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Response of Cabbage (*Brassica Oleracea*) Under Variable Irrigation and Lateral Spacing

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Abstract

In order to evaluate the effect of irrigation levels (50, 75, 100, 125 and 150 % of pan evaporation replenishment) and lateral spacing (0.5 m and 1.0 m) 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 2012-2013 (Nov. to March) on clay loam soil. The highest mean marketable yield of cabbage (84.14 t/ha) during crop growing season was recorded when irrigation was applied at 125 % of pan evaporation replenishment with laterals in every rows and 0.5 m lateral spacing (LS_1). A further increase in irrigation amount resulting from 150% of pan evaporation replenishment reduces the marketable yield significantly. Irrigation at 50% of pan evaporation replenishment gave the higher irrigation production efficiency of 38.33 kg/m^3 with LS_1 irrigation method. Minimum irrigation production efficiency was recorded with 150 % of pan evaporation replenishment (9.29 kg/m^3) with laterals in alternate rows and 0.5 m lateral spacing (LS_2) because it increases seasonal water applied considerably but decreases the marketable yield. Irrigation at 125 % of pan evaporation replenishment and 0.5 m lateral spacing (LS_1) resulted in higher gross return (705066 Rs/ha), net return (633496 Rs/ha) and benefit cost ratio (9.84). In spite of higher initial investment, irrigation level of 125 % of pan evaporation replenishment and LS_1 drip irrigation method is highly profitable for cabbage production in the region..

Keywords: Drip irrigation, lateral spacing, 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. 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. Therefore it is essential to develop irrigation scheduling strategies under local climatic conditions to utilize scarce water resources efficiently and effectively[1]. 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[2]. 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[3]. Therefore, it is important to develope irrigation scheduling techniques under prevailing climatic conditions in order to utilize scare water resources effectively for crop production[4,5].

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[6]. 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. The meteorological approach of scheduling irrigation is relating the evapo-transpiration from crop to evaporation from an open pan, as it is well known that the rate of evapo-transpiration 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. The daily weather data can be used to estimate reference evapo-transpiration using the Penman equation[8]. It was observed that both grain and dry matter yield increased significantly with the increase in water application rates. 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. It also makes possible the application of fertilizers and other chemical along with water application to match the plants requirements at various growth stages. 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[9,10]. Water application efficiency in the drip irrigation is higher than other methods of irrigation. Therefore, the present study was undertaken to cater the need of farmer in order to improve marketable yield, water use efficiency and economic return of cabbage.

Material and Methods

Field experiments was conducted at the irrigation research farm of Sam Higginbottom Institute of Agriculture, technology and Sciences; Allahabad (25˚27'N, 81˚44'E, 98m above mean sea level) during Rabi season of 2012-2013 in order to study the response of cabbage to variable irrigation levels and lateral spacing in under drip irrigation method[11]. The climate in this part of the country is characterized as semi arid with cold winter and hot summer. 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 loss basis. The average bulk density of the soil was 1.3g/cm^3.

The plant available soil moisture was 136.2mm/m. The experiment was laid out in two factor randomized block design (irrigation schedules and irrigation methods) with five replications. The area of experimental plot was 9m^2 (3x3). A buffer zone spacing of 1.0m and 0.5m was provided between the plots and blocks. Cabbage (F1-Hybrid) seeds were sown on 22nd October 2012 in the nursery at a depth of 0.05m with a spacing of 10cm between the rows. The seed bed was irrigated regularly and covered with dry straw of 6m thickness and treated with gamaxene in order to facilitate good emergence. The seedlings were transplanted on 28th November 2012 with a spacing of 0.5m x 0.5m. Prior to transplanting the experimental field received 68 kg/ha N, 94.3 kg/ha P_2O_5 and 62.9 kg/ha K_2O. The experimental field received 70 kg/ha N at the time of transplanting, 6 weeks and 5 weeks of transplanting.

The experiment consisted of five irrigation levels and three lateral spacing. The details of the treatments are as follows:

Irrigation Levels: I_1 : Irrigation at 50% of pan evaporation replenishment. I_2 : Irrigation at 75% of pan evaporation replenishment. I_3 : Irrigation at 100% of pan evaporation replenishment. I_4 : Irrigation at 125% of pan evaporation replenishment. I_5 : Irrigation at 150% of pan evaporation replenishment.

