



Direct Dry Seeded Rice Production Technology and Weed Management in Rice Based Systems



National Agricultural Innovation Project (NAIP)
Indian Council of Agricultural Research (ICAR)
International Maize and Wheat Improvement Center (CIMMYT)
Cereal Systems Initiative for South Asia (CSISA)

Citation: Gopal, Ravi; Jat, R.K.; Malik, R.K.; Kumar, V.; Alam, M.M.; Jat, M.L.; Mazid, M.A.; Saharawat, Y.S.; McDonald, Andrew and Gupta, Raj. 2010. Direct dry seeded rice production technology and weed management in rice based systems. Technical Bulletin. International Maize and Wheat Improvement Center, New Delhi India. pp 28.

This publication was jointly supported by National Agricultural Innovation Project (NAIP) of the Indian Council of Agricultural Research (ICAR), Cereal Systems Initiative for South Asia (CSISA) and International Maize and Wheat Improvement Centre (CIMMYT). The views expressed in this publication are those of authors and do not necessarily reflect the views of NAIP, ICAR, CSISA or CIMMYT.

The International Maize and Wheat Improvement Center, CIMMYT® (www.cimmyt.org), is an international, not-for-profit research and training organization. The center applies science to increase food security, improve the productivity and profitability of farming systems, and sustain natural resources in the developing world. CIMMYT is funded by the Consultative Group on International Agricultural Research (CGIAR) (www.cgiar.org) and also receives support from national governments, foundations, development banks, and other public and private agencies.

©International Maize and Wheat Improvement Center (CIMMYT) 2010. All rights reserved.

The designations employed and the presentations of the material in this publication do not imply the expression of any opinion whatsoever on the part of the International Maize and Wheat Improvement Center (CIMMYT), concerning the legal status of any country, person, territory, city, or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries. Where trade names are used this does not constitute endorsement of or discrimination against any product by the CIMMYT.

Direct Dry Seeded Rice Production Technology and Weed Management in Rice Based Systems

Ravi Gopal, RK Jat, RK Malik, Virender Kumar, MM Alam, ML Jat,
MA Mazid, YS Saharawat, Andrew McDonald and Raj Gupta



National Agricultural Innovation Project (NAIP)
Indian Council of Agricultural Research (ICAR)
International Maize and Wheat Improvement Center (CIMMYT)
Cereal Systems Initiative for South Asia (CSISA)

CG Block, National Agriculture Science Centre (NASC) Complex, DPS Marg,
New Delhi 110 012, India

2010

Authors

Ravi Gopal: Hub Coordinator, CSISA, Bihar Hub

RK Jat: Research Scientist, CIMMYT-India, Bihar

RK Malik: Hub Coordinator, CSISA, Eastern UP Hub

Virender Kumar: Weed Scientist, IRRI-India, New Delhi

MM Alam: Research Platform Coordinator, CSISA, Gazipur Hub

ML Jat: Cropping Systems Agronomist, CIMMYT, New Delhi

MA Mazid: Hub Coordinator, CSISA, Dinazpur Hub

YS Saharawat: Senior Associate Scientist, IRRI, New Delhi

Andrew McDonald: Cropping Systems Agronomist, CIMMYT, Kathmandu

Raj Gupta: South Asia Coordinator and Head, CIMMYT India & Bangladesh

Contents

1.0. Introduction	1
2.0. Production Technology for DSR	2
2.1. Land leveling	2
2.2. Planting time	2
2.3. Cultivar Choices	3
2.4. Establishing the crop	3
2.5. Seed rate and seeding depth	3
2.6. Seed priming	4
2.7. Nutrient management	5
2.8. Irrigation management	6
2.8.1. Pre-sowing irrigation	6
2.8.2. Post-sowing irrigation	7
2.9. Weed management	7
2.9.1. Cultural methods	7
2.9.2. Chemical weed control	8
2.9.3. Guidelines for effective use of herbicide molecules	10
2.9.4. Weed management in flood prone areas	11
2.9.5. Management of rice sprouts/ ratoons	11
3.0. Weed spectrum in predominant cropping systems of Indo-Gangetic Plains	11
4.0. Weed management in winter crops under rice based cropping systems	11
4.1. Wheat	11
4.1.1. Major weeds in wheat	15
4.1.2. Weed management practices in wheat	15
4.2. Maize	16
4.2.1. Major weeds in maize	16
4.2.2. Weed management practices in maize	16
4.3. Legumes in rice-wheat systems	16
4.3.1. Major weeds in winter legumes	17
4.3.2. Weed management in legumes	17
5.0. Recommendations of herbicide molecules for weed management	18
6.0. Soil cover management in rice based systems	20
6.1. Surface mulching with crop residues	20
6.2. Sesbania Co-culture (Brown manuring) and cover crops	21

Direct Dry Seeded Rice Production Technology and Weed Management in Rice Based Systems

1.0. Introduction

In South Asia, rice-based cropping systems account for more than 50% of the total acreage with rice grown in sequence with rice or upland crops like wheat, maize or legumes. In most areas, rice is traditionally grown by transplanting seedlings into puddled fields (henceforth 'TPR').

There are strong incentives in many parts of S. Asia to promote alternatives to puddled rice cultivation, including:

- ***Optimizing system productivity*** Puddling is achieved by intensive tillage under ponded water conditions, which serves to break down soil aggregates, reduce macro-porosity, disperse the clay fraction, and form a dense zone of compaction (i.e. 'plough pan') at depth. In addition to facilitating transplanting, puddling serves several functions including weed control and to reduce deep percolation losses of water. Although the soil physical changes from puddling can be favorable for rice cultivation, they can also be very detrimental to the growth of subsequent non-rice crops by causing temporary water logging, poor crop emergence, and restricted root development.
- ***Reducing irrigation requirements*** Around 30% of the total water (1400-1800 mm) required for rice culture is dedicated to puddling and

transplanting. In cases where deep percolating waters are not recovered (e.g. in canal irrigated areas), these constitute true losses from the system. Water availability for agriculture is becoming increasingly scarce because of competition with other economic sectors and from accelerating demands for direct human consumption. Per capita availability of water has declined by 40-60% between 1955 and 1990 in several Asian countries, and in some areas this trend is accelerating. For areas with groundwater-based systems, pumping costs and energy consumption are directly related to the number of irrigations. Hence puddle rice cultivation aggravates the energy crisis in many parts of the Indo Gangetic Plains (IGP) and elsewhere.

- ***Reducing labor requirements*** Timely transplanting of rice is based on the premise of cheap and readily available labor. Across S. Asia, labor scarcity is no longer a projection, but rather a hard felt reality. Rice production technologies that require less labor are urgently required.

Fortunately, alternative establishment practices for rice such as direct seeding into dry, unpuddled soil (henceforth 'DSR') are suitable for different production environments in South Asia and may alleviate many of the problems associated with TPR. In South Asia, DSR is already

practiced in many medium deep- and deep-water rice ecologies of eastern Gangetic plains of India and Bangladesh; and on terraced and sloping lands in the north-east and Western Himalayan region and the Ghats along west coast of India. The acreage of DSR in India, Pakistan and Bangladesh is 14.2 million hectares (M ha) of the total rice acreage of 55.3 Mha (ca. 26%). Without proper management, however, DSR productivity can be low. Common factors contributing to poor yields include supra-optimal seeding rates (60-100 kg/ha), increased weed competition, insufficient fertilizer use, and lack of improved cultivars selected for good stand establishment with direct seeding.

