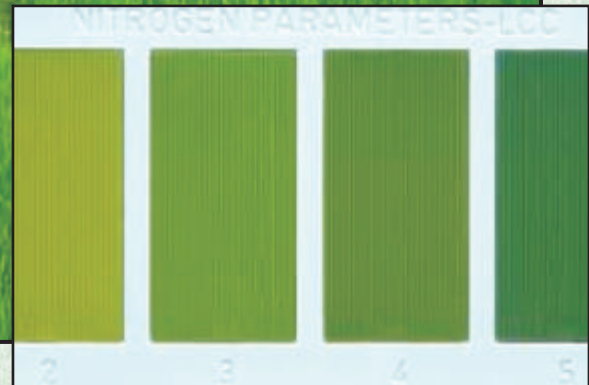


Direct Seeded Rice Technology in Western Indo-Gangetic Plains of India: CSISA Experiences



Cereal Systems Initiative for South Asia (CSISA)
International Maize and Wheat Improvement Centre (CIMMYT)
International Rice Research Institute (IRRI)

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Direct Seeded Rice Technology in Western Indo-Gangetic Plains of India : CSISA Experiences

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Direct Seeded Rice Technology in Western Indo-Gangetic Plains of India : CSISA Experiences

Executive Summary

This bulletin summarizes the experiences of direct seeded rice (DSR) during CSISA, phase-I (2009-2011) as well as outcomes of a multi stakeholder travelling seminar on dry direct seeded rice (DSR) organized by Cereal Systems Initiative for South Asia (CSISA) Haryana Hub on 20th September 2011. About 70 stakeholders of CSISA Haryana hub including scientists from Central Soil Salinity Research Institute (CSSRI) and Krishi Vigyan Kendra's (KVKs), officers from State Department of Agriculture, agriculture extension officers from private sector, members of Technical Working Group (TWG) of Haryana hub, local machine manufacturers, and participating farmers gathered together to share their experiences on DSR. The underlying objectives were to (i) visit on-farm and on-station trials on DSR in Karnal district of Haryana for participatory assessment and learning of performance and potentiality of DSR, (ii) create awareness about DSR technology, (iii) facilitate interaction among different stakeholders who are engaged in developing, refining and out-scaling of DSR technology and share experiences, (iv) summarize and update technological package of DSR for Haryana, (v) identify constraints associated with DSR, and (vi) identify the future research needs.

The travelling seminar was strategically structured into two parts; (i) visit farmer participatory DSR fields as well as on-station strategic research trials on DSR and (ii) a round table discussion by all stakeholders. During

field visit, a total of three sites were covered, including one on-station site (CSISA Research Platform at CSSRI, Karnal) and two farmer's participatory conservation agriculture (CA) modules established with innovative farmer cooperatives at village clusters of Taraori and Modipur of Karnal district. At CSISA Research Platform, performance of zero-till (ZT) DSR under double ZT systems was elucidated to the participants. In addition, trials on weed management and varietal screening for DSR conditions were briefed. At farmer participatory CA modules at Modipur & Taraori, participants were exposed to large scale demonstrations on DSR and adaptive research trials on different component technologies of DSR (varietal evaluation, weed management, water management and nutrient management) conducted through farmer cooperatives in collaboration with CSISA hub and partners. Based on large number of demonstrations on DSR using super fine varieties and hybrids of rice conducted in 8 hub districts across 3 years (2009-2011), it was verified that grain yield of DSR in comparison to puddled transplanted rice was either similar or higher with US\$ 128-137/ha higher net profitability. Demonstration on DSR under double ZT system at village Taraori was also highly appreciated as the population of earthworms and vermicast was visible on the plot. All the participants were impressed with the performance of DSR and potential benefits it can endow on farmers like savings in labour, water (20-25%), and cost of cultivation.

During round table discussion on DSR at CSSRI Karnal, Dr. D. K. Sharma (Director, CSSRI & TWG Chair, CSISA Haryana) highlighted the importance of DSR while elaborating the issues of declining water table due to over exploitation of ground water, labour scarcity, escalating cost of cultivation and deteriorating soil health under current management practices of rice-wheat cropping system. CSISA Hub coordinator, Haryana) while sharing the joint experience of CSISA and partners on DSR in Haryana, presented the summary of the technological package of DSR for North-western IGP including Haryana for discussion and finalization of the recommendations of DSR package for large scale delivery. This was based on the outcomes of farmers' participatory adaptation and demonstrations of DSR and its component technologies in Haryana in CSISA phase-I during past 3 years (2009-2011).

Approaching the consensus, everyone confirmed that precise land levelling with laser land leveller, effective weed management, precise sowing depth and time of sowing are critical for the success of DSR. The DSR technology may also play vital role

in recharge of ground water and reduction in water runoff during heavy rain fall. Partners from public (KVK's, ICAR, CCSHAU) and private sector (DevGen seeds, Bayer, HKB) shared their experiences on DSR and advocated its large scale promotion. Participating farmers also shared their experiences and found weed control being the most challenging task in DSR and thus achieving optimal weed control a route to its success. They experienced that pre and post-emergence herbicide application is important to manage weeds effectively in DSR. The issue of poor crop establishment due to sudden rainfall soon after sowing was also put up by some of the farmers. All participants very much convinced about DSR, pledged to make it a revolution in Haryana, and hence emphasized the access to literature on technology package for DSR. Finally, the participants suggested that to attain potential benefits of the DSR technology, further refinements of some of the component technologies for example varietal development for DSR, water management, nutrient management etc needs immediate efforts of the researchers.

