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RESEARCH PAPER

Techno economic feasibility of drip irrigation for vegetable cultivation

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Abstract : Vegetable cultivation is a highly practised agricultural activity in India.Commercial horticulture includes the cultivation of both indigenous and exotic vegetables. Vegetable cultivation under the drip irrigation system provides favourable environment for crops growth to achieve higher yield and good quality produce. Adaption of improved irrigation method and supply of precision amount of irrigation water and nutrients to crops are the important in achieving greater yield and avoiding loss of water and nutrients. Micro irrigation can be used to irrigate vegetable crops efficiently in the greenhouse and open field conditions. Both the pan evaporation and FAO-56 Penman-Monteith methods have been adopted to estimate the water requirement of crops under greenhouse structures and in an open field condition. The fertilizer application along with micro irrigation system optimizes the water and fertilizer use efficiency. Vegetables require precision amount of irrigation and fertilizers application and suitable climatic conditions. A very limited information is available on the supply and management of these important inputs.This report presents the role of micro irrigation forthe cultivation of vegetable crops. The design and installation of micro irrigation system, estimation of irrigation requirement of various vegetable crops using micro irrigation are also presented in this manuscript of the report.

Key Words : FAO-Penman montieth, B:C ratio, Temperature, Solar radiation, Relative humidity

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INTRODUCTION

Vegetables are an abundant source of vitamins, minerals and fibres and they play an important role in maintaining the human diet. In India, vegetables such as tomato, cauliflower, broccoli, cabbage, brinjal and capsicum are an important part of diet and livelihoods and have a significant role in the national economy. The pro-duction of commercial vegetables mainly depends on temperature and availability of water. Seasonal vegetables are normally grown in the open field. The off-seasonal vegetables are grown in an open field and also under protected cultivation structures. Growing vegetables under protected cultivation structures are proving to be a highly profitable venture as it gains higher returns as well as its higher benefit-cost ratio and it also contributes significantly to food security in our country (Ghosal and Das, 2012). Poly house, shade net house,

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and walking tunnels are the structures that are commonly adopted by the Indian farmers.

The irrigation system is one of the most important components affecting the yield and quality of vegetable crops both in the open field and protected cultivation structures. In these vegetable crops, the irrigation water should be given in a precise amount and at the appropriate time to achieve greater yield. Many researchers have advocated the importance of irrigation systems in the cultivation of vegetables (Coolong, 2016 and Cahn and Johnson, 2017). For efficient use of irrigation water, advanced irrigation methods such as micro irrigation can be adopted. Generally, these vegetables show an under developed shallow root system; high water content retained in a plant for a short cycle, deficit moisture content can severely affect the production. Optimum soil water content is needed to increase the crop yield and quality in vegetable production. Due to the shortfall of rainfall in arid and semi-arid areas of the world, a deficit of soil water in root zone depth can be met by micro irrigation. With the micro irrigation systems, water and nutrients can be applied directly to the plant at the root zone, having positive effects on yield and water savings and increasing water productivity (Nagaz *et al*., 2012). Furthermore, the soil above the ground stays dry when irrigated using subsurface drip irrigation. Hence, they are less susceptible to bacterial or fungal infections (Jeznach, 2007). The available literature reports that there is 50 to 70 per cent saving inirrigation water and 10 to 70 per cent increase in yield of fruits and vegetable crops by using drip irrigation (Sivanappan, 1987; Jadhav *et al.,* 1990; Shrivastava *et al.,* 1994 and Cetin *et al.,* 2004).

Despite recent advances and an increase in the popularity of micro irrigation in India, there is a lack of research on the potential exploitation of this technology for different varieties of vegetables in different climatic regions. Such studies could optimize irrigation water use, enhancing crop yields and quality, especially for cultivars of high production capacity. Considering the above factors present study aimed to determine the water requirement and economic feasibility of drip irrigation system for different vegetable crops for local climatic condition of Odisha.