2.0. Production Technology for DSR

The intent of this document is to describe a comprehensive set of management principles and practices that can help ensure high rice yields and economic returns with DSR, including direct seeding without tillage (zero-till DSR, henceforth 'ZTDSR'). When combined with residue retention from the preceding crop, ZTDSR follows the principles of Conservation Agriculture (CA) and may offer economic, energy, labor, and water saving advantages that exceed what is possible with DSR. Most of the management strategies described below are relevant to DSR with or without tillage.

2.1. Land leveling

Elevation differences between high and low-lying spots can be as high as 10-20 cm or more in a single hectare field under traditional land leveling practices. This condition often leads to poor establishment of DSR due to uneven depth of seeding



Laser land leveling improves water use efficiency

and also due to uneven water distribution in irrigated fields. Laser land leveling improves crop establishment and also enables the farmer to apply uniform irrigation, leading to improved weed control and nutrient use efficiencies.

2.2. Planting time

For the continental monsoonal-type climate of the Indian subcontinent, the main rice growing season is during the summer monsoon when rainfall is high (*Aman/Kharif*). Farmer experiences with DSR in field trials across Indo-Gangetic Plain (IGP) suggests that seeding after onset of monsoon is difficult due to problems of field access for machinery in wet soil conditions. Under such conditions, there are also problems in depth control of the drills/planters, clogged seed tubes, and other associated issues that result in poor crop establishment. The best time of planting *Kharif* DSR is about 10-12 days before the historical onset of the monsoon. For example, if in western Uttar Pradesh monsoon arrives around 21-23 June, so the best seeding time for DSR in this region is around 10-12 June. Sowing after pre-seeding irrigation or applying irrigation just after seeding is helpful to support germination and early growth when pre-

monsoon showers are insufficient. Vigorous early growth of rice crop before the arrival of inundating monsoon rains reduces seeding mortality due to submergence and, by hastening crop development, makes it easier to ensure timely planting of succeeding crops after rice harvest.

2.3. Cultivar Choices

Some varieties, such as basmati types and some hybrids, have proven to be suited for DSR than others. Varieties that have been identified as suitable for DSR are given in Table 1 by area of geographic adaptation.

2.4. Establishing the crop

Rice seed has a husk cover and pubescence that limits good seed germination under comparatively dry soil conditions. Seed placement and water management is the key to obtain good establishment. Surface covers, seed and labor costs, soil moisture regimes and

intensity of weed infestation determine planting techniques and associated practices enabling good germination and seedling emergence. Depending on the weed intensity, we envisage four scenarios as listed below and the DSR production technologies for these four different scenarios have been schematically presented in Fig. 1.

- Fields those are weed-free
- Fields that are relatively weed-free but have a history of high weed pressure/ weed seed bank
- Fields that are weedy and some of them are perennial nature
- Rainfed and/or hilly areas

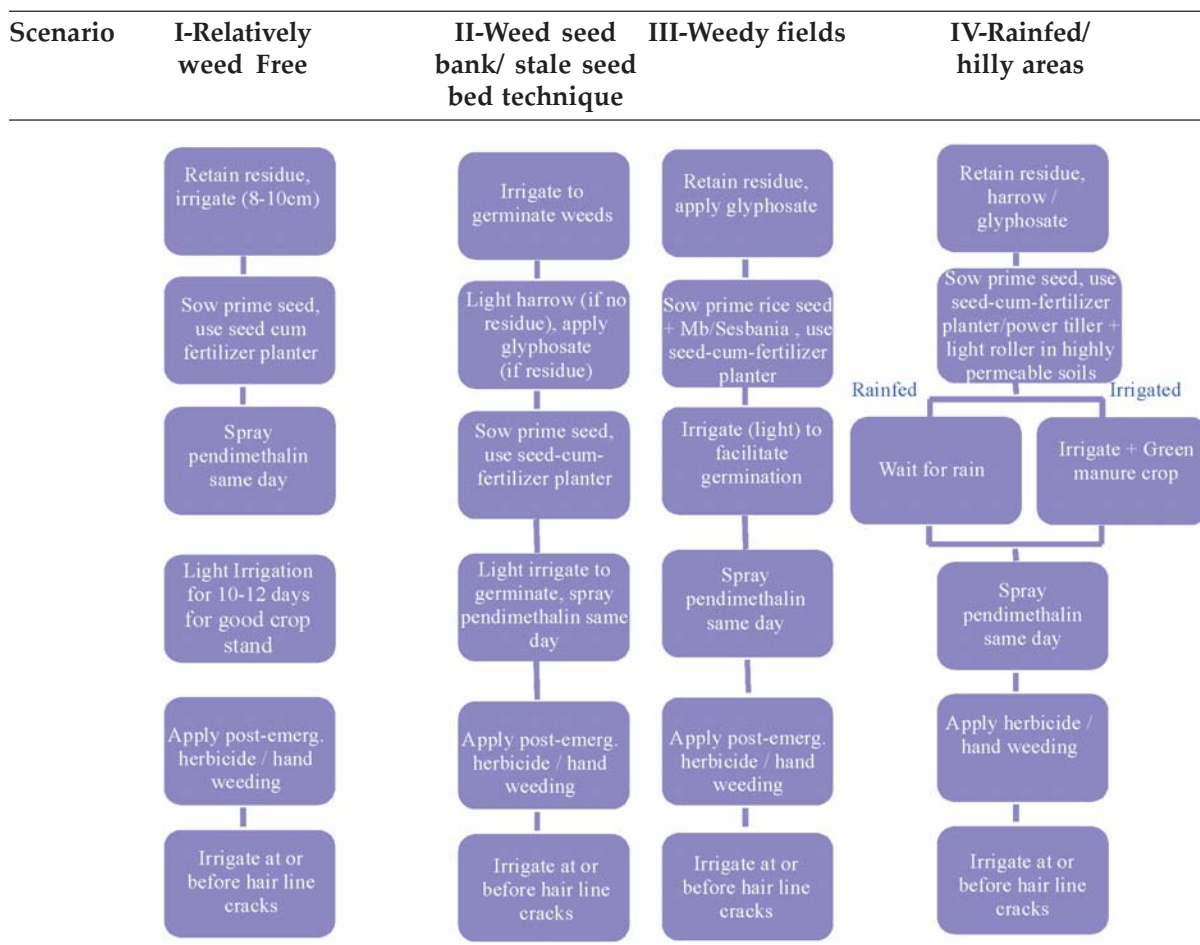
2.5. Seed rate and seeding depth

In literature, use of high seed rate (80-120 kg ha⁻¹) is often recommended for establishment of DSR. However, high seed rate can cause nitrogen deficiency, an increased proportion of ineffective tillers, lead to attack of brown plant hoppers, and

Table 1. Cultivar choices for DSR in different production environments

S. No.	Areas/Cropping Systems	Preferred variety/Hybrids
1.	Punjab (Rice-wheat)	PAU 201, Arize 6129, Pusa 1121 (Sugandha 4), CSR-30, Pusa Basmati-1, Proagro 6444
2.	Western UP and Haryana (Rice-wheat, Rice-potato-wheat/maize/sunflower)	CSR-30, Pusa 1121 (Sugandha 4), Pusa 2511 (Sugandha 5), PRH-10, Pusa Basmati-1, Tarawadi Basmati, PAU 201, Pant Dhan-12, Sharbati, Arize 6129, Proagro-6444
3.	Eastern UP (Rice-wheat, rice-maize/pulses, Rice-potato-maize)	NDR 359, Sarjoo 52, Mahsoori, Swarna (MTU 7029) Moti, PAU 201, Arize 6129, Proagro 6444
4.	Tarai of Uttaranchal (Rice-wheat)	Nidhi, UPRI-92-79, Narendra-359 and PD 4, Sarbati, PR-113, HKR-120, Sarjoo-52
5.	Bihar (Rice-wheat, rice-maize/pulses, Rice-potato-/+ maize)	Rajendra Mahsuri-1, Swarna, MTU 1001, PAU-201, NDR 359, Prabhat (OPV), PHB -71, Proagro 6444, RH 664 (Hybrids)
6.	Tarai of Nepal (Rice-wheat/pulses)	Sona Masuli, Hardinath, Radha-4, Radha-11
7.	Bangladesh (Rice-rice, rice-wheat, rice-maize, rice-potato-/+maize)	BRR1 Dhan 33, BRR1 Dhan 39, BRR1 Dhan 44 and Zata
8.	Multi location trials by DRR Hyderabad (rice-rice, rice-maize/pulses)	IET 9994, Vikas, Rasi, Krishna hamsa
9.	Punjab, Pakistan (Rice-wheat)	Basmati super, Basmati 385, IRRI 6, KSK 282, Niab 9

Fig. 1. Crop establishment, weed management and irrigation scheduling in DSR under four different scenarios based on weed infestation, soil and climatic conditions.