1. Introduction

South Asian countries comprising India, Pakistan, Bangladesh and Nepal, having a total geographical area of 437.45 million ha (3.26% of world geographical area), hold about 1.58 billion population (about a quarter of world population). The total rice-wheat production in these countries is 314.5 million tonnes, about 25% of world food production (FAO, 2010). The agricultural scenario in South Asian countries during the mid- 1960s to 1990 was in favour of high input and high productivity technology, which resulted in production enhancement to meet food grain demand of the accelerating population. However, the decade of 1990-2000 witnessed over-exploitation, causing widespread deterioration in soil and water resources. The conventional systems created problems of high production cost, low input-use efficiency, decline in groundwater, deterioration in soil health, and environmental pollution. The intensive use of water in conventional puddled transplanted rice (CT-TPR) cultivation in northwest IGP is depleting aquifers at the rate of 11-13 km² annually. Therefore, it has been imperative to use conservation agricultural techniques for sustained production.

Rice is the major *Kharif* crop of India covering 42.8 million ha amounting to 85.7 million tonnes of production (India.gov.in, 2012). Haryana contributes more than 1 million ha area under rice cultivation. The demand of cereals to meet the food requirements of the burgeoning population is increasing while on the other hand most vital inputs of agriculture viz. water and labour are depleting in the area. The conventional system of rice production (CT-TPR) in this region is basically water, labour and energy intensive, adversely affecting the environment. Therefore, to sustain the long term production of rice, more efficient alternative methods of rice productions are needed. For this, Dry direct Seeded Rice (DSR) is the technology which is water, labour and energy

efficient along with eco-friendly characteristics and can be a potential alternative to CT-TPR (Kumar and Ladha 2011).

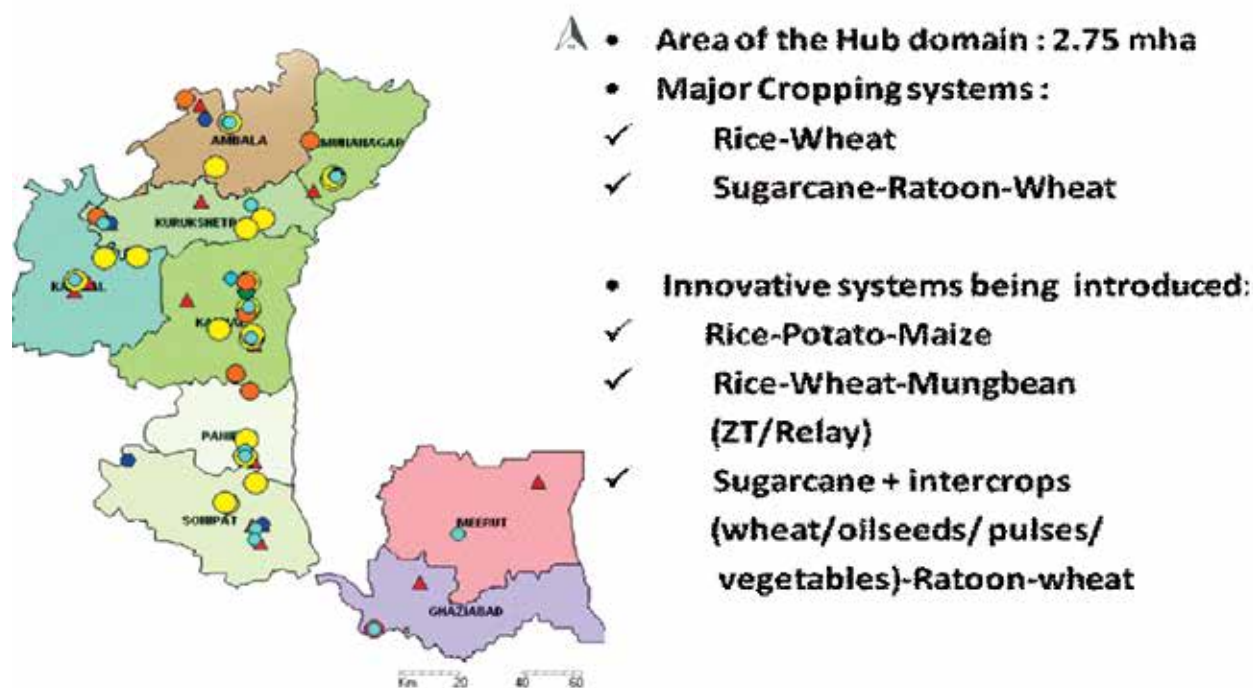
The travelling seminar is a regular activity of CSISA to help in the dissemination of the new technologies, demonstrate the socio-economic and biophysical impacts of the emerging technologies and generate new ideas for the refinement and upscaling of technologies in a farmers' participatory mode. The seminar provides a unique opportunity to all the participants to discuss about the advantages, component technology management and constraints to promote wider adoption of DSR. The objectives of the seminar were to:

- ❖ Visit on-farm and on-station trials on DSR in Karnal district of Haryana to assess the potential and performance of DSR,
- ❖ Increase awareness about DSR technology,
- ❖ Facilitate interaction among different stakeholders involved in studies related to DSR
- ❖ Summarize technological package of DSR for Haryana,
- ❖ Identify constraints associated with DSR, and
- ❖ Identify the future research needs

The travelling seminar was divided into two parts. The part-1 was field visit of both on-farm and on-station demonstrations/trials on various aspects related to DSR. The part-2 was a round table multi-stakeholders discussion on DSR technology.

2. CSISA Haryana Hub-An introduction

CSISA Haryana Hub (CSISA Hub #3) has been operationalized in 7 districts of Trans-Gangetic plain in Haryana (Karnal, Krukshetra, Ambala, Kaithal, Panipat, Sonapat, Yamuna Nagar) and 2 districts of Upper-Gangetic plain in



(Map source: CSISA hub characterization report by HCP-aWhere)

Figure 1. The map showing the operational area of CSISA Haryana hub

western Uttar Pradesh (Meerut, Ghaziabad) (Figure 1) wherein rice-wheat and wheat-sugarcane systems were prioritized for rolling-out of matured CA technologies and fine-tuning of potential CA technologies. Monotonous and intensive cropping systems with low system diversity, deteriorating soil health, multiple nutrient deficiency, declining nutrient response, residue burning, receding ground water table, labour & energy shortages coupled with emerging issues of climate change, mismatched policy perceptions (for example rotavators versus zero-tillage) and less existence of public-private partnership for R&D leading to shrinking farm profitability have been identified as key problems in these 2 cropping systems. To address the problems of cropping systems, delivery and adaptive research plan has been developed through identification of key technological interventions in consultation with the strong public and private sector partners and Technical Working Group (TWG) of hub and other stake holders of the project.