Lateral Spacing: LS_1= 0.5m (laterals in every rows), LS_2= 1m (laterals in alternate rows), LS_3= 0.5m (laterals at between plants)

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 3l/hr online drippers. The irrigation water was pumped directly from borehole to the concrete tank. The irrigation water was lifted from the concrete tank with the help of motor to the drip irrigation system. Screen filter was installed on the main line to minimize dripper blockage. The sub-main line was connected to a water meter and control valve in order to deliver the desired amount of water to the respective treatments shows in Figure-9, 10 and 11 with different lateral spacing diagram. Standard cultural practices were adopted during the crop growing seasons. The crop was harvested from 14th February 2013 to 8th march 2013.

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 components	= 0
Useful life of tube well, pump, motor and pump house	= 25 years.
Useful life of drip irrigation systems	= 8 years.
Useful life of weeding and spraying equipments	= 7 years.
Interest rate	= 14%
Repair and maintenance	= 7.5%
No. of crops/year	= 2

The fixed cost including water development (tube well, pump, motor, pump-house and other accessories) and irrigation system poly vinyl chloride (PVC) and low density polyethylene pipes (LDPE) for main, sub-main and laterals, filters, fertilizer unit, pressure gauges, control valves, water meter, drippers and other accessories was calculated for different irrigation levels and lateral spacing by the following approach (James and Lee 1971).

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

where, CRF= capital recovery factor, I= interest rate (fraction) n= useful life of the component (years)

Annual fixed cost/ha = CRF × fixed cost/ha (2)

Annual fixed cost/ha = (Annual fixed cost/ha)/2 (3)

The operating cost which includes labor (system installation, fertilizer, chemical application and harvesting etc.) land preparation, seeds, fertilizer, chemicals (insecticides and pesticides) and water pumping (electricity) and repair and maintenance (tube well pump, motor, pump house, irrigation systems 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 wholesome price of cabbage. Subsequently, the net return for the cabbage was calculated considering total cost of production (fixed and operating costs) and gross return.

Results and Discussion

Marketable yield, yield components and irrigation production efficiency: Yield and irrigation production efficiency of cabbage influenced by irrigation methods and irrigation schedules are presented in table 1. The mean crop yield for different irrigation level ranged from 40.25 to 84.14 t/ha. Irrigation at 125 % of pan evaporation replenishment resulted in significantly higher mean crop yield of 84.14 t/ha. A further increase in irrigation level resulting from 150 % of pan evaporation replenishment reduced the mean crop yield (79.44 t/ha) significantly. Irrigation at 50 % of pan evaporation replenishment resulted minimum crop yield of 40.25 t/ha. Irrigation methods also influenced the mean crop yield of cabbage significantly[12]. Among the three irrigation methods applied LS_1 gave highest mean crop yield of 70.79 t/ha followed by LS_3 (68.04 t/ha) and LS_2 with minimum mean crop yield of 62.01 t/ha. The effect of irrigation methods and irrigation levels on irrigation production efficiency of cabbage is presented in table-1. From table it is shown that the irrigation production efficiency for different irrigation levels varies from 9.29 to 38.33 kg/m^3. The irrigation production efficiency decreased significantly with the increase in irrigation levels because increase in the mean crop yield was lower than the seasonal water irrigation production efficiency applied. Maximum mean irrigation production efficiency of 38.33 kg/m^3 was observed at 50 % of pan evaporation replenishment irrigation level and minimum mean irrigation production efficiency value of 9.29 kg/m^3 was observed at 150 % of pan evaporation replenishment irrigation level. This is because with the increase in irrigation level seasonal water application is increased while mean crop yield decreases[13]. The mean irrigation production efficiency values of cabbage for all three irrigation methods i.e. LS_1, LS_2 and LS_3 were 20.61, 17.64, 19.63 kg/m^3 respectively. Minimum mean irrigation production efficiency was observed for LS_2. It is also noted that both LS_1 and LS_3 shows slight difference in the mean crop yield as well as mean irrigation production efficiency whereas LS_2 resulted in considerably low mean crop yield as well as low mean irrigation production efficiency compare to both LS_1 and LS_3.

Table-1
Effect of different irrigation schedules and irrigation methods on marketable yield, yield components and irrigation production efficiency of cabbage

Treatments	Mean yield of cabbage, (t/ha)	Mean irrigation production efficiency, (kg/m^3)
Irrigation schedule (pan evaporation replenishment) %		
50	40.25	38.33
75	57.77	21.03
100	73.14	15.32
125	84.14	12.50
150	79.44	9.29
CD (0.05)	0.75	0.24
Irrigation methods: (Drip irrigation)		
LS_1	70.79	20.61
LS_2	62.01	17.64
LS_3	68.04	19.63
CD (0.05)	0.36	0.11

Water supply and marketable yield: The relationship between seasonal water applied and marketable yield of cabbage for different irrigation methods are presented in figure-1. The seasonal water applied varied from 105 to 850 mm where as crop yield for LS_1, LS_2 and LS_3 irrigation method ranged from 43.83 to 83.8 t/ha, 36.03 to 73.66 t/ha and 40.9 to 80.86 t/ha respectively. The seasonal water applied and crop yield of cabbage for LS_1 (R^2 = 0.99), LS_2 (R^2 = 0.98) and LS_3 (R^2 = 0.99) irrigation methods exhibited a strong quadratic relationship. The result revealed that higher seasonal water applied did not increase the evapo-transpiration as well as crop yield however it increased deep percolation[14,15].