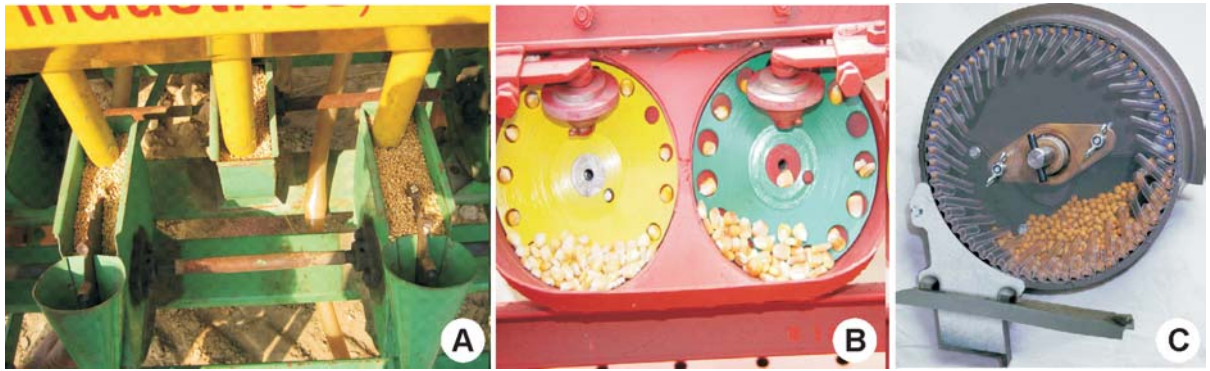
increase the probability of crop lodging. Based on multi-year research trials, our evidence suggests that for cultivars with medium fine grain, seed rates of 15-20 kg ha⁻¹ are optimum using planters that have precise seed metering systems (e.g. inclined plates, cupping systems, or vertical plates). Especially at lower seed rates, fluted roller mechanisms are not ideally suited for DSR because they often damage the rice seed coat and do not maintain adequate plant spacing within the row.

Seeding depth plays a pivotal role in early germination and emergence of seedlings in DSR system. In most cases, the seeding depth should be approximately 2.5 cm. Placement of seeds too deep or shallow adversely affects the dynamics of seedling

emergence. Seeding depth can be adjusted with the depth control wheels fitted to most drills/planters. Before planting, it is also advisable to ensure that the wheels and seed tynes are leveled. Planking after seeding can also create better seed-soil contact, which is especially important when seeding is done after pre-sowing irrigation in the absence of rain.

2.6. Seed priming

DSR is typically sown at shallow depth (≤ 2.5 cm) in advance of the monsoon rains and dry soil conditions are commonly the main constraint to rapid establishment of a good crop stand. In such situations, pre-hydration of seeds for 10-12 hours (seed priming) can improve germination. Primed



Precision seed metering systems, A- Cupping type, B- inclined plate, C- Vertical plate

seeds are subsequently dried in shade to decrease moisture content, which facilitates the proper functioning of seed metering mechanisms during planting. Priming induces a wide range of biochemical changes in the seed, the products of which persist following desiccation and are expressed quickly once the seeds again absorb water. Thus priming accelerates seed germination and crop emergence. Priming can also be used to treat the rice seed with bavistin or thirum to eliminate or reduce certain seed and soil borne diseases. Priming may be especially useful if seeding is done after pre-seeding irrigation.

2.7. Nutrient management

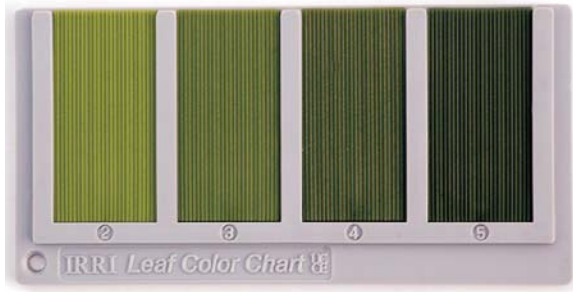
General recommendation is to apply full dose of P and K and $ZnSO_4$. However, nitrogen can be applied in 3-splits based on fixed time LCC recommendations (basal, tillering and panicle initiation stage). The nutrient application rates for different rice cultivar types are given in Table 2.

When wheat straws are incorporated in soil it causes rapid immobilization of available nitrogen (N) and may result in N deficiency in rice. In order to reduce the adverse effects of N-immobilization, N-fertilizer should be placed below the surface soil layer. With high rates of

Table 2. Nutrient application rates for different rice cultivar types

S. No.	Cultivar type	Nutrient rates (Kg ha ⁻¹)*				
		N	P ₂ O ₅	K ₂ O	ZnSO ₄	Other secondary & micro nutrients
1.	Fine grain scented traditional basmati rice	60-70	40-60	-	25	Need based
2.	Fine grain scented evolved basmati rice	80-100	60-75	60-75	25	Need based
3.	Coarse grain varieties	120-150	60-80	60-80	25	Need based
4.	Coarse grain hybrids	150-175	60-80	60-80	25	Need based

*The nutrient applications should be site-specific depending on cropping system, soil nutrient supplying capacity, duration and productivity potential of cultivars but the general recommendations are given here. In rice wheat system practiced in alkali soils, it is often recommended to apply zinc sulfate in both rice and wheat crops @ 10-12kg /ha. However, during the initial 2-3 years of alkali soil reclamation stages, rational fertilizer use recommendation is to apply P to only wheat crop and not to rice.



Leaf Colour Chart for N application

residue retention from the previous crop, 80% of the recommended dose of nitrogen fertilizer may be applied at sowing using a seed-cum-fertilizer drill/planter and the remaining N can be applied as needed using a leaf color chart (LCC). For hybrids and high yielding in-breds/varieties of rice, N application should be based on a critical LCC value 4. However, a critical LCC value of 3 is used for scented basmati type rice cultivars. In the case where DSR results in less continuous flooding and reducing soil conditions, the rice crop often suffers from iron chlorosis, particularly in sandy soils. Seed treatment with iron sulphates could prove very helpful in improving health of the young rice plants in some circumstances and if the iron chlorosis persists further, foliar spray of iron is recommended.