3. About the travelling seminar

Travelling seminar was organized into two parts. The part-1 was field visit of both on-farm and on-station demonstrations and trials on DSR. The part-2 was round table discussions on DSR technology.

3.1. Part-1 (Field visit)

During field visit, three sites were covered including one on-station site (CSISA Research Platform at CSSRI, Karnal) and two farmer's participatory conservation agriculture (CA) hubs established at village Taraori and Modipur of Karnal district.

3.1.1. Visit of CSISA research platform, CSSRI (On-station site)

At research platform, participants were explained about ongoing long term cropping systems trials to address emerging problems

of labour and water shortage, declining factor productivity, farm profitability and soil health. Four scenario treatments varying in tillage and crop establishment methods, residue management, and cropping systems were included (i) Scenario 1 - Farmer's practice with rice-wheat rotation under conventional tillage, crop establishment (transplanting in rice and broadcasting in wheat), and residue management (removed), (ii) Scenario 2 - Best integrated crop and resource managed rice-wheat-mungbean rotation, (iii) Scenario 3 - Best integrated crop and resource managed rice-wheat-mungbean rotation with zero-tillage, direct seeding and retention of crop residue to deal with the rising scarcity of labour, water, energy and deteriorating soil health and changing climate, and (iv) Scenario 4 - Futuristic and diversified cropping systems with best integrated crop and resource managed maize-wheat-mungbean rotation with zero-tillage, direct seeding and retention of crop residue to deal with rising scarcity of

labor, water, energy, deteriorating soil health and changing climate. Participants showed their interest and were impressed with the performance of DSR under continuous ZT systems. Dr. Virender Kumar, Research Platform Coordinator also briefed about the on-going research on water and weed management and breeding rice varieties appropriate for mechanized direct-seeding conditions.

3.1.2. Visit to Modipur and Taraori (On-farm sites)

At farmer participatory CA hub at Modipur and Taraori, participants were exposed to large scale demonstrations on DSR conducted through farmer's societies. Results of adaptive research trials on varietal evaluation, weed management, water management and nutrient management conducted by CSISA were also explained. At these sites farmers as well as other partners raised queries like whether there are special varieties suited



Figure 2. View of Field Visit during travelling seminar on DSR

to DSR conditions, how to manage weeds effectively and how much water is saved by growing rice under direct-seeding method. Dr. B.R. Kamboj showed the performance of different herbicide molecules in terms of weed control and told that Pre-emergence (topstar or pendimethaline) followed by post-emergence (bispyribac or azimsulfuron) treatments were effective in controlling most of the weeds. Mr. Pardeep Kumar (DSR Grower, Modipur) notified that one can manage 15 acres of paddy under DSR technology with same amount of water required for managing 10 acres of puddled transplanted rice. At Taraori, DSR demonstration under double no-till system, brought immense persuasion among the participants, as the population of earthworms and vermicast was visible on the plot. The performance of crop was also remarkably superior in double no-till field. All the Participants highly appreciated the trials and demonstrations on DSR technology.

3.2. Part-2 (round table discussion)

During round table discussion on DSR at CSSRI Karnal, Dr. D.K. Sharma (Director, CSSRI) highlighted the importance of DSR looking at the issues of declining water table and over exploitation of under-ground water, rising labour scarcity and cost of cultivation and sustainability in rice wheat cropping system. He highlighted the benefits of DSR technology including water, labour, time & energy savings, reduction in cost of cultivation as compared to puddled transplanted rice. Dr. Sharma emphasized to conduct more farmer participatory research trials to fine tune this technology. He appreciated the collaborative farmer participatory research trials approach and expressed that such approach will be helpful in getting rich feedback from the farmers to overcome the shortcoming of the technology. Such demonstration/trials will play a vital role in wide spread adoption as these demonstrations are based on the concept

