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REVIEW ARTICLE

Direct seeded rice: An alternative rice establishment technique in north-west India – A review

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Abstract

Rice is most prominent crop in India and is the staple food of the people of the eastern and southern parts of the country. Transplanting after puddling (A process where soil is compacted to reduce water seepage) has been a major traditional method of rice establishment. Repeated puddling adversely affects soil physical properties by dismantling soil aggregates, reducing permeability in subsurface layers, and forming hard-pans at shallow depths which make land preparation becomes difficult and requires more energy to achieve proper soil tilth for succeeding crops. Excessive pumping of water for puddling in peak summers in north west Indo-gangetic plains (IGP) resulted in declining water table. Rice production with transplanting method has been limited by a number of factors such as water scarcity, high input costs, shortage of skilled labour, suboptimal plant population. Rice seedlings are transplanted by hired skilled labour that resulted in skilled labour shortage throughout the transplanting period which results into low plant population and eventually low rice yield. To overcome this problem, direct seeding of rice seems only viable alternatives in rescuing farmers. Simultaneously, the availability of high-yielding, short-duration varieties, and chemical weed control methods made such a switch technically viable. This technique reduces labour needs, input requirements, investment and save time by timely sowing of rice and shorten crop duration by 7–10 days than transplanted rice. Direct seeded rice, if managed properly, and provide grain yield comparable with that of transplanting. The potential advantages and problems with direct seeding are discussed in this paper.

Introduction

Rice (*Oryza sativa* L.) is a member of graminae family and is relished as staple food by majority of world's population. In India, rice occupied 39.16 million hectares area with a production of 85.59 million tonnes and average yield 2.2 t ha^{-1} (Anonymous, 2013). Productivity of rice in Punjab is 3.8 t ha^{-1} with a production of 10.5 million tonnes from an area of 2.8 million hectares (Anonymous, 2013). Rice is primarily grown by transplanting of seedling in puddled field which is very cumbersome and labour intensive as it requires 30 man days ha^{-1} (Prasad, 2004). Puddling takes upto 30% of total irrigation water application in rice in light textured soils (Aslam *et al.*, 2002). It requires nursery raising, it's uprooting and supply for transplanting in the field and continuous ponding of water for the first 15 days. This leads to nutrient losses through leaching besides causing high evapotranspiration (ET) losses during the hot summer months. Conventional flooded rice receiving the largest amount of fresh water compared to any other crop is the major contributor to the problem of declining ground water table (0.1 – 1.0 m -1) and increasing energy use (Singh *et al.,* 2002). Moreover, under practical situation of contractually transplanted fields, it often, at cultivars' fields leads to lesser plant population, which generally varied from 16-21 hills m^{-2} against the optimum 33 hills m^{-2} and is major yield limiting factor at farmer's field (Gill *et al.,* 2006). Presently, in Punjab the underground water is being over exploited by excessive pumping to meet the water need of transplanted paddy. As a consequence it has been causing a sharp decline in water table. It is imperative to identify alternative methods of rice cultivation to overcome these constraints. The direct seeding technique offers an useful option to reduce the limitations of transplanted paddy. Direct-seeded rice offers the advantage of faster and easier planting, ensure proper plant population, reduce labour and hence less drudgery, 10-12 days earlier crop maturity, more efficient water use and higher tolerance to water-deficit, and often high profit in areas with assured water supply (De Datta, 1986).

Effect of crop establishment nethods on growth of rice

Sharma and Ghosh, (1999) studied two establishment methods (direct seeding and transplanting) and found that both establishment methods did not influence plant height but tillers m^{-2} and dry matter m^{-2} was higher in direct seeded rice. Establishment of roots from the start of germination and lack of

than transplanting. Higher leaf area index in direct sowing of rice related with higher dry matter production due to better growth and development (Fig. 2).

Effect of establishment methods on yield of rice

Gangwar *et al.,* (2005) revealed that effective tillers and panicle weight were significantly higher in drum-seeding and mechanical transplanting (unpuddled). However manual transplanting (puddled) gave significantly lower effective tillers m^{-2} and panicle weight. Similarly 1,000 grain weight and grain yield were significantly higher in drum seeding but at par with direct-seeding and mechanical transplanting (puddled). Mechanical transplanting (unpuddled) and manual transplanting (puddled) gave lower 1000 grain weight and grain yield

found that direct seeded rice gave 50.87 % higher yield than transplanted rice (Table 3). This was due to higher number of panicles m^{-2}, more tillers m^{-2} and