2.8. Irrigation management

The physics, chemistry and biology of puddled soil can differ considerably from the direct dry seeded and zero till rice soils mainly because of the differences in water regimes and the practice of puddling. Knowledge and understanding of the rice physiology for direct seeded and zero till crop is still inadequate in terms of crop water requirements. Whereas puddled fields show up soil cracking behavior very early if adequate water is not maintained in the field, DSR/zero till

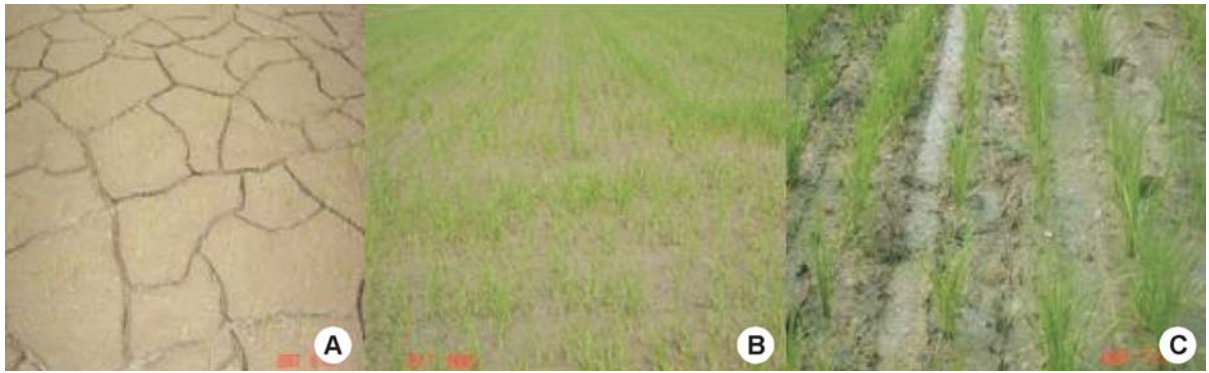
soils generally do not crack as substantially up on drying. Hence, for irrigation scheduling, the common rule applied in TPR of irrigating at the first sign of hairline cracks may not be suitable for DSR. From the perspective of water stress, rice does not require continuous submergence across growing season but any attempt to reduce irrigation should not be at the cost of yield penalty. Therefore, water stress must be avoided 2 weeks after seedling emergence at tiller, panicle initiation and flowering growth stages. It is suggested to practice intermittent flooding after disappearance of the ponded water.



Irrigation management in DSR crop at maximum tillering

2.8.1. Pre-sowing irrigation

DSR crop is commonly established by farmers using stale seed-bed technique with pre-plant irrigation. This significantly reduces weed pressure in DSR crop. If the moisture conditions are still favorable, DSR can be seeded without additional irrigation. In a weed-free field, it is advisable to apply a heavy irrigation 2-3 days before planting primed seed. In rainfed situations, weeds are allowed to grow for some time after pre-monsoon showers and then knocked down using herbicides or by shallow tillage.



A-Wet DSR showing cracks even at wet soil surface, B- Dry DSR showing no cracks at dry surface, C- Zero till rice in standing stubbles

2.8.2. Post-sowing irrigation

In South Asia, rice is generally planted during peak summers (June-July) when soil moisture losses due to evaporation are generally high and surface soil dries out very fast. In such situations, irrigation immediately after seeding may become necessary to facilitate emergence. After germination, the soil should be kept wet and at tillering, panicle initiation and grain filling stages, water stress should be avoided. Under limited irrigation water availability and monsoon failures, irrigation at fine hairline cracks can be safely practiced. In drought like situations, even with the delayed application of irrigation, yield penalty in DSR can be minimized compared to puddled transplanted rice.

2.9. Weed management

Weeds are a major concern for high productivity of the DSR. Effective weed management in DSR depends on several factors, including the timeliness of the control operations during the early crop growth stages and, in some cases, good control in preceding crops. In TPR, weed control is conducted just before transplant and the rice has a significant size and competitive advantage over subsequently emerging weeds. DSR has no such advantage and yield losses to weed

competition can approach even up to 90% in poorly managed fields.

Integrated approaches to weed management combine multiple tactics and knowledge of site-specific field conditions are essential to increase the efficacy and sustainability of weed control. Individual tactics for weed management in DSR are described as below. The focus of weed management should ideally combine agronomic practices that increase crop competitiveness with the judicious use of chemical and other methods of direct weed control.

2.9.1. Cultural methods

A. Stale seed bed: In this technique, weed seed germination is encouraged by applying light irrigation and then emerged seedlings are killed using a non-selective herbicide before crop sowing. It has been observed that this technique can reduce weed population by 53%.

B. Good crop establishment: Spatially uniform establishment of healthy, vigorous rice seedlings increases crop competitive ability and suppresses weed growth.

C. Surface mulch and cover crops: Surface retention of crop residues provides a physical barrier to emerging weeds, thereby delaying emerging and increasing seedling mortality. In addition, decomposing residues release allelochemicals



Zero-till using multi-crop planter

which have inhibitory effects on the germination and early growth of some weed species. Inter-row cover crops like mungbean or cowpea can also suppress weed growth. The details of the technology and detailed benefits of mulching are described in succeeding section “Soil cover management”.

D. Sesbania co-culture (Brown Manuring): “Brown Manuring” practice involves seeding of rice and *Sesbania* crops together and killing the *Sesbania* crop 25-30 days after sowing with 2, 4-D ester at 0.40- 0.50 kg ha⁻¹. *Sesbania* grows rapidly and suppress weeds. Co-culture technology can reduce weed population by nearly half without any adverse effect on rice yield. The details of the technology and detailed benefits are described in succeeding section “Soil cover management”.

E. Tillage system: Technologies like zero-till seeding systems can reduce the weed problems if managed properly. If weeds are controlled effectively for initial 2-3 years, ZT helps in reducing the effective weed seed bank as soil is not being disturbed and therefore weed seeds from lower depths are not being brought back towards the soil surface where they can more readily germinate and emerge. In zero-till systems, newly produced weed

seeds remain on or near the soil surface. Most weeds germinate optimally at shallow depths (2-3 cm). In addition, the physical environment created when surface residues are retained in ZT systems (e.g Conservation Agriculture) provides habitat for weed seed predators and also offers conditions more conducive for microbial decay of weed seeds, thereby increasing weed seed mortality.



DSR on permanent beds

2.9.2. Chemical weed control

The right herbicide for use in DSR depends on the weed flora present in a given field; individual herbicides have strength and also weakness, e.g. Bispyriback is very good on grasses but can't control *Leptochloa*. Rotational use of herbicides with different modes of actions is also desirable to check the possible development of herbicide tolerant or resistant weed biotypes.

The control efficacy of herbicides is also contingent on the use of proper spray techniques. For example, it is better to use flat fan nozzles in combination with multiple nozzle booms to achieve spray uniformity across the field. Guidelines on use of chemical molecules for efficient weed management in DSR are described below:

A. Pre-plant herbicides: These are used to knock down existing annual and perennial weeds prior to crop planting. For pre-plant herbicides to be effective, weeds must be physiologically active. Light irrigation can be used to stimulate weed growth and ensure better uptake of pre-plant herbicides. Pre-plant irrigation also facilitates weed seed germination and emergence (i.e. stale seedbed approach). Existing and newly germinated weeds can be knocked down with timely and judicious use of glyphosate (systemic herbicide), paraquat (contact herbicide), or mechanically by 1-2 shallow ploughing (with harrow). It is essential that clean water is used for making spray solution with glyphosate or paraquat. These herbicides bind with suspended soil particles and metal surfaces (e.g. iron buckets), and significantly reduced efficacy is possible if care is not taken in this regard. Non-reactive surface such as plastic containers can be used for preparing sprays solutions. Animals should not be allowed to graze in treated fields as this can adversely affect translocation of herbicides and decrease efficacy.

