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Influence of different establishment methods of rice on the parameters of water, weed, growth and yield under rice - rice - blackgram system

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Abstract
Field experiments were conducted at Tamil Nadu Rice Research Institute, Aduthurai during 2016-2018. Field experiments were laid out in randomized block design with four replications. The six treatments under system basis were T_1 - NPTR (*Kharif)* - NT (*Rabi*) - NT (Summer), T_2 - NPTR (*Kharif)* - PTR (*Rabi*) - NT (Summer), T_3- DSR (*Kharif)* - NT (*Rabi*) - NT (Summer), T_4 – DSR (*Kharif)* - PTR (*Rabi*) - NT (Summer), T_5 – PTR (*Kharif)* - NT (*Rabi*) - NT (Summer) and T_6- PTR (*Kharif)* - PTR (*Rabi*) - NT (Summer). The results revealed that among different crop establishment methods, dry seeded rice(DSR) produced significantly higher growth attributes, weed and water parameters which ultimately resulted in higher yield attributes, grain and straw yields during both the years of *kharif* season. During *rabi* seasons, among different crop establishment methods, puddled transplanted rice (PTR) preceded by dry seeded rice (DSR) produced significantly higher growth parameters, weed and water parameters which eventually resulted in higher yield attributes, grain and straw yields.

Keywords: Cucumber, boron, yield, quality, Konkan

Introduction

Rice (*Oryza Sativa* L.) is the staple food for more than half of the world population and 75 per cent of the rice cultivation is under irrigated condition (Bouman *et al.*, 2007) [3]. Though 50 per cent of total irrigation water applied is consumed by irrigated Rice (Barker *et al.*, 1999) [2] and the irrigated rice alone has the ability to increase productivity to meet the demand of growing population. Increasing water scarcity is the major threat in rice cultivation (Barker, 2004) [17]. Globally, 476 million tonnes of rice was produced from an area of around 157 million ha during 2012 - 13. Of this, Asia accounts for 90 per cent of the production and consumption of rice (India Stat, 2015) [18]. India has world's the largest area under rice with 44.1 million ha and is the second largest producer (105 million tonnes, 2014) next to China (India stat, 2017) [19]. It contributes 22.34 per cent of global rice production. In Tamil Nadu, rice is grown in an area of 2.04 million hectare with total production of 9.98 million tonnes (DES, 2016). In Cauvery Delta Zone (CDZ), major crop is rice which is grown in an area of 14.47 lakh ha which contributes 11 per cent of the total area of Tamil Nadu. The CDZ includes Thanjavur, Nagapattinam, Tiruvarur, Trichy and parts of Karur, Ariyalur, Pudukkottai and Cuddalore districts of Tamil Nadu.

The practice of double cropping of rice in *kuruvai* (June - September) and *thaladi* (October - February) is on the increase because of the development of short and medium duration high yielding rice varieties (Subrahmaniyan *et al.*, 2016) [13]. But the double cropped lands have been subjected to lot of hardship in the past years due to uncertainty in the monsoon as well as release pattern of canal water. The delay in release of canal water leads to delayed planting of *kuruvai* crop in the month of July which subsequently results in delayed planting of second crop (*thaladi*). Problems and prospects of rice production in different ecosystems vary greatly (Senthilkumar *et al.*, 2007) [20]. Now-a-days, agriculture in general and rice farming in particular are facing threats of water and labour scarcity in the delta in alarming rate, besides energy usage for land preparation. In India, rice is cultivated by transplanting seedlings in the puddled soils. In the system of puddled transplanted rice, fields are kept under submergence condition continuously throughout the crop period until shortly before the harvest

(Pandey and Velasco, 1999) [21]. Transplanting is the most common method of rice establishment which is another major concern in existing production system as it involves planting of seedlings in puddled soil. Higher costs involved in tillage operation, ill effects on soil structure and more water requirement for crop establishment were the major constraints in puddled transplanted rice (So and Ringrose-Voase, 2000) [22]. The quantity of irrigation water required for puddling varies from 100 mm to 544 mm (Gill *et al.*, 2011) [7]. Under transplanted rice system, puddling alone not only consumes up to 30 per cent of total water requirement for rice cultivation, but also it requires much energy and longer time from the tillage point of view for land preparation. Hence, this existing rice production system is labour, water, and energy intensive and is becoming less profitable as these resources are now precious and becoming increasingly scarce. So, management strategies that reduce irrigation water and labour as well as energy requirement for rice cultivation while maintaining or increasing its yield and profitability by minimizing production cost are urgently needed.