From figure-2 it is observed that pan evaporation replenishment ranged between 50 and 150 % whereas the crop yield of cabbage for LS_1, LS_2 and LS_3 irrigation method ranged from 43.83 to 83.8 t/ha, 36.03 to 73.66 t/ha and 40.9 to 80.86 t/ha respectively. Pan evaporation replenishment and crop yield of cabbage for LS_1 (R^2 = 0.98), LS_2 (R^2 = 0.98) and LS_3 (R^2 = 0.97) irrigation methods exhibited a strong quadratic relationship. The crop yield of cabbage increased with the increase in pan evaporation replenishment and attained its maximum value for LS_1, LS_2 and LS_3 irrigation method at 125 % of pan evaporation replenishment and thereafter it started to decline.

Cost of Production: Effect of irrigation schedules and irrigation methods on fixed, operating and total cost of production of cabbage is presented in table 3. From table it is shown that the operating cost and consequently total cost of production increases with the increased in irrigation levels for all three methods of irrigation. This is mainly due increased in pumping cost induced by variation in seasonal water applied. It is also noted that fixed cost, operating cost and total production of cabbage is highest for LS_1 followed by LS_3 and LS_2 for each level of irrigation which is due to increase in number of drippers/ ha and lateral length in case of LS_1 as dripper was installed for every plant at every row[16]. The fixed cost for LS_1, LS_2 and LS_3 irrigation methods were 56818, 19168 and 55000 Rs/ha respectively. Operating cost for LS_1, LS_2 and LS_3 varied from 63065 to 74240 Rs/ha, 62124 to 73299 Rs/ha and 63030 to 74195 Rs/ha respectively when irrigation level varied from 50 % to 150 % of pan evaporation replenishment. The total cost of production for LS_1, LS_2 and LS_3 irrigation methods varied from 119883 to 131058 Rs/ha, 81292 to 92467 Rs/ha and 118020 to 129195 Rs/ha respectively when irrigation level varied from 50 % to 150 % of pan evaporation replenishment.

Economic Return: The total cost of production, gross return, net return and benefit cost of cabbage in relation to irrigation methods and irrigation schedules are presented in table 2. Table shows that gross return of increases sharply from 50 to 125 % of pan evaporation replenishment and its value decreases after that for all three methods of irrigation because from 125 % of pan evaporation replenishment the mean crop yield is reduced. The gross return of cabbage for LS_1, LS_2 and LS_3 irrigation methods varied from 350666 to 705066 Rs/ha, 288266 to 632266 Rs/ha and 327200 to 681333 Rs/ha respectively. It is observed that maximum gross return is observed at 125 % of pan evaporation replenishment and minimum at 50 % of pan evaporation replenishment for each method of irrigation[17, 18]. Same trend as described in gross return is observed for net return too as shown in table 2. The net return of cabbage for LS_1, LS_2 and LS_3 irrigation methods varied from 287601 to 633496 Rs/ha, 226137 to 561637 Rs/ha and 264180 to 609808 Rs/ha respectively. The net return of cabbage is highest for LS_1 followed by LS_3 and LS_2 for each level of irrigation due to fact that highest crop yield is obtained from LS_1 method of irrigation as compared to LS_2 and LS_3.

Like the gross and net return, benefit cost ratio has the same trend i.e. under different irrigation levels its value increases considerably from 50 to 125 % of pan evaporation replenishment due to increase in the value of gross return for all three methods of irrigation[19]. A further increase in pan evaporation replenishment irrigation level decreases the benefit cost ratio. The benefit cost ratio of cabbage for LS_1, LS_2 and LS_3 irrigation methods varied from 5.55 to 9.84, 4.63 to 8.95 and 5.18 to 9.52 respectively. Among the three methods of irrigation maximum benefit cost ratio is observed for LS_1 followed by LS_3 and LS_2 as shown in table 2. The maximum benefit cost ratio of cabbage for LS_1 (9.84), LS_2 (8.95) and LS_3 (9.52) are obtained at 125 % of pan evaporation replenishment irrigation level[20]. The overall result shows that highest gross return, net return and benefit cost ratio is obtained at 125 % of pan evaporation replenishment among the five selected irrigation levels. Further it is also observed that among the three methods of irrigation LS_1 gives highest gross return, net return and benefit cost ratio.

