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ENERGY EFFICIENCY ASSESSMENT OF MICRO IRRIGATION

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Abstract: In India, variation in crop yield is occurs due to wide variation in energy inputs, agro-climatic conditions, and different resources used. Keeping this in view, a study has been carried out to find the energy efficiency of micro irrigation. The field experiment was carried out with drip method of irrigation (*DMI*) and conventional method of irrigation (*CMI*) at 100 per cent *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 $t{\cdot}ha^{-1}$) higher against *CMI* (59.1 and 52.5 $t{\cdot}ha^{-1}$) 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).

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.

Key words: *banana (Musa sp.), drip irrigation, energy consumption, efficiency and CO_2 emission*

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INTRODUCTION

Global warming is the most dreaded problem of the new millennium. Greenhouse gases (*GHG*s) mainly contribute for the cause of global warming. There are various sources of *GHG*s 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 [8]. In contrast, drip irrigation has field level application efficiencies of 70-90 per cent as surface runoff and deep percolation losses are minimized [10].

All agricultural operations require energy inputs in various forms (human labor, 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 ([2] [11]).

In India 52 per cent of its total power comes from coal from which agriculture consumes 28.5 per cent of total electricity [4]. The power generation in India has increased from 1400 Mw in 1947 to 2.00 Lakhs Mw at the end of 2010-11, which is comprised of power from hydroelectric, thermal, wind and nuclear power stations. The power availability for production agriculture in India is 1.5 $kW \cdot ha^{-1}$ and lies higher its requirement in Punjab which is about 3.5 $kW \cdot ha^{-1}$ [7]. According to BERI [12], 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 *GHG*s emission. Thus, energy efficiency in agriculture would have huge impact on overall scenario.

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 M t 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.

MATERIAL AND METHODS

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 May 2009 to May 2010. 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*). The statistical analysis of the treatments was done for all the parameters recorded during the study by the technique of Analysis of Variance (ANOVA).

Water requirements

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 [$mm \cdot d^{-1}$]- peak water requirement,
A [$mm \cdot d^{-1}$]- evapotranspiration rate (pan co-efficient x evaporation),
B [-] - crop factor,
C [-] - canopy factor,
E [-] - 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 per irrigation was calculated as follows.

$$Volume\ of\ water\ required\ (m^3) = \frac{PWR\ (mm \cdot d^{-1}) \times treatment\ area\ (m^2)}{1000} \tag{2}$$

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

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

Where:

D [cm] - net amount of water to be applied during irrigation,
M_{fc} [%] - moisture content at field capacity,
M_{bi} [%] - moisture content before irrigation,
A_s [$g \cdot cc^{-1}$] - bulk density of soil,
d_s [cm] - effective root zone depth.

From the net amount of water, the quantity of water required for irrigation (m^3) was measured by multiplying the net depth of irrigation (m) with the treatment area (m^2). 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.

Observations recorded

The observations such as daily evaporation (mm), water consumption (kL), number of pumping hours per irrigation (h), electricity consumption (kWh), number of labours required for different farm operations, growth parameters, growth stages and yield parameters were recorded during the study.

Energy evaluation

The energy consumption in the farm operations was determined by calculating the total energy input which included animate labors, water for irrigation, electricity for pumping, fertilizers and micronutrients for crop improvement. Also, the output got from crop yield and biomass of plant was considered as the output energy.

Biomass is considered as strategic potential, not only because it is a renewable source of energy and it is widespread, but also because its application can provide a sufficient amount of energy to reduce emissions of CO_2 and other greenhouse gases, resulting in a minimum negative impact on environment [3]. Energy from inputs and outputs was calculated by converting their physical units into respective energy units by using appropriate energy equivalents [9], were used during the study. The energy figures used in the study were expressed in mega joule (MJ) and giga joule (GJ) units (Tab. 1).

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 labor			*Fertilizers*		
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 tone per km*	*4.86*	*Leaves*		*10*

Source: [5] [6] [9]

RESULTS AND DISCUSSION

Water and electricity consumption

The minimum water was required in *DMI* (1455.6 and 1669.7 mm·ha^{-1}) when compared to its counterpart *CMI* treatment (2244.2 and 2359.8 mm·ha^{-1}) in both the fields (Tab. 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^{-1}). 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.

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^{-1})	*1455.6*	*2244.2*	*1669.7*	*2359.8*
Total water consumption (kL·ha^{-1} or m^3·ha^{-1})	*14.556*	*22,442*	*16.697*	*23.598*
Total electricity consumption (kWh·ha^{-1})	*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^{-1})	*397.7*	*1726.3*	*456.2*	*1815.3*
Hours used per irrigation	*2.6*	*43.2*	*3.6*	*43.1*

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 (Tab. 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. 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^{-1} against 59.1 and 52.5 t·ha^{-1} in *CMI* resulting in 22.84 and 28.38 per cent yield increase under experimental and farmer's fields, respectively.

