DIRECT WET SEEDING IN RICE - A REVIEW
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ABSTRACT
Transplanting is the most popular method of rice cultivation in south and south-east Asia. In India transplanted rice covers 19.0 m ha which is 44% of the total rice area. In recent years, transplanting is becoming increasingly difficult option due to shortage and high cost of labour, scarcity of water and the reduced profit. Wet seeding on puddled soil either through broadcasting or in lines is gaining popularity due to lower labour requirement, shorter crop period and efficient water use. Wet seeding of rice differs with respect to varietal choice, seed rate, weed, water and fertilizer management. Genotypes with less tillering ability, limited leaf area production during the reproductive stage coupled with high initial vigour, submergence resistance and lodging resistance were suitable for direct wet seeding. Direct wet seeded rice was efficient in nitrogen uptake in the initial stages due to absence of transplanting shock, however, the yields were low at lower levels of N in comparison to transplanted rice. Fertilizer N loss was lower with broadcast surface flooded rice (BSFR) because of more lateral root development. Agronomic efficiency was low in direct wet seeded rice (DWSR) due to lodging in the later stages. Infestation of weeds in general, grassy and broad weeds in particular was more in DWSR compared to transplanting. Pre-emergence application of butachlor+Safener @ 1.0 kg a.i./ha controlled weeds effectively. DWSR saved 18% water over transplanting. Higher WUE was obtained with continuous submergence at 2.5 cm depth in DWSR and at par with 5 cm depth of irrigation. Effects of DWSR were more promising due to lesser man hour requirement (16 h) in comparison to transplanting (347 h) per ha of land. Higher net returns and B:C ratio were obtained in DWSR. DWSR will be inevitable in the near future. To make this into a successful reality identifying of suitable genotypes, better water, weed, green manuring and fertilizer management practices are essential. DWSR may be adopted under sufficient water availability and weed control measures.

Transplanting is the most popular method of rice cultivation in south and south-east Asia. In India 44 per cent (19 m ha) area is under transplanting in irrigated lowlands. Though transplanting is the effective means of rice cultivation, of late it is becoming difficult in terms of economics due to the following reasons, where direct wet seeded may be adopted.

• Delay in transplanting especially under command areas where shortage of rainfall may hamper the timely release of water.
• Declining productivity of land and labour.
• Costly and labour intensive method.
• Reduced plant population/unit area as most of the work is being done by labourers on contractual basis.
• Difficult to cover larger area in a short span.
• Ultimately the reduced profits.

Advantages of Direct Wet Seeding
In comparison to transplanting, direct wet seeding has the following advantages (Subbaiah and Balasubramanian, 2000);

• Faster and easier crop establishment.
• Reduced labour use
• Lesser drudgery
• Earlier crop maturity (8-10 days)
• More efficient water use due to reduced crop duration
• Increased benefit-cost ratio.
However, direct wet seeding has some disadvantages which are as follows:

* Precision levelling and water management is a must
* Uneven emergence of rice seedlings
* Weed management is very difficult

Prospects of Direct Wet Seeding

Direct seeding is becoming the most efficient method of planting rice in many developed countries where labour supply is limited and expensive (De Datta, 1986). In developing nations also its area is increasing. The area under direct wet seeding increased from 40 to 65 per cent in dry season in Philippines. In wet season the area increased from 15 to 30 per cent (Bhuiyan et al., 1995). The area under direct wet seeding ranged from 40 per cent in Philippines, 70 per cent in Malaysia, 75 per cent in Mekong Delta and 35 per cent in Thailand in the year 1995 (Hill et al., 2000). This indicates the possibility of wet seeding in dry season.

Direct seeded rice is an ancient practice of rice cultivation in India and it is practiced in all states either in the form of dry seeding in rainfed lowland, upland and flood prone areas or wet seeding under irrigated areas except Punjab, Haryana and Western Uttar Pradesh. Out of 43 m ha of area planted in rice, the rainfed lowland ecosystem occupies nearly 14.8 m ha (35%) where, there is a possibility of puddling and broadcasting of pre-germinated seeds (Subbaiah and Balasubramanian, 2000). Direct wet seeding has every potential to occupy the place of transplanted rice in command areas of Karnataka, Andhra Pradesh, Tamil Nadu and Uttar Pradesh.

