Recent Advances in Resource Conserving Technologies for Rice

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In South Asia, rice-based cropping systems accounts for more than half of the total acreage where rice is grown in sequence with rice or upland crops like wheat, maize or legumes. Rice based cropping systems provides food security and livelihoods for millions. Rice-wheat cropping systems alone occupy 13.5 million hectares in the Indo-Gangetic Plains (IGP) of South Asia (Gupta and Seth, 2007).

Traditionally rice is grown by hand transplanting of 25-30 day old seedling after puddling (PTR). Puddling achieved by extensive tillage in standing water, which creates impervious layer 10-15cm below soil surface. Normally puddling is done to reduce percolation losses, to control weeds and to makes transplanting operation easier. Puddling require lot of tillage and water (>300 mm). Puddling destroys soil structure, which affects growth and development of succeeding upland crops in the rotation, thereby reducing system productivity. (Hobbs et al. 2002). Excessive pumping of water for puddling in peak summers in north west IGP causing problems of declining water table and poor quality water for irrigation on one hand. Whereas, in eastern IGP rice transplanting depends mainly on monsoonal rains; need of ponded water for customary practice of puddling delays rice transplanting by one to three weeks on the other. Delayed transplanting of rice affects growth and yields not only of rice but also succeeding crops, thereby reducing system productivity and profitability.

The traditional system of hand-transplanting rice is based on the premise of cheap and readily available labour. However, in present scenario, rapid labour migration from agriculture to non agriculture sectors like construction, industries etc are seen in India. Country is currently experiencing an impressive phase of economic development causing drastically reduced availability of farm labour, especially for drudgery like transplanting and weeding in rice.

More over ever increasing energy prices for pumping water and running tractors for puddling and other operations, limited water and labour availability for transplanting, stressed farmers as well as researchers to develop alternative production systems for rice. Farmers need technologies that can reduce their costs of cultivation and improve their returns. They also need technologies favorable to environment and having less deleterious effect on natural resources. Conservation agriculture based resource conserving technologies (RCTs) like dry direct seeded rice, zero tillage are being promoted in rice-wheat areas of Indo-Gangetic plains. The advantage of reducing tillage, retaining crop residues back in field and diversifying rotation to improve soil health and productivity is been realized. Similarly, development of
selective and cost effective herbicides is replacing dependency on traditional intensive tillage (puddling) and manual weeding.

Direct seeded rice

Direct seeding of rice mainly done by two methods, dry direct seeding (DSR) and wet direct seeding (WSR). DSR practiced by seeding dry seeds in unsaturated soil by line sowing or broadcasting. In wet seeding, sprouted seeds of rice broadcasted in puddled soil.

DSR seeded with a planter or a seed cum fertilizer drill have many advantages over conventional puddled transplanting i.e. viz. easier and timely planting, reduced labour burden at least 50% (Isvilanonda 1990, Fujisaka et al. 1993, Singh et al. 1994, Pandey et al. 1995, 1998, Pandey and Velasco 1998), 8-10 days earlier crop maturity (helpful in timely planting of succeeding crop), higher water and nutrient use efficiency, efficient root system development that enhance drought tolerance reduced lodging problem and higher yield of succeeding upland crops. Having experienced the benefits of zero-till in wheat, acceptance of zero-till direct dry seeded rice gaining popularity in South Asian counties.

In a long-term trial on crop establishment methods in rice-wheat system started in 2006 at Rajendra Agriculture University, Pusa, Samastipur, to find out the effect of rice wheat establishment methods on productivity of either crops. Treatments including puddle transplanted or puddle direct seeded rice, tilled dry direct seeded rice and zero till direct seeded rice in presence or in absence of residue in combination with conventional and zero till wheat were evaluated on faovable low land silty clay soil at Pusa. Results revealed that growing rice and wheat without tillage and direct seeding in presence of residues led {ZTR-ZTW (+R)} to stable and higher crop yields of rice and wheat plots over the years. However in initial years the grain yield of rice was slightly higher in puddle transplanted rice but since 2008 not much difference in rice yield was observed due to puddling and transplanting. (Fig 1) while the cost of production was significantly low in zero tillage rice (ZTR). Grain yield of wheat was always higher when wheat is planted after unpuddled rice than puddle transplanted or direct seeded rice. Wheat growth was always better in unpuddled soils, resulting highest system productivity. It is interesting to see that zero tillage rice followed by zero tillage wheat with residue retention {ZTR-ZTW (+R)} continuously improved the rice and wheat yield over the years.
Production technology for direct seeded rice.