So, these factors discussed above lead to a major shift in rice cultivation from traditional Puddled Transplanted Rice (PTR) to Direct Sown Rice (DSR), Non-Puddled Transplanted Rice (NPTR) and No - till (NT). Under non-puddled and no - till soil conditions,transplanting can be done after saturating the soil. For dry seeded rice, sowing could be done on non-puddled dry soil and these establishment methods can reduce water requirement for crop establishment (Balasubramanian and Hill, 2002; Malik *et al*., 2011) [1, 9]. This may result in increased water productivity, reduced labor through use of seed drill and transplanter and save energy for land preparation, since DSR, NPTR and NT do not require puddling. Weeds are the major problem in DSR, NPTR and NT cultivation which may lead to severe yield reduction up to 35 per cent (Chauhan, 2012) [4]. However, weeds can be managed by timely applying of effective herbicides which may result in similar or higher yield to puddled transplanted rice. Repeated puddling also negatively affects following non-rice upland crops under rotation by dismantling soil aggregates, reducing permeability in subsurface layers and forming hard pans at shallow depths (McDonald *et al.,* 2006) [24].

Hence, through following DSR and NPTR along with no - till, Blackgram can be grown successfully in the rice based cropping system.

Late release of canal water and also sometimes, late onset of monsoon there will be scarcity of water for cultivation of rice for puddling. In such situation, non-puddled and dry seeded rice establishment methods would serve as a contingency measures to reduce water requirement during initial stage of cultivation.

In order to address all these constraints, this study is planned to be undertaken at TRRI, Aduthurai during 2016-2018 to compare the performance of DSR, NPTR and NT with traditional PTR under Rice - Rice- Blackgram cropping system

Materials and Methods

Field experiment was conducted at Tamil Nadu Rice Research Institute, Aduthurai during *2016-2018* in both kharif and rabi seasons followed by rice fallow Blackgram sequences. The experimental area located at latitude of 11^0 N, longitude of 79^0 E and an altitude of 19.5 m above MSL. The region is characterized by a sub-tropical climate with a hot dry summer (March -June) and extended wet period from September to February. The mean annual rainfall is about 1176 mm majority of which was received during North East Monsoon. The mean annual maximum and minimum temperatures were 33.3 ºC and 23.5 ºC. The mean annual relative humidity was 89 per cent. The mean wind velocity and bright sunshine hours were 5.2 kmph and 6.7 hours day^{-1}.

Weather and climate during the cropping period

During *kharif* 2016, the amount of rainfall received during cropping season was 214.7 mm in 11 rainy days. Whereas in *kharif* 2017, the amount of rainfall received during cropping season was 474.6 mm in 27 rainy days. The maximum temperature ranged from 32.1, 32.2 to 36.7, 37 ºC, while minimum temperature ranged from 23.8, 23.8 to 26.3, 26.3 ºC, during both *kharif* 2016 and 2017 respectively. The mean maximum and minimum temperatures are 34.6, 34.3 and 25, 25 ºC respectively during *kharif* 2016 and 2017. The range of relative humidity that prevailed during the *kharif* 2016 was 74 to 90 per cent and 46 to 70 per cent during forenoon and afternoon respectively. In *kharif* 2017, the relative humidity ranges from 75 to 94 per cent and 46 to 76 per cent during forenoon and afternoon respectively. The mean sunshine hours during *kharif* 2016 and 2017 were 5.5 and 5.7 hours day^{-1}respectively.

During *rabi* 2016, the amount of rainfall received during cropping season was 205.2 mm in 18 rainy days. Whereas in *rabi* 2017, the amount of rainfall received during cropping season was 770.8 mm in 29 rainy days. The maximum temperature ranged from 24.9, 27.7 to 34, 33.7 ºC, while minimum temperature ranged from 17, 17.3 to 24.9, 24.9 ºC, during *rabi* 2016 and *rabi* 2017 respectively. The mean maximum and minimum temperatures are 30.5, 30.3 and 21, 21.7 ºC respectively from *rabi* 2016 and *rabi* 2017. The range of relative humidity that prevailed during the *rabi* 2016 was 88 to 97 per cent and 46 to 80 per cent during forenoon and afternoon respectively. In *rabi* 2017 the relative humidity ranges from 86 to 98 per cent and 47 to 91 per cent during forenoon and afternoon respectively. The mean bright sunshine hours during *rabi* 2016-17 and 2017-18 were 6.6 and 5.8 hours day^{-1} respectively.

In both summer 2017 and 2018, the total rainfall of 32 mm was received in 3 rainy days. The average maximum and minimum temperature are 36.1, 36.8 ºC and 24.8, 20ºC, respectively for summer 2017 and summer 2018. An average of 90 per cent and 53 per cent of relative humidity was recorded at forenoon and afternoon was recorded in summer 2017. In summer 2018, an average of 90 per cent and 53 per cent of RH was recorded at forenoon and afternoon. The bright sunshine hours during summer 2017 and 2018 were 8.7 and 8.7 hours.