- **Glyphosate** is a non-selective, systemic herbicide that controls annual and perennial weeds and should be applied 5 to 7 days before seeding. If possible, weeds especially perennials, should be allowed to grow after irrigation to develop a canopy, so that they can receive enough glyphosate to kill underground storage organs. Use flat fan nozzles for spraying. Best results are obtained when weeds are in active growth stages. Glyphosate controls all weeds including *Cynadon dactylon* and *Cyperus rotundus*. Glyphosate is absorbed by the foliage and rapidly translocated throughout the plant. It is inactivated immediately on contact

with soil and has no residual activity. It should be used preferably in areas highly infested with perennial weeds. Use glyphosate 1.0 kg a.i./ha mixed with 500 L water ha⁻¹. Glyphosate is best applied when evaporative demand is low. Spray droplets dry out quickly in sun as this can result in poor absorption and translocation, thereby significantly reducing its efficacy. Crop can be planted as soon as symptoms (yellowing, drooping etc.) are visible.

- **Paraquat** is a non-systemic contact herbicide. It is used in areas infested primarily with annual weeds at the rate of 0.5 kg a.i. mixed with 400 L water ha⁻¹. Since visual symptoms of injury are readily apparent, seeding of rice can be done 4-5 hours after application; therefore, it is useful in areas where rice sowing is getting delayed. It is contact-type herbicide and is not translocated to the below-ground storage organs of perennial weeds. If a large number of perennial weeds are present, then use of glyphosate is often a better choice.

B. Pre-emergence herbicides: These are generally used before emergence of weeds and are applied immediately after the sowing of the crops.

- **Pendimethalin (Stomp)** is applied @ 1000 g a.i./ha for managing weeds in DSR. However, it should be properly applied in a clod free soil. For scenarios I and III of crop establishment (Fig. 1), pendimethalin should be applied on same day of sowing, whereas in case of scenario II, which is also called stale seed bed technique, pendimethalin should be applied within 3 days of sowing depending on soil moisture status. High soil moisture is a pre-requisite for application of this chemical.

- **Pyrazosulfuron** is applied @ 20 g a.i./ha for the control of grasses, broad leaf and sedges. High soil moisture is a prerequisite for higher efficacy of this chemical. This herbicide is effective against *Leptochloa*.

C. Post-emergence herbicides: These are used to control emerged weeds. To be effective, herbicide molecules must be absorbed through above-ground plant parts (leaves) and consequently, liquid sprays generally work better than dry, granular materials. These herbicides are selective and for better efficacy should be sprayed using boom fitted with 2-3 flat fan nozzles in 400-500 L water ha⁻¹. Following options can be used depending on types of weeds:

- **Bispyribac (Nominee gold)** @ 25 g a.i./ha at 15-25 DAS is effective in controlling all three types of weed flora (grasses, broadleaved and sedges). However, this herbicide is poor in controlling *Leptochloa* spp, *Eragrostis*, *Dactyloctenium aegyptium* and *Cyperus rotundus*. Soil saturation is required for good weed control.
- **Penoxsulam** @ 22.5 g a.i./ha applied at 15 DAS is also effective in controlling all three types of weeds flora except *Leptochloa*, *Dactyloctenium*, and *C. rotundus*.
- **Fenoxaprop (Whip super)** @ 60 g a.i./ha at 25 DAS is effective against grassy weeds including *Leptochloa* and *D. aegyptium*. However, Whip super can be toxic to rice if not applied properly or applied at early stage. Fenoxaprop can also control *Cynodon dactylon* in rice. However, for early applications at 15 DAS, a new formulation (Rice Star) is safe for the rice crop.
- **Azimsulfuron** @ 17.5 g a.i./ha is effective in controlling broadleaf weeds

and sedges including *Cyperus rotundus* but is weak on grasses. Therefore, for mixed weed flora, it should be tank mixed with other herbicide which control grasses effectively, Bispyribac or penoxsulam can be mixed with Azimsulfuron. Tank mix of Bispyribac + azimsulfuron (25 g + 17.5 g a.i./ha), or Fenoxaprop (Rice star) + ethoxysulfuron (Sun rice) (60 + 18 g a.i./ha) can be used if broadleaf and sedges are more severe along with grasses. Azimsulfuron (17.5 g a.i./ha) or ethoxysulfuron (sun rice) applied 12 - 20 DAS can provide good control, if the problem is only of broadleaved weeds and sedges.

- **2,4-D** @ 500 g a.i./ha is an inexpensive herbicide for the control of broadleaf weeds. It is also very useful in managing *Fimbristylis mileacea*. Apply 2,4-D ethyl ester when annual sedges like *F.miliacea* starts germinating (10-30 DAS).
- **Triclopyr** @ 500 g a.i./ha at 20-25 DAS is very effective for controlling broadleaf weeds. For mixed weed flora, it can tank mixed with propanil (Propanil + triclopyr; 3000 g + 500 g a.i./ha). Propanil can give initial phytotoxicity especially if rice is treated with an organophosphate. Propanil can also desiccate *Cynodon dactylon*.

2.9.3. Guidelines for effective use of herbicide molecules

- Use flat fan nozzle with multiple nozzle booms for spraying. With single nozzle boom (if multiple nozzle boom is not available), cut type nozzle should be used.
- Select right herbicide at right dose and time depending on types of weed flora present in the field

- Rotate herbicides to avoid development of resistance in weed biotypes against any single herbicide.
- For pre-emergence herbicide, apply when there is sufficient soil moisture.

2.9.4. Weed management in flood prone areas

In flash flood prone areas, before seeding rice, apply glyphosate plus 2,4-D ester mixtures to knock down the existing weeds and use pre-emergence herbicide molecules to control the second flush of weeds. There may not be any need for post-emergence herbicide molecules as flood water and crop canopy can take care of them. Therefore, post-emergence herbicide molecules should be used on an 'as needed' basis.

2.9.5. Management of rice sprouts/ratoons

The re-sprouting of rice or rice ratooning is a major problem in no-till rice-rice and rice-maize/pulses systems of eastern Gangetic plains as well as peninsular India. If not managed, they will menace with main rice crop and compete for water, nutrients and other critical resources. Therefore, for management of rice ratoons/re-sprouts following strategies should be adopted:

- Pre-plant application of paraquat (0.5 kg a.i./ha) or 2 L of commercial product e.g. Gramaxone 24%. Paraquat is a non-selective (total killer) contact herbicide and can kill all green vegetation and does not have any residual activity.
- Atrazine @ 1.25 kg a.i./ha alone (pre-emergence or early post-emergence) can be used for controlling weeds together with rice ratoons. Alternatively, a combination of atrazine 0.65 kg a.i./ha with alachlor 1 kg a.i./

ha (pre-emergence only) can be used only at stages.

- Ammonium sulphate 2% or vegetable oil 2% mixed with glyphosate can also be used to improve efficiency of applied glyphosate.
- Glufosinate (Basta), a non-selective herbicide can also be used for control of rice ratoons together with weeds.

3.0. Weed spectrum in predominant cropping systems of Indo-Gangetic Plains

The problem of weeds in the same crop varies with cropping system and production environments. Therefore, understanding the weed spectrum in relation to cropping system, season, and production environment is a must for effective and economical weed management. The weed spectrum in different cropping systems of western and eastern IGP are given in Table 3.

4.0. Weed management in winter crops under rice based cropping systems

4.1. Wheat

Wheat is second most important crop in Indo Gangetic Plains and normally rotated with rice or maize. Wheat production in IGP took a quantum jump with the green revolution, however the dwarf wheat is more vulnerable to weeds, especially under high nutrient and water availability. Normally weeds offer severe competition to wheat and cause upto 40 to 50 % reduction in grain yield if not managed at critical time.