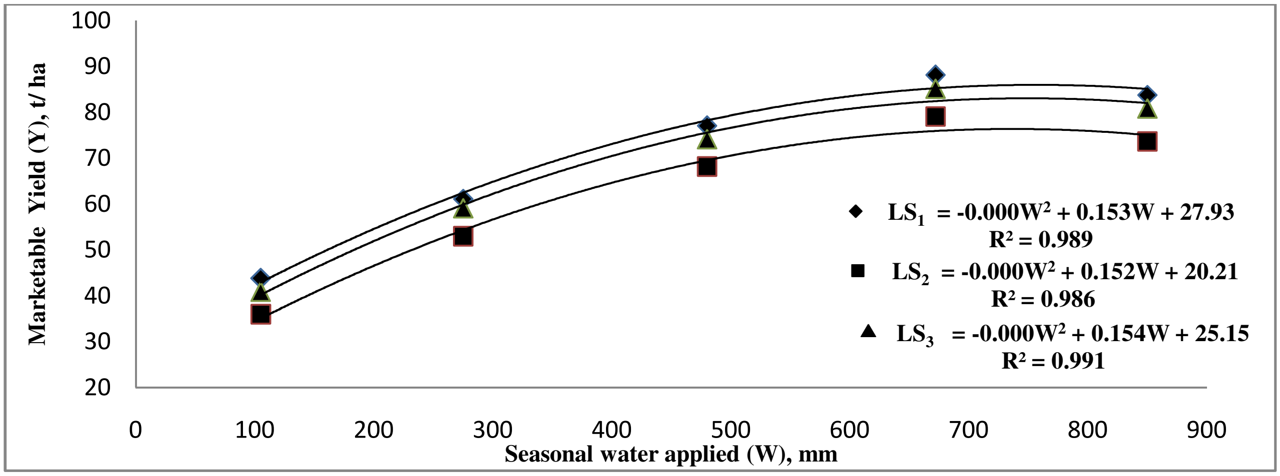
Water Supply and Economic Return: The relationship between seasonal water applied and gross return of cabbage for all three methods of irrigation are presented in figure-3. The seasonal water applied varied from 105 to 850 mm where as gross return for LS_1, LS_2 and LS_3 irrigation method ranged from 350666 to 665066 Rs/ha, 288266 to 584533 Rs/ha and 327200 to 646933 Rs/ha respectively. The seasonal water applied and gross return of cabbage for LS_1 (R^2 = 0.98), LS_2 (R^2 = 0.98) and LS_3 (R^2 = 0.99) irrigation methods exhibited a strong quadratic relationship. It is revealed from the figure that higher seasonal water applied beyond the above mentioned value did not increase the gross return. The fitted regression method can be used for optimizing gross return of cabbage under different irrigation methods and levels[21]. The same graph is plotted between gross return and pan evaporation replenishment in order to see their relationship and shown in figure-4. The relationship between seasonal water applied and net return of cabbage and between net return and pan evaporation replenishment for all three methods of irrigation are illustrated in Figure-5 and 6 respectively. The seasonal water applied varied from 105 to 850 mm and pan evaporation replenishment ranged between 50 and 150 %. It is found that net return for LS_1, LS_2 and LS_3 irrigation method ranged from 287601 to 590860 Rs/ha, 226137 to 511234 Rs/ha and 264180 to 572738 Rs/ha respectively. Both seasonal water applied and pan evaporation replenishment exhibit a strong quadratic relationship with net return and developed equation can be used for optimizing net return of cabbage under different irrigation methods and levels[22]. Similarly graph is also plotted between seasonal water applied and benefit cost ratio of cabbage and between benefit cost ratio and pan evaporation replenishment in order to examine their relationship for all three methods of irrigation and shown in Figure-7 and 8. It is found that benefit cost ratio for LS_1, LS_2 and LS_3 irrigation method ranged from 5.55 to 8.95, 4.63 to 7.97 and 5.18 to 8.71 respectively. From graph it is observed that both seasonal water applied and pan evaporation replenishment exhibit a strong quadratic relationship with benefit cost.