The soil of the experimental site at TRRI, Aduthurai was sandy loam in texture and moderately drained. The soil was low in available nitrogen (130 kg ha^{-1}), high in available phosphorus (65 kg ha^{-1}) and medium in available potassium (400 kg ha^{-1}). Composite soil samples were collected from the experimental fields. The soil samples were air dried and ground pass through the required sieve size and used for various analysis including physico - chemical properties. The data on soil properties of the experimental sites and methods of soil analysis were furnished in Table 1.

Table 1: Physico - chemical characteristics of the experimental fields

Particular	2016-17			2017-18		
	Kharif Rice	*Rabi* Rice	Summer Blackgram	*Kharif* Rice	*Rabi* Rice	Summer Blackgram
A. Mechanical analysis						
Clay (%)	10.25	10.30	10.23	10.26	10.25	10.32
Silt (%)	3.25	3.20	3.18	3.22	3.23	3.22
Sand (%)	86.5	86.50	86.59	86.52	86.52	86.46
B. Textural class	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam	Sandy Loam
C. Physical properties						
Bulk density (g cc-1)	1.55	1.54	1.54	1.55	1.54	1.54
Particle density (g cc-1)	2.55	2.53	2.54	2.53	2.55	2.54
Porosity (%)	42.66	42.67	42.65	42.62	42.65	42.64
Infiltration rate (cm hr -1)	3.12	3.20	3.19	3.21	3.22	3.19
D. Chemical analysis						
Available nitrogen (kg ha^{-1})	230	262	233	237	234	220
Available phosphorus (kg ha^{-1})	35	47	37	43	44	38
Available potassium (kg ha^{-1})	288	261	250	263	284	250
pH (1: 2 of soil: water)	7.4	7.5	7.4	7.3	7.4	7.4
Electrical conductivity (dSm^{-1})	0.15	0.14	1.15	1.15	1.14	1.14
Organic carbon (%)	0.12	0.14	0.18	1.03	1.05	1.06

The treatment details are followed in all three seasons furnished below:

Treatments	*Kharif* (*Kuruvai*) Rice	*Rabi* (*Thaladi*) Rice	Summer Rice fallow black gram
T_1	NPTR	NT	NT
T_2	NPTR	PTR	NT
T_3	DSR	NT	NT
T_4	DSR	PTR	NT
T_5	PTR	NT	NT
T_6	PTR	PTR	NT

Note: NPTR: Non-puddled transplanted rice, PTR: Puddled transplanted rice, DSR: Dry seeded rice, NT: No-till

The experiment was laid out in split plot design with three replications. The experimental field was initially dry ploughed with tractor drawn disc harrow followed by cultivator and rotovator operations to get fine tilth. Perfect leveling is required for this experiment to undulation which determines the plant population especially in NPTR. Hence laser leveling was done to get further benefits such as higher yields of rice and upland crops, faster irrigation times and reduced irrigation input and more efficient machinery operations. Puddled transplanted rice (PTR): In preparing the field for puddled condition, the ploughed field was given flooded irrigation. Then the field was puddled well with cage wheel and leveled with wooden leveling board. Non- puddled transplanted rice (NPTR): In preparing the field for non-puddled condition, initially dry ploughed with tractor drawn cultivator followed by rotovator to get fine tilth. After leveling with laser guided land leveler the ploughed field was given a surface wetting with 50 mm of water which was just sufficient to soak the soil for smoother transplanting of seedling with transplanter. Dry seeded rice (DSR): In dry seeded rice initially dry ploughed with tractor drawn cultivator followed by rotovator to get fine tilth. The ploughed land was leveled with laser guided land leveler to enable easy for sowing with seed drill. No-tillage (NT): For zero tillage condition there is no-tillage was given. The field was maintained under saturated condition until transplanting. In dry seeded rice, sowing was done using seed drill during Kharif(Kuruvai) season. The rice variety ADT 46 was sown with a seed rate of 75 kg ha^{-1}. The seeds were first treated with carbendazim @ 2.0 g kg^{-1} of seed and sowing was taken up with tractor drawn seed drill.

Rice varieties ADT 43 and ADT 46 were sown in mat nursery for mechanical transplanting under puddle and non-puddled condition during both *Kharif* (*Kuruvai*) and *Rabi* (*Thaladi*) seasons. The seeds were first treated with carbendazim @ 2.0 g kg^{-1} of seed. Totally 200 plastic trays with length and breadth of 60 x 30 cm were used to raise nursery for transplanting one hectare. The seed requirement in this method was 20 kg ha^{-1} (100 g per tray). The growing media for tray nursery is equal proportion of sieved soil with farm yard manure. Initially the trays were placed in a plain field. Then one fourth of each tray was filled with growing media.Sprouted seeds were spread uniformly on the tray and covered with media. Prepared trays were placed properly on the raised bed and covered with four layer of black net.The trays were irrigated 2 times every day through rose cans. After 6^{th} day, the black net was removed and watering was continued till seedling attained 2-3 leaf stage (18 days old seeding).