dry matter production and taller plants in direct seeded rice. Singh and Singh (1993) concluded that direct seeded rice gave significantly higher grain yield (28.6 q ha^{-1}) than transplanted rice (27.4 q ha^{-1}). Yield attributes panicle m^{-2}, panicle length, panicle weight, 1000 grain weight were superior with direct sowing of rice. Transplanted crop show poor vigour of seedlings due to transplanting shock and poor root penetration due to hard soil and poor growth, yield attributes and less grain yield due to re-flooding after transplanting, compared with well established direct-seeded rice crop. Gill *et al.,* (2006) reported that effective tillers m^{-2} were significantly higher under direct – sowing than transplanting which were important yield determinants (Table 4). More tillers m^{-2} were due to greater plant population rather than tillers $plant^{-1}$. Panicle length and test weight were not differ significantly among methods of sowing. Grains $panicles^{-1}$ were higher under transplanted rice which was due to higher panicle intensity. Grain yield was higher under direct-sowing than transplanted rice due to more dry matter production, leaf area index and effective tiller m^{-1}

Effect of establishment methods on maturity and water productivity

Sharma *et al.,* (2005) examined the effect of rice establishment methods on performance of rice (Fig. 3). They reported that direct seeding of rice results in early maturity and short the crop duration than transplanted rice. Gill (2008) reported that direct seeding results in early maturity. This was due to better root establishment from the day of germination and lack of transplanting shock leads to 12 days early maturity than transplanted rice. Transplanting on the day of sowing gave higher yield due to 25-days old nursery advantage. Irrigation water application was higher in transplanted rice than direct seeded rice. Direct seeded rice gave more water productivity than transplanted rice. Transplanted rice gave

lower water productivity because continuous ponding of water for first 15 days and irrigation at 2 days interval upto 15 day before harvesting. In direct seeded rice there was no ponding of water and irrigations were applied at 2-3 days interval which helped to save water. Direct seeded rice also gave higher water productivity by reducing the growing season by 12 days (Table 5). Gill *et al.,* (2006) revealed that irrigation water application was higher in transplanted rice (PTR) than direct seeded wet rice DSR (wet) because continuous ponding of water is required for rice seedlings establishment other transplanting for first 15 days in PTR (Fig. 4). But in direct seeded rice no ponding of water is required and irrigation was given at 3 days interval. Water productivity was also higher under DSR (wet) and showing superiority of DSR (wet) over TPR by saving water. Days taken to maturity were less in direct seeded rice because it did not experienced transplanted shock. Saharawat *et al.,* (2010) in a field study evaluate crop establishment methods in rice to improve system productivity and found that irrigation water application is more in drum direct seeded rice than other treatments. But irrigation water application in dry direct seeded rice is lowest and it save 10-12% irrigation water than transplanted rice. Irrigation water application was higher under drum seeding (puddled) because of 30 days earlier planting than transplanted rice. Seepage and evaporation losses may be higher in drum seeded rice as there was no crop in adjoining fields and the temperature was higher. Unless all the farmers plant their crop at the same time, drum seeding to not feasible. Irrigation water use efficiency was higher in direct seeded rice. Per day water use was 24% lower in direct seeded rice than other treatments (Fig. 5). Yadav *et al.,* (2011) found that the irrigation amount in all alternative wetting drying (AWD) treatments was much lower (by 50-80%) than in the daily irrigated treatments, and the amount of irrigation water applied to direct seeded rice (DSR) with AWD was significantly lower or similar to the amount applied to respective transplanted rice (PTR) treatments. The irrigation input in daily-irrigated DSR was significantly higher than in PTR (Fig. 6).

Irrigation water productivity (WP_1) was significantly higher in all AWD treatments than in daily irrigated treatments. WP_1 of DSR irrigated at 20 kPa was significantly higher than in all other treatments, while WP_1 of the other two AWD treatments was similar within each establishment methods. WP_1 of DSR irrigated at 40 and 70 kPa was similar to or significantly lower than that of PTR at 40 and 70 kPa due to the large reduction in grain yield than irrigation amount in DSR at 70 kPa.

