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Resource use efficiency of bitter gourd cultivation under drip v/s conventional irrigation method in Central India

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Abstract
Vegetable is the important source of human nutrition and characterize a dynamic segment of Indian's agriculture. Demand for vegetables is cumulative in national and international market. Despite high revenues, non-availability of irrigation water is hindering the expansion of area under vegetables. Commercial production of vegetable is not possible without adequate water availability throughout the growing season. Vegetable cultivation through drip method, as an efficient water-saving technology, has been widely used in crop, but its effects on crop production, irrigation water productivity (IWP) and water productivity (WP) vary with field managements, climatic conditions and soil properties. A multi-stage stratified random sampling method was apply for selection of districts, blocks, villages and respondents. A Dhar district was selected based on greater irrigated area under drip irrigation, among all districts of Malwa Plateau Agro-Climatic Region. 180 adopters (who adopted drip method of irrigation) and 60 non-adopters (who adopted conventional irrigation method) vegetable grower, constituting sample size of total 240 vegetable growers were selected from the area under study.
Cobb-Douglas production function was apply to estimate the resource use efficiency. Seed gave positive and highly significant response over yield of bitter gourd, while plant protection chemical, irrigation and human labour show moderate significant response over the yield of bitter gourd in cultivated at non-adopter farm. Reveals that if all things remain constant and in the current level of technology adoption increase of ₹1.00 of investment on seed, plant protection chemical, irrigation and human labour will be able to increase 0.259, 0.131, 0.109 and 0.406 quintal yield of bitter gourd, respectively at non-adopter farm in the study area. The elasticity of production (Σbi) indicates that constant return to scale in cultivation of bitter gourd at non-adopter farm. Chemical fertilizers, FYM/organic manures, plant protection chemical, machine power, human labour gave positive and highly significant response over yield of bitter gourd, while irrigation show moderate significant response over the yield of bitter gourd cultivated at adopter farm. Reveals that if all thing remain constant and in the current level of technology adoption increase of ₹ 1.00 of investment on chemical fertilizer, FYM/organic manure, plant protection chemical, irrigation, machine power and human labour will able to increase 0.147, 0.047, 0.129, 0.062, 0.144 and 0.382 quintal yield of bitter gourd, respectively at adopter farm in the study area. The summation of regression (Σbi) indicates that constant return to scale in cultivation of bitter gourd at adopter farm.

Keywords: Resource use efficiency, bitter gourd, drip V/s conventional irrigation method

1. Introduction
Vegetable is the important source of human nutrition and characterize a dynamic segment of Indian's agriculture. Demand for vegetables is cumulative in national and international market. Despite high revenues, non-availability of irrigation water is hindering the expansion of area under vegetables. Commercial production of vegetable is not possible without adequate water availability throughout the growing season. (Iqbal, *et al*. 2014) [2] Vegetable is greatest commercial cultivated and consumed across the world. Thus, harvested global amounts of vegetables are huge – more than one billion metric tons per year. Over 834 MT of fresh vegetable is produced in Asia. (Statista Research Department, 2020). On an average, the productivity of vegetable is about 5 to 8 times more than these of cereals and pulses. They are quick growing and shorter duration. Vegetable crop is labor intensive and generate additional farm employment.

Universally, the water obtainability is a great challenge and in the present scenario, India may face an acute absence of irrigation water. Due to an expected lack of water in the future, water use efficient crops can only manage with the increasing demand. Adoption of a more efficient water saving techniques will allow flexibility in growing time, establishing a more uniform crop stand, better quality, higher yield for off season vegetables with existing inadequate water resources. (Ismail, *et al*. 2015) [3]

Vegetable cultivation through drip method, as an efficient water-saving technology, has been widely used in crop, but its effects on crop production, irrigation water productivity (IWP) and water productivity (WP) vary with field managements, climatic conditions and soil properties. The results showed that drip irrigation significantly increased yield, IWP and WP by 5.39%, 6.75% and 3.97% relative to drip irrigation, respectively. The large percentage increase in yield was observed in vegetable was found to be 5.39%. (Wang, *et al.* 2022) [8] The technical and economic feasibility of drip irrigation in several crops and have proven it's potential to save water and energy and rise crop yields. The findings indicate that besides savings of water (40%), drip irrigation reduces the use of other inputs, e.g. fertilizers (31%), and enhances yield by 52%. On the entire, its application in vegetable results in 54% higher net revenues over the conventional method of irrigation.

In India, total vegetable growing area is 10.26 M.ha. and production is 184.39 MT while the productivity is 17.97 tonnes ha^{-1} respectively. The major vegetable cultivated states are UP (13.91%), WB (13.65%) and MP (8.67%), as well also the major producing states are UP (15.40%), WB (15.03%) and MP (9.52%) in the country.