During *kharif* and *rabi* season, eighteen days old seedlings were transplanted in puddle and non-puddled condition by using the rice transplanter. After the harvest of previous season crop (*kharif*), for no-tillage treatment, the field was maintained under saturated condition and glyphosate herbicide was sprayed @ 10 ml / litre of water + 2% Ammonium Sulphate to kill the weeds and previous rice crop stubbles and volunteer paddy.

For dry seeded rice recommended dose of nutrients *viz*., 75:25:37.5 kg N,P_2O_5, K_2O $ha^{-1}$was applied uniformly for all treatments. The entire P fertilizer was applied as basal in the form of single super phosphate (16 % P_2O_5). N andK_2O was applied in three splits at 20-25, 40-45 and 60-65 days after germination. In addition, Zinc Sulphate was applied @ 25 kg ha^{-1}.

For non - puddled transplanted rice and puddled transplanted and no-tillage, recommended dose of nutrients viz., 150:50:50 kg N, P_2O_5, K_2O $ha^{-1}$was applied uniformly for all treatments. Entire dose of phosphorus as Superphosphate was applied as basal in addition to Zinc Sulphate @ 25 kg ha^{-1} and gypsum @ 500 kg ha^{-1}. The fertilizer N was applied in 4 split doses at basal, active tillering (35-40 days), panicle initiation (45-50 days) and heading stages (70-75 days). The K fertilizer was applied in the form of Muriate of Potash (60% K_2O) in two equal splits, one at basal and another at panicle initiation stage.

For the first three weeks in order to get proper crop establishment, rice crop was irrigated based on visual observation of soil moisture condition. After 3 weeks, irrigation water was applied to each plot based on average soil moisture tension reading of 2 tensiometers (10 kPa) installed at middle of the plot at soil depth15 and 30 cm. Polyvinyl chloride (PVC) pipe of 30 cm length and 15 cm diameter in which perforated with holes of 0.5 cm and the tube was opened on both the sides. The tube was mounted on the soil with one perforated holes visible at ground level. The tube was placed at the side of the field close to the bund for easy recording of the level of water depth. The soil inside the tube was removed so that the bottom of the tube is visible. Water will flow through the holes into the tube. Irrigation was given when water depth goes below the soil surface to 15 cm. Water depth in the tube was measured by using scale. Subsequent irrigation was given by re-flooding the field to a depth of 5 cm. Irrigation was withheld 10 days prior to harvest.

For DSR, Pendimethalin @ 1.0 kg a.i. ha^{-1} was applied on 3 DAS keeping a thin film of water in the field. For PTR and NPTR, Bensulfuron-methyl 0.6% + Pretilachlor 6% granules @ 10 kg ha^{-1}mixed with 50 kg sand was uniformly applied on the soil surface by manual broad casting 3 days after transplanting to ensure uniform application of herbicide. Early post-emergence herbicide application of Bispyribac sodium 250 ml ha^{-1} was sprayed at 2-3 leaf stage of weeds with the help of hand operated knapsack sprayer using 750 liters of spray solution ha^{-1}.

The blackgram (ADT 3) was raised without disturbing the layout of experiment. After the harvest of rice crop, seeds were dibbled in rice stubbles. A seed rate of 25 kg/ha was adopted and sown at a spacing of 30 × 10cm. For summer fallow blackgram post emergence herbicide with the combination of Imezathpyar 500 ml/ ha and Quizalofop ethyl 1 ml/ ha was sprayed using hand operated knapsack sprayer. Subsequent irrigations were given to maintain moist condition and need based plant protection was given. The observation on growth parameters, yield and yield attributes were recorded and statistically analyzed at 5 % level of significance (Gomez and Gomez, 1984) [23].

Results and Discussion

Effect of crop establishment method on weeds

The crop establishment methods were significantly influenced on weed density and weed dry weight in all the three years of kharif and *Rabi* seasons. The total weed density ($Nos.m^{-2}$) and weed dry weight ($g.m^{-2}$) were ranged from 15.33 - 23.67:19.60-29.20; 18.70-29.20:19.5-29.50 and 16.5-24.70: 20.10- 30.0 during kharif 2016, 2017 and 2018 respectively. Among the different establishment methods, higher weed density and weed dry weight were recorded maximum under direct seeded rice compared to non puddled and puddled transplanted methods in all the years of kharif season. The lower weed density and dry weight were observed in puddled rice establishment method. The similar findings were recorded by Singh *et al.*, 2011 [9] and Singh *et al.*, 2008 [26] and they were expressed that reduce rice yields by 12 to 98 per cent depending on method of rice establishment. Rice yield losses due to uncontrolled weed growth and weed competition were the least in transplanted rice and higher in direct seeded rice and dry-seeded rice sown without tillage. Hence, in rice cultivation, puddling plays key role in controlling weeds.

