
175	23651	46546	70197	3.61	14247	46311	60558	4.48
225	23651	48076	71727	3.42	14247	47841	62088	4.16

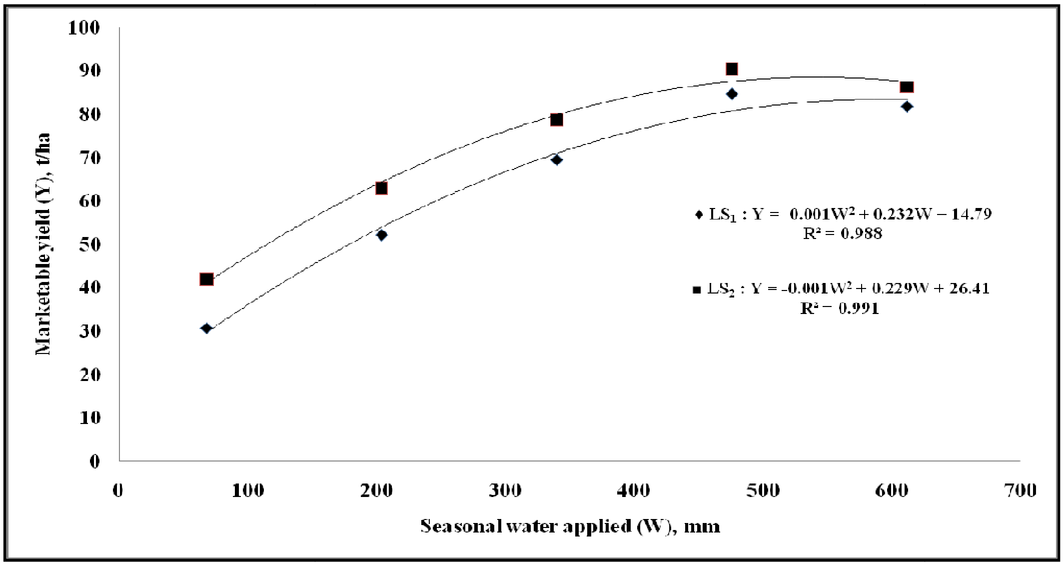

Figure-1
Relationship between seasonal water applied and marketable yield of cabbage for 0.5m (LS_1) and 1.0m (LS_2) lateral spacing

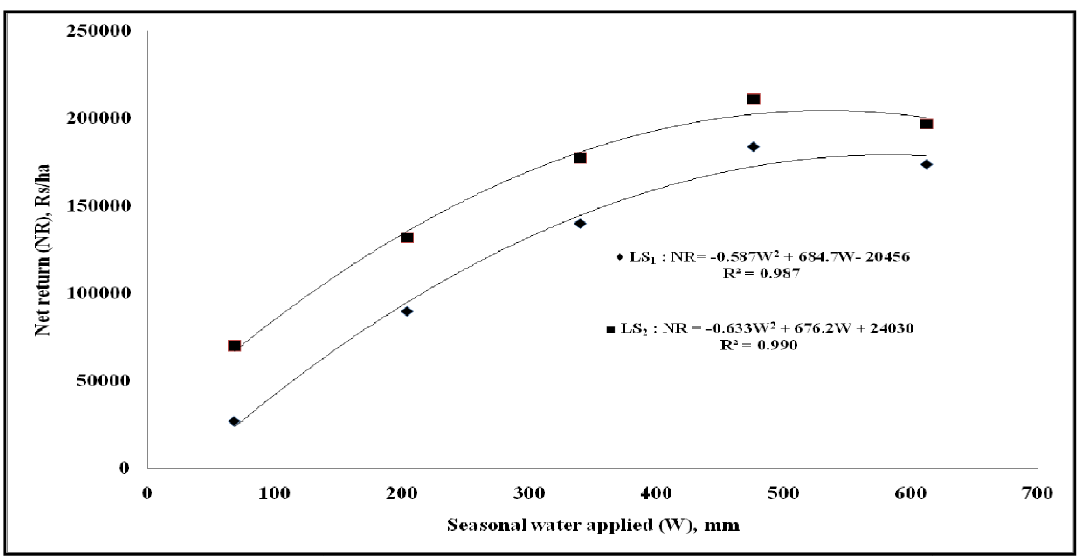

Figure-2
Relationship between seasonal water applied and net return of cabbage for 0.5m (LS_1) and 1.0m (LS_2) lateral spacing