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*
Yield (t·ha^{-1})	*72.6*	*59.1*	*67.4*	*52.5*
Biomass from stem and fallen leaves (kg)	*9.0*	*8.1*	*8.9*	*8.5*

Different efficiencies

Tab. 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.

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*
Fertilizer use efficiency	*0.25*	*0.08*	*0.24*	*0.07*
Electricity use efficiency (kg·kWh^{-1})	*15.6*	*7.8*	*12.6*	*6.5*
Pumping efficiency (kg·hph^{-1})	*36.5*	*6.9*	*29.6*	*5.8*

Energy analysis

The input energy usage was very high in case of *CMI* treatment (121.68 and 124.53 GJ·ha^{-1}) against *DMI* treatment (81.89 and 87.18 GJ·ha^{-1}). 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 (Tab. 5). This might be due to less consumption of inputs and efficient use of energy sources i.e. water, fertilizers, electricity, pumping hours and human labor 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.

Table 5. Energy analysis in banana crop production

Source	*Experimental field*		*Farmer's field*	
	DMI	*CMI*	*DMI*	*CMI*
Input energy (GJ·ha^{-1})	*81.89*	*121.68*	*87.18*	*124.53*
Output energy (GJ·ha^{-1})	*1107.88*	*925.30*	*1045.92*	*916.78*
Energy ratio / Energy efficiency	*13.5*	*7.6*	*12*	*7.4*
Net energy gain (GJ·ha^{-1})	*1025.99*	*803.62*	*958.73*	*792.25*
Specific energy (MJ·kg^{-1})	*1.1*	*2.1*	*1.3*	*2.4*
Energy productivity (kg·MJ^{-1})	*0.9*	*0.5*	*0.8*	*0.4*

Economics

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^{-1}) and net returns (2,19,540 and 1,82,594 Rs·ha^{-1}) 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^{-1}) was 4.99 and

7.10 per cent higher than the *CMI* treatment (1,64,206 and 1,69,346 Rs·ha^{-1}); 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.

CONCLUSIONS

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

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ENERGETSKA EFIKASNOST SISTEMA MIKRO-NAVODNJAVANJA

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Sažetak: U Indiji, na prinos ratarskih kultura utiču agro-klimatski uslovi regiona, tehnologija gajenja i utrošena energija putem repromaterijala, navodnjavanja, tehničkih sistema i ljudskog rada. Imajući sve ovo u vidu, sprovedeno je istraživanje na polju potrošnje energije putem mikrosistema za navodnjavanje. Poljsko ispitivanje je podrazumevalo dva tipa sistema i to sistem mikrokapanja (*DMI*) i konvencionalni sistem navodnjavanja (*CMI*) sa 100% ET na dve lokacije u Jalgaon-u u okrugu Maharashtra tokom 2009 i 2010. Kod useva banane je, u sistemu *DMI* bila minimalna potrošnja vode u poređenju sa *CMI* sistemom, sa 35.14 i 29.24 % uštedom vode i 38.96 i 33.41% uštedom električne energije, na eksperimentalnom polju i kod farmera redom. U *DMI* sistemu je registrovano ranije cvetanje i ubiranje kao i skraćenje perioda do ubiranja, u poređenju sa *CMI* sistemom. Prinos banana u *DMI* sistemu je, takođe, bio viši u poređenju sa *CMI* sistemu. Ostvareni prinosi su bili 72.6 i 67.4 $t{\cdot}ha^{-1}$ i u *CMI* sistemu 59.1 i 52.5 $t{\cdot}ha^{-1}$, na eksperimentalnom polju i kod farmera, redom. U *DMI* sistemu je ostvareno 32.70 i 29.99% uštede u energiji sa istovremenim porastom energetskog output-a za 19.73 i 14.09% u poređenju sa *CMI*. Energetska efikasnost u *DMI* sistemu je takođe bila viša u poređenju sa *CMI* sistemom. U *DMI* sistemu ostvaren je porast energetske efikasnosti za 13.5. i 12% dok su u *CMI* sistemu te vrednosti iznosile 7.6 i 7.4. Na oba polja je registrovan viši *BC* u slučaju *DMI* sistema.

Prikazana studija ukazuje da se primenom drip irigacije mogu ostvariti zanačajne uštede u energiji u smislu smanjenja potrošnje vode i niže potrošnje električne energije. Ovim sistemom navodnjavanja se može umanjiti uticaj klimatskih promena u Indijskoj poljoprivredi.

Ključne reči*: banana (Musa, sp), mirko-navodnjavanje kapanjem, potrošnja energije, efikasnost i* CO_2 *emisija*

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