In Madhya Pradesh total vegetable cultivating area is 0.89 M.ha. and production is 17.55 M.T. while the yield is 19720 $kgha^{-1}$. The yield of vegetables in Madhya Pradesh is higher than the average yield rate of India. (Source: Horticultural Statistics at a Glance, 2018). Vegetable is cultivate throughout the year in almost all the districts of Madhya Pradesh. However, The Malwa Plateau knows as - areas are "vegetable hub" in the State.

Objectives

To estimate resource use efficiency of bitter gourd cultivation under drip V/s conventional irrigation method.

2. Research Methodology

2.1 Sampling Technique

A multi-stage stratified random sampling method was apply for selection of districts, blocks, villages and respondents.

In 1st stage, a district was selected based on greater irrigated area under drip irrigation, among all districts of Malwa Plateau Agro-Climatic Region. Thus, Dhar district was selected for the study. In 2nd stage, 2 blocks namely Badnawar and Dhar were selected from selected district. In 3rd stage, a list of all the villages in each selected block was prepared and Tilgara, Bakhatpura, Jabada, Sandla, Bhaisola and Mungela villages of Badnawar block and Kalsada, Tornod, Berchha, Billoda, Gardawad and Pachlana villagesof Dhar block were selected purposely. Thus, total 12 villages were selected for purpose of the study.

There was identical number of vegetable grower was selected from each village and 15 adopter (who adopted drip method of irrigation) and 5 non- adopter (who adopted conventional irrigation method) vegetable grower were selected from each village. Thus, 20 vegetable growers were selected from each selected village. Thus, 180 adopters (who adopted drip method of irrigation) and 60 non-adopters (who adopted conventional irrigation method) vegetable grower, constituting sample size of total 240 vegetable growers were selected from the area under study.

2.2 Resource Use Efficiency

Cobb-Douglas production function was used to estimate the resource use efficiency.

$$Y = aX_1^{b1} X_2^{b2} X_3^{b3} X_4^{b4} X_5^{b5} X_6^{b6} X_7^{b7} X_8^{b8} X_9^{b9}$$

Which was linear in log

$$\text{Log } Y = \log a + b1 \log X1 + b2 \log X2 + b3 \log X3 + b4 \log X4 + b_5 \log X_5 + b_6 \log X_6 + b_7 \log X_7 + b_8 \log X_8 + b_9 \log X_9 + E$$

Where

Y = Dependent variable (yield)
a = Constant or Intercept Value
X_1 to X_9=are Independent variable
X_1 = Expenditure on seed (Rs./ha)
X_2 = Expenditure on fertilizer (Rs./ha)
X_3 = Expenditure on FYM/organic manure
X_4 = Expenditure on plant protection chemicals (Rs./ha)
X_5 = Expenditure on irrigation (Rs./ha)
X_6 = Expenditure on stacking materials
X_7 = Expenditure on farm power
X_8 = Expenditure on human labour
X_9 = Expenditure on mulching films
E = Error
b_1 to b_9= regression coefficient of X_1, X_2, ……. X_9
R^2 = Determination of regression coefficient

2.3 Marginal Value Productivity (MVP)

Resource use efficiency was determined by calculating MVP, i.e.

$$MVP = MPPixPy$$

Where,
MVP = Marginal Value Product
MPPi = Marginal Physical Product of the 'i'th input
Py = Price of Output

$$MPPi = bi\frac{Y}{Xi}$$

Where,
bi= Regression coefficient of the 'i'th independent variable
Y= Geometric mean of the output, and
X_i= Geometric mean of the input.

Returns to Scale

Returns to scale is sum of the regression coefficients

$$\textbf{Returns to scale} = \sum_{i=1}^{i=6} b_i$$

3. Results and Discussion

Resource use efficiency of bitter gourd by sample farmers. In order to examine the impact of different input resources on yield of bitter gourd, the values of production elasticity (b1) along with value of coefficient of determination (R2) were calculated for each size of farm.

3.1 Non-Adopter Vegetable Grower

The resource use efficiency of different variables over yield of bitter gourd is present in table 1. It is observed from data that fitted Cobb-Douglas production function found to be good fit it explain 99 per cent response of selected variables on yield of bitter gourd at non-adopter farm in the study area. Remaining 1 per cent might to unknown variable.

The variables i.e., seed, chemical fertilizers, plant protection chemical, irrigation, stacking materials, machine power and human labour were found to be gave positive response on yield of bitter gourd, while FYM/organic manure was found to be gave negative response on yield of bitter gourd at non-adopter farm. Seed gave positive and highly significant response over yield of bitter gourd, while plant protection chemical, irrigation and human labour show moderate significant response over the yield of bitter gourd in cultivated at non-adopter farm.

