International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-4 Issue-10, March 2015

Energy Efficiency of Banana (*Musa sp.)* Crop under Different Irrigation Methods

V. S. Malunjkar, P. Balakrishnan, S. K. Deshmukh, S. B. Dugad

Abstract— The field experiment was carried out with drip method of irrigation (DMI) and conventional method of irrigation (CMI) at 100 per cent Evapotranspiration (ET) at two locations in Jalgaon district of Maharashtra during 2009-'10. The irrigation water requirement of the banana crop was noticed minimum in DMI compared to CMI treatment indicating 35.14 and 29.24 per cent water saving and 38.96 and 33.41 per cent electricity saving in experimental and farmer's fields, respectively. Early flowering and harvesting was noticed with reduction in growth period in DMI against CMI. The banana yields in DMI were (72.6 and 67.4 t/ha) higher against CMI (59.1 and 52.5 t/ha) under experimental and farmer's fields, respectively. In DMI about 32.70 and 29.99 per cent input energy savings and 19.73 and 14.09 per cent increase in output energy were noticed against CMI. Also, the higher energy efficiency of 13.5 and 12 was noticed in DMI as compared to CMI (7.6 and 7.4). In both the fields, 17.01 and 20.36 per cent higher BC ratios were recorded in DMI (2.27 and 2.01) over CMI (1.94 and 1.67).

In both the fields, additional benefit of 2,125 and 1,870 Rs./ha could be obtained by getting more carbon credits due to use of drip irrigation. The potential of carbon credits then projected over 5,000 ha area under banana crop in Jalgaon district. The present study reveals that drip irrigation has a definite role in minimizing the energy use in terms of water and electricity as well as reducing the impacts of climate change in Indian agriculture.

Index Terms— Drip irrigation, energy consumption, CO_2 emission and carbon credits.

I. INTRODUCTION

Global warming is the most dreaded problem of the new millennium. Greenhouse gases (GHGs) mainly contribute for the cause of global warming. There are various sources of GHGs emission among that power generation based on fossil fuel is the major source. The electricity requirement for pumping of water and its inefficient utilization are also a cause of concern. Conventional irrigation methods are employed for more than 80 per cent of the world's irrigated lands yet their field level application efficiency is only 40-50 per cent [1] In contrast, drip irrigation has field level application efficiencies of 70-90 per cent as surface runoff and deep percolation losses are minimized [2].

All agricultural operations require energy inputs in various forms (human labour, animal power, fertilizer, fuels and electricity) and in varying magnitudes with variation as per different agro-climatic zones and even farmers to farmers. The largest need of energy services is for pumping of irrigation water. Various research studies showed that water saving, electricity saving, irrigation efficiencies and yield of crops using drip irrigation are substantially higher than crops irrigated by the flood method of irrigation [3], [4].

In India 52 per cent of its total power comes from coal from which agriculture consumes 28.5 per cent of total electricity [5]. According to [6], India is among the 10 fastest growing economies in the world and fossil fuel share is expected to rise to 74 per cent of total energy used by 2010, with corresponding increase in CO_2 emissions to 1,646 Mt. The use of fossil fuels increases the GHGs emission. Thus, energy efficiency in agriculture would have huge impact on overall scenario. The United Nations Framework on Climate Change (UNFCCC) has made it mandatory that any carbon saving in the developing world, which could be traded with the developed world, has to be duly validated through certified emission reductions (CERs). The energy efficiency related work in the developing world then can sell these certificates to any entity from the developed world. This trading could be done at a mutually agreeable price.

Considering all the above aspects, a pilot study was undertaken to study their impacts on banana (*Musa sp*.) crop, as this is one of the major consumer of water and energy. Banana is a globally important fruit crop produced in tropical and subtropical regions of developing countries with 97.5 Mt of production. India is the world's largest producer of banana, accounting for about 27 per cent to the global output. Taking this fact into consideration, the present research work was undertaken in order to generate the scientific information regarding the same aspect and standardize the energy savings for banana crop due to use of drip irrigation compared to conventional irrigation.

II. METHODOLOGY

Study area: A study was conducted at two different locations in Jalgaon district of Maharashtra ($21^0 01'$ N, $75^0 34'$ E and 209 m) during 2009 to 2011. One at the Research and Development Farm of the Jain Irrigation Systems Ltd., and another set up in farmer's field. In both the fields, soils are well drained and slightly alkaline with good water holding capacity. Banana crop (Musa sp.) cv. Grand Naine (tissue cultured) was selected with 1.82 x 1.82 m planting distance.