Similar trend was also observed during Rabi seasons of 2016-2018. Among the different establishment methods, higher weed density and weed dry weight were recorded maximum under direct seeded rice followed by no till, non puddle followed by no till and puddled followed by no till compared to puddled transplanted methods in all the years of Rabi seasons. The lower weed density and dry weight were observed in puddled rice establishment method. To avoid these problems, alternative establishment methods like DSR, NPTR and No-tillage were followed. Puddling is an essential operation for transplanted rice to minimize water percolation and to suppress weeds (Gupta e*t al*., 2006) [6].

Effect of crop establishment methods on growth and yield attributes (Table.3-6)

The growth and yield attributes were significantly influenced by different crop establishment methods in all two seasons of three years. Generally, establishment methods had significant effect on plant height, dry weight $hill^{-1}$ and effective tillers $hill^{-1}$ reported by Singh and Singh (2006) [6]. Among the three establishment methods during kharif season, direct seeded rice recorded higher growth and yield attributes such as plant height, LAI, No. of tillers, No, of productive tillers, no. of grains per panicle and yield as compared NPTR and PTR. In case of *Rabi* seasons, among two different method of establishment, direct seeded rice followed by puddled transplanted recorded maximum growth and yield attributes as compared to other combinations. The higher yield of 5500 t ha^{-1} recorded under direct seeded rice as compared to non puddled (4900 t ha^{-1}) and puddled rice establishment (5050 t ha^{-1}) during kharif season. In case of Rabi seasons, puddled rice establishment method recorded higher yield (7500 t ha^{-1}) as compared to no till method of establishment techniques.

Similar research findings were reported by many authors. Higher leaf area index was recorded by Shrirame *et al*. (2000) [12] in mechanized puddle transplanting (4.14) followed by manual transplanting (3.78) and the lowest LAI was recorded under broadcasting method (3.21). This was owing to the fact that, younger seedlings planted at proper spacing enhanced the root growth which facilitated increased cell division and cell enlargement and more number of tillers with more leaves and subsequently, higher photosynthetic rate for increased LAI. Kukal *et al.* (2014) [8] evaluated the performance of establishment methods under zero and conventional tillage for irrigation water productivity and crop performance. The leaf area index was similar in all the establishment methods at 60 DAS while at 90 DAS, puddled transplanted rice had significantly higher LAI over all other treatments. The mechanized transplanting registered the highest number of tillers (629 m^{-2}) as compared to 355 m^{-2} under broadcasting method (Raj *et al*., 2012) [11].

Direct seeded rice produced significantly higher straw yield and similar grain yield to that of transplanted rice (Tripathi *et al*., 2003) [15]. Shahand Bhurer (2005) [25] also reported similar findings in which DSR rice produced slightly higher grain and straw yields as compared to conventional puddled method.

Table 1: Impact of crop establishment methods on weed parameters in rice during *kharif* season

Treatments	2016		2017		2018	
	Weed density m^{-2}	Weed dry weight ($g\ m^{-2}$)	Weed density m^{-2}	Weed dry weight ($g\ m^{-2}$)	Weed density m^{-2}	Weed dry weight ($g\ m^{-2}$)
T_1-NPTR	4.66 (21.67)	4.91(24.10)	4.91(24.10)	5.03(25.30)	4.52(22.90)	5.08(26.30)
T_2-NPTR	4.57(20.90)	4.84(23.40)	4.84(23.40)	5.01(25.10)	4.30(22.30)	5.03(25.90)
T_3-DSR	4.87(23.67)	5.19(27.00)	5.19(27.00)	5.43(29.50)	4.93(24.70)	5.61(30.40)
T_4-DSR	4.83(23.33)	5.40(29.20)	5.40(29.20)	5.37(28.80)	4.91(24.10)	5.40(29.10)
T_5-PTR	3.96(15.67)	4.32(18.70)	4.32(18.70)	4.42(19.50)	4.05(16.80)	4.44(20.50)
T_6-PTR	3.92(15.33)	4.23(19.60)	4.23(19.60)	4.44(19.70)	4.02(16.50)	4.56(20.10)
SEd	0.38	0.53	0.53	0.47	0.56	0.45
CD (P=0.05)	0.82	1.13	1.13	1.01	1.16	1.05

Table 2: Impact of crop establishment methods on weed parameters in rice during *Rabi* season

