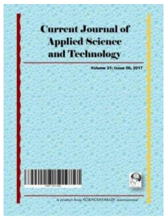


*Current Journal of Applied Science and Technology*

***26(6): 1-9, 2018; Article no.CJAST.40579***
***ISSN: 2457-1024***
*(Past name: British Journal of Applied Science & Technology, Past ISSN: 2231-0843, NLM ID: 101664541)*

# Growth, Production Potential and Inputs Use Efficiency of Rice under Different Planting Methods in Drip Irrigation

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***Authors' contributions***

*This work was carried out in collaboration between all authors. Authors AKB and PS designed the study, performed the statistical analysis, wrote the protocol. Authors TP, SC and TCS wrote the first draft of the manuscript. Authors AKB and TP managed the analyses of the study. Authors RKB and BL managed the literature searches. All authors read and approved the final manuscript.*

***Article Information***

DOI: 10.9734/CJAST/2018/40579
Editor(s):
(1) Farjana Sultana, Professor, College of Agricultural Sciences, International University of Business Agriculture and Technology (IUBAT University), Bangladesh.
Reviewers:
(1) Koksal Aydinsakir, Batı Akdeniz Agricultural Research Institute, Turkey.
(2) Leyla Idikut, Sutcu Imam Universty, Turkey.
(3) Nusret Ozbay, University of Bingol, Turkey.
Complete Peer review History: http://www.sciencedomain.org/review-history/24079

***Original Research Article***

***Received 12th January 2018***
***Accepted 26th March 2018***
***Published 11th April 2018***

## ABSTRACT

Rice (*Oryza sativa L.*) is the most vital staple food crop in Asia and human consumption accounts for 85% of total production of rice. The conventional rice production system with standing water not only leads to wastage of water but also causes ecological problems and reduces the use-efficiencies of inputs. An effort to increase crop and water productivity either by reducing water consumption or by increasing the yields or both will automatically facilitate higher growth in agricultural production. Keeping these in view, field experiments were conducted in 2011 and 2012 at the University Farm, G.B. Pant University of Agriculture and Technology, Pantnagar. Data were collected to assess the growth, yield, yield components and use efficiencies of nutrient and water of rice under drip irrigation and conventional irrigation practices. The experiment was laid out in a

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Randomized Complete Block Design comprising of 4 replications and 4 treatments. Results show that growth, yield and their attributes, input use and economics differed significantly among the treatments in both years. All the growth factors studied were found to be higher in the flatbed method of Dry Seeded Rice (DSR) and drip irrigation. Shoot height was found significantly maximum in DSR with flood irrigation. Similarly, yield and yield attributes were superior in the flatbed method of DSR with drip irrigation in both years. Water and nutrient use efficiencies were found to be maximum in drip irrigated rice with 52% water savings than traditional flood-irrigated rice. It is also noted that Returns and Benefit-Cost ratio were higher with drip-irrigated rice than flooded irrigated rice.

*Keywords: Direct seeded rice; drip irrigation; flatbed; raised bed; transplanted rice; yield.*

## 1. INTRODUCTION

India is the world's second-largest rice producer accounting for more than 20 percent of global production. According to Govt. of India (GoI), the rice production ranges 99.5 -110 million ton per year. Rice production accounts for a large amount of water use in India. Typical irrigation rates average 1200 mm $ha^{-1}$ $year^{-1}$, and in extremely dry years, can exceed 1400-1500 mm.

Water is considered to be a scarce natural resource. Agriculture is the largest water user consuming about 83 percent of the total available water in India. Increased demand for industrial and domestic water will result in a reduction in water diversions to agriculture [1]. If the irrigated area is kept without expanding, rice production requirement in 2025 AD could only be achieved by increasing the yield and the cropping intensity [2].