Effect of establishment methods on net income of rice

Thakur (1993) found that cost of cultivation (Rs ha^{-1}) was 8.87% low in direct seeded rice but cost : benefit ratio was 3.96 % higher in direct seeded rice than transplanted rice (Fig. 7). Budhar and Tamilselvin (2000) concluded that significantly higher grain yield in wet seeding by manual broadcasting. Higher grain yield may be due to higher plant population in direct seeding by manual broadcasting and followed by drum seeding which provide more facility for intercultural operations like weeding and spraying due to definite row arrangement than transplanting. Cost of cultivation (Rs ha^{-1}) was higher in transplanting method but net income (Rs ha^{-1}) and benefit : cost ratio were higher in direct seeding by manual broadcasting followed by wet seeding by drum seeder and lower in transplanting method (Table 6).

Effect of establishment methods on soil physical parameters

Dhiman *et al.,* (1998) reported that bulk density (g cc^{-1}) was higher under transplanted rice compared with dry seeding of rice (Table 7) and this might be due the puddling effect under transplanting method. Available water content was higher in dry seeding of rice because with decrease in bulk density there was increase in available water content which was due to increased porosity with decrease in bulk density. Gangwar *et al.,* (2008) report that the higher infiltration was recorded under direct seeded rice which reveal the quality of seed bed prepared which allow greater amount of water to penetrate into the field and allowed subsequent crops to grow vigouraly. Higher value of bulk density was recorded under puddled conditions because puddling resulted in destruction of soil aggregates and dispersion of soil particles to form a compact layer with reduced porosity. Higher grain yield was recorded under drum seeding which was at par with direct seeding and significantly higher than transplanted rice. Higher yield under drum seeding was due to higher shoot and root biomass, leaf area index and effective tillers m^{-2} (Fig. 8).

EFFECT OF ESTABLISHMENT METHODS ON QUALITY OF RICE

Brar (2007) found that brown, milled, head rice recovery and length breadth ratio of rice were not significantly influenced by direct seeding and transplanting methods. Rice qualities were similar in both methods of establishment (Table 8). Gill (2013) reported that effect of different establishment methods on brown, milled and head rice recovery was non-significant. However, direct seeded basmati rice with brown manuring recorded higher brown, milled and head rice recovery closely followed by direct seeded basmati rice (Table 9).

- **There may be severe deficiency of iron in direct seeded rice on light soils**
- **Major weed flora under DSR**

  Critical period of weed competition in DSR is 15 to 45 DAS**.**

  Grasses: E. crusgalli, Echinochloa colona, Leptochloa alba, L. chinensis, Eragrostis tenella, Brachiaria reptans, Dactyloctenium aegyptium, Paspalum sp., Digitaria ciliaris**.**

  Broad Leaf Weed: Trianthema monogyna, Eclipta alba, Caesulia axillaries, Sphenochlea zeylenica, Commelina sp., Lindernia crustaceae, Euphorbia hirta, Phylanthus niruri, Amaranthus viridus, Celosia argentia, Digera arvesis

  Sedges: Cyperus rotundus, C. difformis, C. iria, Fimbristylis miliaceae

  Emerging problematic weeds in DSR

- *Weedy rice*
- *Leptochloa chinensis*
- *Eragrostis japonica*
- *Dactyloctenium aegyptium*

Conclusion

- ✓ Direct seeded rice gave higher crop and water productivity, net return than transplanted rice.
- ✓ Direct seeding of rice results in early maturity and short the crop duration than transplanted rice.
- ✓ Dry seeding of rice increased porosity with decrease in bulk density
- ✓ Quality wise direct seeded rice is comparable to transplanted rice.