Genotypes

Most of the high yielding varieties developed for transplanting system are suitable for wet seeding. However, they perform well only in favourable conditions but often give lower yields under direct seeding. The varieties for direct wet seeding must have the following characteristics for good and high yields.

* They should have early seedling vigour
* Tolerance to submergence condition in the initial stages of the crop.
* Tolerance to drought in the initial stages.
* Capacity to withstand weed competition.
* Resistance to lodging in the later stages i.e. at harvest
* Better root system, anchorage and culm strength.
* Adaptability to denser planting.
* Less number of tillers/sq m
* High yield with good quality.

(Singh and Pillai, 1996).

Among more than 20 genotypes tested at the Directorate of Rice Research, Hyderabad for their suitability to direct wet seeding, IET 9994 (4.67 t/ha), Seshu (4.60 t/ha), IET 9691 (4.50 t/ha), Vikas (4.34 t/ha), IR-64 (4.27 t/ha), Tulsi (4.25 t/ha) and IET-10890 (4.20 t/ha) were found better. Remaining varieties performed better under transplanting condition (Singh et al., 2000). The performance of IR-58 and IR-64 was better or comparable to transplanting under different rates of nitrogen application. However, IR-36 and IR-42 yielded better only under low to medium nitrogen application rates (IRRI, 1986).

Variety ADT-36, IET-9221 at Aduthurai, ADT-36 and ASD 16 at Coimbatore (Tamil Nadu); Jalpriya, Vikas at Ghagrahat (Uttar Pradesh); Saket-4, IET-9994 at Pusa (Bihar); Vikas and Luit in Assam; Vikas, IET-9994 at Hyderabad and IET-9994 at Mandya recorded the best results under direct wet seeding (DRR, 1994).

Methods of establishment did not influence the grain yield of rice while varieties differed significantly (Singh and Pillai, 1996). Under direct seeded conditions varieties like
Rasi, IET 9978, Vikas, RP 2144 and Pusa 615 recorded higher grain yield while under transplanted conditions varieties like IET 10402, IET 7987 and IET 9221 performed better.

**Plant Population**

Plant population is directly influenced by the amount of seed rate used for sowing. The seed rate varied from 35-125 kg/ha by different workers. Commonly used seed rate was 100 kg/ha. Equal rice yields were obtained with 60 kg/ha in direct wet seeding in comparison to transplanting (Schnier et al., 1990). Use of Directorate of Rice Research, Hyderabad row seeder at 20 cm spacing gave higher yields, but was at par with the transplanting (Subbaiah and Balasubramanian, 2000). Sowing with the drum seeder at 20 cm gave 4.92 t/ha and 5.96 t/ha while 15 cm spacing gave significantly lower yields of 4.61 and 5.69 t/ha in kharif and rabi seasons, respectively. Hand broadcasting gave significantly the lowest yields of 3.08 and 5.30 t/ha in kharif and rabi (Subbaiah and Balasubramanian, 2000).

Direct wet seeding (5.23 t/ha) gave significantly on par yields with dry seeding (5.67 t/ha) at Mugad, where direct dry seeding is the main practice (Angadi et al., 2000). Transplanting in lines at two seedling/hill, interculture with weeder gave significantly lowest yields (3.83 t/ha) as it is risky due to high flooding (Sahoo et al., 2000). Initial flooding after the seeding also governs the stand establishment. Seeding in the puddled soil and thereafter irrigating at 14 days ensured 81 per cent establishment in the dry season while irrigation at 7 days after seeding ensured 88 per cent establishment in the wet season (Hill et al., 2000). Seeding under watered condition performed poorly due to poor stand establishment in both the seasons.

**Nutrient Management**

Efficiency of N fertilizer is generally low, with normally less than 40 per cent of the applied N taken up by the flooded rice. Broadcast seeded puddled rice differed in its response to applied nitrogen from transplanted rice (Schnier et al., 1995).