Supply of water to the plant with correct quantity at the correct time without creating any hazardous effect of the soil-plant environment is considered to be proper irrigation. In most of the cases, irrigation efficiency is low due to the absence of proper field water management practices and the soil-plant-environment is deteriorating due to the absence of proper drainage. Consequently, the agricultural productivity of the system would diminish. Therefore, efficient method of irrigation and proper drainage are considered as the key factors for the successful irrigated farming system. One of the best methods to increase the efficiency and the uniformity of irrigation is the use of micro-irrigation or localized irrigation techniques. The drip system can control the rate of water application to achieve application efficiency as high as 90 - 95 percent. As the entire soil surface does not get wet, weed growth is checked by drip systems. The system is also excellent for soils with higher infiltration rates. Unlike surface and sprinkler irrigation, the drip system can keep the soil water content always near the field capacity without creating any soil moisture deficit to the crop. Drip associated with fertigation also enhances crop productivity by 60-100 percent. Besides, drip- fertigation technology increases the crop productivity with lesser and more efficient resource use. This would be the crux for future green revolution to ensure food security.

As for water use efficiency, Chartzaulakis and Michelakis [3] reported higher water use efficiency under the controlled environmental condition in drip irrigation over furrow irrigation with no significant difference in crop yield. Thus, efficient use of water in any irrigation system is becoming important, particularly in arid and semiarid region where water is a scarce commodity. In-furrow and border irrigation systems, loss of applied irrigation water from the reservoir to the field under unlined irrigation system is 71 percent [4]. Drip irrigation reduces deep percolation, evaporation and controls soil water status more precisely within the crop root zone. At present, although such micro-irrigation systems are promoted in small-scale irrigation, information on rice crop performance is limited in the literature, especially under local North Indian conditions [5,6]. Therefore, the present study was undertaken with the primary objective of evaluating the productivity and use efficiency of critical inputs and monetary benefits from rice farming.

## 2. MATERIALS AND METHODS

### 2.1 Location, Climate and Soil

Field experiments were conducted at the University Farm of G.B. Pant University of Agriculture and Technology, Pantnagar, India, for 2 consecutive years 2011 (I year) and 2012 (II year) in the *Kharif* (June-October) season. Mean annual rainfall of the area from 2001 to 2012 is

1364 mm. Total rainfall during the rice growing season from June to October was, respectively, 1770 mm in 2011 and 1042 mm in 2012. The soil is a silty clay loam mixed hyperthermic Aquic Hapludoll (Haplic Chernozem). Texturally, the soil contained 150 g $kg^{-1}$ sand, 530 g $kg^{-1}$ silt and 320 g $kg^{-1}$ clay, with a high concentration of organic carbon (28 g $kg^{-1}$). Chemically, the soil contained a low concentration of $KMnO_4$ extractable nitrogen (250 kg $ha^{-1}$), medium of 0.5 M sodium bicarbonate ($NaHCO_3$) extractable phosphorus (15.3 kg $ha^{-1}$), and 225 kg $ha^{-1}$ available potassium.

### 2.2 Experimental Design and Treatment Details

The experiment was laid out in the complete randomized block design with four treatments with four replications. The treatments consisted of a combination of two levels of planting methods, i.e., direct seeded rice (DSR), transplanted rice (TPR) and two methods of irrigation, *i.e.,* drip irrigation and flood irrigation. Further two treatments, *i.e.*, flatbed and raised bed has set under DSR planting method of drip irrigation plots. The treatments were repeated in the same plots in both years. The rice seedlings were transplanted at a spacing of 20 cm × 10 cm in rows accommodating 4,00,000 plants per hectare. The sowing of PR-113/HKR-47 variety of rice maturing in about 120 days was taken up in a nursery on the first week of June during both the years for the establishment of seedlings. During its seedling establishment in the nursery, the plant was not subjected to differential irrigation treatments. Just before transplanting, the soil profiles of all the experimental plots were uniformly brought to the saturated condition. The healthy seedling was then selected from the nursery bed and transplanted to the experimental plots at a spacing of 20 x 10 cm intervals on last week of June month in I Year and II Year.

In case of DSR, same variety was sown in a main field after the field had thoroughly been prepared. Then rows were formed at a spacing of 20 cm interval. The irrigation water requirement for the drip irrigated blocks was estimated using Pan Evaporation data. The furrow irrigation had a frequency of water application consistent with local practices. The recommended fertilizer rates of 150-60-40 kg NPK $ha^{-1}$ was used in this experiment. Nitrogen and potash were applied through drip irrigation at 15 days interval from 20 DAS onwards. The full rate of Phosphorus was applied at the time of land preparation in non-puddled direct seeded plots and at the time of transplanting for puddled soil. The experimental area was hand weeded to control the weeds.