Two treatments, drip method of irrigation (DMI) and conventional method of irrigation (CMI) were divided in to 10 equal parts (replication) by maintaining the same plant population and irrigation was applied by considering 100 per cent evapotranspiration (ET).

Manuscript published on 30 March 2015.
***Correspondence Author(s)**
Er. V. S. Malunjkar, Department of Soil and Water Engineering, UAS Raichur, Karnataka, India.
Dr. P. Balakrishnan, Department of Soil and Water Engineering, UAS Raichur, Karnataka, India .
Dr. S. K. Deshmukh, Jain Irrigation Systems Ltd., Jalgaon, Maharashtra, India.
Dr. S. B. Dugad, Jain Irrigation Systems Ltd., Jalgaon, Maharashtra, India.

The statistical analysis of the treatments was done for all the parameters recorded during the study by the technique of Analysis of Variance.

Irrigation water requirement: The peak water requirement for the banana crop was calculated from the following equation,

$$PWR = \frac{A \times B \times C}{E} \tag{1}$$

Where, PWR, A, B, C and E refers to peak water requirement (mm/day), evapotranspiration rate (mm/day), crop factor, canopy factor, efficiency of irrigation system. The daily evaporation data was obtained from Class-A open pan evaporimeter. Then from peak water requirement, the amount of water required (WR) per irrigation was calculated as,

$$WR\left(m^3\right) = \frac{PWR(mm/day) \times Area(m^2)}{1000} \tag{2}$$

In conventional irrigation treatment, the water requirement was calculated in terms of depth of irrigation using following equation,

$$D = \frac{(M_{fc} - M_{bi})}{100} \times A_s \times d_s \tag{3}$$

Where, D, M_{fc}, M_{bi}, A_s and d_s refers to net amount of water to be applied during irrigation (cm), moisture content at field capacity (%), moisture content before irrigation (%), bulk density of soil (g/cc) and effective root zone depth (cm). From the net amount of water, the quantity of water required for irrigation (m3) was measured by multiplying the net depth of irrigation (m) with the treatment area (m2). Then, calculated amount of water applied to fields by deducting the effective rainfall at every alternate day in DMI treatment and as per field moisture status in CMI treatment.

Energy evaluation: The energy consumption in the farm operations was determined by calculating the total energy input which included animate labours, water for irrigation, electricity for pumping, fertilisers and micronutrients for crop improvement. Also, the output got from crop yield and biomass of plant was considered as the output energy. Energy from inputs and outputs was calculated by converting their physical units into respective energy units by using appropriate energy equivalents [7], were used during the study. The energy figures used in the study were expressed in mega joule (MJ) and giga joule (GJ) units (Table 1).

Emission reductions: The main aspect of the study was to reduce water consumption, and thereby, reduce the electricity consumption with the introduction of drip irrigation. The reduction in electricity consumption ultimately leads to the reduction of carbon dioxide (CO_2) emissions in the study area. For the determination of CO_2 emission reductions, specific electricity consumption (SEC) and grid emission factors were calculated.

$$SEC = \frac{EC(kWh)}{A(ha)} \tag{4}$$

Where, SEC, EC and A refers to specific electricity consumption in the treatments (kWh/ha), electricity consumption in the treatments (kWh) and area under the treatments (ha).

CO_2 emission reductions and carbon credits: Then carbon dioxide (CO_2) emission reductions due the introduction of DMI in study area were estimated as,

$$CO_2 \ emission \ reductions = (SEC_{CMI} - SEC_{DMI}) \times EF \tag{5}$$

Where, EF refers to grid emission factor (tCO_2/MWh) it is the tones of CO_2 emissions in the atmosphere during a megawatt electricity generation into the thermal power plants. It is 0.8401 tCO_2/MWh for the year 2009-2010 [8]. Jalgaon district covers about 5,000 hectare area under banana crop owned by about 2,400 farmer's, with an average holding size of 1.25 ha. Then from CO_2 emission reductions of the study area (experimental field and farmer's field), CO_2 emission reductions were projected for the Jalgaon region by multiplying the total area under banana cultivation.