Reveals that if all things remain constant and in the current level of technology adoption increase of ₹1.00 of investment on seed, plant protection chemical, irrigation and human labour will be able to increase 0.259, 0.131, 0.109 and 0.406 quintal yield of bitter gourd, respectively at non-adopter farm in the study area.

The summation of regression (Σbi) indicates that constant return to scale in cultivation of bitter gourd at non-adopter farm.

Table 1: Resource use efficiency in cultivation of bitter gourd at non-adopter farm

Particulars	Regression (b)	GM	MVP
Seed	0.259***	16347.31	8.05
Chemical fertilizer	0.000 ^{NS}	17373.07	0.01
FYM/organic manure	-0.034 ^{NS}	6312.112	-2.70
Plant protection chemical	0.131**	13009.78	5.14
Irrigation	0.109**	2470.45	22.47
Stacking materials	0.020 ^{NS}	19231.52	0.52
Farm power	0.106 ^{NS}	11479.88	4.71
Human labour	0.406**	62629.41	3.30
Intercept	-5.03		
Σbi	1.00		
R^2	0.99		

*** Significant at 1 % level, ** Significant at 5 % level, *Significant at 10 % level

All the resources used by non-adopter farmers were found to be economical viable and utilized properly. Amongst all the variables the MVP of irrigation (22.47) was found to be maximum as compared to seed (8.05), plant protection chemical (5.14), machine power (4.71), human labour (3.30), FYM/organic manure (-2.70), Stacking materials (0.52) and chemical fertilizer (0.01) in cultivation of bitter gourd at non-adopter farms.

3.2 Adopter Vegetable Grower

The resource use efficiency of different variables over yield of bitter gourd is present in table 2. It is observed from data that fitted Cobb-Douglas production function found to be good fit it explain 99 per cent response of selected variables on yield of bitter gourd in the study area. Remaining 1 per cent might to unknown variable.

Seed, chemical fertilizers, FYM/organic manures, plant protection chemical, irrigation, stacking materials, machine power and human labour were found to be gave positive response on yield of bitter gourd, while mulching films was found to be gave negative response on yield of bitter gourd at adopter farm.

Chemical fertilizers, FYM/organic manures, plant protection chemical, machine power, human labour gave positive and highly significant response over yield of bitter gourd, while irrigation show moderate significant response over the yield of bitter gourd cultivated at adopter farm.

Reveals that if all thing remain constant and in the current level of technology adoption increase of ₹ 1.00 of investment on chemical fertilizer, FYM/organic manure, plant protection chemical, irrigation, machine power and human labour will able to increase 0.147, 0.047, 0.129, 0.062, 0.144 and 0.382 quintal yield of bitter gourd, respectively at adopter farm in the study area.

The summation of regression (Σbi) indicates that constant return to scale in cultivation of bitter gourd at adopter farm.

Table 2: Resource use efficiency in cultivation of bitter gourd at adopter farm

Particulars	Regression (b)	GM	MVP
Seed	0.037^{NS}	15416.41	1.58
Chemical fertilizer	0.147***	15461.32	6.21
FYM/organic manure	0.047***	5014.07	6.11
Plant protection chemical	0.129***	10931.94	7.73
Irrigation	0.062**	1499.85	27.15
Stacking materials	0.061 ^{NS}	16955.53	2.34
Machine power	0.144***	10384.93	9.09
Human labour	0.382***	53947.26	4.64
Mulching	-0.012 ^{NS}	6356.21	-1.21
Intercept	-4.62		
Σbi	1.00		
R^2	0.99		

*** Significant at 1 % level, ** Significant at 5 % level,* Significant at 10 % level

All the resources used by adopter farmers were found to be economical viable and utilized properly. Amongst all the variables the response of irrigation (27.15) was found to be maximum as compared to machine power (9.09), plant protection chemical (7.73), chemical fertilizer (6.21), FYM/organic manure (6.11), human labour (4.64), stacking material (2.34), seed (1.58) and mulching films (-1.21) in cultivation of bitter gourd at adopter farms.

3.3 Non-Adopter V/s Adopter Vegetable Grower

The resource use efficiency of different variables over yield of bitter gourd is present in table 3. It is observed from data that fitted Cobb-Douglas production function found to be good fit it explain 99 per cent response of selected variables on yield of bitter gourd in the study area. Remaining 1 per cent might to unknown variables at both non-adopter and an adopter farm.

Seed, chemical fertilizer, plant protection chemical, irrigation, machine power and human labour were found to be gave positive response on yield of bitter gourd, while FYM/organic manures was found to be gave negative response on yield of bitter gourd at non-adopter farm. Seed gave positive and highly significant response over yield of bitter gourd, while plant protection chemical, irrigation and human labour show moderate significant response over the yield of bitter gourd in cultivated at non-adopter farm. Reveals that if all things remain constant and in the current level of technology adoption increase of ₹ 1.00 of investment on seed, plant protection chemical, irrigation and human labour will able to increase 0.259, 0.131, 0.109 and 0.406 quintal, respectively yield of bitter gourd at non-adopter farm in the study area.