Table-2
Economic return of cabbage under different irrigation schedules and irrigation methods

Methods of irrigation (Drip irrigation)	Irrigation schedules (pan evaporation replenishment)	Total cost of production, (Rs/ha)	Gross return, (Rs/ha)	Net return, (Rs/ha)	Benefit cost ratio
0.5 m lateral spacing (LS_1) for every rows	50	121458	350666	287601	5.55
	75	122585	489333	423718	7.45
	100	123963	621866	553176	9.04
	125	125283	705066	633496	9.84
	150	126408	665066	590860	8.95
1.0 m lateral spacing (LS_2) for alternate rows	50	82867	288266	226137	4.63
	75	83992	426133	361459	6.58
	100	85372	545600	477851	8.04
	125	86702	632266	561637	8.95
	150	87817	584533	511234	7.97
0.5 m lateral spacing (LS_3) in between the rows	50	119595	327200	264180	5.18
	75	120720	473066	407497	7.21
	100	122100	598666	531047	8.71
	125	123420	681333	609808	9.52
	150	124545	646933	572738	8.71

Table-3
Effect of irrigation schedules and irrigation methods on fixed, operating and total cost of production of cabbage

Methods of irrigation (Drip irrigation)	Irrigation schedules (pan evaporation replenishment)	Fixed cost (Rs/ha)	Operating cost (Rs/ha)	Total cost of production (Rs/ha)
0.5 m lateral spacing (LS_1) for every rows	50	56818	63065	119883
	75	56818	65615	122433
	100	56818	68690	125508
	125	56818	71570	128388
	150	56818	74240	131058
1.0 m lateral spacing (LS_2) for alternate rows	50	19168	62124	81292
	75	19168	64674	83842
	100	19168	67749	86917
	125	19168	70629	89797
	150	19168	73299	92467
0.5 m lateral spacing (LS_3) in between the rows	50	55000	63020	118020
	75	55000	65570	120570
	100	55000	68645	123645
	125	55000	71525	126525
	150	55000	74195	129195



Figurge-1

Relationship between seasonal water applied and marketable yield of cabbage for 0.5 m (◆), 1.0 m (■) and 0.5 m (▲) lateral spacing

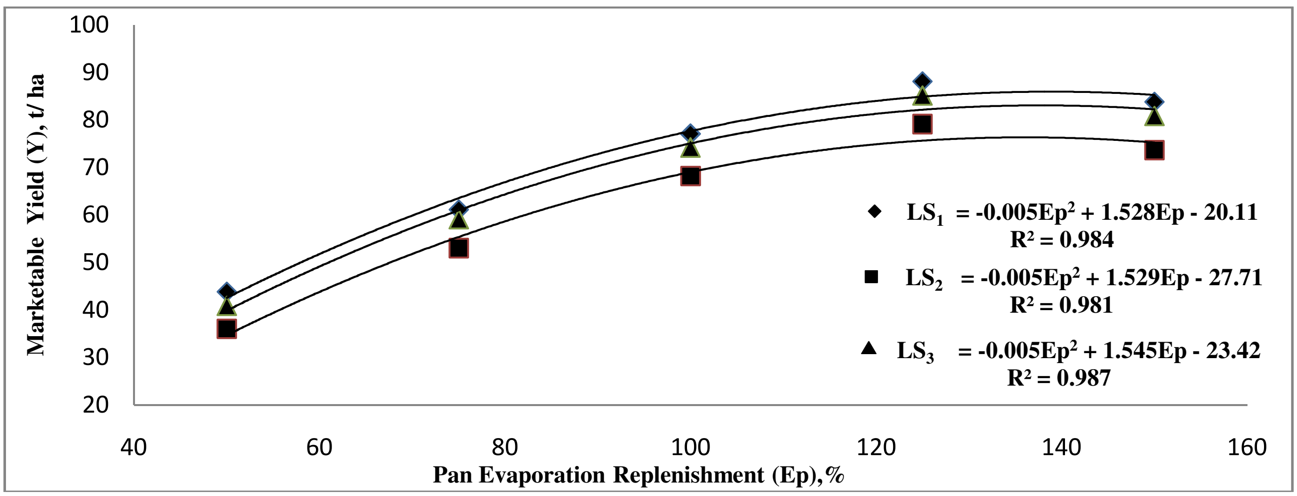


Figure-2

Relationship between pan evaporation replenishment and marketable yield of cabbage for 0.5 m (◆), 1.0 m (■) and 0.5 m (▲) lateral spacing