The drip system consisted of a pump (7.5 HP), a control head unit, PVC mainline, polyethylene sub mains and laterals, and emitters. The water was supplied to drip irrigated treatment plots through drip irrigation system after filtering through sand and screen filters. From the mainline, water was taken to the fields through sub-main and 16 mm laterals laid out at 60 cm distance were connected to the sub-main. The emitters on the laterals are fixed at 40 cm. First irrigation was given immediately after sowing and subsequent irrigations were scheduled once in two days based on wetting of soil.

The growth and yield component observations were made from five plants in one square meter area and computed average. While yield data have been recorded from net plot area of 5 $m^2$. The net plot area was harvested after removing the border rows and threshed. The grain yield was recorded after cleaning and drying and expressed in kg $ha^{-1}$. The agronomic fertilizer use efficiency of NP&K was calculated in term grain yield of rice per kg of nutrient applied. Similarly, the water use efficiency was computed as the ratio of grain yield (kg/ha) and total water applied including the effective rainfall.

### 2.3 Statistical Analysis

The data obtained in respect of various observations were statistically analyzed by the method described by Cochran and Cox [7]. The significance of “F” and “t” was tested at 5% level of significance.

## 3. RESULTS AND DISCUSSION

### 3.1 Growth Attributes

Drip-irrigated rice had accumulated more total dry matter than flood-irrigated rice. DSR (flatbed) with drip irrigation produced more dry matter accumulation (1427 and 1398 g $m^{-2}$ in I Year and II Year, respectively). Both in drip and flood irrigation treatments, DSR and transplanted rice were not significantly different in terms of total biomass. Relatively higher total dry matter accumulation seen under drip irrigation treatments is worth noting.

Root length of rice was significantly influenced by irrigation and establishment methods. Rice root length was more in flatbed DSR (36.12 and

35.98 cm in I Year and II Year, respectively) than raised bed DSR (33.87 and 29.83 cm in I Year-12, respectively) within drip irrigation treatment. DSR rice, in general, had more root length than transplanted rice in flood irrigation. Establishment methods also influenced the root length of rice. Longer root was found under flatbed irrigation than raised bed irrigation. The difference was statistically significant. In the flooded rice the differences in root length were not consistent, in I Year, DSR and transplanted rice under flood irrigation did not differ significantly but it was significantly different in II Year (Table 1). Root length will increase generally, when water does not available in shallow soil strata and roots tend to go deeper to absorb water from the vicinity of the root zone. In contrast, transplanted rice had shorter root length. But in case of drip irrigated under DSR had longer root length and it accounts for 24 to 36 percent over control treatments. Thus, most of the root characters were more pronounced in the drier or moderate moisture regimes. Such deeper root system might play an important role not only for continuous water uptake under limited water supply situations [8,9] but also for nutrient uptake. Stressed (drip) as well moderate (DSR with flood irrigation) moisture regimes showed comparable values for total root length.

Plant height was positively related to increased levels of irrigation. Flood irrigation of both DSR and transplanted rice registered slightly more plant height as compared to drip irrigated rice crops in both the years (Table 1). The treatment of DSR with flood irrigation had increased plant height to the tune of 4.7 and 3.0 percent in I Year and II Year, respectively followed by transplanting rice with flooded irrigation; the differences are, however, not statistically significant.

The plant height was greatly influenced by the irrigation methods. Bouman and Tuong [10] stated that when rice is subjected to moisture stress lead to inhibition of leaf production, the decline in leaf area, reduction in plant height, reduced tillering and enhanced leaf senescence. Similar results also were confirmed by Matsuo and Mochizuki [11]; Matsunami et al. [12]. The severity of the plant height at lower water supply is in accordance with the findings of Russo [13]; Vanitha [14]. Sarvestani et al. [15] also reported an effective reduction in biomass due to water stress owing to decrease in photosynthetic rate.

### 3.2 Yield Components

Drip and flood irrigation methods had significantly influenced the number of tillers per square meter (Table 2). DSR produced significantly higher tillers $m^{-2}$ than transplanted rice. Among DSR, number of tillers $m^{-2}$ were more in drip irrigation than flood during the year I Year and II Year.The treatment of DSR with flat bed (539and 543 in I Year and II Year, respectively) produced higher active tillers $m^{-2}$ followed by DSR on raised bed under drip irrigation.