Table 3. Weed Spectrum in Different Cropping Systems of Indo-Gangetic Plains

Botanical Name	Local Name	Cropping Systems and Seasons			
		Kharif Season		Winter Season	
		North-west-IGP	Eastern-IGP	North-west-IGP	Eastern-IGP
Grassy Weeds					
<i>Avena ludoviciana</i>	Jangli Jai			R-W ² ; Sc-W ¹ , MSPO-W ¹ , R-PVM ²	
<i>Brancharia reptans</i>	Para Ghas, Bhosi	Sc ³ -W, R ⁴ -PVM, MSPPO ⁴ -W	M ² -W, R ⁴ -M, R ⁴ -W		R-W ⁷ , M-W ⁹ , R-L ⁶ , F-L ⁶
<i>Cynodon dactylon</i>	Doob	Sc ² -W, R ³ -PVM, MSPPO ² -W	M ⁵ -W		
<i>Dactyloctenium aegyptium</i>	Makra	R-W, M-W, Sc-W	M ³ -W,		
<i>Digitaria ciliaris</i>	Jharnia	R ⁷ -W, Sc ⁵ -W, R ⁷ -PVM	M ⁴ -W, M ³ -P+M, M ³ -P		
<i>Echinochloa crusgalli</i>	Barata, masta	R ¹ -W, R ³ -PVM			
<i>Echinochloa colonum</i>	Sawank, Sawa, Sami	R ² -W; Sc ⁴ -W; R ¹ -PVM, MSPO ³ -W	R ¹ -W, M ⁹ -W	Sc ⁴	
<i>Eleusine indica</i>	Balraja	R ⁶ -W, Sc ⁶ -W	M ⁶ -W		
<i>Eragostis tenella</i>	Chiria Ghas, Sihul	R ⁷ -PVM	R ⁶ -W/M		
<i>Ischaemum rugosum</i>	Kanki	R ⁷ -PVM			
<i>Panicum repens</i>			R ⁷ -W/M		
<i>Phalaris minor</i>	Baluri, Mandusi				R-W ⁴
<i>Paspalum distichum</i>	Besak	R ⁵ -W			
<i>Poa annua</i>	Buchi buchhi				
<i>Polypogon monspeliensis</i>	Baru	Sc ⁷ -W, MSPO ⁵ -W			R-W ¹⁰
<i>Sorghum halepense</i>					
Broad leaf weeds					
<i>Alternanthera sessilis</i>	Dabhi		R ⁸ -W		
<i>Anagallis arvensis</i>	Krishan neel				R-W ² , M-W ³ , M-P+M ³ , M-P ³
<i>Amaranthus viridis</i>	Jangli Chohli	Sc ⁵ -W, MSPO ³ -W, R ⁶ -PVM			
<i>Brassica arvensis</i>	Jangli sarson				
<i>Cannabis sativa</i>	Bhang				
<i>Celostia argentea</i>	surmari				R-W ⁶ , M-W ⁴ , M-P+M ² , M-P ²
<i>Cirsium arvense</i>	Kandai, Autan		R ¹⁰ -W, M ⁷ -W, R ⁸ -L	Sc-W ⁷ , MSPO-W ⁷	R-W ⁸ , M-W ⁵ , R-L ⁴ , F-L ⁴

Contd...

Contd...

Botanical Name	Local Name	Cropping Systems and Seasons		
		Kharif Season		Winter Season
		North-west-IGP	Eastern-IGP	North-west-IGP
<i>Caesulia axillaris</i>	-	R ¹ -W, R ² -PVM	R ³ W/ M, M ⁶ -W	
<i>Chenopodium album</i>	Bathu			R-PVM ¹ , Sc-W ¹ , R-W ⁶ , MSPO-W ¹
<i>Convolvulus arvensis</i>	Hiran khuri	Sc ⁶ -W		Sc-W ⁴ , R-W ⁷ , MSPO-W ²
<i>Commelina bengalensis</i>	Kankawa, Kanna	Sc ⁸ -W	M ⁷ -W, R ¹⁰ W/ M,	
<i>Corchorus olitorius</i>	Kaga roti	Sc ⁷ -W		
<i>Coronopus didymus</i>	Pithpapda			R-PVM ³ , MSPO-W ⁶ , Sc-W ⁶ , R-W ⁴
<i>Cucumis spp</i>	Ghurmi		R ⁴ W/ M, M ⁴ -W	
<i>Digera arvensis</i>	Junkhunna		R ² -W, R-M ³ , M ⁸ W	
<i>Eclipta alba</i>	Jalbhanga, Bhangraia	R ¹ -W	R ¹⁰ W/ M ¹⁰ -W,	
<i>Euphorbia hirta</i>	Bari Doodhi	Sc ⁴ -W, MSPO ² -W, R ³ -PVM	M ⁷ -W	
<i>Eriogon canadensis</i>	Phulni			
<i>Fumaria parviflora</i>	Gajri	Sc ⁵ -W		R-PVM ² , MSPO-W ⁵ , Sc-W ⁵
<i>Ipomea aquatica</i>	Bel	Sc-W ⁹ , MSPO-W ⁹		R-L ³ , F-L ³ R-W ⁵ , M-W ⁵
<i>Lathyrus aphaca</i>	Matri, Jangali matar			
<i>Launaea nudicaulis</i>	Jangali gobhi	R ² -W		
<i>Lindernia crustaceae</i>	-			
<i>Medicago denticulate</i>	Maini	R ⁷ -W		R-W ³
<i>Monochoria vaginalis</i>				
<i>Melilotus indica</i>	Senji	R ⁵ -W, Sc ⁹ -W, R ⁵ -PVM	M ⁴ -W	MSPO-W ³ , Sc-W ³ , R-W ²
<i>Phyllanthus niruri</i>	Hazar dana, Ban Manijara			R-W ⁶ , M-W ⁶
<i>Physalis minima</i>	Bhutkuiyan		R ³ -W, R ³ -M	
<i>Parthenium hysterophorus</i>	Congress grass, Fulki, Titki	Sc ¹⁰ -W, MSPO ⁵ -W		R-W ⁹ , M-W ⁷
<i>Portulaca oleraceae</i>	Bara lumia	R ⁴ -PVM		
<i>Rumex dentatis</i>	Jangli Palak			MSPO-W ⁴ , Sc-W ² , R-W ¹
<i>Spergula arvensis</i>	Jangli dhamia			Sc-W ¹⁰ , MSPO-W ¹⁰

Contd...

Contd...

Botanical Name	Local Name	Cropping Systems and Seasons		
		Kharif Season	North-west-IGP	Winter Season
<i>Solanum nigrum</i>	Lalbhutka			Eastern-IGP
<i>Stellaria media</i>	Buch-bucha		R-W	R-W ² , M-W ² , R-W
<i>Tribulus terrestris</i>	Bhakri	MSPO ⁴ -W		
<i>Trianthema portulacastrum</i>	Santhi	Sc ¹ -W, MSPO ¹ -W, R ¹ -PVM		
<i>Vicia sativa</i>	Chatri/ Acra/ Acta	Sc-W ⁸ , MSPO-W ⁸ , R-L ¹ , FL ¹		R-L ¹ , F-L ¹ , R-W ⁵ R-L ² , F-L ²
<i>Vicia hirsuta</i>	Pipta,			
<i>Lathyrus aphaca</i>	matri, Jangali matar			
<i>Oxalis corniculata</i>			R-W	
<i>Xanthium strumarium</i>	Baigan bichiya			R-W
Sedges				
<i>Cyperus iria</i>	Motha	R ¹ -W, Sc ¹ -W, MSPO ¹ -W, R ¹ -PVM, R ² W/ M, M ³ W		R-PVM ²
<i>Cyperus compressus</i>	Motha	R2-W, Sc2-W, MSPO2-W, R2-PVM		R-PVM ³
<i>Cyperus difformis</i>	Motha	R ⁴ -W, M ² W	R ² W/ M, M ⁵ W	
<i>Cyperus rotundus</i> M-P ¹	Motha	R ⁴ -W, Sc ⁴ -W, MSPO ⁴ -W, R ² -PVM, M ¹ W		M ¹ W, R ⁸ W/ M, M ¹ P+M, M ¹ M R-PVM ⁴ M-W ⁶ , M-P+M ¹ .
<i>Fimbristylis quinqueangularis</i>	Chhoti dili	R ² -W, Sc ² -W, MSPO ² -W, R-PVM ¹		
<i>Fimbristylis milicea</i>	Jhirua		R ⁵ W/ M	