The production technology of DSR revolves around weed management, crop establishment and likely shifts in weed flora due to adoption of direct-seeded rice.

Need of levelled field for DSR

Most of the traditional levelled fields in IGP have 8-15 cm deviation in level which affects crop establishment of rice due to unequal distribution of water in soil profile and inundation of newly germinating seedlings at initial stages. Moreover, uneven fields hold poor water, nutrient use efficiency causing low crop productivity. Water is a limiting input in present day agricultural production system. In many parts of country, depleting water tables and high pumping costs makes rice growing difficult and uneconomical. It is need of the hour to introduce technologies that can save water and improve water use efficiency. Precision land levelling using laser guided system helps a lot in obtaining a perfectly leveled field. It has a laser source (transmitter) and a receiver attached to a scraper bucket behind a tractor. The vertical movement of bucket is guided by a control box using a hydraulic jack for levelling the field.

Lantican et al (1999) studied the effect of precise land levelling on yield DSR in the Philippines and concluded that yield for DSR was significantly improved with precise land leveling. They found that mean standard deviation for land-leveling precision was 8 cm and farmers lost 925 kg ha$^{-1}$ of yield. They also reported that précised levelled field showed less seasonal water stress. Rickman et al (1999) also reported yield advantage in both DSR and PTR with laser land levelling.

Fig 1. Effect of crop establishment methods on productivity of rice in rice-wheat system (3 years mean) (Ravi Gopal, unpublished 2010)
In India it has been experienced in many farmers participatory trails that a saving of 20-25 per cent of irrigation water can be achieved by laser land levelling, apart from several other benefits as indicated below.

- Better crop establishment, improve fertiliser use efficiency.
- Uniform spread of water controls weed emergence especially annual sedges
- Improved weed control efficiency of the post emergence herbicides.
- Easy farm operations due to larger plot size.
- Uniformed of crop maturity.
- Increased in cultivable area (2-3%) due to removal of bunds of small plots.
- Reduce run-off losses of applied fertilizers and herbicides.

Therefore, Laser land-leveling is a precursor technology and rather an entry point for the successfulness of DSR through improved water and crop management.

**Seeding time for direct dry seeded rice**

Late planting of rice is a major problem in most rice growing area. Rice planting is delayed mainly due to (i) non-availability of canal water supplies, (ii) non-development of the ground waters for nursery during Kharif season and (iii) excessive preparatory tillage operations after onset of monsoon or canal water and customary practice of puddling before transplanting. This often leads to terminal water stresses and consequent low productivity of Kharif rice. Late rice planting leading to late harvesting also adversely affect yields of the following crop in the systems. The experiences of DSR under farmer participatory trial and field trials across IGP suggests that seeding of rice after onset of monsoon become difficult due to problem in movement of machinery in the wet fields. Moreover, under wet field conditions, there are problems in depth control of drill, clogging of seed tubes etc makes seeding difficult resulting in to poor crop establishment. Also the applied pre-emergence herbicide may cause phyto-toxicity to young rice seedlings due to leaching if rain occurs after spray. More over, a dry spell for 2-3 days after sowing in wet soil may cause surface crust formation resulting poor emergence.

Timely planting ensures proper crop stand and higher yield. For the continental monsoon type climate in main rice season (kharif), planting of DSR, 10-12 days before historical date of onset of monsoon was found better than planting early or late (Ravi Gopal *et.al. 2010). In a date of seeding experiment conducted at Rajendra Agriculture University, Pusa, Samastipur in Bihar for two years a long duration variety (Sawarna, 160 days) produced more yield than short duration variety (Prabhat, 110 days), early planting (7th June) of sawarna resulted in to better yield, however bit delayed planting (June 14th) of
Prabhat (110 days) resulted in to higher yields. Grain yield of DSR was higher than puddled transplanted rice crop when seeding dates were same (Ravi Gopal, 2008).

This observation may be of significance in establishing a DSR crop with less water, just before onset of rains. It is obvious that date of planting had significant influence on productivity of two distinctly different rice cultivars thereby suggesting that full season cultivars must be planted timely for improving yields, however, under late planting conditions early maturing variety should be selected.

