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Estimation of water productivity of different varieties of rice in Burhi Gandak basin of north Bihar

Kumari Namrata and Dr. Ravish Chandra

Abstract

Water scarcity has become a constrained to attain goals of food security and sustainable natural resource management. In this study, experiments were conducted to determine water productivity, land productivity, process depletion and deep percolation losses of three different varieties of rice namely *Turanta, RAU1428, Boro-3* in Pusa Farm of Dr. Rajendra Prasad Central Agricultural University, Bihar for *kharif* 2009 season. The water productivity values for gross inflow ranges from 0.10 kg/m^3 to 0.14 kg/m^3. The value of irrigation water productivity was 0.26 kg/m^3 for *Boro-3,* followed by 0.21 kg/m^{3}for *Turanta* and then 0.16 kg/m^3 for *RAU-1428.*It was revealed that the crop water requirement was lowest for *Turanta* and highest for *RAU1428* and deep percolation losses range from 70 -74 %. (Low water use Efficiency).

Keywords: Water productivity, land productivity, deep percolation losses, process depletion, water use efficiency

Introduction

Agriculture plays a vital role in Indian economy and contributes around 17-18% to the country's GDP. The total productivity of rice in eastern India increases at the rate of 0.36% per annum during 1972-89 as compared to the rate of increase of 0.76% per annum for the southern region [1]. To achieve planned level of food grains, crop production must be increased. Rice (*Oryza sativa*) is a cereal crop grown in many countries with rice-wheat cropping pattern, supply approximately 78.01% of carbohydrates and trace amount of protein 7.5 % required by man. Rice occupies about 40% of irrigated area in India and major consumer of 65.7% of the water resource, thus needs careful water management to increase its water use efficiency. Rice is grown under varied soil and climatic conditions. It grows best on clay loams to clay, because of low percolation rates (1-5mm/day). It thrives best under high temperature and humid condition.

Water is a most important key input for agriculture production. Irrigated agriculture is the largest water-consuming sector and it faces competing demands from other sectors, such as the industrial and the domestic sectors. With an increasing population and less water available for agricultural production, the food security for future generations is at stake. The agricultural sector faces the challenge to produce more crops per drop of water for increasing Crop Water Productivity (CWP) [2]. To increase CWP through the principle of same production from less water resources or a higher production from the same water resources. Therefore, in addition to increase in crop yield, application of organic manures decreases the amount of water used in the production process and increases crop water productivity substantially [3].

The world has finite water resources, which are under increasing stress as the human population and water demand per capita both increases. These problems are now becoming more wide spread and devastating. It is likely that 78% of the world population will live in areas facing physical and economic water scarcity by 2025 (IWMI, Colombo). In physical water scarce regions, there is simply not enough water to meet agricultural, industrial and domestic needs.

This has provided additional impetus for the search for solutions to problems arising from the mismatch between demand and supply in terms of water quantity, quality and timing. Increasing water productivity has been identified as one of the global challenges that require urgent attention.

The Agricultural sector in India, Bihar is the centre stage in the overall economic progress and development. The (undivided) Bihar as per 1998-1999 occupies about 7.1% of the total cultivated area and produces only 6.4% of the total food grains. Although the state is rich in soil and water resources, the existing gap in experimental and average yields of rice-wheat cropping system is computed as 5.9-2.04 t/h on account of poor management of water.

The challenge for irrigated agriculture will be to grow more food with less water. The focus from improving land productivity needs to shift to improve water productivity. Keeping the importance of the water the present study was undertaken to estimate water productivity, land productivity, process depletion and deep percolation losses of three different varieties of rice namely *Turanta*, *RAU1428*, *Boro-3* in Pusa Farm of Samastipur district of Bihar.

Materials and methods

Site Description

The experiments were conducted in *kharif* season 2009 at the research farm of Dr Rajendra Prasad central Agricultural University, Pusa is samsatipur district of Bihar on the western and southern bank of Burhi Gandak at an altitude of 52.00 m above Mean sea level and lies at 25.98^0 N latitude and 85.67^0E longitude. The climate is sub-tropical characterized mainly by hot-dry summer and cool winter with the average annual rainfall is 1260 mm out of which approximately 90 per cent is received from middle of June to middle of October. The period from last week of November to February receives occasional showers. May-June is the hottest months of the year. January is the coldest month with average maximum temperature ranging from 21.4 to 23.7^0C and minimum from 5.7 to 8.8^0C. The rainfall for the year 2009 was about 28% lower than the average rainfall. Rise in temperature takes places at slow pace from February and picks-up from March and reaches the climax somewhere during May-June. The maximum relative humidity falls ranging from 85-95% during rainy months of July- September and the minimum in the range of 40-60% during summer month of March- April. The highest record of solar radiation is 650 ly/day in the month of May and lowest 380 ly/day in the month of December. The rainfall received at Pusa from the year 2000-2009 (Fig 1). The data shows that maximum rainfall (2430.9 mm) was received in the year 2007 and minimum rainfall (636.7mm) in the year 2003.