Seed, chemical fertilizers, FYM/organic manures, plant protection chemical, irrigation, stacking materials, machine

power and human labour were found to be gave positive response on yield of bitter gourd, while mulching films was found to be gave negative response on yield of bitter gourd at adopter farm. Chemical fertilizers, FYM/organic manures, plant protection chemical, machine power, human labour gave positive and highly significant response over yield of bitter gourd, while irrigation show moderate significant response over the yield of bitter gourd of cultivated at adopter farm.

Reveals that if all things remain constant and in the current level of technology adoption increase of ₹ 1.00 of investment on chemical fertilizer, FYM/organic manure, plant protection chemical, irrigation, stacking materials, machine power and human labour will able to increase 0.147, 0.047, 0.129, 0.062, 0.144 and 0.382 quintal, respectively yield of bitter gourd at adopter farm in the study area.

Table 3: Resource use efficiency in cultivation of bitter gourd at non-adopter and adopter farm

Particulars	Non-adopter		Adopter	
	Regression (b)	MVP	Regression (b)	MVP
Seed	0.259***	8.05	0.037 ^{NS}	1.58
Chemical fertilizer	0.000 ^{NS}	0.01	0.147***	6.21
FYM/organic manure	-0.034 ^{NS}	-2.70	0.047***	6.11
Plant protection chemical	0.131**	5.14	0.129***	7.73
Irrigation	0.109**	22.47	0.062**	27.15
Stacking materials	0.020 ^{NS}	0.52	0.061 ^{NS}	2.34
Machine power	0.106 ^{NS}	4.71	0.144***	9.09
Human Labour	0.406**	3.30	0.382***	4.64
Mulching films	-	-	-0.012	-1.21
Σbi	1.00		1.00	
R^2	0.99		0.99	

*** Significant at 1 % level, ** Significant at 5 % level, *Significant at 10 % level

The response of variables in cultivation of bitter gourd at adopter farm were compared with non-adopter farm in the farm study and reveals that if all thing remain constant and in the current level of technology adoption increase of ₹ 1.00 of investment on plant protection chemical, irrigation and machine power will able to increase less 0.002, 0.047 and 0.024 quintal yield of bitter gourd, respectively in adopter as compared to non-adopter farm, while plant protection chemical, irrigation and stacking materials will able to increase less 0.046, 0.08 and 0.095 quintal yield of bitter gourd, respectively in adopter as compared to non-adopter farm in the study area.

The scale of return was found to show constant return at both non-adopter and an adopter farm in cultivation of bitter gourd in the study area.

All the resources used by non-adopter farmers were found to be economical viable and utilized properly. Amongst all the variables the MVP of irrigation (22.47) was found to be maximum as compared to seed (8.05), plant protection chemical (5.14), machine power (4.71), human labour (3.30), FYM/organic manure (-2.70), Stacking materials (0.52) and chemical fertilizer (0.01) in cultivation of bitter gourd at adopter farms, while response of irrigation (27.15) was found to be maximum as compared to machine power (9.09), plant protection chemical (7.73), chemical fertilizer (6.21), FYM/organic manure (6.11), human labour (4.64), stacking material (2.34), seed (1.58) and mulching films (-1.21) in cultivation of bitter gourd at adopter farms.

4. Conclusion

Chemical fertilizers, FYM/organic manures, plant protection chemical, machine power, human labour gave positive and highly significant response over yield of bitter gourd, while irrigation show moderate significant response over the yield of bitter gourd in drip irrigation system. Seed gave positive and highly significant response over yield of bitter gourd, while plant protection chemical, irrigation and human labour show moderate significant response over the yield of bitter gourd in conventional irrigation system. Seed, chemical fertilizers, FYM/organic manures, plant protection chemical, irrigation, stacking materials, machine power and human labour were gave positive response on yield of bitter gourd, while mulching films was gave negative response on yield of bitter gourd in drip irrigation system.

The scale of return was found to show constant return in both drip and conventional irrigation system from cultivation of bitter gourd in the study area.

All the resources used in drip irrigation system were economical viable and utilized properly. Amongst all the variables the MVP of irrigation was more as compared to machine power, plant protection chemical, chemical fertilizer, FYM/organic manure, human labour, stacking material, seed and mulching films from cultivation of bitter gourd in drip irrigation system, while MVP of irrigation was found to be maximum as compared to seed, plant protection chemical, machine power, human labour, FYM/organic manure, Stacking materials and chemical fertilizer from cultivation of bitter gourd in conventional irrigation system.

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