Treatments	2016-17		2017-18		2018-19	
	Weed density m^{-2}	Weed dry weight ($g\ m^{-2}$)	Weed density m^{-2}	Weed dry weight ($g\ m^{-2}$)	Weed density m^{-2}	Weed dry weight ($g\ m^{-2}$)
T_1 - NPTR-NT	5.60(31.34)	5.87(34.40)	4.81(23.10)	5.93(35.11)	5.05(24.10)	7.32(35.70)
T_2 - NPTR-PTR	5.21(27.13)	4.93(24.30)	3.80(14.46)	5.01(25.10)	4.22(16.20)	6.71(25.70)
T_3 - DSR-NT	5.62(31.53)	5.91(34.90)	4.92(24.20)	5.96(35.50)	5.30(26.10)	7.24(35.90)
T_4 - DSR-PTR	5.32(28.31)	5.03(25.30)	4.03(16.21)	5.10(26.06)	4.26(17.30)	6.56(26.80)
T_5- PTR-NT	5.42(29.35)	5.75(33.10)	4.84(23.41)	5.78(33.37)	5.00(24.30)	7.03(34.10)
T_6 - PTR-PTR	5.12(26.22)	4.87(23.70)	3.77(14.25)	4.99(24.89)	4.20(15.90)	6.73(25.50)
SEd	1.15	2.03	0.94	2.07	1.32	2.30
CD (P=0.05)	2.45	4.32	2.01	4.41	2.66	4.80

Table 3: Effect of crop establishment methods on growth attributes of rice during *kharif* season

Treatments	2016			2017			2018		
	Plant height (cm)	LAI	No. of tillers m^{-2}	Plant height (cm)	LAI	No. of tillers m^{-2}	Plant height (cm)	LAI	No. of tillers m^{-2}
T_1-NPTR	95.2	3.64	346	95.6	3.74	352	95.4	3.64	266
T_2-NPTR	95.4	3.66	350	95.9	3.80	354	95.6	3.73	261
T_3-DSR	110.2	4.55	406	111.5	4.82	408	110.8	4.69	313
T_4-DSR	111.3	4.85	407	112.6	4.65	410	111.9	4.75	318
T_5-PTR	98.3	3.81	358	98.5	3.90	355	98.4	3.86	265
T_6-PTR	98.5	3.92	360	99.3	3.98	356	98.9	3.95	269
SEd	5.5	0.20	23	6.4	0.19	25	5.9	0.20	24
CD (P=0.05)	11.7	0.45	49	13.7	0.40	50	12.7	0.43	49

Table 4: Effect of crop establishment methods on growth attributes of rice during *Rabi* season

Treatments	2016-17			2017-18			2018-19		
	Plant height (cm)	LAI	No. of tillers m^{-2}	Plant height (cm)	LAI	No. of tillers m^{-2}	Plant height (cm)	LAI	No. of tillers m^{-2}
T_1 - NPTR-NT	87.4	3.65	325	89.3	3.64	329	88.3	3.65	333
T_2 - NPTR-PTR	101.9	5.17	423	101.3	5.14	425	101.6	5.16	363
T_3 - DSR-NT	89.7	3.76	326	90.6	3.84	331	90.1	3.80	329
T_4 - DSR-PTR	113.8	5.30	428	106.5	5.33	430	110.1	5.32	369
T_5- PTR-NT	87.4	3.55	315	87.9	3.54	320	87.6	3.55	325
T_6 - PTR-PTR	101.8	4.28	341	95.2	4.34	391	98.5	4.31	359
SEd	6.3	0.08	34	6.0	0.08	24	6.1	0.08	29
CD (P=0.05)	13.1	0.17	73	12.7	0.17	51	13.0	0.17	62

Table 5: Effect of crop establishment methods on yield attributes of rice during *kharif* season

Treatments	2016			2017			2018		
	No. of productive tillers m^{-2}	No. of grains per panicle	Yield (kg/ha)	No. of productive tillers m^{-2}	No. of grains per panicle	Yield (kg/ha)	No. of productive tillers m^{-2}	No. of grains per panicle	Yield (kg/ha)
T_1-NPTR	248	125	4813	253	115	4860	266	120	4893
T_2-NPTR	248	127	4820	256	120	4880	261	124	4922
T_3-DSR	300	130	5328	308	131	5410	313	131	5505
T_4-DSR	303	135	5355	310	137	5420	318	136	5521
T_5-PTR	257	128	4858	260	130	4930	265	129	5019
T_6-PTR	258	129	4862	263	128	4970	269	128	5071
SEd	11.6	6.2	206.1	10.5	5.6	197.2	10.6	6.0	201.2
CD (P=0.05)	24.2	12.02	439.2	22.8	11.4	414.4	23.8	11.98	427.6

Table 6: Effect of crop establishment methods on yield attributes of rice during *Rabi* season

Treatment	2016-17			2017-18			2018-19		
	No. of productive tillers m^{-2}	No. of grains per panicle	Yield (kg/ha)	No. of productive tillers m^{-2}	No. of grains per panicle	Yield (kg/ha)	No. of productive tillers m^{-2}	No. of grains per panicle	Yield (kg/ha)
T_1 - NPTR-NT	303	128	6102	320	123	6111	333	126	6229
T_2 - NPTR-PTR	353	130	7565	356	125	7621	363	128	7698
T_3 - DSR-NT	314	135	6400	326	133	6402	329	134	6445
T_4 - DSR-PTR	364	137	7650	366	135	7820	369	136	7853
T_5- PTR-NT	298	133	5980	317	130	6019	325	132	6037
T_6 - PTR-PTR	349	131	7025	350	128	7236	359	130	7251
SEd	21.5	6.4	283.2	18.1	5.4	273.3	19.4	6.2	278.2
CD (P=0.05)	45.3	13.1	604.3	37.3	10.4	582.2	41.8	12.9	593.6