Panicle length and panicle weight were not significantly influenced by the treatments. Higher panicle lengths and panicle weights were 26.18 and 26.95 cm in I Year and II Year and 5.02 g and 5.08 g in I Year and II Year, respectively under DSR (flatbed) + drip irrigation followed by DSR (raised bed) + drip irrigation treatment (Table 2). In the drip irrigation treatment, the field was free from weed growth. Therefore, there was no competition between weeds and rice plants for utilizing various critical inputs and eventually it may have influenced in the number of tillers $m^{-2}$ under drip irrigation plots. In contrast, transplanted rice showed fewer tillers because of the higher mortality rate under transplantation. This could be due to the favourable plant water relations as observed with drip system [16]. Similar results were also expressed by Deivanai et al. [17].

**Table 1. Influence of drip irrigation on shoot height (cm), total dry matter accumulation (g $m^{-2}$) and root length (cm)**

| Treatments | Shoot height | | Total dry matter accumulation | | Root length | |
|---|---|---|---|---|---|---|
| | I Year | II Year | I Year | II Year | I Year | II Year |
| DSR(Flatbed) + drip irrigation | 102.80 | 99.30 | 1427 | 1398 | 36.12 | 35.98 |
| DSR (Raised bed) + drip irrigation | 98.48 | 93.57 | 1198 | 1154 | 33.87 | 29.84 |
| DSR+ flood irrigation | 114.50 | 108.70 | 1114 | 1108 | 27.28 | 26.81 |
| TPR + flood irrigation | 109.40 | 105.56 | 1109 | 1085 | 26.48 | 25.57 |
| S. Em. | 1.79 | 1.57 | 25.91 | 12.84 | 0.56 | 0.27 |
| CD (p=0.05) | 5.74 | 5.10 | 82.86 | 41.67 | 1.78 | 0.86 |

**Table 2. Influence of drip irrigation on number of tillers ($m^2$), panicle length (cm) and panicle weight (g $panicle^{-1}$)**

| Treatments | Number of tillers | | Panicle length | | Panicle weight | |
|---|---|---|---|---|---|---|
| | I Year | II Year | I Year | II Year | I Year | II Year |
| DSR(Flat bed) + drip irrigation | 543 | 530 | 26.18 | 26.95 | 5.02 | 5.08 |
| DSR (Raised bed) + drip irrigation | 519 | 501 | 25.12 | 24.94 | 4.46 | 4.96 |
| DSR+ flood irrigation | 499 | 475 | 22.98 | 22.16 | 3.92 | 4.35 |
| TPR + flood irrigation | 442 | 430 | 24.31 | 22.50 | 4.04 | 4.61 |
| S. Em. | 10.56 | 3.73 | 0.46 | 0.20 | 0.20 | 0.15 |
| CD (p=0.05) | 33.76 | 12.09 | 1.46 | 0.65 | 0.63 | 0.48 |

Thousand grain weight or test weight of rice was not significantly different in I Year but it was significant among treatments in II Year. However, among the treatments, grain weight in DSR (flatbed) + drip irrigation rice was significantly higher than in all other treatments in the year II Year (24.05g) followed by DSR (flatbed) + drip irrigation treatment (23.11g). Grain yield of rice was significantly influenced by establishment method, irrigation regime and planting pattern. The planting pattern of DSR registered maximum grain yield than transplanted rice (Table 3). Among the DSR, drip irrigated rice had recorded significantly more grain yield than flood irrigation. The establishment methods have also influenced yield and grain weight, flatbed method of DSR under drip irrigation produced highest grain yield (7962 kg $ha^{-1}$ and 7889 kg $ha^{-1}$ in I Year and II Year, respectively) followed by DSR (raised bed) + drip irrigation (7452 and 7391kg $ha^{-1}$ in I Year and II Year, respectively). The lowest grain yield was recorded with DSR + flood irrigation treatment (6720 and 6673 kg $ha^{-1}$ in the years I Year and II Year, respectively).

Harvest index of rice was significantly influenced by all the treatments in I Year. The highest harvest index of rice was observed in DSR (raised bed) + drip irrigation (43.72%) followed by DSR (flatbed) + drip irrigation (40.57%) treatment. The lowest value had been recorded in DSR+flood irrigation. The test weight of grains showed moderate variations in the drip irrigation. Enhancing the test weight due to higher rates of filling of developing grains because of increased translocation efficiency for photo-assimilates [18]. The grain yield of rice is often influenced by sink capacity rather than source strength under stress-free environment [19]. In our investigation, grain yield had increased by 14.40% and15.0% more than the control treatment of transplanted rice in I Year and II Year, respectively (Fig. 1).