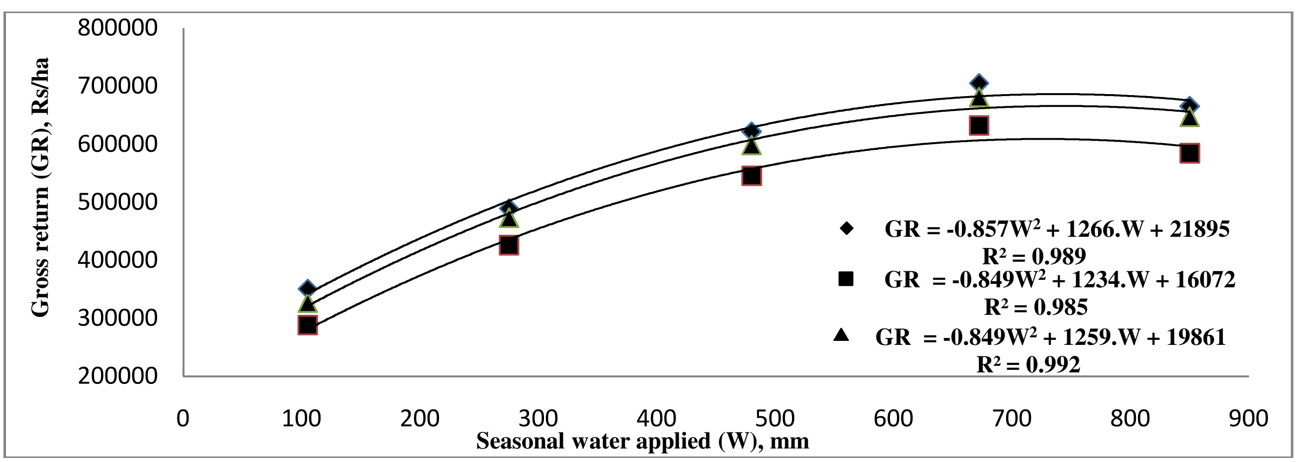


Figure-3

Relationship between seasonal water applied and Gross return of cabbage for 0.5 m (◆), 1.0 m (■) and 0.5 m (▲) lateral spacing

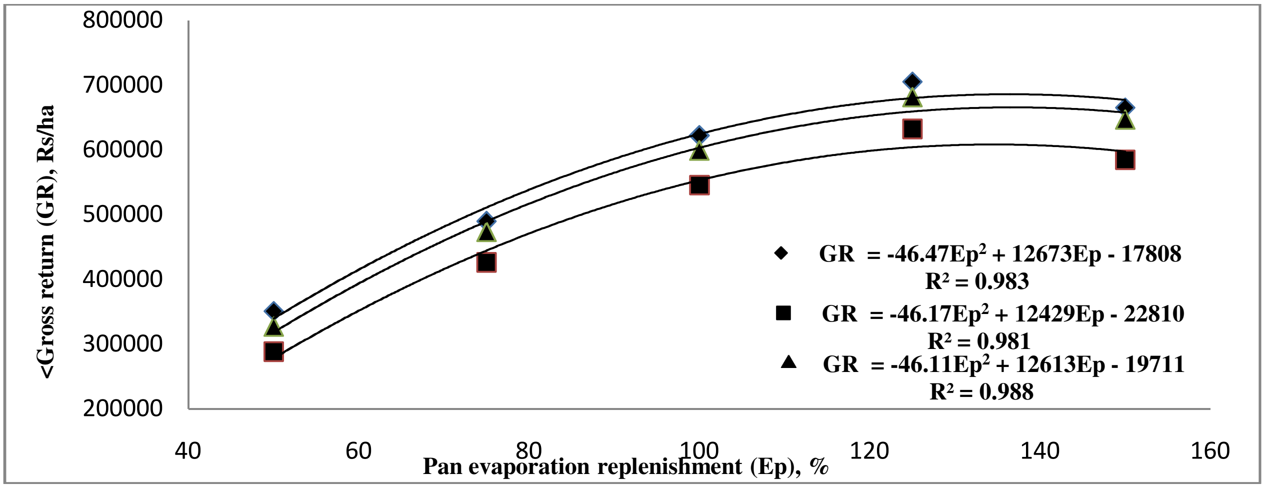


Figure-4

Relationship between pan evaporation replenishment and Gross return of cabbage for 0.5 m (◆), 1.0 m (■) and 0.5 m (▲) lateral spacing