Sc = sugarcane, R = rice W = wheat; P = potato; M = mustard; V = vegetables; O = okra ; M = maize; S = sorghum; PP = pigeonpea L = lentil, F = Fallow; C = Chickpea
= pigeonpea L = lentil, F = Fallow; C = Chickpea

4.1.1. Major weeds in wheat

The wheat crop is mainly affected by grasses and broad leaf weeds. *Phalaris minor*, *Avena ludoviciana*, *Polypogon monspeliensis* are grassy, where as *Chenopodium album*, *Melilotus*, *Anagalis*, *Rumex*, *Fumaria*, *Vicia*, *Lathyrus*, *Cirsium*, *Solonum*, *Physalis*, and *Convolvulus* are common broad leaf weeds in region. Grassy weeds such as *Phalaris* are of great concern in the North West part of the IGP where as broadleaf weeds and perennial weeds like *Cynodon dactylon* are more important for wheat crop in the eastern IGP.

4.1.2. Weed management practices in wheat

A. Cultural: The critical stage for weed competition in wheat ranges from 15 to 45 days after sowing of wheat as this is the stage where the crop is sensitive for weed competition. Therefore, weeds need to be controlled during this window of crop growth. Varieties with high early vigour or practices such as fertilizer placement, timely planting etc improves the competitive ability of wheat crop thereby reducing losses due to weeds. Adopting zero tillage and retention of crop residues on surface has been found very effective in reducing germination of *Phalaris minor*, *Chenopodium album*, *Chenopodium*, *Solonum*, *Physalis*, *Anagalis* etc. Managing water effectively in rice can be helpful in reducing populations of *Rumex* in wheat, as it appears mostly in wet soils.

B. Chemical weed control: In areas with high soil moisture, perennial weeds and some annual weeds germinate and start growing before wheat crop and offer a tough competition to wheat. These fields are often found full of tiny seedling of *Phalaris* or *Polypogon monspeliensis* and

farmers many times ignore these tiny seedlings and end-up with the severe infestation of weeds even after application of herbicides like isoproturon or sulfosulfuron. Because these post emergence herbicides work well at 3-4 leaf stage of weeds and in situations where weeds are older, the effectiveness of herbicides becomes lesser and these weeds can be a potential source of herbicide resistance. In such conditions, pre-plant application of glyphosate at 1 kg ai/ha is effective for controlling pre-germinated or established weeds before wheat planting.

Clodinafop (Topik) at 60 g ai/ha or sulfosulfuron (Leader) at 25 g ai./ ha applied post emergence after first irrigation at 30 DAS was found effective in controlling annual grassy weeds in wheat. Isoproturon at 1 kg ai/ha can also be applied where herbicide resistance is not that much serious issue. Fenoxaprop at 100 g ai.ha at 30 DAS was found effective in controlling grasses especially *Cynodon dactylon*. Clodinafop can also arrest growth of *Cynodon dactylon* besides other grassy weeds. Sulfosulfuron has some control on broadleaf weeds too. Nevertheless, it is important to note that application of sulfosulfuron should be avoided in fields where farmers are willing to grow spring maize.

Post emergence application of 2,4-D at 500 g ai/ha or metsulfuron (Algrip) 4 g ai/ha or carfentrazone (Affinity) at 20 g ai/ha at 30 DAS has been found effective in managing broad leaf weeds. It is important to know that 2,4-D is weak on *Solonum*, *Physalis*, *Convolvulus*, whereas Metsulfuron is weak on *Solonum* and *Physalis*, therefore in fields infested with these weeds, carfentrazone at 20 g ai/ha is the better option.

2,4-D can also be mixed with Isoproturon and formulated mixture of sulfosulfuron (Leader) and metsulfuron can be used in

order to get a broad-spectrum weed control. However, clodinoxop (Topik) cannot be mixed with any other herbicide. It is important to remember that the herbicides need to be rotated across cropping seasons to avoid herbicidal resistance. The recommendations of herbicide molecules for targeted weeds in zero till wheat under rice-wheat rotation are given in Table 4.

4.2. Maize

Winter maize after rice is becoming a popular and remunerative crop option for the farmers in non-traditional maize areas of eastern Gangetic plains, peninsular India and Bangladesh. However with changed ecologies, weeds are a potential threat to the maize crop especially in winter cycle as it is planted widely spaced and grows very slow due to low temperatures. Weeds can cause 40-45 % reduction in winter maize yields.

4.2.1. Major weeds in maize

The common weeds of winter maize are mostly broad leafs eg. *Chenopodium album*, *Melilotus*, *Anagalis*, *Rumex*, *Fumaria*, *Vicia*, *Lathyrus*, *Cirsium*, *Solonum*, *Physalis*, and *Convolvulus*. Grassy weeds such as *Avena ludoviciana*, *Polypogon monspeliensis* and *Cynodon dactylon* are less competitive. Nevertheless, sedges such as *C. rotundus* can create a serious problem in the eastern IGP where temperatures remain warmer than in the western IGP.

4.2.2. Weed management practices in maize

C. rotundus, one of the noxious weed can be controlled easily by adopting stale bed technique and zero tillage on flat or on permanent beds. Allow the *C. rotundus* to grow and apply tank mixture of

Glyphosate 1 kg ai/ha with 250 g ai of 2,4-D 7 to 10 days before planting. This combination is found to be very effective in controlling *C. rotundus* and *C. dactylon* through-out the year. Atrazine @ 1 kg a.i./ha can control most grassy and broadleaf weeds, however, it is weak on weeds like *Bracharia*, *Cynodon* and *Cyperus rotundus*. Tank mix application of atrazine + pendimethalin (500 g ai. each/ha) or alachlor + atrazine (1250 g+ 375g a.i./ha) has been found effective in controlling complex annual weeds in summer maize. Intercropping of potato or pea as cover crop (1:1 or 2:1) in winter maize has also been found effective in controlling complex weed flora.

4.3. Legumes in rice-wheat systems

There is a very distinct possibility of growing legumes (mungbean, cowpea) as grain or as cover crops in spring season after wheat harvest. Many farmers grow extra-short duration pigeon pea (ICPL88039) to avoid late planting of wheat and/or fallowing. Late planted wheat is generally more prone to forced maturity leading to reduced productivity and shriveled low quality grains. This can be avoided by irrigation at grain filling stage. Therefore, the twin strategy for promoting irrigation at grain filling stage in wheat is to toss seed of spring season grain legumes in standing wheat and irrigate. Our initial experiences are quite encouraging in IGP.

In winter maize, farmers commonly grow garden peas and faba beans as intercrops. Winter legumes such as lentil and chickpea offer a huge opportunity for farmers to reduce 'rice fallows' after rainfed rice crop in low lying eastern-IGP. It is observed that many of these grain legume crops are heavily infested with pod borer which is best controlled by a spray

of 'Spinosad 45% SC' at initiation of flowering.