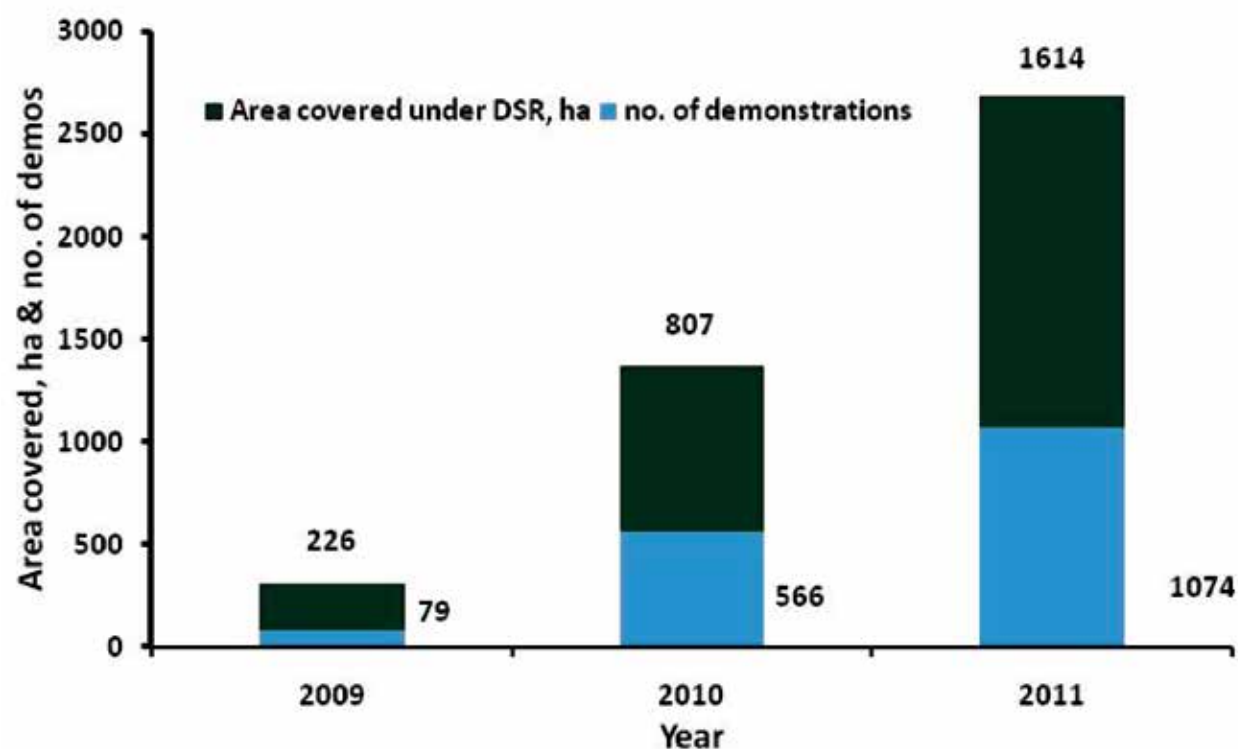


Figure 3. Number of demonstrations and outreach of DSR in Haryana

of “seeing is believing”. He emphasized to develop literature on DSR in Hindi for better understanding by the farming community and suggested to tie a partnership to achieve wider adoption of the technology.

Dr. B.R. Kamboj (Hub coordinator, CSISA) briefed about current status and scope of DSR in Haryana state. He shared the outcomes of demonstrations and adaptive research trials conducted during Phase-1 of CSISA by hub partners and summarized the technological package of DSR for North-western IGP including Haryana state which is discussed in section 4. He shared with the participants that with the concentrated efforts of all stakeholders, area

under DSR technology has increased from 226 ha during *Kharif* 2009 to 1614 ha during *Kharif* 2011 (Figure 2). The results of trials/demonstrations conducted on DSR in experimental fields as well as at the farmers’ fields clearly justify this expansion of area under DSR revealing reducing cultivation cost besides addressing the issues of farm labour shortage and declining water table in rice-wheat cropping systems.

He stressed that strong public private partnership (PPP) was the key in expanding the area under DSR in Haryana under CSISA project. No. of DSR demonstrations conducted by partners increased from zero in year 1 to 898 in third year of the project (Table 1).

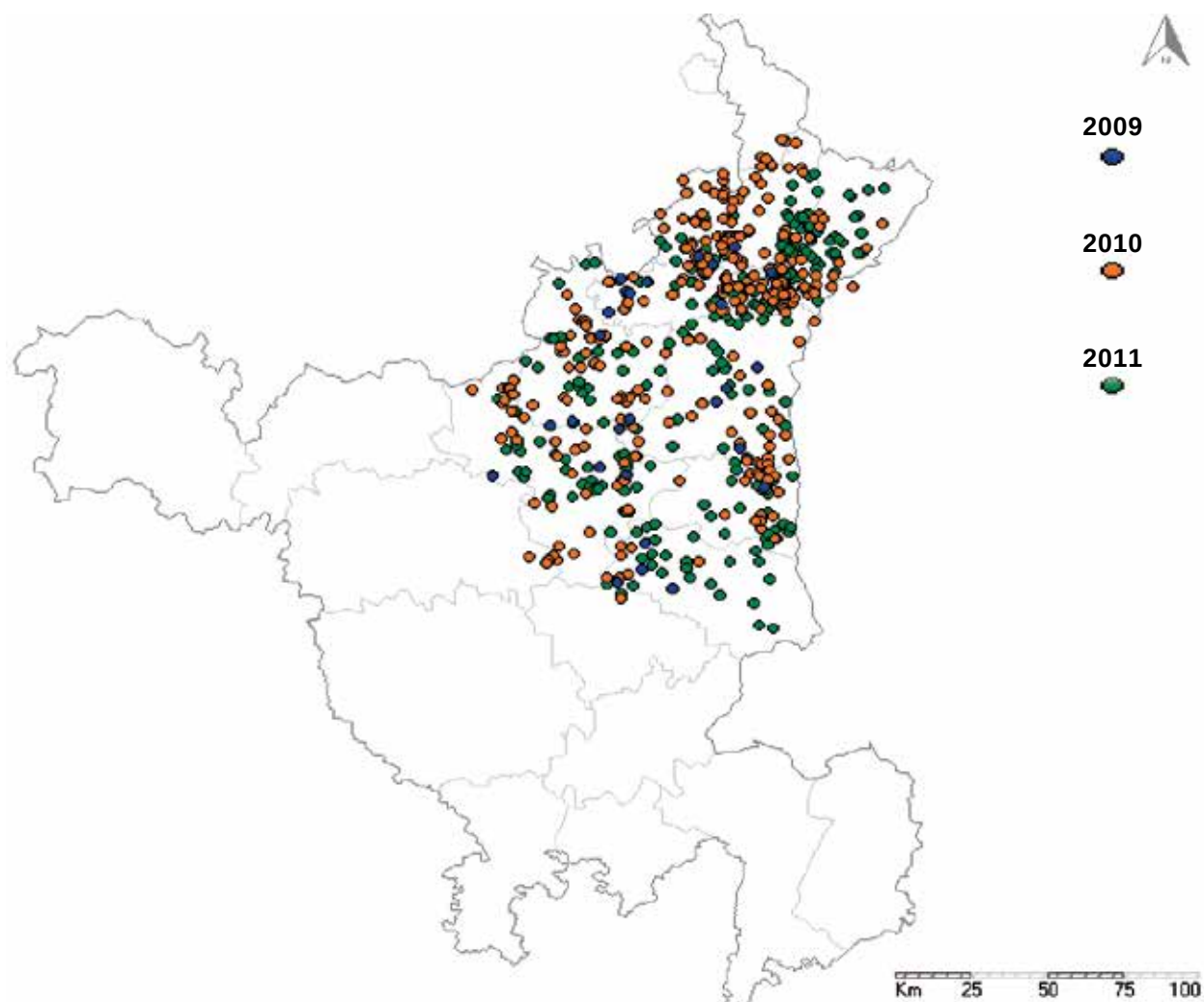


Figure 4. Adoption of DSR in Haryana (Map source: CSISA-HCP)