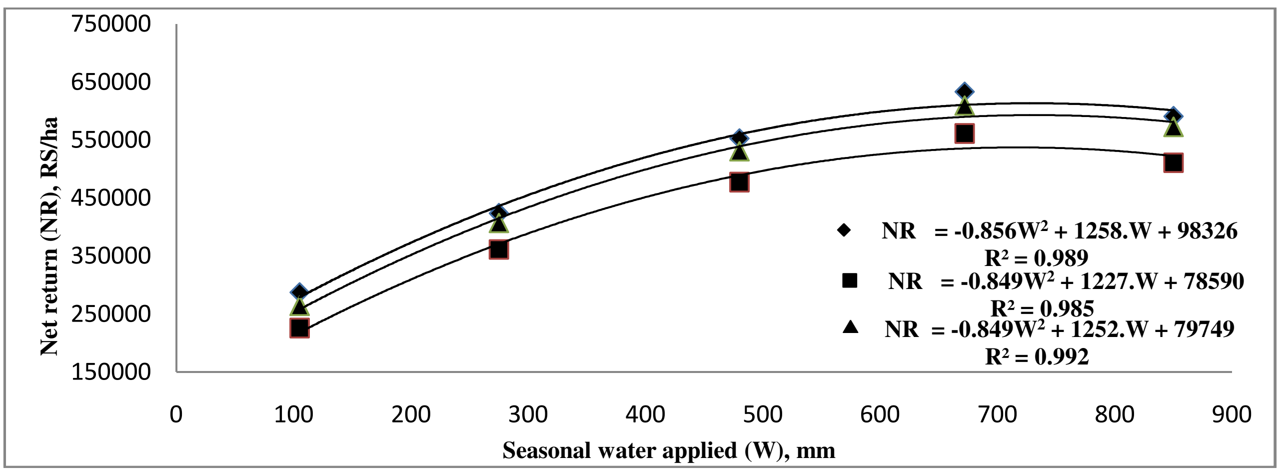


Figure-5

Relationship between seasonal water applied and net return of cabbage for 0.5 m (◆), 1.0 m (■) and 0.5 m (▲) lateral spacing

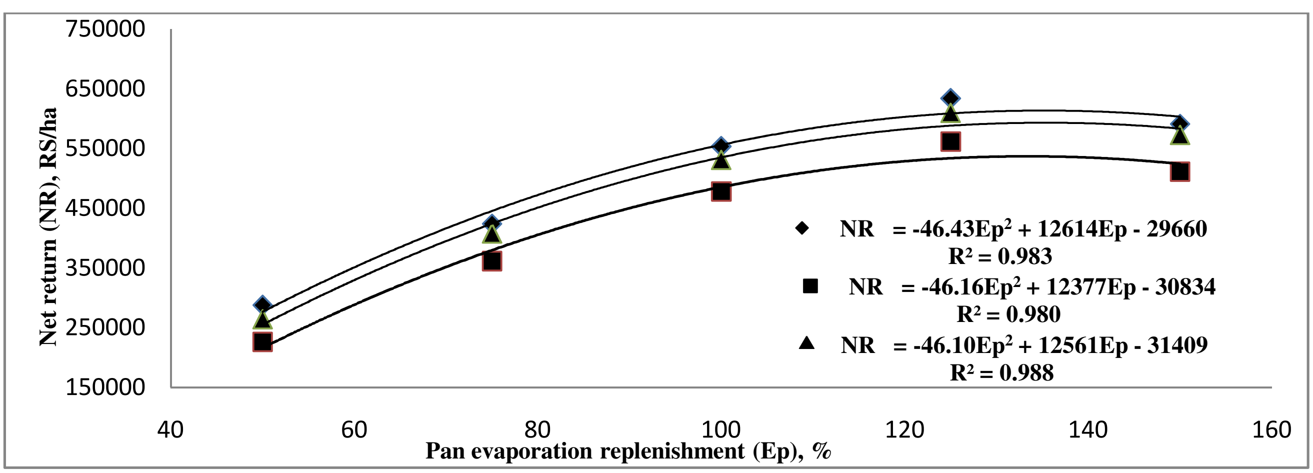


Figure-6

Relationship between pan evaporation replenishment and Net return of cabbage for 0.5 m (◆), 1.0 m (■) and 0.5 m (▲) lateral spacing