Thangjam et al. [20] reported rice grain yield of drip irrigation in DSR was increased up to 35.31% over conventional transplanted rice. Grain yield also showed significant positive correlations with the above ground dry matter, number of panicles per square meter, and spikelet's per square meter, which were the yield components determined before anthesis [21]. The harvest index values were found to be higher (43.72 and 41.81 percent) for drip systems. This might be attributed to the fact of producing larger sink size and efficient transport of assimilates from leaves and stems (source) into developing spikelets (sinks) thus resulting in the increased grain yield [22, 23].

## 3.3 Use Efficiency of Critical Inputs

Drip irrigation is an efficient and precise method to deliver water and nutrients to rice plants because the water is directly applied to the effective root zone of crop plants. The maximum nutrient use efficiency was obtained from drip-irrigated rice than conventional methods of transplanted rice (Table 4). DSR (flatbed) + drip irrigation had recorded significantly higher agronomic use efficiency of nitrogen in both the year I Year and II Year (53.08 and51.20 kg grain yield per kg applied, respectively) followed by DSR (Raised bed) + drip irrigation treatments. Lowest agronomic use efficiency of nitrogen was obtained at DSR+flood irrigation during both years. Similar trends have been observed in case of phosphorus and potassium use efficiencies.

In general, nutrient use efficiency in rice plants is low as compared to other arable crops, possibly due to more losses through leaching and denitrification from the flooded paddy field [24]. The rice grown under drip irrigation in our experimental field had achieved a more agronomic use efficiency of nitrogen, phosphorus and potash as compared to that in flood irrigation. Nutrient use under drip irrigation was more. Low nutrient use efficiency under DSR + flood irrigation method could be due to denitrification loss. When a field is aerated, ammonium form of nitrogen easily converts into a nitrate form of nitrogen. Then, while irrigating the field, it is easily converted into the gaseous form of nitrogen by denitrifying bacteria. [25,26].

Drip irrigation enhances water use efficiency. DSR (flatbed) + drip irrigation had registered higher water use efficiency (11.21 and 12.46 kg ha $mm^{-1}$ in I Year and II Year, respectively) followed by DSR (raised bed) + drip irrigation. The lowest water use efficiency was observed in case of transplanted rice+ flood irrigation.

Drip irrigation saved water by 51.36 and 51.79% over conventional flood method. DSR is saving 22.66 and 22.85% than transplant control in the year I Year and II Year, respectively (Table 5).

**Table 3. Influence of drip irrigation on thousand grain weight (g), grain yield (kg $ha^{-1}$) and harvest index**

| Treatments | Thousand grain weight | | Grain yield | | Harvest index | |
|---|---|---|---|---|---|---|
| | I Year | II Year | I Year | II Year | I Year | II Year |
| DSR(Flatbed) + drip irrigation | 23.98 | 24.05 | 7962 | 7889 | 40.57 | 41.41 |
| DSR (Raised bed) + drip irrigation | 23.76 | 23.11 | 7452 | 7391 | 43.72 | 41.81 |
| DSR+ flood irrigation | 22.95 | 22.78 | 6720 | 6673 | 39.37 | 40.65 |
| TPR + flood irrigation | 23.14 | 22.95 | 6960 | 6857 | 40.21 | 41.11 |
| S. Em. | 0.40 | 0.25 | 124.56 | 87.20 | 0.83 | 1.15 |
| CD (p=0.05) | NS | 0.79 | 398.32 | 282.91 | 2.66 | NS |