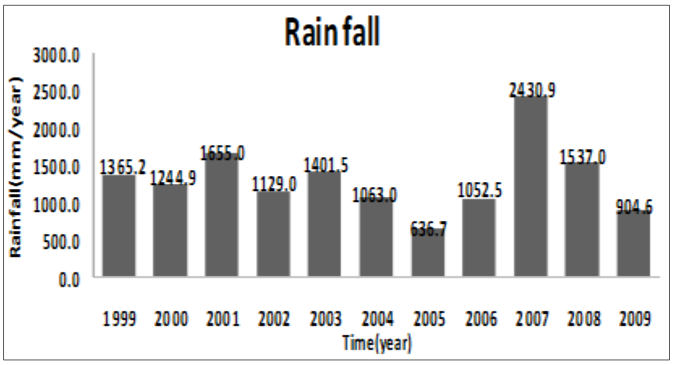

Fig 1: Annual rainfall (mm) received at Pusa Farm (2000-2009)

Experimental Setup

Three varieties of rice namely *Turanta*, *RAU-1428*, *Boro-3* were sown in Maysore plot in water management Farm of Pusa.

Irrigation application was the prominent work to be carried out during the experiment. The source of irrigation was a submersible pump operated by motor located near the field. Waterways conveyed through RCC pipe from tube well to an open earthen channel near the experimental site. DAP, Urea, MOP were applied in the field to increase crop yield.

Data Collection

Turanta is an upland rice variety and is a cross of *Rasi* and *Satari*. It is a short duration crop of 70-75 days. Grains are short and bold has potential yield of 3t/ha, and it is suitable for delayed sowing. The crop height is generally 80-90 cm. *RAU 1428* is suitable for rainfed low land. It is medium fine grain rice. It is medium duration crop of 120-125 days. Its plant height is 115 cm. and the potential yield is 5-5.5 t/ha. It is suitable for normal sowing. *Boro-3* is upland rice. Grains are short and bold. The duration of the crop is 120-125 days. Plant height is 110-115 cm. It is a suitable for *Boro* cultivation and yield potential is 4-4.5 t/ha. The daily climatic data such as rainfall, wind speed, relative humidity, sun shine hours and temperature for year 2009 were collected from the metrological department of Dr Rajendra Prasad Central Agricultural University,

Measurement

Tube well discharge

Tube well discharge was measured by using coordinate method (Michel, A.M.; 1978).For this vertical distance (y- co-ordinate) from the jet at the end of the delivery pipe to ground surface and horizontal distance (x-co-ordinate) on the ground surface from the end of pipe to center of fall of jet are measured. The discharge is estimated as

$$Q=CAXg^{0.5}/ (2y)^{0.5}$$

Where,

Q= Discharge (m^3/sec), C= coefficient of construction, A= cross sectional area, (m^2), X= x-coordinate, Y= y-coordinate, g= acceleration due to gravity, (ms^{-2})

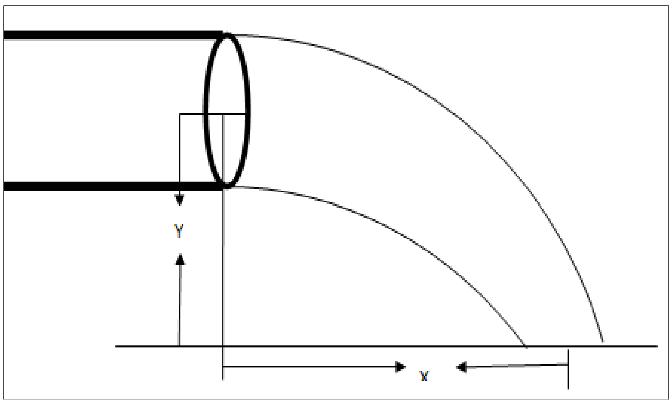

Fig 2: Co-ordinate-Method of discharge measurement

Discharge measurement at field

For the measurement of discharge at field a 7.5 cm Parshall flume was installed in the conveyance channel. The prescribed ratio of H_b and H_a for 7.5 cm Parshall flume should be less than 0.5 for free flow condition. If the ratio exceeds 0.5 then flow is considered submerged. The seepage losses were very high due to earthen channel, weed population and poor maintenance of channel.