MATERIAL AND METHODS

A study was conducted to design a drip system for different vegetable crops using the climatic data collected from Meteorological Department, Centurion University of Technology and Management (CUTM) Paralakhemundi. The experimental farm is located on the flat land at18°47' N latitude, 84°06' E longitude and altitude of 116 m above mean sea level. Experimental field soil is characterized as red lateritic with sandy loam in texture. The Paralakhemundi climate is classified as subtropical with high humidity. The temperature varies between 18°C-48 °C. It is characterized as hot and humid in summer (April and May), rainy season during June to September, moderately hot and dry inautumn (October and November), cool and dry in winter (December and January) and moderate spring in February and March. The average climatic data *i.e.* rainfall, maximum and minimum temperature, relative humidity and wind speed of three years (2018-2020) were collected Meteorological Department, Centurion University of Technology and Management (CUTM) Paralakhemundi.

The soil characteristics of the district show wide variation according to their physical and chemical properties, mode of origin and occurrences. Soils are having average to good fertility status. Red soil include red sandy soils and red loamy soils of which red sandy soils are conspicuously available is almost all blocks except in Parlakhemundi block which is characterized by red loamy soils. These are deficient in nitrogen, phosphate, organic matter and lime and are good for paddy crops. Entisols or Alluvial soil are younger in origin deficient in nitrogen, phosphoric acid and comparatively rich in potash, lime and ore, alkaline is nature. These are the most fertile soils in the district. The profile depth characterized as sandy loam with an average bulk density of 2.65 g cm^{-3}. The saturated hydraulic conductivity of soil varies between 0.34 and 9.72 cm day $^{-1}$, whereas field capacity and wilting point of soil profile vary from 0.24 to 0.28 cm 3 cm $^{-3}$ and from 0.10 to 0.11 cm 3 cm^{-3}, respectively.

The water requirement of the plant depends on the water transpired by the plant and the amount of water evaporating from the soil and plant leaves the surface. The daily irrigation water requirement of a vegetable crop grown under protected cultivation structures or open field condition irrigated by the micro irrigation system can be estimated by using the following equation

$$\mathbf{WR = ET_0 \times Kc \times Wp \times A} \quad ..(1)$$

where,

WR = Crop water requirement (L day^{-1})

ET_0 = Reference evapotranspiration (mm day^{-1})

Kc = Crop co-efficient

Wp = Wetting fraction (vary from 0.3 during early growth stage to 1.0 during fully grown maturity growth stage for close-growing vegetable crops).

A = Plant area, m^2 (*i.e.*,the spacing between rows, m x spacing between plants, m).

The modified Penman-Monteith method suggested by Allen *et al*. (1998) is the most reliable method to compute ET_0. Reference evapotranspiration (ET_0) was determined using the Penman-Monteith equation with the weather data collected on daily basis. The FAO-56 Modified Penman-Monteith equation (Allen *et al.*, 1998) for estimation of ET_0 is mentioned below:

$$ET_0 = \frac{0.408\Delta(R_n - G) + \frac{\gamma(900)}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1+0.34u_2)} \quad .. (2)$$

where,

ET_0 = Reference evapotranspiration (mm day^{-1})

R_n = Net radiation at the crop surface (mj m^{-2} day^{-1}),

G = Soil heat flux density (mj m^{-2} day^{-1}),

e_s - e_a= Saturation vapor pressure deficit (kPa),

e_s= Saturation vapor pressure at T_c (kPa),

e_a= Actual vapor pressure (kPa),

Δ = Slope of the saturation vapor pressure temperature relationship (kPa^0C^{-1})

γ = Psychrometric constant (kPa^0C^{-1}) and

u_2 = Wind speed at 2 m height (m s^{-1}).

Crop co-efficient (K_c) specifies the changes that take placein vegetation and ground cover of the crop during the crop season. The K_c takes into account the crop type and crop development to adjust the ET_0 for the specific crop. There may be several crop co-efficients used for a single crop throughout an irrigation season depending on the stage of development of the crop. Crop co-efficients also vary in bare soil, mulch condition and growth stage of the plant. This needs certain adjustments in the crop co-efficient (K_c) values according to the local soil, moisture and crop cover conditions.

Economic analysis of vegetable crops cultivation under drip irrigationwas carried out considering the all associated costs such as initial investment, cost of cultivation and economic return through vegetables yield taken from the other literatures.