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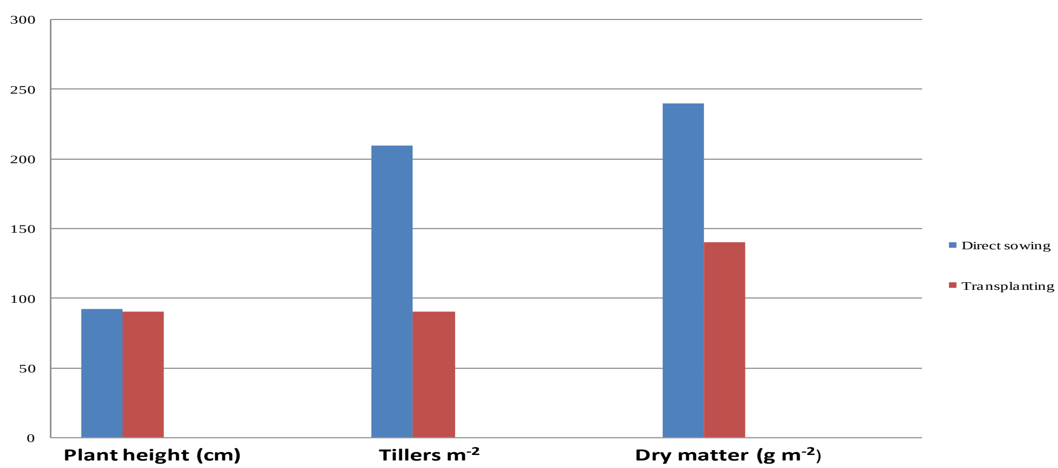
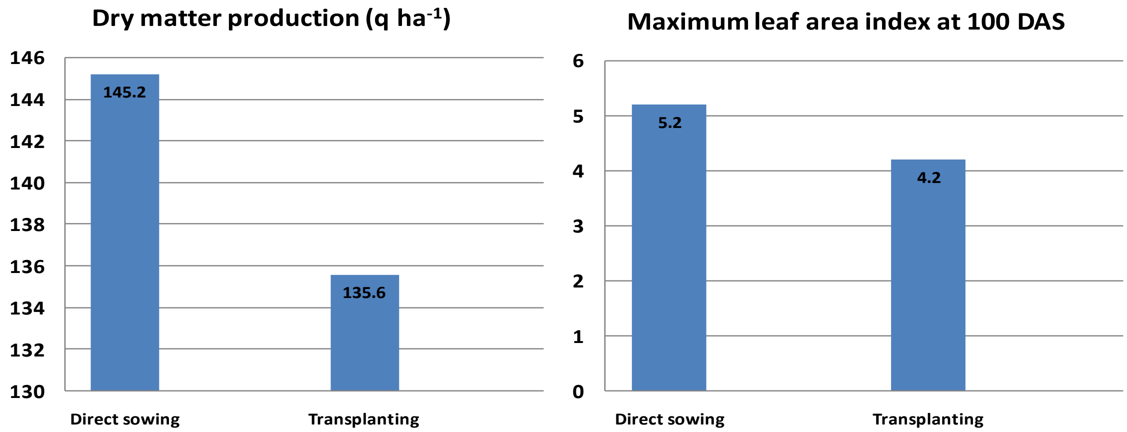
Fig. (1). Effect of establishment methods on growth attributes of rice



Soil: Sandy clay loam
Cultivar: Gayatri
Design: Split -split plot design

Fig. (2). Dry matter accumulation at maturity and maximum leaf area index (LAI) of rice under various methods of sowing



*Direct sowing was done by broadcasting the pre-sprouted seeds after puddling

Cultivar: PR 115, PR 116, PR 111, IR 64
Soil type: loamy sand
Design : Split plot

transplanting shock in direct seeded rice favour to good growth, more tillers m^{-2} and dry matter m^{-2} (Fig. 1). Gill *et al.*, (2006) reported that dry matter production and maximum leaf area index at 100 DAS was higher in direct sowing

Table (1). Effect of establishment methods on yield and yield attributes of rice

Treatments	Effective tillers m^{-2} at harvest (g)	Panicle weight (g)	1000 grain weight (g)	Grain yield (q ha^{-1})
Direct seeding (dry bed, aerobic)	361	3.45	26.8	78.4
Drum seeding (wet bed, urpuddled)	381	3.72	27.1	81.1
Mechanical transplanting (puddled)	352	3.30	26.4	77.5
Mechanical transplanting (unpuddled)	297	3.00	26.0	73.3
Manual transplanting (puddled)	332	3.17	26.2	74.6
CD (P=0.05)	10.89	0.15	0.73	3.8

Soil: Sandy loam
Cultivar: PHB 71

Table (2). Effect of crop establishment methods on yield contributing characters and yield of rice

Establishment methods	Plant height (cm)	Effective tillers m^{-2}	Panicle weight (g)	1000 grain weight (g)	Grain yield (q ha^{-1})
Unpuddled (Dry seeding in lines 20 cm apart)	109.9	71.5	2.9	22.8	49.0
Transplanted	111.6	72.1	3.1	23.2	49.3
CD (P=0.05)	NS	NS	0.1	0.1	NS

Soil: Sandy loam
Design: Split plot

and were at par with each other (Table 1). Higher grain yield under drum seeding and direct seeding was due to higher number of effective tillers panicle weight and 1000 grain weight. Sharma *et al.*, (2005) reported that both unpuddled and transplanted rice gave similar yield owing to almost equal crop stand under unpuddled and transplanted conditions (Table 2). Sharma and Ghosh (1999)

Table (3). Effects of crop establishment methods on growth and yield performance of lowland flood prone rice