According to Kyoto Protocol and methodologies, suggested by the UNFCCC for energy efficiency in agriculture, the potential of carbon credits was estimated. According to the UNFCCC, one carbon credit is equal to one tone CO_2 reduction which is also called as CERs (Certified Emission Reductions). The gain of carbon credits by improving energy efficiency of banana and electricity savings in pumping of water due to drip irrigation was then calculated from the total emission reductions obtained [9].

III. RESULTS AND DISCUSSION

Water and electricity consumption: The minimum water was required in DMI (1455.6 and 1669.7 mm/ha) when compared to its counterpart CMI treatment (2244.2 and 2359.8 mm/ha) in both the fields (Table 2). Also, 35.14 and 29.24 per cent water saving was noticed in DMI treatment in both the fields. The number of irrigations applied during the crop period was observed higher in DMI treatment (151 and 126) but the amount applied in each irrigation was very less than its counterpart. It was to maintain the moisture level at the root zone of plant; water was applied drop by drop in DMI as compared with CMI treatment. In addition, the number of pumping hours required for irrigating hectare area was minimum in DMI treatment (397.7 and 456.2 h/ha). Due to less water consumption and less number of pumping hours the electricity consumption for pumping of irrigation water was also found to be minimum in DMI treatment in both the fields. Also, 38.96 and 33.41 per cent saving of electricity used for pumping in DMI treatment was observed in the experimental and farmer's fields, respectively.

Growth and yield parameters: The DMI treatment had better and early growth as indicated by higher pseudo stem height, pseudo stem girth and number of functional leaves as compared to CMI treatment (Table 3). Drip irrigation treatment resulted in early flowering and harvesting and thus reduction in crop period by 22.1 and 24.2 days as compared with its counterpart.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

The banana crop performed well in terms of yield and yield contributing parameters under DMI treatment. Higher bunch weights of 24 and 22.3 kg were noticed in DMI compared to 19.6 and 17.4 kg in CMI under different fields. The banana yields in DMI were 72.6 and 67.4 t/ha against 59.1 and 52.5 t/ha in CMI resulting in 22.84 and 28.38 per cent yield increase under experimental and farmer's fields, respectively.

Effect of irrigation methods on different efficiencies: Table 4 shows there was a remarkable increase in water, fertiliser, electricity use and pumping efficiency in DMI treatment as compared to CMI treatment. This might be attributed to the efficient use of water and fertilisers, reduced electricity for pumping and pumping hours in DMI treatment. Due to efficient application and use of inputs, the yield also increased, which was reflected in the increase in input efficiency.

Energy analysis: The input energy usage was very high in case of CMI treatment (121.68 and 124.53 GJ/ha) against DMI treatment (81.89 and 87.18 GJ/ha). The energy savings of 32.70 and 29.99 per cent was found in DMI treatment as compared to CMI treatment in experimental and farmer's fields (Table 5). This might be due to less consumption of inputs and efficient use of energy sources i.e. water, fertilisers, electricity, pumping hours and human labour in DMI treatment. For irrigation and fertigation operation the electricity energy, water energy and human energy were used maximum in case of CMI treatment. The yield and biomass gain from the banana crop production was converted into output energy by multiplying with appropriate energy equivalents. In both the fields, 19.73 and 14.09 per cent increase in output energy were noticed in DMI against CMI treatment. With regard to energy efficiency in the production of banana crop, DMI treatment was found excellent in both the fields. The present results on net energy, specific energy and energy productivity gain in banana crop production were also found maximum in DMI treatment as compared with CMI treatment. This might be attributed to the maximum gain on output energy with minimum consumption of input energy.

Economics of banana cultivation: The acceptance of new technology by the farming community depends on the economic indicators in the crop production. In the present study, DMI treatment recorded higher gross returns (3,91,932 and 3,63,960 Rs./ha) and net returns (2,19,540 and 1,82,594 Rs./ha) in both the experimental and farmer's fields. However, the cost of cultivation of banana under investigation in DMI treatment (1,72,392 and 1,81,366 Rs./ha) was 4.99 and 7.10 per cent higher than the CMI treatment (1,64,206 and 1,69,346 Rs./ha); it might be due to higher investment in drip accessories. Even though, DMI treatment recorded 17.01 and 20.36 per cent higher BC ratios (2.27 and 2.01) in both the fields, it was mainly due to higher yield and gross returns as compared with its counterpart.