**Crop Growth**

Maximum tiller number increased with N dose and was higher in row seeded than in transplanted rice. Maximum tiller number ranged from 544 to 925 tillers/m² in transplanted rice, and from 819 to 1338 tillers/m² in row seeded rice (Schnier et al., 1990), higher tiller numbers in row seeded rice were due to higher plant population rather than more tiller number per plant. In fact, tiller number per plant was less in row seeded rice (4.6 to 7.5) than in transplanted rice.

In transplanted rice, dry matter production increased steadily after crop establishment until maturity and responded positively to N rate. But in row seeded rice, dry matter accumulation slowed down during ripening and was negative during the last week before maturity. This decline was partly due to lodging and earlier leaf senescence caused by low N level.

Leaf area index values steadily increased before peaking at 1 to 2 weeks before heading and decreased thereafter. Leaf area index was affected by N rate, the highest LAI values being 10 in transplanted and 11.8 in row seeded rice. In row-seeded rice, leaf area growth started 2 week earlier and LAI generally was higher than in transplanted rice (Schnier et al., 1990).

**Root growth**

Significantly high mean root length was observed in broadcast seeded flooded rice over transplanted rice. At all the depths the root length was significantly higher except at 5-10 cm depth. The average increase was 38 per cent (De Datta et al., 1988). Comparatively more root length fraction in the surface area
(0-5 cm) may be another reason for lesser soil cracking in wet seeded rice. With the increasing depth of more than 5 cm, transplanted rice had more root biomass than the wet seeded rice (Kondo et al., 2000).

Yield and yield components

Rice yields were significantly higher in transplanted condition in 1985 (6.6 t/ha) and 1986 (7.4 t/ha) than broadcast seeded flooded rice (6.1 and 6.7 t/ha, respectively). Straw yields behaved similarly. However, both grain and straw yields did not differ on two years mean basis (De Datta et al., 1988).

Schnier et al. (1990) recorded significantly lower rice yields (4.2 t/ha) under row seeded than transplanted (5.2 t/ha) at no nitrogen application. Similar trend was observed up to 90 kg/ha of N application. However, similar yields were obtained at higher rates of N application in row seeded rice. Agronomic efficiency was relatively equal in comparison to transplanted and significantly lower in another experiment. Wet drum seeding produced similarly high yields and was at par with manual transplanting, machine transplanting and wet broadcasting at Mandya (Kenchaiah et al., 2000). Even under traditional rainfed drill sown tracts of northern transitional zone of Karnataka, drum seeding was the next best option after dry seeding in comparison to transplanting (Angadi et al., 2000). Similar yields were also reported in conjunction with herbicide application and nitrogen management (Ganajaxy et al., 2000).

Nitrogen Uptake, Recovery and Loss

Total nitrogen uptake did not differ significantly between the two crop establishment techniques. The BSFR utilized fertilizer-N more efficiently than did transplanted rice as reflected by plant 15-N recovery and plant N derived from the fertilizer. Moreover, fertilizer-N loss was presumably lower with broadcast surface flooded rice (BSFR) because of more rapid uptake of applied N, which could be attributed to greater plant density and initial plant growth (De Datta et al., 1988). In transplanted rice the uptake of applied N was delayed by the transplanting shock.

Nitrogen concentration in leaves decreased from crop establishment until maturity. Concentration of nitrogen content per leaf area was high in transplanted than in row seeded rice, particularly during the reproductive growth phase. Because of high plant population and faster crop establishment and subsequent N dilution in the tissue, foliar N content decreased more rapidly in direct seeded than in transplanted rice. This influenced the higher grain yields in transplanted rice hence, total yield is less under row seeded rice (Schnier et al., 1990).

Source and Method of Nitrogen Application

Urea deep placement and three split application gave the lowest urea N losses and highest yields and agronomic efficiencies for broadcast surface flooded rice (BSFR). The farmers split application of urea or ammonium sulphate in two splits i.e. 1/3 at 15 DAS and 2/3 at 10 days after panicle initiation gave higher or comparable plant 15-N recoveries but not yields. However the Researchers split (2/3 as basal and 1/2 top dressed at 5/7 DBPI), gave higher yields because of timely application. In case of farmers split the yields were reduced due to delayed N application (De Datta et al., 1988). Based on a comparison with two methods of N application to broadcast surface flooded rice, ammonium sulphate gave higher 15-N recovery and lower N loss than urea; but yields were not significantly greater with ammonium sulphate.