Table 1. Number of demonstrations by hub and partners

No. of DSR Demonstrations					
2009		2010		2011	
Hub	Partner	Hub	partner	Hub	Partner
79	00	221	345	176	898
Partners : CCS Haryana Agricultural University, KVKs, State Agriculture Department, Bayer Crop Science, DevGen Seeds & Crop Technologies limited, Syngenta, DOW Agro, Haryali Kisan Bazar, Farmer Cooperatives, Service providers, ICAR Institutions					

Participating scientists from KVKs told that laser levelling, effective weed management, date of sowing and sowing depth are key factors for success of DSR technology. Mr. Harpreet Singh, farmer of Kalvehri village, Karnal also supported critical role of laser leveller in the success of DSR. Dr. S.S. Dahiya shared his experiences of farmer fields' demos/trials in detail. He also reiterated the fact that laser land leveling is must to improve the success rate of DSR as uneven topography will lead to poor crop establishment besides more water requirement.

Dr. Dahiya shared the results of the trails conducted on date of sowing of DSR during *Kharif* 2010, which varied from 15th May to 24th June. The outcome was that crop of paddy sown on 24th June with PUSA 1121 gave highest yield. He further explained that the farmer was able to harvest 15% higher wheat yield sown after implementing DSR as compared to wheat crop sown after puddled transplanted rice. They observed high runoff in puddled transplanted rice at the time of high rain falls, however percolation was much higher in DSR which may help in rejuvenation of ground water. Therefore, DSR technology on one hand helps in saving irrigation water by avoiding water for puddling as well as ponding condition during crop growth season and on the other hand works for replenishment of ground water table.

Dr Rajbir Garg urged to conduct more research to quantify water saving in DSR. He was of the

view that in puddled transplanted rice we can not be as precise with respect to transplanting time as it is dependent on labor availability but in case of DSR with the introduction of multi-crop planter we can sow the crop on time. Dr. Anil Khippal from KVK Kaithal highlighted the importance of depth of sowing in dry and vattar conditions. He shared that depth of sowing may be 3-4 cm in vattar sowing but in dry sowing should not exceed 2.5 cm. Dr. S.P. Goyal (KVK, Kurukashetra) shared his 3-4 years of experience of working with DSR. He informed the participants that he has observed very less incidence of foot-rot/bakani disease in DSR compared to TPR.

Partners from private sector viz. DevGen seeds, Bayer, HKB shared their experiences on DSR and were happy with the performance of DSR demonstrations conducted at farmers' field in collaboration with CSISA. Dr. Rajesh Bhatia from Dev Gen seeds shared his experience on DSR work undertaken in collaboration with CSISA and expressed contention with the success rate during *Kharif* 2011 compared to *Kharif* 2010. He explained that short duration hybrid RH 257 performed equally well in DSR as in TPR. and emphasized to remain more cautious about iron & zinc deficiency particularly in light soils in case of DSR. Further he directed the need to develop extension literature with best management practices to update the knowledge of extension functionaries of public and private sector with the new information on new chemicals for weed management, seed rate; nutrient management water

management and other management practices which have been fine-tuned by the research organizations. Mr. S.S. Bisth from Haryali Kisan Bazaar (HKB) shared that HKB has conducted DSR demonstrations in more than 300 acres during Kharif 2011. He told that the farmers were happy with the performance of DSR and desired for increase in area under this technology provided farmers have ready access to more machines and technical knowhow with help of flexible Govt. facilities. Dr. J.R. Jat from Syngenta and J.S. Chauhan from Dow Agro stressed on capacity building of extension agents for wider adoption of the technology.

Participating farmers while sharing their experiences highlighted that effective weed management is the key for the success of DSR and pre & post emergence herbicide application are imperative to keep weed under check in DSR. They expressed the need for and demanded updated literature on the best management practices of DSR in local language.

Harpreet Singh resident of village Kalvehri who adopted the DSR technology on his farm during Kharif 2011, emphasized the need of laser land leveling for proper crop establishment in DSR and proper spray technique for managing weed in DSR. He told that at least 200 liters of water per acre is required for spraying pre-emergence herbicides. Like wise optimum moisture in the field after post emergence herbicide application of bispyribac-sodium improves its efficacy. Mr. Deevan Singh resident of village Kalvehri raised the issue of early sowing of DSR on around 15th May instead of 15th June as DSR crop needed to be sown 20-25 days earlier than transplanted crop. Responding to the query Mr. Rajbir Singh, official from Department of Agriculture clarified that the deadline of 15th June has been fixed for transplanted paddy not for DSR.

Sharing his experiences Sh. Sukhjinder Singh, progressive farmer from Pehowa elaborated

that he has been growing DSR since kharif 2010 and opined that good crop establishment and weed management are the key factors for success of DSR. He adopted the technology after seeing the DSR crop at CSSRI and farmers' field during travelling seminar. He experienced saving of water and labor in his DSR crop compared to conventional puddled rice.

4. Technological package of DSR for north-western IGP

Based on previous experiences and the current experience of working on DSR during Phase-1 of CSISA, technological package of DSR for north-western IGP conditions has been summarized here.