Carbon credits analysis: The potential of carbon credits gain in banana cultivation due to use of drip irrigation was by virtue of saving in electricity and it was found 12 per cent maximum in experimental field (2.5 tCO_2e/ha of 2,125 Rs./ha) than farmer's field (2.2 tCO_2e/ha of 1,870 Rs./ha) (Table 6). From the average of both the fields, the potential of credits were projected for the Jalgaon district (11,750 tCO_2e of Rs. 100 Lakh per 5000 ha). Further, at this rate if every year 5,000 ha is going to be added under drip irrigation as per the projected estimates for Jalgaon district, then additionally similar CERs and equivalent money worth could be obtained.

IV. CONCLUSION

The present study clearly indicates that the drip irrigation technology was very beneficial for banana crop not only in terms of water saving and fertiliser saving but also it saved considerably the electricity required for pumping of water required for irrigation. Also the present study was attempted to minimise the carbon dioxide emissions that mainly leads to the global warming, by adopting the drip irrigation technology in banana crop.

ACKNOWLEDGMENT

This study is based on work supported by Jain Irrigation Systems Ltd., Jalgaon, Maharashtra. Also technical guidance from the Department of Soil and Water Engineering, UAS, Raichur, Karnataka has made this project possible.

REFERENCES

1. R. K. Sivanappan, "To overcome the demand for water." *Kisan World.* 2005, **32**(8), p: 47.
2. S. V. Westarp, S. Chieng, and H.Schreier, "A comparison between low-cost drip irrigation, conventional drip irrigation, and hand watering in Nepal." *Agric. Water Mgmt.*, 2004, **64,** p: 143-160.
3. S. S. Magar, N. N. Firke and J. R. Kadam, "Importance of drip irrigation." *Sinchan*, 1988, **7**(2), p: 61–62.
4. A. Narayanamoorthy, "Micro-irrigation and electricity consumption linkages in Indian agriculture: a field based study." *Int. Conf. linkages between Energy and Water Management for Agriculture in Developing Countries*, Hyderabad, India, 29-30 Jan. 2007.
5. Rekha Krishnan, "India's energy security: imperatives for change." *Energy Sec. Insights*, 2009, **4**(4), p: 2.
6. BERI, "Biomass Energy for Rural India", 2007, Available: http://nitpu3.kar.nic.in/bioenergyindia.
7. S. Singh and V. K. Mittal, "Energy requirement for cultivation of major crops of Punjab. *Proc. Energy Agric. Indian Soc. Agric. Engg.,* 1989, pp: 90-94.
8. CEA, "All India Electricity Statistics-general review". Central Electricity Authority, Government of India, New Delhi. 2008.
9. Gold Standards, Version 2, "Premium quality carbon credits", 2009, Available: abwww.cdmgoldstandard.org/gsv2_toolkit.pdf.
10. A. K. Saini, K. P. Sharma, K. P. Pant, and D. R. Thakur, "Energy management for sustainability of hill agriculture: A case of Himachal Pradesh." *Indian J. Agric. Econ.*, 1998, **53**(3), p: 223-239.
11. S. Shahin, A. Jafari, H. Mobli, S. Rafiee, and M. Karimi, " Effect of farm size on energy ratio for wheat production: A case study from Ardabil Province of Iran." *American-Eurasian J. Agric. and Environ. Sci.*, 2008, **3**(4): 604-608.

AUTHOR PROFILE

Er. V. S. Malunjkar, M.Tech (Ag.Engg.) student, Department of Soil and Water Engineering, University of Agricultural Sciences Raichur, Karnataka. e-mail: vaibhav.agroneer@gmail.com.

Dr. P.Balakrishnan, Ph.D. (Ag.Engg.), Department of Soil and Water Engineering, and Dean (Ag.Engg), College of Agricultural Engineering Raichur, UAS Raichur, Karnataka.

Dr. S. K. Deshmukh, Ph.D. (Ag.Engg), Chief Coordinator, Corporate Social Responsibility, Jain Irrigation Systems Ltd., Jalgaon, Maharashtra.

Dr. S.B. Dugad, Ph.D. (Civil Engg.), Sr. Manager, Jain Irrigation Systems Ltd., Jalgaon, Maharashtra.