Table 7: Effect of crop establishment methods on total water use (mm), water use efficiency (kg ha mm^{-1}) and water productivity (kg m^{-3}) during *kharif* season

Treatment	2016			2017			2018		
	TWU	WUE	WP	TWU	WUE	WP	TWU	WUE	WP
T_1-NPTR	1015	4.7	0.475	1015	4.8	0.480	1025	4.8	0.478
T_2-NPTR	1015	4.7	0.474	1015	4.8	0.480	1025	4.8	0.477
T_3-DSR	1165	4.6	0.457	1215	4.4	0.440	1235	4.5	0.449
T_4-DSR	1165	4.6	0.460	1215	4.4	0.440	1235	4.5	0.450
T_5-PTR	1260	3.9	0.386	1240	4.0	0.400	1255	4.0	0.393
T_6-PTR	1260	3.9	0.386	1240	4.0	0.400	1255	4.0	0.393
SEd	21.2	0.1	0.008	22.1	0.1	0.008	21.2	0.1	0.008
CD (P=0.05)	45.6	0.2	0.020	46.3	0.2	0.020	45.6	0.2	0.020

Table 8: Effect of crop establishment methods on total water use (mm), water use efficiency (kg ha mm^{-1}) and water productivity (kg m^{-3}) during *Rabi* season

Treatment	2016-17			2017-18			2018-19		
	TWU	WUE	WP	TWU	WUE	WP	TWU	WUE	WP
T_1 - NPTR-NT	1030	6.3	0.630	1200	5.5	0.547	1240	5.0	0.589
T_2 - NPTR-PTR	1280	6.0	0.600	1450	5.2	0.524	1465	5.3	0.562
T_3 - DSR-NT	1030	6.4	0.640	1200	5.5	0.552	1240	5.2	0.596
T_4 - DSR-PTR	1280	6.0	0.600	1450	5.2	0.535	1465	5.4	0.568
T_5- PTR-NT	1030	6.4	0.640	1200	5.3	0.543	1240	4.9	0.592
T_6 - PTR-PTR	1280	6.1	0.610	1450	5.1	0.507	1465	4.9	0.559
SEd	21.2	0.1	0.011	24.2	0.1	0.010	22.2	0.1	0.010
CD (P=0.05)	44.6	0.2	0.020	51.6	0.2	0.020	48.4	0.2	0.020

Effect of different establishment techniques on water parameters

The indices such as total water use, water use efficiency and water productivity were significantly influenced by different establishment methods in irrespective of the seasons. The maximum water use and water use efficiency were maximum in direct seeded rice as compared to non puddled and puddled rice ranged from 1165 mm – 1235 mm and 4.4 - 4.6 respectively during kharif seasons in all three season. However, the water productivity higher in non puddled rice establishment method as compared to other methods such as puddled and direct seeded rice. The lowest water consumption was observed in non puddled condition and no till methods under kharif and Rabi seasons respectively. Patel (2000) [10] stated that continuous submergence required maximum quantity of water (1,535 mm) without any significant increase in grain yield as compared to saturation upto tillering and submergence up to ripening (1,340 mm).

Dawe (2005) [5] also observed that substantial water savings in DSR. Jehangir *et al*. (2007) [7] also reported that DSR consumes less irrigation water than puddled transplanted rice. Dry seeded rice provides an opportunity for earlier crop establishment to make better use of early season rainfall and to increase crop intensification in some rice based systems (Tuong *et al*., 2000) [16]. Direct seeding methods required four times lesser irrigation than transplanting method during cropping period which contributed to additional water requirement in the direct seeded crops (Thiyagarajan *et al.*, 2002) [14].

Conclusion

The results of the experiments concluded that the enhanced growth and productivity of rice was observed in DSR in *Kuruvai* season followed by PTR in *Thaladi* season would be viable practice for obtaining higher yield and also reduced weed manace and consumed lesser water.

Reference

1. Balasubramanian V, Hill J. Direct seeding rice in Asia. Emerging issue and strategic research needs for the 21st century. In: Pandey *et al.* (Eds) Direct Seeding: Research strategies and opportunities: IRRI publications, 2002, 15-39.
2. Barker R, Dawe D, Tuong T, Bhuiyan S, Guerra L. The outlook for water resources in the year 2020: challenges for research on water management in rice production. Southeast Asia. 1999; 1:1-5.
3. Bouman B, Barker R, Humphreys E, Tuong TP, Atlin G, Bennett J *et al*. Rice: feeding the billions IN: Water for food, water for life: A comprehensive assessment of water management in agriculture. Colombo, Sri Lanka: IWMI, 2007, 515-549.