Treatments	Plant height at maturity (cm)	Panicles m^{-2}	Grain yield (q ha^{-1})	Straw yield (q ha^{-1})
Dry direct seeding	121	156	33.3	62.9
Transplanting	102	96	26.1	30.9
CD (P=0.05)	5.0	9.0	1.8	3.8

Cultivar: Gayatri

Soil Type: Sandy-clay-loam

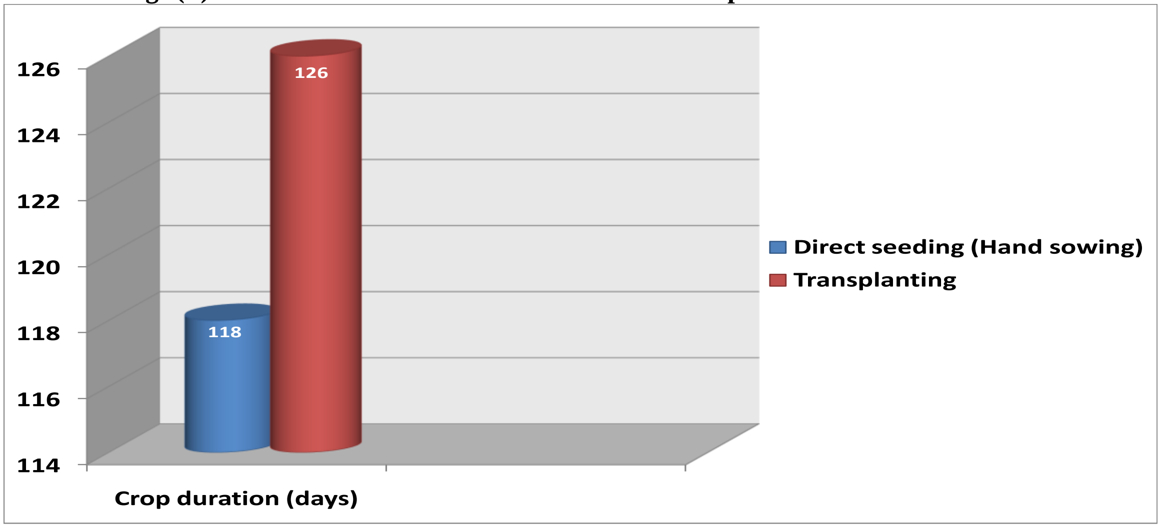
Table (4). Effect of different methods of planting on grain yield and yield-contributing components of rice (mean data of 2 seasons)

Treatments	Effective tillers m^{-2}	Panicle length (cm)	Grains $panicle^{-1}$	Test weight (g)	Grain yield (q ha^{-1})
Direct seeding (Broadcasting pre - sprouted seeds in puddled field)	245.9	23.5	115.8	22.74	48.3
Transplanting	200.7	23.6	128.9	22.64	42.8
CD (P=0.05)	4.7	NS	3.8	NS	2.5

Soil Type: Loamy sand

Design: Split-plot

Fig. (3). Effect of establishment methods on crop duration rain-fed lowland rice



Cultivar: Mahamaya

Soil type: Loamy

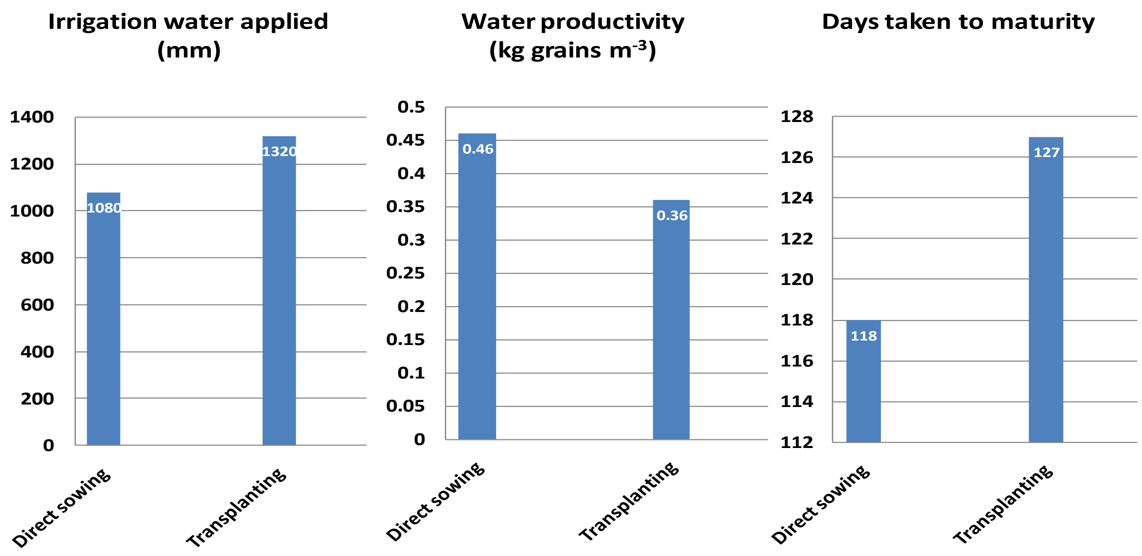
Table (5). Water productivity as influenced by sowing methods (average of 6 years)