Table 1. Energy equivalents for different energy input and output sources

Particulars	Input/ Output Units	Energy equivalents, MJ	Particulars	Input/ Output Units	Energy equivalents, MJ
Human labour			**Fertilisers**		
Man	Man-hour	1.96	Nitrogen, N		60.6
Woman	Woman-hour	1.57	Phosphorous, P_2O_5		11.1
Animals			Potassium, K_2O	kg	6.7
Bullocks (Wt. above 450 kg)	Pair-hour	14.05	Farmyard manure, FYM		6.7
Fuel			**Chemicals**		
Diesel	Litre	56.31	Superior		120
Irrigation water	kilolitre	1.02	Zinc sulphate	kg	209
Power			Inferior		10
Electricity	kWh	11.93	**Fruit**		
Machinery			High value (Banana)	kg	11.8
Electric motor	kg	64.8	**By Products**		
Tractor	Tractor-hour	331.59	Stalk	kg (Dry mass)	18
Tractor trailer	Per tonne per km	4.86	Leaves		10

Source: [7], [10], [11].

Table 2. Irrigation water and electricity consumption in irrigation methods

Particulars	Experimental field		Farmer's field	
	DMI	CMI	DMI	CMI
Depth of irrigation applied (mm/ha)	1455.6	2244.2	1669.7	2359.8
Total water consumption (kL/ha or m^3/ha)	14,556	22,442	16,697	23,598
Total electricity consumption (kWh/ha)	4657.8	7630.3	5343	8023.5
Total number of irrigations applied	151	40	126	42.1
Total pumping hours used for irrigation application (h/ha)	397.7	1726.3	456.2	1815.3
Hours used per irrigation	2.6	43.2	3.6	43.1

Table 3. Effect of irrigation methods on growth and yield parameters of banana crop

Parameters	Experimental field		Farmer's field	
	DMI	CMI	DMI	CMI
Pseudo stem height at flowering stage (cm)	192.6	189.2	193.1	183.3
Pseudo stem girth at flowering stage (cm)	71.7	69.5	72.5	70.9
Number of functional leaves at flowering	16.6	16.1	16.4	16.3
Days required to flowering stage	232.9	253	230.6	251.6
Days required to harvesting stage	321.5	343.6	312.8	337.0
Bunch weight (kg)	24	19.6	22.3	17.4

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Yield (t/ha)	72.6	59.1	67.4	52.5
Biomass from stem and fallen leaves (kg)	9.0	8.1	8.9	8.5

Table 4. Effect of irrigation methods on different efficiencies

Efficiency	Experimental field		Farmer's field	
	DMI	CMI	DMI	CMI
Water use efficiency (kg/m^3)	5.0	2.6	4.0	2.2
Fertiliser use efficiency	0.25	0.08	0.24	0.07
Electricity use efficiency (kg/kWh)	15.6	7.8	12.6	6.5
Pumping efficiency (kg/hph)	36.5	6.9	29.6	5.8

Table 5. Energy analysis in banana crop production

Source	Experimental field		Farmer's field	
	DMI	CMI	DMI	CMI
Input energy (GJ/ha)	81.89	121.68	87.18	124.53
Output energy (GJ/ha)	1107.88	925.30	1045.92	916.78
Energy ratio/Energy efficiency	13.5	7.6	12	7.4
Net energy gain (GJ/ha)	1025.99	803.62	958.73	792.25
Specific energy (MJ/kg)	1.1	2.1	1.3	2.4
Energy productivity (kg/MJ)	0.9	0.5	0.8	0.4

Table 6. Potential carbon credits gain in banana cultivation in Jalgaon district

Particulars	Experimental field		Farmer's field	
	DMI	CMI	DMI	CMI
Specific electricity consumption, SEC (kWh/ha)	4657.8	7630.3	5343	8023.5
Carbon dioxide (CO_2) emission reductions (tCO_2e/ha)*	2.5		2.2	
Potential of carbon credits (CERs) gain due to DMI** (Rs./ha)	2,125		1,870	
Projected potential of emission reductions from Jalgaon district (tCO_2e/year)***	11,750			
Projected potential of carbon credits gain from Jalgaon district (lakh Rs.)***	100			

*Grid emission factor = 0.0008401 tCO_2e/kWh, **Current price of carbon credit = 850 Rs.
*** Per 5,000 ha area under banana cultivation.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)