4.1. Laser land leveling

The precise land leveling is a pre-requisite for growing successful crop of DSR which can be achieved by laser land leveler. It facilitates good and uniform crop stand, enabling the farmer to apply uniform irrigation, leading to improved weed control and nutrient use efficiencies in comparison to traditional land leveling. Other benefits include savings in irrigation water, and higher crop productivity (Jat *et al.* 2009). It facilitates seed drills/ planters to place seeds at uniform spacing and depth and uniform distribution of water hence resulting in uniform crop stand (Kumar and Ladha 2011). Undulation in traditionally level fields often leads to poor establishment of DSR due to uneven depth of seeding and uneven water distribution; henceforth precision in land leveling is first step for better DSR crop.

4.2. Soil type

DSR can be grown in almost all type of soils suitable for rice, but medium textured soils are more suited to DSR.

4.3. Field/seedbed preparation

The method of seedbed preparation will depend on tillage method and will vary for conventional and conservation tillage systems. For conventional till DSR, field should be pulverized to maintain good soil moisture and to maximize soil to seed contact. For ZT DSR, existing weeds should be killed by burning down herbicides such as paraquat (0.5 kg ai/ha or glyphosate (1.0 kg ai/ha) (Kumar and Ladha 2011; Gopal *et al.* 2010).

4.4. Planting dates

In northern western IGP, rice is grown during the monsoon season (*Kharif*) when rainfall is high. To optimize the use of monsoon rain, the optimum time for sowing DSR is about 10-15 days prior to onset of monsoon. Based on the historical trend of onset of monsoon in the north-western IGP, the optimum time of seeding rice in the region is from June 1 to July 20 which can go up to July 1. (Kumar & Ladha, 2011)

4.5. Cultivar selection

Among the existing varieties and hybrids which are though bred for puddled rice, some hybrids & basmati varieties have been found suitable for DSR. These are given in Table 2.

Table 2 : Rice varieties found suitable for DSR in Haryana.

Group	Varieties/ Hybrids
Basmati	Pusa-1121 (Sugandha 4), Pusa Basmati-1, CSR-30
Coarse rice	Hybrids : PRH-10, Arize 6129, RH 257, Arize 6444, PHB-71 Inbred varieties : PR-114, HKR 47

4.6. Crop establishment

For conventional till DSR, rice can be established by two ways *i.e.* vattar sowing (seeding after

pre-sowing irrigation at field capacity) or dry sowing followed by light irrigation. Vattar Sowing or applying irrigation just after seeding in dry is helpful to support germination and early growth when pre-monsoon showers are insufficient. In vattar sowing, planking after seeding helps in conserving soil moisture, hence maximize uniform crop establishment. For ZT-DSR, rice can be drilled in dry followed by a light irrigation for uniform crop stand.

4.7. Seed rate, seeding depth and seed treatment

A seed rate of 16-20 kg/ha has been found optimum for DSR. The seeding depth for rice is critical and it should not be drilled deeper than 2-3 cms. Seed treatment with recommended fungicide is necessary to manage soil born diseases. For this weighed quantity of seeds are soaked in water + fungicide (Bavistin @ 1g/kg rice seed or Emisan @ 1gm/kg rice seed) solution for 24 hours. Amount of water used for soaking is equivalent to quantity of seed used for seed treatment. After 24 hours, seeds are removed from fungicide solution and dried in shade for 1-2 hours before sowing. Seed treatment with imidacloprid (Guicho) @ 3ml/kg seed alone to protect from soil-borne pathogens such as termites or other insects or in combination with tebuconazole (raxil) @ 1 ml/kg seed to protect from both soil borne fungi and insects have been found effective in improving uniform crop establishment.

4.8. Sowing machines

For precise seeding, rice should be drilled with a multi-crop planter fitted with inclined plates seed metering systems and inverted T-type tynes (Figure 5). For ZT-DSR, when only anchored residues are retained, then same multi-crop planter can be used for seeding. However, when loose crop residues are present on the soil surface, specialized machines are



Figure 5. Different machines which can be used for seeding rice: a) Multi-crop planter with inclined plate seed metering system, b) turbo happy seeder

needed for drilling rice. In such situations, rice can be drilled using any of the following machines: turbo happy seeder, rotary disc drill (Gopal *et al.* 2010; Kumar and Ladha 2011) (Figure 5).

4.9. Fertilizer management

Fertilizer recommendation for DSR is same as for puddled transplanted rice. However, it is advisable to apply 12-15 kg extra N in DSR than puddle transplanted rice. For Haryana conditions, following fertilizer doses are recommended for DSR:

Coarse rice : 150 to 165 kg N/ha, 60 kg P_2O_5 /ha, 60 kg K_2O /ha, and 25 kg Zinc sulphate/ha)

Basmati rice : 60-75 Kg N/ha , 30 kg P_2O_5 and 25 kg $Zn SO_4$

Apply full dose of P, K, and $ZnSO_4$ and 23 kg N/

ha as basal at the time of sowing using seed-cum fertilizer drill/planters. The remaining N should be applied in three equal splits at early tillering, active tillering and panicle initiation.

Nitrogenous fertilizers can also be managed using leaf colour chart (LCC). Two approaches have been recommended to apply Nitrogen using LCC (Figure 6) :

A) Fixed time approach : After basal application of N, remaining N is applied at preset timing of active tillering and panicle initiation and dose is adjusted based on LCC reading of N application should be based on LCC value of 3 and 4 depending on cultivars.