Weed Management

Weeds are the most commonest problem in wet seeded rice mainly grasses (Moody, 1993). Weed competition is greater in wet seeded than in transplanted rice, moreover hand weeding is more difficult and
the crop is more sensitive to herbicides. However, where weeds can be controlled effectively, wet seeded rice will yield comparable to transplanted rice. Losses caused by weeds are likely to increase as direct seeding increasingly replaces transplanting. The shift from transplanting to direct seeding in South East Asia has resulted in a change in the weed distribution. Grassy weeds and dicot broad leaved weeds are becoming dominant under such conditions. The competitive advantage of transplanted rice is due to the age difference between two to three week old seedlings (15-30 cm tall) and the weeds that have just emerged, where as in wet seeding germination of rice seeds and the emergence of weeds take place almost at the same time. Because of this reason the weed menace is more under direct wet seeding.

Water is the key component in managing weeds. Shallow flooding early in the early stage of the crop generally promote germination and growth of grass weed species like *Echinocloa* and continuous flooding encourages broad leaf weeds (Hill *et al.*, 2000). Increasing the flooding depth from 5 to 20 cm controlled the *Echinocloa* from 16 to 77 per cent (Williams *et al.*, 1990). However, water management of 5 cm depth in combination with herbicide application effectively controlled the weeds and improved the yields significantly (Williams *et al.*, 1990).

Preventing infestation of new weeds, land preparation, water management, plant spacing, fertilizer application, hand weeding and use of herbicides are some of the means of weed control in rice (Moody, 1993).

Pooled yields of rice for four years gave significantly higher yields with Butachlor with safener @ 1.0 kg a.i./ha at Mandya. Butachlor with safener gave 5.33 t/ha which was more than 2 hand weedings at 20 and 40 DAS i.e. 5.15 t/ha (Subbaiah and Balasubramanian, 2000). Weed density and total weed dry weight were significantly low compared to unweeded check. Even pretilachlor alone with safener behaved in a similar way.

In sandy clay soils of Bangalore, butachlor with safener @ 1.5 kg a.i./ha recorded significantly higher yield (4.51 t/ha) during wet season and Anilophos (1.92 t/ha) in the dry season (Madhu *et al.*, 1996). The dry season yields were low compared to wet season. This was mainly due to higher sterility per cent owing to damage caused by rainstorm at the time of flowering.

Angiras and Rana (1998) reported the lowest weed dry matter per m² with butachlor 2.0 kg/ha + Safener 0.188 kg/ha at 7 DAS with the highest yield of 44.6 q/ha. Direct application of butachlor 1.5 kg/ha (2 DAS) has recorded lowest emergence and this may be due to interference of amylase activity in the seed by the herbicide (Venkataraman and Kempuchetty, 1996). Toxicity to rice seedlings was significantly less at 7 DAS than 2 DAS.

Application of butachlor @ 1.5 kg a.i./ha along with the safener at 3 DAS gave better control of weeds coupled with crop stand (Jayadeva *et al.*, 1998). Pretilachlor with safener @ 1.0 kg/ha was also found better.

Covering the rice seeds with inert materials like charcoal (1%) improved the germination percentage, and increased the rice yields. Reduction in the possible crop toxicity may be the reason (Venkataraman and Kempuchetty, 1996). In Korea weedicides are commonly used in wet seeded rice. Some of them are Pyrazosulfuron for early and intermediate application (10-20 DAS) and for late applications of 30-40 DAS, bentazon, 2, 4-D and propanil are used (Kim *et al.*, 2000).