Sowing methods	Days taken to maturity	Paddy yield (q ha^{-1})	Irrigation water applied (mm)	Water productivity (kg grain m^{-3})
Direct sowing (Broadcasting pre-sprouted seed after puddling)	113	68.2	1480	0.461
Transplanted on day of sowing	125	75.9	1740	0.436

Cultivar: PR 115 (Short-duration, early maturing)

Soil type: Loamy sand

Fig. (4). Effect of different methods of sowing on water productivity and days taken to maturity of puddled irrigated rice (mean data of 2 seasons)

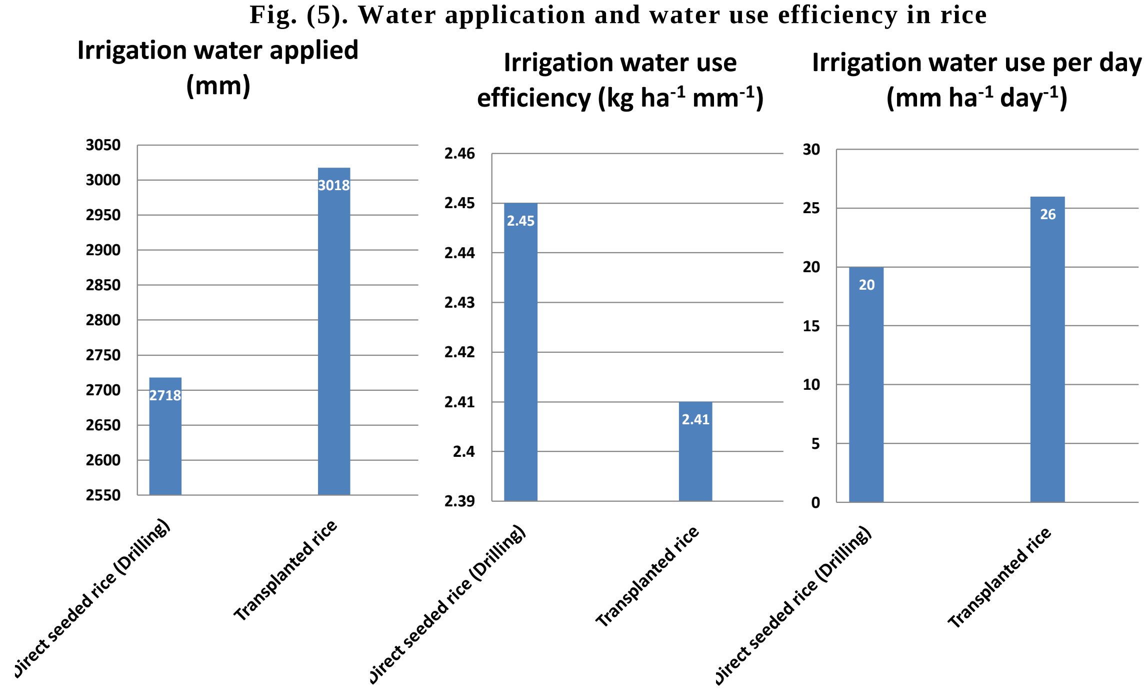


*Direct sowing was done by broadcasting the pre-sprouted seeds after puddling

Soil type: Loamy sand
Design: Split-plot

Rainfall : 590 mm

Fig. (5). Water application and water use efficiency in rice



Soil: Clay loam
Design : Randomized complete block

Fig. (6). Interactive effect of establishment methods and irrigation schedules on grain yield (t ha^{-1}), water use and water productivity of rice