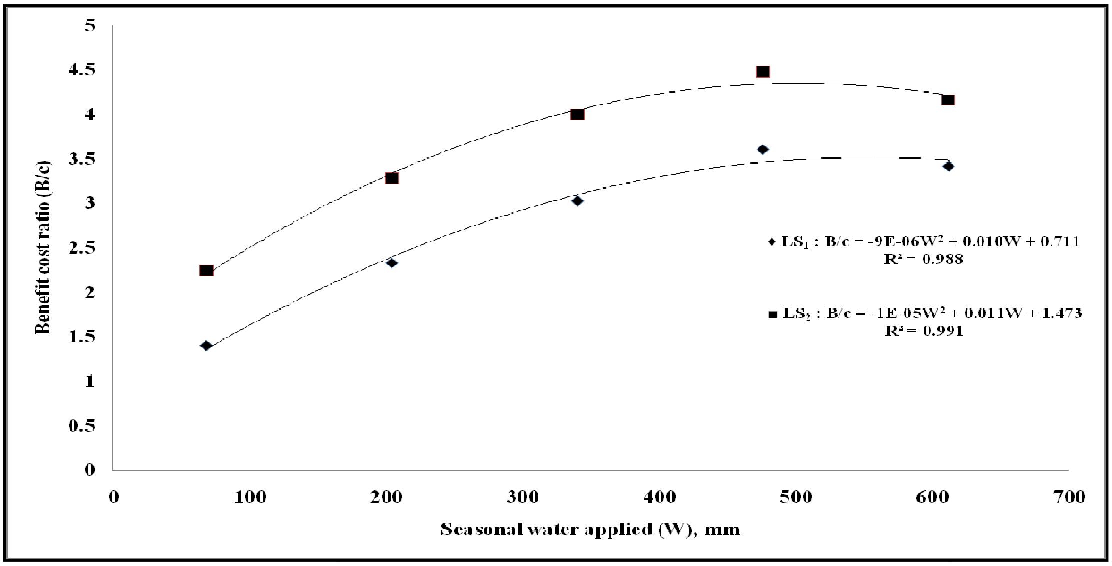

Figure-3
Relationship between seasonal water applied and benefit cost ratio of cabbage for 0.5m (LS_1) and 1.0m (LS_2) lateral spacing

Conclusion

The overall results clearly revealed that in order to obtained optimum cabbage yield and economic return as well as allocate limited water resources suitably; cabbage should be irrigated at 175% of pan evaporation replenishment with both 1.0 m and 0.5 m lateral spacing. However, 1.0 m lateral spacing was found to be more economic than 0.5 m lateral spacing as its gross return and net return were higher than that of 0.5 m lateral spacing. Also, the cost of production for 1.0 m lateral spacing was lower than that of 0.5 m lateral spacing.

References

1 Stegman E.C., Efficient irrigation timing methods for corn production, *Trans ASAE,* **29(1)**, 203-210 **(1986)**

2 Wanjura D.F., Upchurch and Mahan J.R., Evaluating decision criteria for irrigation scheduling in cotton, *Trans ASAE* **33**, 512-518 **(1990)**

3 Imtiyaz M., Mgadla N.P., Chepet B. and Manase S.K., Marketable yield, water use efficiency an decobomicreturn of cabbage, carrot an donion as influenced by irrigation schedules, *Proc. Of international AgricultralEngineerng coference*, Asian institute of technology, Bangkok, 312-328 **(2000d)**

4 Mateos L., Bregena J., Orgaz F., Diz J and Froress E., A comparison between drip and furrow in cotton at two levels of water supply, *Agric. Water Manag.*, **119**, 313-324 **(1991)**

5 Tiwari K.N. and Reddy K.Y., Economic analysis of trickle irrigation system considering planting geometry, *Agric. Water Manage.*, **34**, 195-206 **(1998)**

6 Goldberg D. and Sumeli M., Drip irrigation- A method used under arid conditions of high water and soil salinity, *Transactions of the ASAE,* **13(1)**, 38-41 **(1970)**

7 Mgadla N.P., Imtiyaz M. and Chepte B., Wheat production as influenced by limited irrigation, *Irrigation Research paper No.-2* Department of Agricultural Research, Botswana, 22 **(1995)**

8 Imtiyaz M., Mgadla N.P., Chepet K. and Mothobi E.O., Yield and economic return of vegetables crops under variable irrigation, *Irrig. Sci.* 1987-1993 **(2000a)**

9 Camp C.R., Sadler E.J. and Busscher W.J., A comparison of uniformity measures for drip irrigations systems, *Transactions of the ASAE*, **40(4)**, 1013-1020 **(1977b)**

10 Mahadi M., Kaisi A.I., Berrada A. and Stack M., Evaluation of irrigation scheduling programme and spring wheat yield response in South Western Colorado, *Agricultural water management*, **34,** 37-148 **(1997)**

11 Srivastava P.K., Parikh M.M., Swami N.G. and Raman S. Effect of irrigation and mulching on tomato yield, *Agric Water Manage*, **25**, 179-184 **(1994)**

12 Fekadu Y. and Teshome T., Effect of drip and furrow irrigation and plant spacing on yield of tomato at Dire Dawa, Ethopia, *Agric. Water Manage*, **35**, 201-207 **(1998)**

13 Sivanappam R.K., Kumara O.P. and Kumar V., Drip irrigation, *Deerthi publishing House*, Coimbatore, India **(1987)**