**Water Management**

Water use productivity of rice in India is the lowest with only 18.5 kg rice grain produced per ha cm which needs to be improved.
In the conservation tillage experiments conducted at the DRR farm during the 1998-99 winter season, indicate that the total quantity of water required was 94.7 cm/ha for broadcast-sown rice, 59.2 cm/ha for drum seeded rice and 86. cm for transplanted rice. Saving of 31% of water was possible when drum seeding was adapted on puddled soil. There is also scope for reducing number of puddlings for rice, if effective weed control is practiced (Subbaiah and Balsubramanian, 2000), which is practically not available in India.

Maintaining 5 cm of water throughout the season did not differentiated the rice yields under transplanting or wet seeded rice. However significant difference in the water consumed was observed for transplanting (Balsubramanian et al, 2000). Reduced water consumption in the transplanted rice was because of non inclusion of nursery water consumption (Bhuiyan et al., 1995). However, for seed to seed duration, wet seeded rice matured two weeks earlier than transplanted.

Wet seeded rice has the ability to withstand water stress in comparison to transplanted rice. Withholding water after 30 days in wet seeded rice and after 11th day in transplanted rice for continuously 10 days or 20 days significantly affected rice yields under transplanted condition but did not in wet seeded rice. Even at panicle initiation stage also withholding of water significantly affected the grain yield by less than 359 kg/ha and 1005 kg/ha when water was withheld successively for 10 and 20 days respectively in transplanted. Considerable water saving was observed in wet seeded rice by 219 mm to 249 mm (Bhuiyan et al., 1995). Balsubramanian et al. (2000) found similar saving of 31.3 per cent of water in irrigating with 2.5 cm of water after a day of disappearance of water over transplanted and irrigated with 5 cm. Continuous submergence of 2.5 cm throughout the crop period recorded the highest crop productivity because of more grain yield with a minimum amount of water. Under severe water stress, more soil cracks at deeper perched water table levels were found in transplanted rice plots compared to wet seeded rice plots, which leads to the hypothesis that wet seeded rice roots held the soil together better against cracking in water short condition and were better supplied with soil-water during periods of stress.

The amount of water saved was 29 per cent in wet seeded rice for land preparation, 9 per cent in crop irrigation and in all 18 per cent of water was saved in wet seeded rice. The probable decrease in water requirement may also be due to shorter duration of nearly two weeks in wet seeded rice, hence yield level was also lower in majority of the cases.

Economics

Effects of direct wet seeded rice were more promising due to lesser man hour requirement (16 h) in comparison to transplanting (347 h) per ha of land (Subbaiah et al., 1999). Cost of cultivation was much lesser in drum seeding with higher gross returns and ultimately net returns. Similarly saving in terms of labour requirement and ultimately in terms of low cost of production was reported by Angadi et al. (2000). Net returns were higher when combined with the weed control methods also (Subbaiah and Balsubramanian, 2000).

Drum Seeders for Wet Seeded Rice

Drum seeder developed by IRRI and later modified to suit to local conditions is the major reason for adapting wet seeding in Andhra Pradesh and Karnataka. Plant population differed from 31-49 plants/m length when the holes were fully opened, to 11-36 in partially opened openings. The seed rate required was 53.3 kg/ha when opened in partial and was higher when opened fully i.e. 75 kg/ha (Murthy et al, 2000). However, the yields were lower in partially opened holes. The present day eight row drum seeder is adjusted
to maintain spacing between lines only, however intraspace adjustment is difficult. This needs to be adjusted with more distance between the holes.

Future Research Needs

So far the drum seeders developed are suitable for light textured soils only and there is a need to modify it for all other types of soils with reduced draft. The current draft is 30-40 kg. The study on application of fertilizers, herbicides and green manuring seeds sowing is required for better adaption.

CONCLUSION

Though transplanting is the popular method of crop raising in rice, it is tedious due to nursery raising, transporting of seedlings to the main field and transplanting. Direct wet seeding is the better option of crop raising as it saves considerable labour, time and water requirement with a possibility of increasing the cropping intensity. Weeds are the most problematic factor in direct wet seeded rice which can be controlled by effective use of chemicals like butachlor or pretachlor along with safener applying at three days after sowing. With suitable cultivars, land levelling, water and weed management it is possible to adapt direct wet seeding for rice cultivation profitably.

REFERENCES