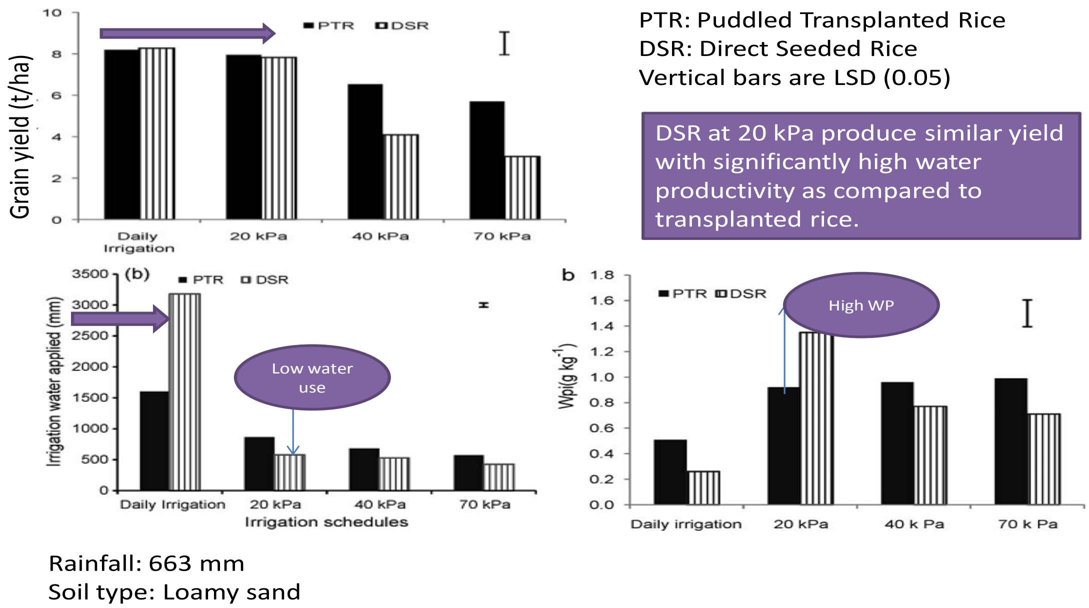
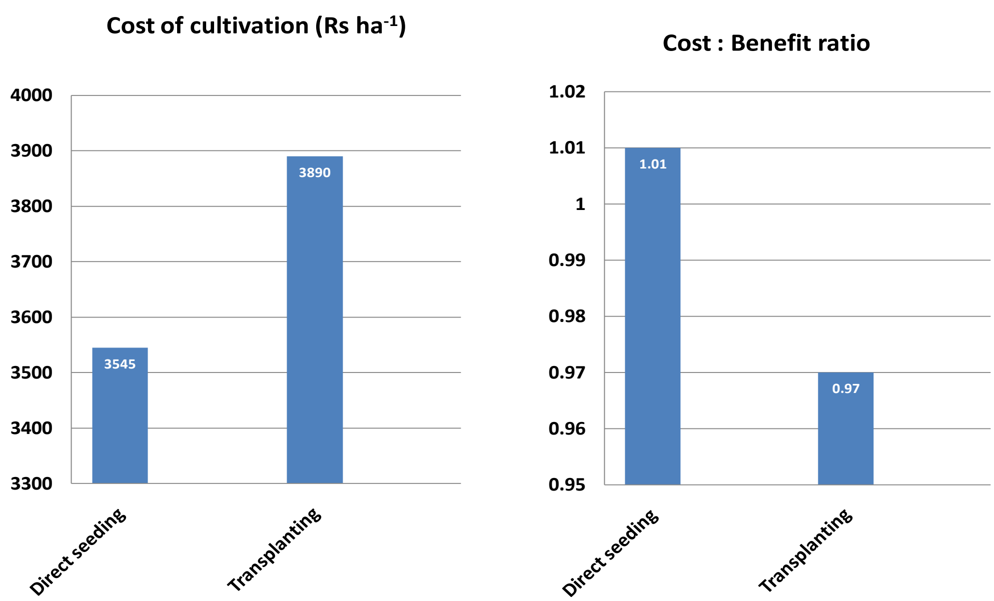


Fig. (7). Influenced of method of planting on cost of cultivation and cost-benefit ratio



*Direct seeding was done by sowing behind the plough

Soil: Silty loam

Design: Split plot design

Table (6). Effect of establishment techniques on yield and economics of lowland irrigated rice