Energy consumption:

To operate drip irrigation system electricity was used as energy. The quantum of electricity consumption for banana crops under different treatments were calculated by following eq.

kWh = [(HP of pump) x (0.746 kW) x (Number of hours per irrigation) x (No.of irrigation)]

Cost of irrigation:

Amortized cost of irrigation is computed as the sum ofamortized cost of well, amortizedcost of pumpset and accessories, amortized cost of conveyance and amortized cost ofover ground storage structure.

Amortized cost of well = [(Compounded cost of well) $*(1+i)^{AL} * i] \div [(1+i)^{AL}-1]$ ..(3)

where,

AL = Average life of wells

Compounded cost of well = (Initial investment on well)* (1+i) (2000-year of construction).

The discount rate of 10.5 per cent was used in amortization reflecting long term sustainablerate. Similarly investment on conveyance, pump set, and electrical installation storage structures were amortized.

Cost of cultivation:

The total cost of cultivation of each treatment of by considering the cost of each input used and field activities (land preparation, seedlings, planting, drip irrigation, plastic mulch application, intercultural operation, desuckering, manure application, fertilizer and plant protection chemicals and harvesting) during the period of experimentation.

Gross return:

Gross return from each treatment was calculated from the yield of banana by taking into account the market price during the year of experimentation.

Benefit cost ratio (BCR):

The BCR is also related to NPV as it is obtained just by dividing the present value of the benefit stream with that of cost stream. Generally, if the BCR is more than one then, the investment of that project can be considered economically viable.

$$\mathbf{B:C\ ratio} = \frac{\sum_{t=1}^{t=n}\frac{B_t}{(1+r)^t}}{\sum_{t=1}^{t=n}\frac{C_t}{(1+r)^t}} \quad .. (4)$$

RESULTS AND DISCUSSION

Temperature is the major regulator of development processes in crops. Each kind of crop grows and develops most rapidly at a favourable range of air temperatures. This is called the optimum air temperature range. For most crops, the optimum functional efficiency occurs mostly between (25°C and 35°C). Most crops (and especially vegetables) can be classified according to the temperature requirements of their optimum air temperature range.

Daily variation of maximum and minimum temperature were collected for three consecutive years (2018, 2019 and 2020) from the weather station maintained by CUTM Paralakhemundi. The monthly average of daily maximum and minimum temperature was shown in the Fig. 1 and 2. From the Fig. 1 it can observe that the maximum daily maximum temperature is ranging between 27 °C to 39 °C. In the winter months (November to February) the maximum temperature lies between the 26 °C and 30 °C. In summer months (March to July) the higher range of maximum temperature was recorded. Fig. 2 shows the monthly average of daily minimum ambient temperature during the day. Daily minimum temperature varies from 8°C in the month of December to 26°C in the month of May.

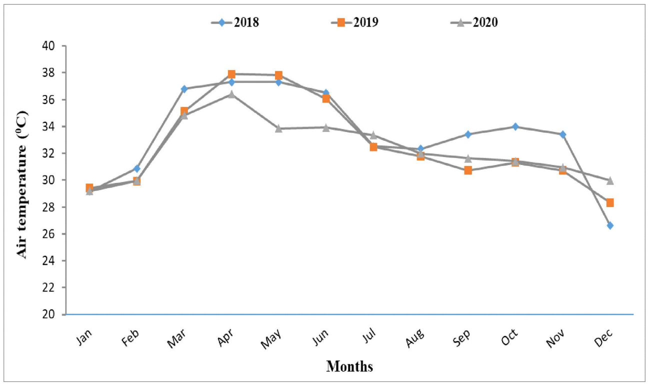

Fig. 1: Monthly average of daily maximum temperature for three years (2018-2020)

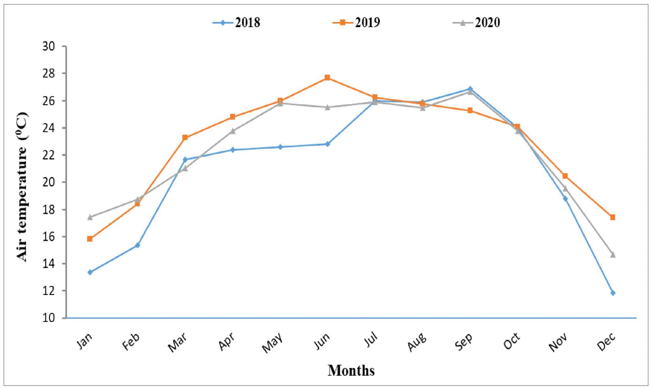

Fig. 2: Monthly average of daily minimum temperature for three years (2018-2020)