**Cultivar Choices for DSR**

Most of our cultivars developed for puddle transplanted conditions. Direct dry seeded rice requires specially bred cultivars having good mechanical strength in the coleoptiles to facilitate early emergence of the seedlings under crust conditions (generally formed after light rains), early seedling vigor for weed competitiveness (Hill et al. 1991), efficient root system for anchorage and to tap soil moisture from lower layers in peak evaporative demands (Dilday et al. 1990) and yield stability over planting times are desirable traits for DSR. In absence of a strong rice improvement program for DSR, suitable varieties for dry direct seeded rice production system are generally not available. Therefore we need to identify suitable cultivar among existing varieties. In Punjab cultivars, PAU 201, Pusa 1121, CSR 30, Pusa Basmati and hybrids like Arize 6129, Arize 6444 were found suitable, in addition to these PRH-10, Tarori Basmati, Pant Dhan 12, Sharbatzi were found suitable in Haryana and Western U.P. In Terai of Uttarnchal cultivars Nidhi, UPRI-92-79, Narendra 359, Pant dhan-4, Sarbatzi PR 113, HKR 120 and Sarjoo-S2 performed better that others. Similarly in Eastern U.P.NDR 359, Sarjoo 52, Mahsuri, PAU 201, hybrids Arize 6129, and Arize 6444 were found suitable. Results of farmer participatory and on station trials in Bihar suggest that short duration cultivars, Saket-4, and Pusa 834 (semi dwarf and 105 days variety) among medium to long duration cultivars Rajendra mahsuri, PAU 201MTU 1001, Swarna and Pusa 44 performed better under DSR. Among hybrids Arize 6444, Arize Dhani, NK Sahyadri and RH 664 werefound better those others.

However, in dry years, short duration cultivars like shusk samarat and aerobic rice variety APO performed better than other long duration cultivars.

**Seed rate and seeding depth:**

In literature, use of high seed rate (80-120 kg ha⁻¹) is being recommended for establishment of DSR. High seed rate causes nitrogen deficiency, reduce tillering, and increases proportions of ineffective tillers, lead to attack of brown plant hoppers and crop lodging. Higher pest and disease incidence because of dense canopy and less ventilation around plants (especially in broadcast-sown rice with high seed rate) was also reported by Sittisuang (1995). Based on many year of research experience, it is found that for cultivars with
medium fine grain, seed rate of 20-25 kg ha$^{-1}$ is optimum for DSR crop (Gupta et al, 2006). In an experiment conducted in Bihar, 150-200 seeds/m$^2$ (26-30 kg/ha) with good weed management condition led to highest grain yield of dry direct seeded rice (Ravi Gopal 2008). Grain yield was lower when seed rate was 100 or 250 seeds/m$^2$ under partial weed control condition. Seed rate higher than this can reduce yield because of the reasons mentioned above. However, seed rate can be lowered down using precision planters. Lower seed rate can be applied for high-tillering varieties and a higher seed rate for medium-tillering types (Soo et al, 1989).

On the other hand most of the rice varieties were found sensitive to depth of seeding. Usually the seed depth should be kept 2-3 cm for ensuring a good crop stand. NCES (1991) recorded higher shoot and root biomass at seeding depth of 3 cm as compared deeper and shallow seeding depth. Placement of seeds too deep or shallow adversely affects the dynamics of seed germination due to week coleoptiles and rapid drying of the soil surface in peak summers. It is also important that seeding depth should be calibrated and maintained using depth control wheels only. Using tractor’s hydraulic system for controlling depth is misleading and led to uneven seed depths leading to poor crop establishment. It is also advised to use spirit level to check the level of planters length wise and width wise to ensure equal seed depth by front and back tynes of a planter. The levelling can be adjusted by loosening or tightening top link of the tractor.

**Establishing the dry direct seeded crop**

Precision planters (optimum seed rate and precise depth), having cup or incline plate seed metering device and depth control wheels are found suitable for DSR. Seed depth plays a very pivotal role in early germination and emergence of seedlings in DSR system it is also observed that usually it is not possible to reduce seed rate with fluted roller type seed-cum-fertilizer drills. These drills often damage the rice seed coats and also do not maintain plant to plant space in a row.