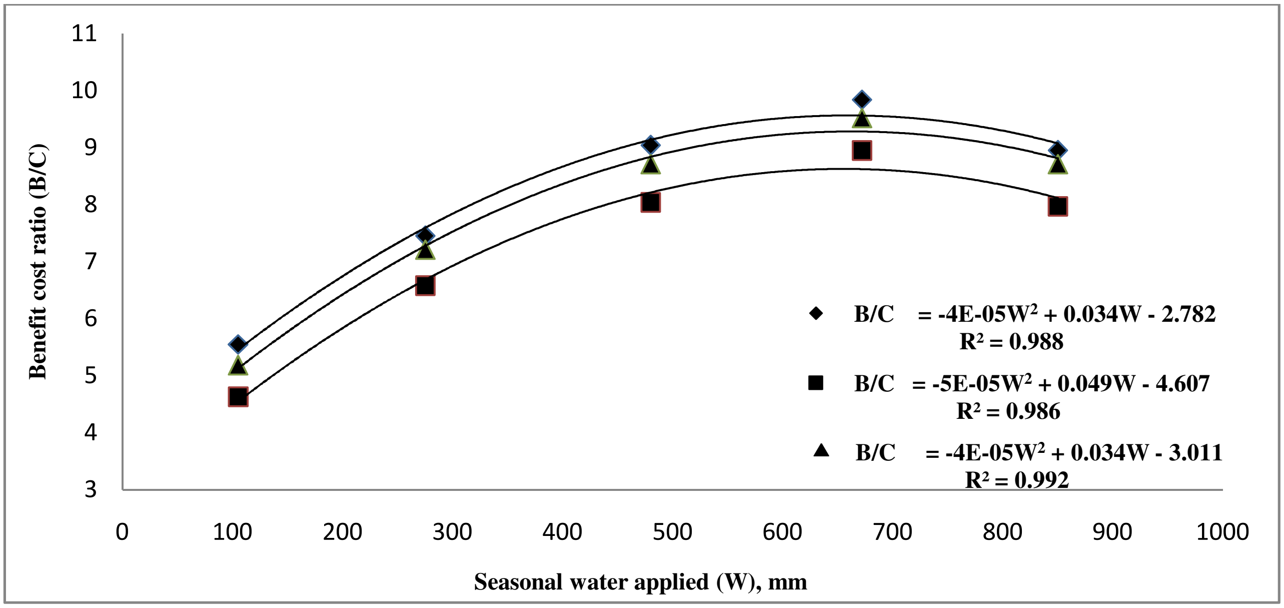


Figure-7
Relationship between seasonal water applied and benefit cost ratio of cabbage for 0.5 m (◆), 1.0 m (■) and 0.5 m (▲) lateral spacing

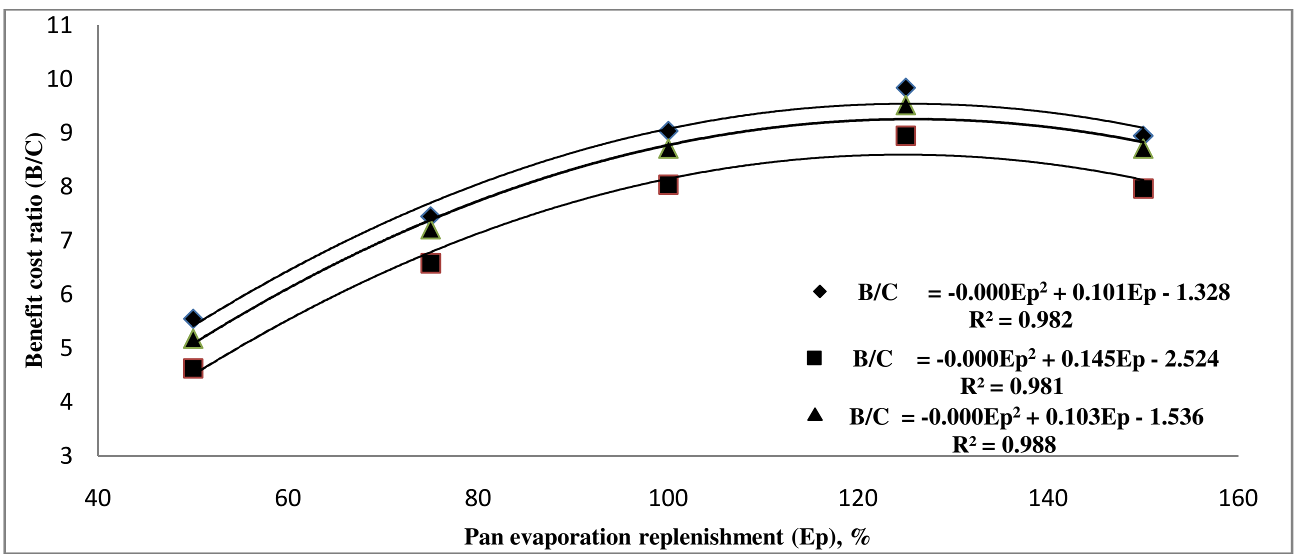


Figure-8
Relationship between pan evaporation replenishment and benefit cost ratio of cabbage for 0.5 m (◆), 1.0 m (■) and 0.5 m (▲) lateral spacing

Conclusion

The overall result of the study shows that highest gross return, net return and benefit cost ratio is obtained at 125 % of pan evaporation replenishment among the five selected irrigation levels. Further it is also observed that among the three methods of irrigation LS_1 gives highest gross return, net return and benefit cost ratio. Thus it can be concluded that in order to procure the higher crop yield, irrigation production efficiency and net return of cabbage during the winter growing season of November to March, the crop should be irrigated at 125% of pan evaporation replenishment with LS_1 drip irrigation method.

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