Daily average relative humidity was collected and analysed to know the humidity percentage of the study area. Monthly average of daily relative humidity variation of three consecutive years (2018, 2019 and 2020) were presented in the Fig. 3. The Fig. 3 shows that relative humidity of the studied area is in range of 60% to 90%. Maximum humidity can be found in summer months (April to June).

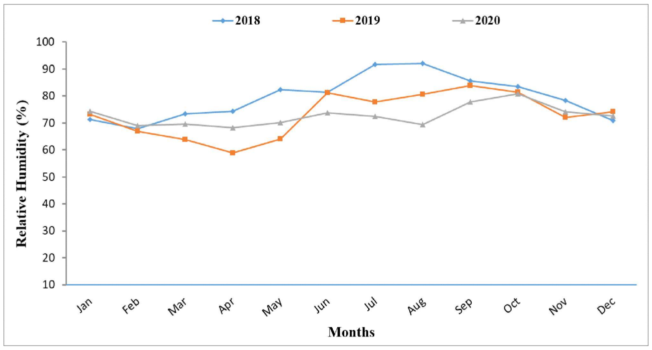

Fig. 3: Monthly average of daily relative humidity for three years (2018-2020)

The data of net solar radiation of the studied area for three consecutive years (2018, 2019 and 2020) are presented in the Fig. 4. From the Fig. 4 it can be observe that the net solar radiation in the study area is ranging between 6 W m^{-2} to 15 W m^{-2}. In the summer months (March – June) solar radiation recorded more than 10 W m^{-2} and in winter and monsoon months the net solar radiation with in the 10 W m^{-2}.

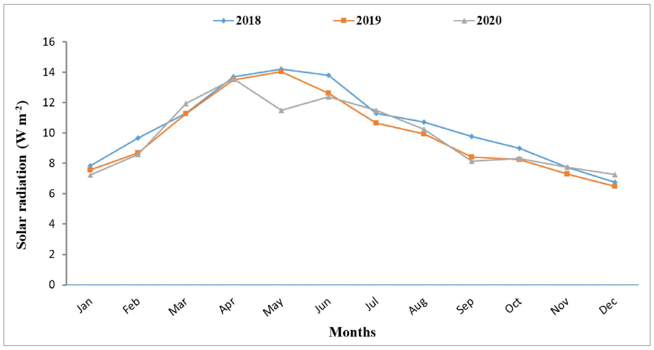

Fig. 4: Monthly average of daily net solar radiation for three years (2018-2020)

The FAO-56 Modified Penman-Monteith (PM) equation used for estimating reference evapotranspiration. Above discussed climatic data plays an important role in estimating the reference evapotranspiration. This method was also applied to estimate the crop water requirement under drip irrigation by other researchers (Chartzoulakis and Drosos, 1997). Baille (1994) claimed that the PM model is believed to be the best adapted to estimate crop water requirements, but requires more sensors for measuring microclimatic parameters, *i.e.* air temperature, relative humidity, wind speed, net solar radiation. Estimated values of reference evapotranspiration for three consecutive years were presented in Fig. 5.

The Fig. 5 shows that monthly average of daily reference evapotranspiration values. The ET_0 values are in the range of 2.5 mm (winter season) to 6.5 mm (summer season). The figure also that higher ET_0 values can be found for the year 2018 and lower ET_0 values for the year 2020. The three years average ET_0 values were considered for the calculation of crop water requirements of different crops.