Considering high evaporation during establishment time in main rice season, it is advised that the rice should be planted in moist soil condition. Retained residues help in getting good germination and early crop establishment. It is better to use press wheel or planking to promptly cover the seeds immediately after seeding.

**Water Management**

The dry direct seeded rice crop can be grown without continuous flooding. Never the less, a deep (5-7 cm) pre-seeding irrigation is required for good crop establishment during peak summer season. Irrigations can be avoided in first two weeks after emergence of seedlings. Intermittent irrigation are needed to avoid
moisture stress especially during panicle initiation to grain filling stage. Any moisture stress during this phase affects rice yields. In rain fed ecologies crop can be planted

**Nutrient Management**

Nutrient management of DSR is not much different than PTR. General recommendation is to apply full dose of phosphorous and potash along with seed. Nitrogen should be applied in three equal splits at basal, tillering and panicle initiation. If wheat or maize straw has been incorporated before sowing little higher dose of nitrogen should be applied at tillering stage.

In an experiment on N management of zero till rice conducted during 2008-2009 in Bihar with two rice distinctly different rice cultivars and five nitrogen doses. The nitrogen doses were applied in three equal splits at 1, 40 and 70 DAS at basal, active tillering and panicle initiation stages of crop growth respectively.

The result of experiment revealed that Rajendra Mahsuri produced more number of total grains /panicle and filled grains/ panicle than PHB 71(hybrid). However, PHB 71 being a bold seeded cultivar had higher test weight than Rajendra Mahsuri. Panicle density and grain yield of both cultivars did not differ significantly.

Among nitrogen doses, highest total and filled grains/panicle was observed at 120 kg N/ha which was significantly higher than 11kg N/ha. However, treatments with 180 kg N/ha had highest panicle density and grain yield being at par with 120 or 240kg N/ha. Treatments with 11 or 60 kg N had significantly low panicle density and less grain yield than 180 Kg N/ha.

However, long duration cultivar Rajendra Mahsuri seemed to better recovery efficiency of applied nitrogen than PHB-71 up to nitrogen doses of 180kg /ha (Fig. 2). It may be concluded that farmers can use Rajendra Mahsuri with a N doses of 120-180 kg/ha if they have enough water or have fields in favorable low lands. Williams (1996) suggested that long duration cultivars require more nitrogen to show full yield potential than medium and short duration cultivars.

Apart from Nitrogen for P and K it is better to use granular complex NPK mixtures for basal application as most of the planters have problem with placements of powdery materials like MoP, moreover when urea is mixed with DAP in fertilizer box it absorbs moisture and creates problems in dropping resulting uneven distribution of fertilizers. Therefore urea should be broadcasted separately. Zink or iron deficiency may
appear in DSR plots especially in light textures soils and it should be treated by foliar application as in case of transplanted rice.

![Graph showing the effect of N doses on grain yield (t/ha) of zero till rice cultivars Rajendra Mahsuri and PHB-71.](image)

**Fig 2** Effect of N doses on grain yield (t/ha) of zero till rice cultivars Rajendra Mahsuri and PHB-71 (Ravi Gopal, 2008-09, unpublished).

**Weed Management in DSR**

Weeds are a major concern for success of DSR. In fact, puddled transplanted rice was introduced mainly because of weed menace in DSR. Weeds compete for moisture, nutrients, light and space and a consequence, weeds infestation in DSR results in yield losses in the range of 30 to 90%, reduces grain quality and enhances the cost of production (Singh et al, 2009). In DSR weeds like *Cyperus rotundus*, *Leptochloa*, *Fimbristylish* and *Cynodon dactylon* become uncontrolled and highly competitive; especially *Cynodon* is becoming a real problem in permanent no till field in eastern Indo Gangetic Plains. Since weed flora is becoming complex and diverse in DSR, and no single herbicide molecule is able to control all weed. Therefore, a broad spectrum herbicide or a combination of herbicides, tank mixed or sequential application along with cultural practices is needed for effective control of grassy, broad leaf and sedges in direct seeded rice. We are experienced that certain weeds are shifting in rice with the change in crop establishment system. On the other hand weedy rice is also seen as big treat to DSR. In a study on continuous DSR it was observed that *Echinochloa crus-galli* appeared after three consecutive seasons, followed by the infestation of *Leptochloa chinensis* (after 10 consecutive seasons), *Ischaemum rugosum* (after 14 consecutive seasons), and weedy rice (after 20 consecutive seasons) otherwise these were observed in first year (Ho 1996).
The weeds can be managed easily in cropping system based integrated weed management approach. Healthy crop husbandry of previous crop, levelled field, selecting a robust competitive vigorous cultivar, timely planting, retaining crop residues, reducing tillage was found helpful in managing weeds. Cover crops, good rice crop establishment, planting rice in a clean field can substantially reduce weed menace.