B) Real time approach : After basal application colour of rice leaves is monitored at regular interval of 7-10 days from active tillering and

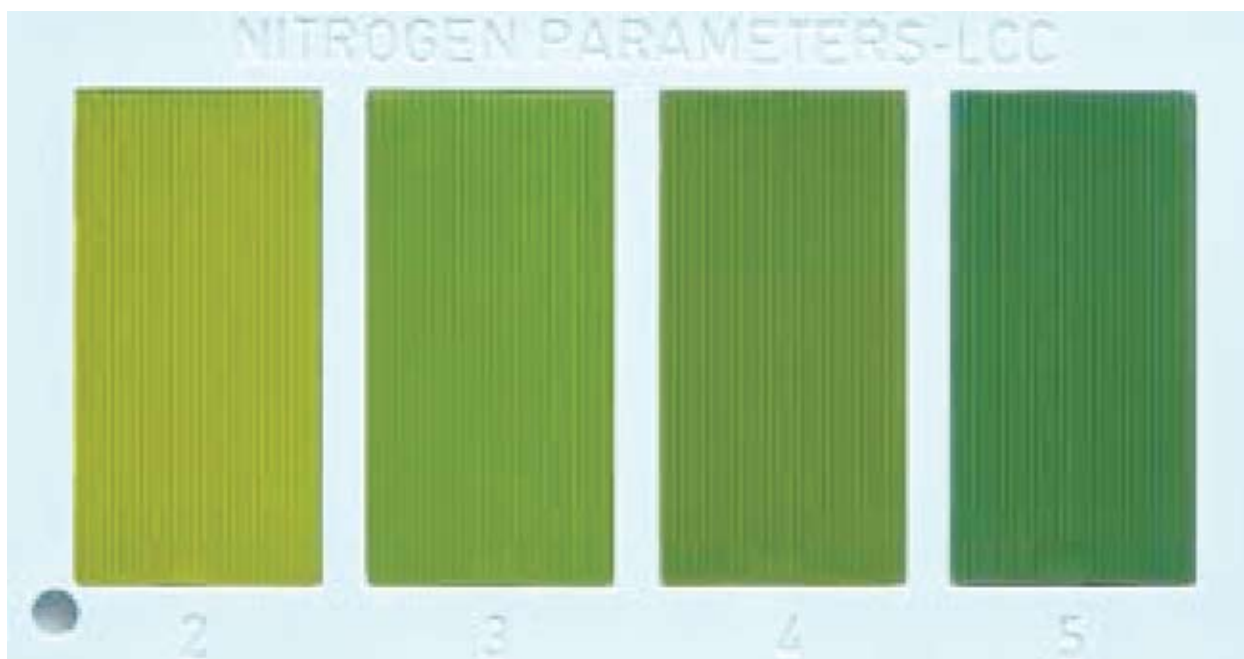


Figure 6. Leaf Colour Chart (LCC)

N is applied wherever leaf colour is below critical threshold value.

For hybrids and high yielding coarse rice varieties N application should be based on a critical LCC value of 4 whereas for basmati rice N should be applied at LCC critical value of 3.

Sometimes deficiency of iron may appear under DSR, which can be corrected by applying 2-3 foliar sprays of 1% FeSO_4 solution at weekly intervals.

4.10. Efficient and economical weed management

Integrated weed management (IWM) approach is needed for effective and sustainable weed management in DSR. IWM consists of (1) cultural, (2) chemical, (3) physical (4) biological control methods which are described below:

Cultural Methods

Stale seedbed technique : In this technique, weeds are encouraged to germinate by giving one irrigation and then killed by either a non-

selective herbicide (paraquat or glyphosate) or by tillage prior to sowing of rice. This method has great potential in suppressing weeds and is feasible under Dry-DSR because of >1 month window of fallow period after wheat harvest and sowing of succeeding rice crop.

Residue mulching : Crop residues of previous crops if left on soil surface as mulch can suppress weeds in DSR through multiple mechanisms, including, creating a physical hindrance to emerging weeds or by releasing allelochemicals in the soil.

Sesbania co-culture : It involves seeding rice and sesbania crops together and then killing sesbania with 2, 4-D ester about 25-30 DAS. Sesbania grows rapidly and suppresses weed. This practice is found more effective in suppressing broadleaf weeds than grasses and therefore if combined with pre-emergence application of pendimethalin, its performance in suppressing weeds increases. However, care should be taken with practice as it may pose some risks if properly not implemented

including (1) competition of sesbania with rice if 2, 4-D application is ineffective or its application is delayed due to continuous rain, and (2) limit the use of several herbicides (e.g. bispyribac) which may be helpful for controlling certain weeds, cannot be used in this system without also killing the sesbania cover crop.

Chemical methods

Pre-plant/burndown herbicides : These herbicides are used to kill existing vegetation prior to rice sowing under ZT-DSR. Glyphosate (1.0 kg ai/ha or 1% by volume) and paraquat (500 g ai/ha or 0.5% by volume) are recommended for burndown application. Clean water should be used for applying these herbicides. Muddy water reduces their efficacy. If fields are infested with perennial weeds, glyphosate should be applied instead of paraquat.

After crop sowing : Based on on-station and on-farm studies, it has been found that pendimethalin (stomp)/oxadiargyl (top star) as pre-emergence followed by post-emergence

application of bispyribac or azimsulfuron or bispyribac + azimsulfuron 15-20 DAS yielded similar to weed-free conditions. Herbicides, alone or in combination, which have been found effective against different weed species are summarized in Table XXX.

Herbicides should be applied using multiple (three) nozzle boom fitted with flat fan nozzle.

Physical control

Physical weed control consists of removing weeds by hand (manual weeding) or by machines (mechanical weeding). It is practically and economically not feasible to control weeds by manual methods because of rising scarcity of labour and rising labour wages. However, one or two spot hand weedings may be justifiable in DSR to remove escaped weeds and prevent weed seed production. Mechanical weeding can be useful in reducing labour use in weeding, for this Motorized cono-weeders are available in the region and can be included as part of IWM. More research is needed to develop new

Table 3. Major pre- and post-emergence herbicides identified suitable for weed control in DSR in the IGP

Herbicide	Dose (g ai ha ⁻¹)	Application time (DAS) ^a	Strengths and weaknesses
Pendimethalin	1000	1-3	Good control of most grasses, some broadleaves and annual sedges. Has residual control. But sufficient moisture is needed for its activity.
Oxadiargyl	90	1-3	Broad-spectrum weed control of grasses, broadleaves and annual sedges. Has residual control. But sufficient moisture is needed for its activity.
Bispyribac-sodium	25	15-25	Broad-spectrum weed control of grasses, broadleaves and annual sedges. Excellent control of <i>Echinochloa</i> species. But it is poor on grasses other than <i>Echinochloa</i> species, including <i>L. chinensis</i> , <i>Dactyloctenium aegyptium</i> , <i>Eleusine indica</i> , <i>Eragrostis species</i> . No residual control.
Penoxsulam	22.5	15-20	Broad-spectrum weed control of grasses, broadleaves and annual sedges. But it is poor on grasses other than <i>Echinochloa species</i> , including <i>L. chinensis</i> , <i>D. aegyptium</i> , <i>Eleusine indica</i> , <i>Eragrostis species</i> .