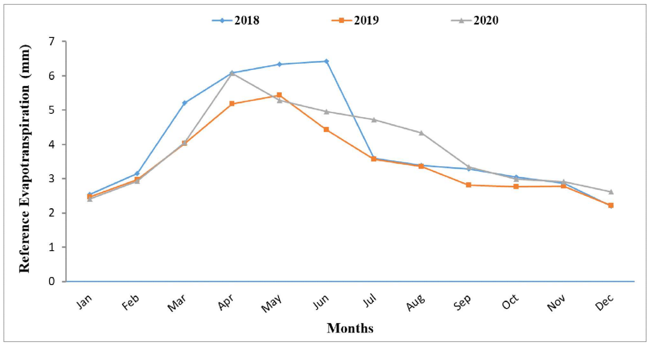

Fig. 5: Monthly average of daily reference evapotranspiration for three years (2018-2020)

The crop evapotranspiration estimated by multiplying reference evapotranspiration with crop co-efficient based on the crop growth stage. For the

Table 1: Crop water requirement of vegetable crops under drip irrigation systems

Months	ET_0(mm)	K_c	ET_c (mm)	Irrigation Water requirement (L day^{-1}plant^{-1})
Okra				
March	4.4	0.40	1.8	0.44
April	5.8	0.80	4.6	1.16
May	5.7	0.98	5.6	1.39
June	5.3	0.85	4.5	1.12
July	4.0	0.60	2.4	0.59
Total			574.1	143.5
Tomato				
March	4.4	0.60	2.7	0.66
April	5.8	0.70	4.0	1.01
May	5.7	0.90	5.1	1.28
June	5.3	1.05	5.5	1.38
July	4.0	0.83	3.3	0.82
Total			630.0	157.5
Capsicum				
November	2.9	0.40	1.1	0.29
December	2.3	0.80	1.9	0.47
January	2.5	0.98	2.4	0.60
February	3.0	0.85	2.6	0.64
March	4.4	0.60	2.7	0.66
Total			321.7	80.4
Brinjal				
July	4.0	0.60	2.4	0.59
August	3.7	0.80	3.0	0.74
September	3.1	1.07	3.4	0.84
October	2.9	0.90	2.6	0.66
November	2.7	0.82	2.2	0.55
Total			414.5	103.6

presentstudy, the valuesofthe crop co-efficient (Kc) of different crops were taken from FAO-50 (Allen *et al.,* 1998). Wetting fraction is considered 1 (100%) of crop area. The product of reference evapotranspiration, Kc and wetting fraction gives the irrigation water requirement of different crops. This study estimates the irrigation water requirement for different crops on daily basis and monthly average of daily crop water requirement is presented in the Table 1.

Okra (*Abelmoschus esculentus*) is a member of the okra mallow family and is considered a heat tolerant vegetable crop that will flower and fruit during high summer temperatures. In current study the okra sowing considered in the month of March and this will give yield upto 5 months. In the initial stage the ET_c values is 1.8 mm day^{-1} and irrigation water requirement (IWR) is 0.44 L day^{-1} $plant^{-1}$. Irrigation water requirement for okra is ranging between 0.44 L day^{-1} $plant^{-1}$ (1.8 mm day^{-1}) 1.39 L day^{-1} $plant^{-1}$ (5.6 mm day^{-1}). Total estimated IWR of okra crop is 143.5 L $plant^{-1}$ (574 mm).

Table 2: Bill of drip materials required for vegetable crop 1 ha area

Material	Nos.	M/no.	Size	Cost/m	Total cost (Rs.)
Main (2" PVC)	1	50	50 mm	143	7150
Sub-main (1.5" PVC)	1	100	35 mm	110	11000
Laterals (16 mm LLDP)	100	50	16 mm	10	50000
Drippers	100	100	4 LPH	3	30000
Cost of start, washer and end cap	50	1	16 mm	10	500
Cost of connectors	200	1	16 mm	5	1000
Screen filter (1.5")	1	1	15 cum/h	1200	1200
Ventury assembly (3/4" for 51 mm)	1	1		2100	2100
bypass accessory	1	1		1500	1500
Flush valve	2	1		160	320
Control valve	2	1		550	1100
Installation charges	-	-		5%	5294
Total					111164

Table 3: Economics of micro irrigation system for different vegetable crops (*Brinjal,* okra, tomato and capsicum)