“Brown Manuring” practice involves seeding of rice and Sesbania crops together and knocking down of Sesbania crop after 25-30 days with 2, 4-D ester at 0.40-0.50 kg ha\(^{-1}\). Sesbania grows rapidly and suppress weeds. Co-culture technology reduces annual sedges weed population by nearly half without any adverse effect on rice yield. Sesbania surface mulch decomposes very fast to supply N.

If a field is infested with perennial weeds like Cynodon, Cyperus rotundus etc pre plant application (7 days before sowing) of Glyphosate @ 2.5 Kg/ha with 300 Lt water was found effective on controlling perennial established weeds. Glyphosate should be applied with clean water with a sprayer fitted with flat fan nozzle booms. It is a nonselective, systemic, pre plant controls annual and perennial weeds. If possible weeds especially perennials should be allowed to grow after irrigation/rain to develop a canopy, so that they can receive enough amount of glyphosate to kill underground parts too. Best results are obtained when weeds are in active growth stages.

Pendimethalin at 1 kg ai/ha applied pre emergence 1-2 days after sowing is found effective in controlling annual weeds. Pendimethalin is effective against weeds like Leptocloa, Eragrostis, Dactyloctenium aegyptium etc. Pendimethalin should be applied in clod free moist soil.

2 4-D at 500 g ai./ ha applied as post emergence is effective against broadleaf weeds and annual sedges eg. Cyperus irea, C.defformis, Fimbristylis etc. Apply 2,4-D when these weed start emerging out (needle stage) in early growth phase of rice. Ethyl Easter formulation of 2, 4-D was found better than Na salt.

Post emergence application (15-25 days after sowing) of bispyribac sodium 25g ai/ha found very effective on most of grasses like Echinocloa sp but it was weak on perennial sedges, Digera arenxis, Leptocloa, Eragrostis spp etc. Bispyribac works well in saturated soil conditions. If water is ponded in the field remove excess water before application and fill in water again after one or two days.

On contrary, Azimsulfuron @ 25g ai/ha or ethoxy sulfuron @15-18g ai/ha post emergence application was found effective to control broadleaf weeds and sedges in DSR. Like bispyribac these herbicides need saturated soil conditions for better actions. Azimsulfuron is particularly very effective on Cyperus rotundus.
Fenoxaprop @ 55-60g ai/ha at 18 – 25 days after sowing was able to manage annual grasses and Cynodon in standing rice crop. In different farmer’s participatory trial from west to east IGP, it was observed that weed flora changed in response to year to year weather variation and change planting system. In dry years (2009) the weeds like Eragrostis and Leptochloa are more prominent and especially in DSR. These weeds were not controlled by Bispyribac. In large numbers of farmers participatory trials it was observed that pre-emergence application of pendimethalin (1.0 kg ai/ha) followed by post emergence application of bispyribac (25g/ha) at 20-25 DAS found effective in controlling complex weed in DSR.

Other than herbicides cultural practices like retained crop residue, Sesbania coculture and cover crops like mungbean or cowpea helped in reducing broadleaf and sedges weeds. Hence, cropping system based weed management strategies like better water management, Laser leveling, timely planting and competitive rice cultivars were found helpful in managing weeds in DSR. Moreover, weed surveillance may also prove beneficial in selecting suitable herbicides and weed management strategies in a region (Singh et al, 2009).

Conclusion:
Based on findings of long-term experiments as well as experience of farmers participatory trials of RCTs in rice based systems, it can be concluded that direct seeded rice under double no till with laser land levelling reduced cost of cultivation and improved the crop yields and system productivity while conserving natural resources. The technology does not affect rice quality and can be practiced in different ecologies including upland, medium and lowland, deep water and irrigated areas by large as well as small farmers.
References