Herbicide	Dose (g ai ha-1)	Application time (DAS) ^a	Strengths and weaknesses
Fenoxaprop-ethyl	60	25	Excellent control of annual grassy weeds. Does not control broadleaves and sedges. Not safe on rice if applied at early stage (before 25 DAS).
Fenoxaprop-ethyl + safner	60-90	15-20	Excellent control of annual grassy weeds, safe on rice at early stage. Does not control broadleaves and sedges.
Azimsulfuron	17.5-35	15-20	Broad-spectrum control of grasses, broadleaves and sedges. Excellent control of sedges, including <i>Cyperus rotundus</i> . Poor on <i>Echinochloa</i> species.
Ethoxysulfuron	18	15-20	Effective on broadleaves and annual sedges. Does not control grasses and poor on perennial sedges such as <i>C. rotundus</i> .
Triclopyr	500	15-20	Effective on broadleaf weeds. Does not control grasses.
2,4-D ethyl ester	500	15-25	Effective on broadleaves and annual sedges. Very economical. Has no residual control.
Carfentrazone	20	15-20	Effective on broadleaf weeds. Does not control grasses. Has no residual control.
Chlorimuron + metsulfuron	4 (2+2)	15-25	Effective on broadleaves and annual sedges. No control of grassy weeds and poor on <i>C. Rotundus</i> .
Bispyribac + azimsulfuron	25+17.5	15-25	Broad-spectrum weed control of grasses, broadleaves and sedges, including <i>C. rotundus</i> . Poor on grasses other than <i>Echinochloa</i> species.
Bispyribac + pyrazosulfuron	25+25	15-20	Broad-spectrum weed control of grasses, broadleaves and sedges, including <i>C. rotundus</i> . Poor on grasses other than <i>Echinochloa</i> species.
Fenoxaprop + ethoxysulfuron	56 + 18	15-25	Broad-spectrum weed control of grasses, broadleaves and sedge. Excellent control of all major grasses, including <i>L. chinensis</i> and <i>D. aegyptium</i> . Poor on perennial sedges such as <i>C. rotundus</i> .
Propanil + pendimethalin	4000 + 1000	10-12	Broad-spectrum weed control with residual effects. Poor on sedges such as <i>C. Rotundus</i> .

(Source: Kumar and Ladha, 2011)

mechanical tools which are more efficient and user friendly.

4.11. Water management

In case of DSR crop established after applying pre-sowing irrigation (Vattar), first irrigation can be applied 7-10 days after sowing depending on the soil type. When DSR crop is established in dry/ ZT conditions followed by irrigation, subsequent 1-2 irrigations are required at interval of 3-5 days during crop establishment

phase. Subsequent irrigations at interval of 5-7 days need to be applied in DSR crop. During active tillering phase *i.e.* 30-45 DAS and reproductive phase (Panicle emergence to grain filling stage) optimum moisture (irrigation at 2-3 days interval) is required to be maintained to harvest optimum yields from DSR crop. It is recommended to avoid water stress at flowering; one of the most sensitive stages of rice to water stress, frequent irrigations should be given one week before and one week after flowering.

5. Lessons Learnt

- ❖ Direct seeding is a viable alternative to puddled transplanting to overcome the problem of labour and water shortage.
- ❖ Large scale adoption of DSR is possible but prioritizing resources and public - private - partnership (PPP) holds the key.
- ❖ Crop establishment determines the success of DSR for which precise leveling (laser leveling), quality multi crop planter (inclined seed metering system) and trained tractor operators are important.
- ❖ Depth of seeding should be manipulated according to soil type, establishment method & moisture level.
- ❖ DSR in double no-till system is even better practice.
- ❖ Short duration hybrids and basmati rice varieties performs better under DSR but tailoring varieties for DSR should form the breeding strategy for further productivity gains in DSR.
- ❖ Pre & post emergence herbicide application is must for effective weed management but the choice of herbicides should be as per the dominant weed flora.
- ❖ Incidence of foot rot and false smut is remarkably lower in DSR.
- ❖ Positive effects on yield of succeeding upland crops.
- ❖ DSR may be helpful in recharging ground water table.
- ❖ The water savings in DSR varies across management practices, soil types etc but still optimization of water saving have to be worked-out in a way so as to avoid any yield penalty due to water stress.



Figure 7. A blooming DSR crop at maturity stage

6. Potential constraints

- ❖ Poor crop establishment due to variable rainfall pattern during crop establishment stage.
- ❖ Difficult to manage mixed weed flora including non paddy weeds like *Leptochloa*, *Eragrostis*, *Dactyloctenium*.

7. Future research needs

- ❖ Develop sustainable and effective weed management options employing integrated approach of chemical and non-chemical strategies
- ❖ Developing cultivars suited to DSR for different rice based systems
- ❖ Develop irrigation scheduling for different soil types and management practices of DSR based systems
- ❖ Understand nutrient dynamics and develop management strategies including dose and application scheduling
- ❖ Monitor GHG emissions and develop strategies to reduce N losses vis-a-vis N₂O emissions under aerobic conditions
- ❖ Optimization of crop residue cover needs in systems' perspective
- ❖ Understanding pest and disease dynamics and define management strategies under DSR

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