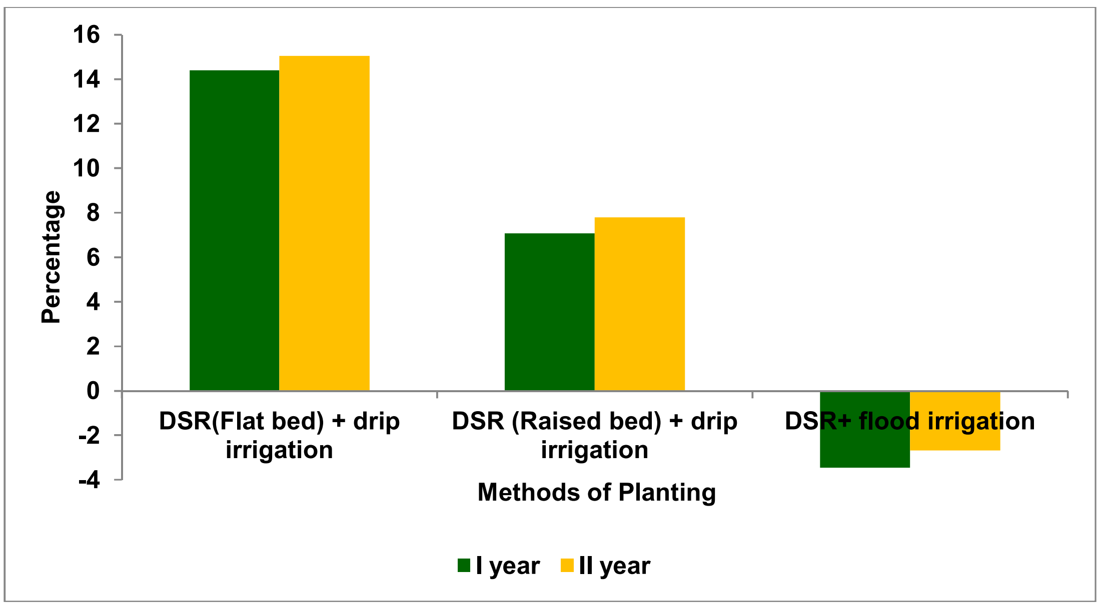


**Fig. 1. Percentage of yield variation of drip irrigation over conventional methods of transplanted rice during an experimental period**

**Table 4. Influence of drip irrigation on agronomic use efficiency of nitrogen, phosphorus and potassium (kg grain yield per kg nutrient applied)**

| Treatments | Nitrogen | | Phosphorus | | Potassium | |
|---|---|---|---|---|---|---|
| | I Year | II Year | I Year | II Year | I Year | II Year |
| DSR(Flatbed) + drip irrigation | 53.08 | 51.20 | 132.70 | 129.03 | 199.05 | 191.72 |
| DSR (Raised bed) + drip irrigation | 49.68 | 46.83 | 124.20 | 117.57 | 186.30 | 183.38 |
| DSR+ flood irrigation | 44.80 | 43.19 | 112.00 | 106.47 | 168.00 | 166.20 |
| TPR + flood irrigation | 46.40 | 45.93 | 116.00 | 111.32 | 174.00 | 169.48 |
| S. Em. | 0.83 | 0.33 | 1.30 | 1.66 | 3.11 | 2.15 |
| CD (p=0.05) | 2.65 | 1.08 | 4.23 | 5.31 | 9.96 | 6.97 |

Total seasonal water input into rice fields (rainfall plus irrigation) is up to two to three times more than for other cereals [27]. Around 1300-1500 mm is a typical value for irrigated lowland rice in Asia [28]. Such a large water input is mostly caused by surface drainage and seepage and percolation flow from the continuously ponded fields into groundwater creeks and drains. Seepage and percolation flow account for about 25-50 percent of all the water inputs in heavy soils with shallow (20-50 cm depth) groundwater tables [29]. In the present investigation, the data on water use in different treatments indicated that there was a saving for the total water applied to the tune of about 51 percent when drip irrigation was scheduled in comparison with the conventional irrigation practice. The term improving water use efficiency implies how one can most effectively improve the yield of a crop per unit of water currently used. Drip irrigation is a way to improve water use efficiency along with increased yield.

The correlation trend line between yields and water use efficiency is showing that water use efficiency increased linearly with yield increases (Fig. 2). The regression coefficient, R-squared value is 0.935, which is a good fit for the line to the data. Although transplanted rice produced higher yields than DSR, it accounts low water use efficiency. Because transplanted rice consuming huge quantities of water than DSR. Proper water management alone is not only required for improving water use efficiency but also other inputs like improved cultivars, fertility management and cultural practices all those influence yield.

Modernization and optimization of irrigation systems can contribute to increased water use efficiency [30].