Determination of Evapotranspiration by crop watt software

Crop watt -8 (FAO, 1992 CROPWATT) Software was used for estimating ET for different varieties of rice. The cropwatt was uses FAO Penman-Monteith based combination formula for estimating reference evapotranspiration**,** The Penman-Monteith Formula is as follows.

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

Where

ET_0 = Reference Evapotranspiration (mm day^{-1}),G = Soil heat flux density ($MJm^{-2}day^{-1}$),R_n = Net radiation at the top surface($MJm^{-2}day^{-1}$),u_2 = Wind speed at 2m height (ms^{-1}),e_s = Saturation vapor pressure (kpa),e_a = Actual vapor pressure (kpa), e_s-e_a = Saturation vapor pressure deficit (kpa), Δ= Slop of vapor pressure curve (kpa^0c^{-1}),Y= Psychometric constant (kpa^0c^{-1})

Crop watt estimates Crop Evapotranspiration by multiplying Reference Evapotranspiration with crop coefficient (k_c) values.

Water productivity

Productivity is a measure of performance expressed as the ratio of output to input. Water productivity (WP) and land productivity measures how the system converts water into goods and services. The value of product might be expressed in different terms (biomass, grain, money) approach focuses on the amount of product per unit of water. WP refers physical mass of production or the economic value of production measured against gross inflow, net inflow, process depleted water. The water accounting methodology developed my IWMI [4, 5]. Was taken by present study. WP expressed in the terms of kg /m^3 of water or INR/m^3 of water. The definitions of the terms adopted in the study are expressed as follows.

$$W_P\ (Gross\ inflow) = \frac{yield}{gross\ inflow}$$

Where, Yield (Kg/ha), Gross inflow, (m^3 /ha)

Weight of grains over cumulative weight of water inputs by irrigation and rain during crop growth

$$W_P\ (irrigation\ inflow) = \frac{yield}{irrigation\ inflow}$$

Where, Yield (Kg/ha), Irrigation in flow (m^3/ha)

$$W_P\ (Process\ depletion) = \frac{yield}{Evapotranspiration}$$

Where, Yield (kg/ha), Evapotranspiration (m^3/ha)

Volume of water delivered at the source (m^3)

= Tube well discharge (m^3/s) **x** hrs of irrigation **x** 3600

Volume of water delivered at the field (m^3):

= discharge by Parshall flume (m^3/sec) **x** hr of irrigation **x** 3600

Or (Tube well discharge –seepage losses) (m^3/sec) x hrs of irrigation x 3600

Total volume of water (m^3)

=Volume of delivered at field (m^3) + total volume of rain fall water (m^3)

Deep percolation (m^3)

=Total volume of water (m^3) - actual evapotranspiration (m^3)

Water Balance

Water balance of a cropped field is calculated as follows:

I+R= ET+P+S (cm)

Where

R is the rainfall, I the irrigation, *ET* the Evapotranspiration, *P* the deep Percolation loss, *S* the seepage.

Results and discussion

Land Productivity

Land productivity is defined as crop yield per square meter of cultivable area. The agricultural year 2009-10 was a drought year up to mid- August, 2009 there was rainfall deficiency of 43%. This year (2009-10) has adversely affected the agricultural production. Rainfall in early period of monsoon helps maintaining groundwater aquifer which facilitates irrigation of crops in case of shortfall of rainfall through groundwater resources, particularly in terminal period of monsoon however situation is just reverse in the year 2009-10.The delay in Monsoon has shifted the transplanting date by 25-30 days which has particularly affected yield. The yield of all three varieties of rice is relatively low in this year.

The analysis revealed that the yield of *Boro*-3 is higher than the other two varieties *Turanta* and *RAU-1428*. The crop yield of *Boro-3* was 1.97 t/ha which is 10.52 % more than *Turanta (*1.786 t/ha) and 10.71% more than *RAU-1428 (*1.783 t/ha)

In general the crop yield of all three varieties of rice is lower than the potential yield becuse delayed transplanting has adversely affected the crop yield of *RAU1428* varieties of rice. The yield of *RAU-1428* is much lower than its potential yield. As discussed earlier, drought has shifted transplanting date of all the three varieties of rice by 25-30 days.

The analysis suggests *Turanta* variety of rice should be preferred over *RAU-1428* of the water scarce region. Yield data of different varieties of rice was presented in (Table 1).