Treatments	Grain yield (q ha^{-1})	Cost of cultivation (Rs ha^{-1})	Net income (Rs ha^{-1})	Benefit : cost ratio
Transplanting	55.8	8,464	15,825	1.93
Wet direct seeding by manual broadcasting	57.2	7,143	19,039	2.33
Wet seeding by drum seeder	56.6	7,182	18,587	2.29
CD (P=0.05)	1.1	NA	NA	NA

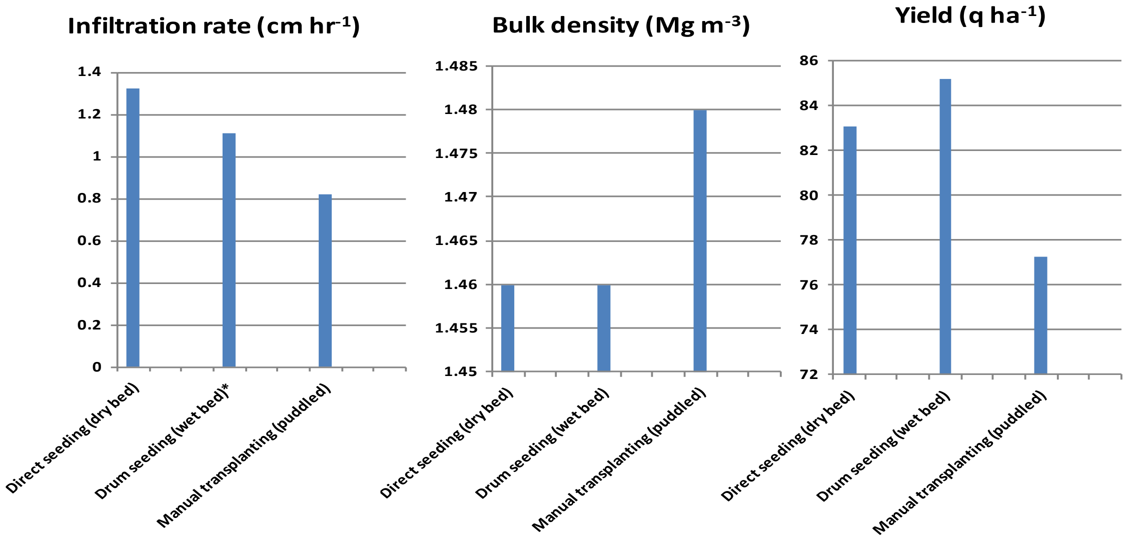
Cultivar: ADT 43
Soil type: Red sandy-loam soil
Design: RBD

Table (7). Bulk density and available water content as affected by crop-establishment methods and fertility levels

Establishment method	Bulk density (g cc^{-1})			Available water content (%)		
	1992	1993	1994	1992	1993	1994
Transplanting	1.64	1.63	1.63	13.04	12.36	11.98
Dry seedling of rice in ploughed field (*drilling*)	1.61	1.59	1.61	13.52	12.55	12.84

Soil: Clay loam

Fig. (8). Physical parameter of soil as influenced by method of crop establishment



*Drum seeding (wet bed) unpuddled

Soil - Sandy loam

rate

(cm hr^{-1})

Table (8). Brown (BRR %), milled (MRR %), head rice recovery (HRR %) and length breadth ratio of basmati rice under two methods of crop establishment

Treatment	BRR		MRR		HRR		L : B Ratio	
	2005	2006	2005	2006	2005	2006	2005	2006
Direct seeded	75.0	76.3	68.4	69.7	51.2	52.7	4.16	4.37
Transplanted	76.5	77.7	69.8	70.4	51.6	53.8	4.36	4.49
CD (P=0.05)	NS	NS	NS	NS	NS	NS	NS	NS

Table (9). Brown (BRR %), milled (MRR %), head rice recovery (HRR %) and length breadth ratio of basmati rice under different methods of crop establishment

Treatments	BRR	MRR	HRR
DSBR	164.59	141.05	102.97
DSBR with brown manuring *Sesbania*	165.34	142.6	106.18
Machine transplanting in ZT with brown manuring	163.26	139.06	100.31

Machine transplanting in ZT without brown manuring	162.55	137.1	98.01
Machine transplanting after puddling	160.8	130.11	98.72
Conventional practice	160.35	126.77	94.85
CD (P=0.05)	NS	NS	NS

Problems of direct seeded rice

Fig. (9). Problem of DSR on Light soils

Fig. (10). Severe iron deficiency in DSR

Fig. (11). Stages of iron deficiency in DSR leaves

Weedy rice

Eragrostis japonica

Leptochloa chinensis

Dactyloctenium aegyptium