4. Chauhan BS. Weed ecology and weed management strategies for dry-seeded rice in Asia. Weed Tech. 2012; 26:1-13.
5. Dawe D. Increasing water productivity in rice-based systems in Asia–past trends, current problems, and future prospects. Plant Production Science. 2005; 8:221-230.
6. Gupta R, Ladha J, Singh S, Singh R, Jat M, Saharawat Y *et al*. Production technology for direct seeded rice. Rice Wheat Consortium Technical Bulletin. 2006; 8:16.
7. Jehangir WA, Masih I, Ahmed S, Gill MA, Ahmad M, Mann RA *et al*. Sustaining crop water productivity in rice-wheat systems of South Asia: A case study from Punjab, Pakistan. IWMI Working Paper 115. Colombo, Sri Lanka: International Water Management Institute, 2007.
8. Kukal S, Bhatt R, Gupta N, Singh MC. Effect of crop establishment methods on performance of rice (Oryza sativa L.) and irrigation water productivity in sandy-loam soil. J. Res. 2014; 51:326-328.
9. Malik R, Kamboj B, Jat M, Sidhu H, Bana A, Singh V *et al*. No-till and unpuddled mechanical transplanting of rice. Cereal Systems Initiative for South Asia, New Delhi, India, 2011.
10. Patel J. Effect of water regime, variety and blue-green algae on rice (*Oryza sativa*). Indian J Agron. 2000; 45:103-106.
11. Raj SK, Mathew R, Jose N, Leenakumary S. Enhancing the productivity and profitability in rice cultivation by planting methods. Madras Agric. J. 2012; 99:759-761.
12. Shrirame M, Rajgire H, Rajgire A. Effect of spacing and seedling number per hill on growth attributes and yield of rice hybrids under lowland condition. J Soils and Crops. 2000; 10:109-113.
13. Subrahmaniyan K, Parasuraman VRP, Senthil Kumar G, Sharmila Rahale C. Impact of conservation tillage on soil properties and rice yield of rice- rice cropping system. Paper presented at the 4th International Agronomy Congress, New Delhi, India, 2016.
14. Thiyagarajan T, Velu V, Ramasamy S, Durgadevi D, Govindarajan K, Priyadarshini R *et al*. Effects of SRI practices on hybrid rice performance in Tamil Nadu, India. Water-Wise rice production, 2002, 8-11.
15. Tripathi J, Shakya N, Kharel T, Duxbury J, Lauren J. Crop residue management in sustaining production of rice-wheat system. Paper presented at the Proceeding of Wheat Research Papers Presented at 25th National Winter Crops Research Workshop, 2003.
16. Tuong TP, Singh AK, Siopongco JD, Wade LJ. Constraints to high yield of dry-seeded rice in the rainy season of a humid tropic environment. Plant production Sci. 2000; 3:164-172.
17. Barker R. Evolution of irrigation in South and Southeast Asia (Vol. 5): Iwmi, 2004.
18. Indiastat. India’s Comprehensive Statistical Analysis. 2015, 16.
19. Indiastat. http://www.indiastat.com. (Accessed 09 June 2017).
20. Senthilkumar K, Ramasamy S, Thiyagarajan T. Effect of younger seedlings/direct wet seeding over conventional transplanting in lowland hybrid rice. Madras Agric. J. 2007; 94:212-217.
21. Pandey S, Velasco L. Economics of alternative rice establishment methods in Asia: a strategic analysis. Social Sciences Division Discussion Paper, International Rice Research Institute, Los Banos, Philippines, 1999.
22. So HB, Ringrose-Voase A. Management of clay soils for rainfed lowland rice-based cropping systems: an overview. Soil and Till. Res. 2000; 56:3-14.
23. Gomez KA, Gomez AA. Statistical procedures for agricultural research. (2nd Ed.), Wiley India Pvt Ltd., India, 1984.
24. Mcdonald A, Riha S, Duxbury J, Steenhuis T, Lauren J. Soil physical responses to novel rice cultural practices in the rice–wheat system: comparative evidence from a swelling soil in Nepal. Soil and Till. Res. 2006; 86:163-175.
25. Shah ML, Bhurer KP. Response of wet seeded rice varieties to sowing dates. Nepal Agric. Res. J. 2005; 6:39-48.
26. Singh S, Sharma R, Gupta R, Singh S. Changes in rice-wheat production technologies and how rice-wheat became a success story: Lessons from zero-tillage wheat. Direct-Seeding of Rice and Weed Management in the Irrigated Rice-Wheat Cropping System of the Indo-Gangetic Plains, 2008, 91-106.