Particulars	Brinjal	Okra	Tomato	Capsicum
1. Cost of installation	111164	111164	111164	111164
Life in years	7.5	7.5	7.5	7.5
(b) Capital recovery factor (Rs.)	0.21	0.21	0.21	0.21
(c) Annual cost of drip installation	23344	23344	23344	23344
(d) Repair and maintenance @ 1% (Rs.)	1111.64	1111.64	1111.64	1111.64
(e) Total annual cost {1(c)+1(d)}(Rs.)	24456	24456	24456	24456
2. Cost of fertilizers, fungicide and pesticides	10000	10000	10000	10000
3. Electricity charges @ 4 rupees per unit (Rs.)	5000	5000	5000	5000
4. Labour charges @ 350 rupees per day (Rs.)	35000	35000	35000	35000
5. Average yield of produce under drip (t/ha)*	24	22	35	40
6. Income from produce	240000	220000	350000	400000
7. Gross cost of production (3+5+7+8) (Rs.)	74456	74456	74456	74456
8. Gross income (10+12) (Rs.)	240000	220000	350000	400000
9. Gross benefit cost (B-C) ratio	3.22	2.95	4.70	5.37
10. Net Income (Rs.)	165544	145544	275544	325544
11. Net benefit cost ratio	2.2	2.0	3.7	4.4

* Yield was taken from the available literature

Tomato (*Solanum lycopersicum*) crop cultivation considered for the month of March to July for the calculation purpose. However, tomato does not have specific season, it can be cultivated throughout the year. The IWR of tomato crop is ranging between 0.66 L day^{-1} plant^{-1} (2.7 mm day^{-1}) and 1.38 L day^{-1} plant^{-1} (5.5 mm day^{-1}). Total irrigation water requirement of tomato crop is estimated as 157 L plant^{-1} (630 mm).

Capsicum (*Capsicum annum* L.) is an important crop in many parts of the world. The season of capsicum cultivation may be throughout the year but for purpose of the calculation of IWR, it is considered the winter months (November to March) as capsicum form cultivation season. The IWR of the capsicum is in range of 0.29L day^{-1} plant^{-1} (1.1 mm day^{-1}) and 0.66 L day^{-1} plant^{-1} (2.7 mm day^{-1}). The total IWR of the capsicum is estimated as 80.4L plant^{-1}(321.7 mm day^{-1}). The IWR is much less for cultivating the capsicum because estimation done for the winter season and other crops are for summer season.

Brinjal (*Solanum melongena* L.) is a popular crop due to the high yield potential, rapid growth and improved quality possible over a longer season. Brinjal also can be cultivated for whole year but for the study purpose it is considered the monsoon season (July to November). The IWR of brinjal crop is ranging between 0.55 L day^{-1} plant^{-1} (2.2 mm day^{-1}) and 0.84 L day^{-1} plant^{-1} (3.4 mm day^{-1}). Total irrigation water requirement of brinjal crop is estimated as 103.6 L plant^{-1} (414.5 mm). These results for different vegetable crops are corroborated with the findings of Tiwari *et al*. (1998a,b) and Singh (2007).

The economic evaluation was carried out for drip system for different vegetable crops. The materials required for installing drip system is presented in the Table 2. The crop yield found using drip irrigation quoted from different literatures and cost of installation were considered for the calculation of drip system economics. Relevant data of the economic calculations are presented in Table 3.

From the Table 3 it is found that from the Brinjal crop can give net income of Rs. 165544 with 2.2 net benefit cost (B-C) ratio under drip irrigation. The net profit from okra is estimated as Rs. 145544 with net B-C ratio 2.0. From the tomato crop one can get the net profit of Rs. 275544 with B-C ratio of 3.7. The capsicum crop gives maximum net profit of Rs. 325544 with B-C ratio of 4.4 under drip irrigation in comparison to all other crops considered for the study.

Conclusion:

The cultivation of vegetables is in high demand in recent times. Due to high demand cultivation of vegetables fetch a high price. Micro irrigation plays an important role in vegetable cultivation as it increases water and fertilizer use efficiency and reduces the cost of other inputs. The water requirement of some of the vegetables grown using drip irrigation has been estimated and presented. This manuscript also presented the cost economics of different vegetable cultivation under drip irrigation system.

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