### 3.4 Economic Benefits

Analyses of the economic benefits were given in Table 6. Drip irrigation provided more benefits than flood irrigation. DSR (flatbed) + drip irrigation recorded more returns followed by DSR (raised bed) + drip irrigation.

The benefit-cost ratio of drip irrigation was higher than transplanted rice. Benefit-cost ratio was highest in DSR (flatbed) + drip irrigation, 3.41 and 3.67 in I Year and II Year, respectively, followed by DSR (raised bed) + drip irrigation (3.09 and 3.35 in I Year and II Year, respectively). The benefit-cost ratio was comparatively low in transplanted rice + flood irrigation.

**Table 5. Influence of drip irrigation on water use and efficiency of rice crop**

| Treatments | Irrigation water applied | | Effective rainfall | | Total water applied | | % saving over control | | WUE (kg mm-ha$^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | I Year | II Year | I Year | II Year | I Year | II Year | I Year | II Year | I Year | II Year |
| DSR(Flatbed) + drip irrigation | 520 | 520 | 124 | 113 | 644 | 633 | 51.36 | 51.79 | 11.21 | 12.46 |
| DSR (Raised bed) + drip irrigation | 520 | 520 | 124 | 113 | 644 | 633 | 51.36 | 51.79 | 10.42 | 11.68 |
| DSR+ flood irrigation | 900 | 900 | 124 | 113 | 1024 | 1013 | 22.66 | 22.85 | 5.79 | 6.59 |
| TPR + flood irrigation (control) | 1200 | 1200 | 124 | 113 | 1324 | 1313 | 0 | 0 | 4.72 | 5.22 |

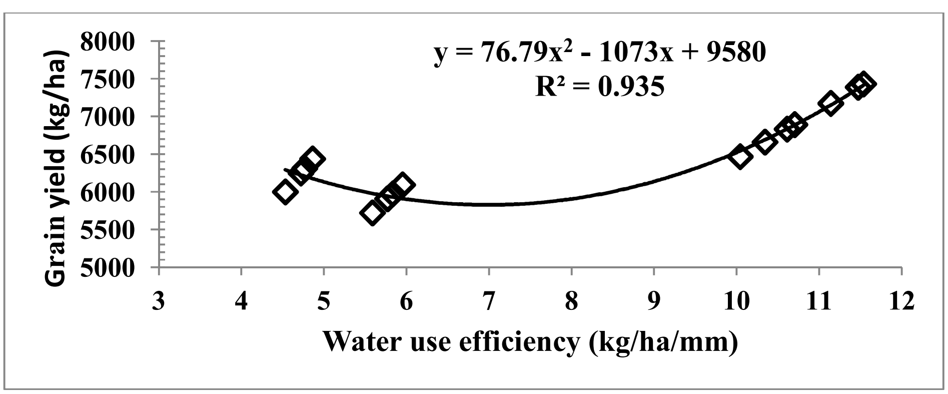


**Fig. 2. Correlation between yield and water use efficiency from various treatments**

**Table 6. Economics (Rs. $ha^{-1}$) of rice crops under drip irrigation system**

| Treatments | Cost of cultivation | | Gross return | | Net return | | B:C Ratio | |
|---|---|---|---|---|---|---|---|---|
| | I Year | II Year | I Year | II Year | I Year | II Year | I Year | II Year |
| DSR(Flatbed) + drip irrigation | 26500 | 26870 | 90263 | 98613 | 63763 | 71743 | 3.41 | 3.67 |
| DSR (Raised bed) + drip irrigation | 27200 | 27570 | 83913 | 92388 | 56713 | 64818 | 3.09 | 3.35 |
| DSR+ flood irrigation | 28326 | 27996 | 74050 | 83413 | 45724 | 55417 | 2.61 | 2.98 |
| TPR + flood irrigation | 31183 | 31553 | 78119 | 85713 | 46936 | 54160 | 2.51 | 2.72 |

## 4. CONCLUSION

From the above study, it can be concluded that rice growing in direct seeding method on the flatbed and with drip irrigation provided the highest yield, besides better crop growth as expressed by the yield components. Drip method of irrigation also ensured higher water and nutrient use efficiencies. Because of the latter (input use efficiency), sustainability of rice production can be achieved by adopting drip technology in rice production.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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