Table 1: Crop yield (t/ha) for different varieties of rice

S. No.	Name of plot	Rice	Crop yield(t/ha)
1	Mayshor –I	*Turanta*	1.786
2	Mayshor-II	*Boro-3*	1.974
3	Mayshor-III	*RAU-1428*	1.783

Water Productivity

The productivity of irrigation water depends on the amount of irrigation water and crop yield. Water productivity for three selected varieties of rice for kharif 2009 was presented in (Table 2). The water productivity values for gross inflow ranges from 0.10 kg/m^3 to 0.14 kg/m^3. This indicates 10,000 L water was used to produce one kg of *RAU-1428* variety of rice where as *Boro-3* variety of rice required 6,800 l water and *Turanta* variety of rice required 8,130 L of water to grow one kg of rice. The water productivity calculated based on irrigation inflow was higher than that of gross inflow. The value of irrigation water productivity was 0.26 kg/m3 for Boro-3, followed by 0.21 kg/$m^3$for *Turanta* and then 0.16 kg/m3 for *RAU-1428*.On making the comparison between the three varieties of rice in terms of total water productivity it was found that total ware productivity of *Boro*-3 variety of rice is higher by 38% than *RAU-1428* and 18% than *Turanta* rice. Water productivity of *Turanta* variety of rice is higher by 29% compared to RAU-1428. Process depletion is defined as yield divided by Crop Evapotranspiration. The value of process depletion is highest for *Turanta* (0.52 kg/m^3), followed by *Boro*-3 (0.48 kg/m^3) and *RAU-1428* (0.39 kg/m^3). The higher value of process depletion for Turanta suggests that the *Turanta* variety of rice requires lowest amount of water and is best suited where water is scarce. The productivity values are very low compared with the other countries in the world. Irrigation water productivity of traditional rice cultivation in Tunalin china is 1.95 kg/m^3 [6].

The analysis suggests that there is significant scope for increasing water productivity by increasing yield through both better water use and other input management. The analysis also suggests that *Turanta* variety of rice is the better choice among the three varieties of rice in terms of water demand. Early harvesting of '*Turanta*' rice (70-75 days) will provide opportunity for early sowing of *Rabi* crops.

Table 2: water productivity (kg/m^3) of three varieties of rice (*kharif '09'*)

Name of plot	Variety	Irrigation water productivity (kg/m^3)	Total water productivity (kg/m^3)	Yield/ET Process depletion (kg/m^3)
Mayshore 1	*Turanta*	0.213	0.123	0.5193
Mayshore 2	*Boro-3*	0.263	0.145	0.4826
Mayshore 3	*RAU-1428*	0.165	0.105	0.3953

Water Balance

The analysis shows that *RAU-1428* variety of rice consumed highest amount of water followed by *Turanta* and *Boro-3* (Table 3). The crop water demand of *RAU-1428* variety of rice was more than 24 % *Turanta* variety of rice. The analysis has shown that the crop water requirement varies from 363 mm to 451 mm. The lower crop water requirement is due to 25-30 days delay in transplanting of paddy and relatively short duration of crop. The irrigation inflow constituted about 58%, 55% and 63% of gross inflow for *Turanta, Boro-3 and RAU-1428* variety of rice respectively. The rainfall was sporadic and there was rainfall deficit in the month of July. The change in root zone storage was assumed as zero. The average seepage and deep percolation losses were very high for all those varieties of rice. The deep percolation losses were ranges from 70-74% due to low water use efficiency, and this large amount of irrigation water and rainfall was not used beneficially by the rice crop and goes out of the root zone over the whole growing season. Deep percolation losses were highest for *RAU-1428* (123.94 cm) and lowest for *Boro-3* (95.29 cm). Besides this the conveyance losses were also very high. This focused the need for better and efficient use of irrigation and rainwater to improve water use efficiency. There is an urgent need to minimize the deep percolation losses to 45-50% for increasing the water productivity.

Table 3: Water balance components for three varieties of rice (kharif'09')

Varity	Total irrigation water (cm)	Total rain fall (cm)	Total depth of water (irrigation and rain fall) cm	Evapotranspiration (cm)	Deep percolation (cm)	% loss
Turanta	83.84	61.18	145.02	36.39	108.63	74
Boro-3	75.01	61.18	136.19	40.90	95.29	70
RAU1428	107.86	61.18	169.04	45.10	123.94	73

Conclusions

The analysis suggests that there is significant scope for increasing water productivity by increasing yield through better water use and other input management. The Lower water productivity is due to inefficient use of irrigation water.

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