4.3.1. Major weeds in winter legumes

The winter legumes after rice in eastern IGP are mainly affected by a variety of weeds and this leads to lower productivity. Being slow growing and short stature crops, chickpea and lentil are affected by a variety of grasses and broad leaf weeds. *Vicia sativa*, *vicia hirsuta*, *Chenopodium album*, *Melilotus*, *Anagalis*, *Argemone mexicana*, *Asphodelus tenuifolius*, *Fumeria*, *Lathyrus*, *Circium*, and *Convolvulus* are common broad leaf weeds in winter season legumes in eastern IGP region.

4.3.2. Weed management in legumes

A. Cultural: Lentils (130 days) and Chickpea (140-150 days) are long duration crops however, critical stage for weed competition in these crops varies from 15 to 50 days after sowing. Therefore, weed management at initial crop growth stages are important in these winter legumes. Farmers normally go for hand weeding by contractual labourers or sometimes prefer intercropping with mustard or wheat. In Tal lands, sometimes they also practice mix cropping with *Lathyrus* as a cover crop which is taken out as fodder. Surface seeding in standing rice crop is also effective practice in Tal lands for minimizing crop weed completion in winter legumes. However, this traditional technology needs refinement with respect to cultivar choice and nutrient management (P and S) apart from mechanization for threshing rice immediately after harvesting. Mechanized rice harvesting is important because farmers generally practice field drying after emergence of surface seeded legumes which causes seedling mortality due to high humidity under rice mulch.

B. Chemical weed control: In winter legumes pre-emergence application of herbicides such as pendimethalin or alachlore at 1 kg a.i./ha at 2-3 days after sowing can help in managing the complex weed flora. However, herbicides like clodinfop at 60 g a.i./ha, fenoxaprop 60-80 g a.i./ha or quizalofop at 50 g a.i./ha can be used effectively for control of grassy weeds.

Herbicides used correctly help farmers to produce higher yield at less cost. It may be noted that some of the herbicides are toxic and can cause health hazards to human and live-stocks. Therefore, care should be taken while storing or using herbicides. Read the label carefully before use and always wear protective clothing while using herbicides. Also, use correct doses and clean water for making spray solutions. Avoid using herbicides in stressed crops, too wet or dry soils and very hot weathers. Also avoid drifts, use correct pressure as spray droplets can cause damage to neighboring crops. Further, adoption of improved spray techniques, using multiple boom nozzles with flat fan nozzles, pressure regulators have also been found very helpful in improving weed control efficiency and increasing crop yields substantially. It is always helpful to calibrate sprayers with water before actual spraying. Some herbicides come with surfactants and herbicides and surfactants should be mixed properly as per 'direction for use' provided with herbicide.

Best results of herbicides are obtained when weeds are in active growth stages. If weeds are under stress, apply a light irrigation before spraying. In noon, spray droplets dry out immediately resulting in poor absorption and translocation of the chemical molecules, thereby significantly reducing its efficacy.

5.0. Recommendations of herbicide molecules for weed management

The recommendations of herbicide molecules for weed management and their time of application and selectivity for different crops are given in Table 4.

Table 4. Recommendations of herbicide molecules for weed management

Herbicide	Application time	Dose g ai. /ha (Spray volume, L water ha ⁻¹)	Application, DAS/ DBF	Weed Control			Remarks (crop selectivity)
				Grasses	Broadleaf	Sedges	
Glyphosate (Non-selective systemic)	Pre-plant	1000-1500 (500)	1-7 DBF	***	***	**	For all crops
Paraquat (Non-selective contact)	Pre-Plant	500 (500)	0 DBF	**	***	*	Control annual weeds
Alachlor (Lasso)	Pre-emergence	1000 (500)	2-3 DAS	***	*		For legumes and maize legumes intercropping
Atrazine	Pre/ early post emergence	1000 (500)	2-15 DAS	***	***	*	For maize, sorghum, pearl millet, sugar cane
Pendimethalin (Stomp/ 30 EC, Stomp xtra)	Pre-emergence	800-1200 (500)	2-3 DAS	***	*	*	For wide range of crops
Pyrazosulfuron (Sathi)	Pre-emergence	20 (500)	12-20 DAS	**	*		For rice, Weak on grasses, Controls Leptochloa
2,4-D (Ethyl ester 38 EC/ Sodium salt 80 WP (Weedmar. Heera)	Post emergence	500 (1315)	30-35 DAS		**	*	For wheat, rice, Solonum, Malwa, lathyrus and Physalis escapes commonly
Azim sulfuron	Post emergence	17.5 (400) on Cyperus rotundus	12-25 DAS	*	***	***	For rice and effective
Bispyribac (Nominee Gold)	Post emergence	25 (500)	15-25	***	*	**	For rice, Eragrostis, Leptocloa, Digera escapes common, Needs saturated soils
Carfentrazone (Affinity 50 WDG)	Post emergence	20 (500)	25-30 DAS		***	*	For wheat, Controls Solonum, Malwa, lathyrus and Physalis. Contact Action, Weed regeneration problem
Clodinafop (Topik 15WP)	Post emergence	60 (400)	30-45 DAS	***			For wheat, also legumes
Ethoxy sulfuron (Sun rice)	Post emergence	18 (500)	12-20 DAS		**	**	For rice. Needs saturated soils
Fenoxaprop (Whip Super) Fenoxaprop (Rice Star)	Post emergence	60 (500)	14-21 DAS	**			For rice, and also control grasses in standing legumes
Fenoxaprop-ethyl (Puma super/ Puma power 10 EC)	Post emergence	100-120 (500)	30-35 DAS	**			For wheat, effective Cynodon
Isoproturon (Iso-guard)	Post emergence	1000 (500)	25-30 DAS	**	*		For wheat, Effective on Phalaris, however no control of resistance biotypes of Phalaris

Contd...

Contd...

Herbicide	Application time	Dose g ai. /ha (Spray volume, L water ha ⁻¹)	Application, DAS/ DBF	Weed Control			Remarks (crop selectivity)
				Grasses	Broadleaf	Sedges	
Mesosulfuron + Iodosulfuron (Atlantis 3.6 WG)	Post emergence	12 +2.4 (400)	30-35 DAS	***	**	**	For wheat, Toxic to wheat at high soil moisture
Metsulfuron (Algrip 20 WP)	Post emergence	4 (400)	30-35 DAS		**	**	For Wheat, Solonum and Physalis escapes commonly
Penoxulam	Post emergence	22.5 (500)	12-25 DAS	***	**	**	For rice, Needs saturated soils, Eragrostis, Leptocloa, Digera escapes commonly
Quizalofop (Targa Super 10 EC)	Post emergence	50 (500)	30-45	***	*	*	For legumes, Jute
Sulfosulfuron (Leader 75 WG)	Post emergence	25 (500)	30 -35 DAS	***	**	*	For wheat, Residual toxicity kills succeeding maize
Sulfosulfuron + metsulfuron (Total 80 WDG)	Post emergence	30+2 (40)	30-35 DAS	***	***	**	For wheat, Solonum, Malwa and Physalis escapes commonly
Tank Mixtures							
Glyphosate + 2,4D-EE	Pre-plant	1000+250 (300)	7-10 DBS	**	**	***	Controls of broad leaf and sedges before maize, rice or wheat
Alachlor + Atrazine	Pre emergence	1250+375	3-5 DAS	**	**	*	For maize
Atrazine + Pendimethalin	Pre emergence	500+500 (500)	3-5 DAS	***	***	*	For maize
Azimsulfuron + Bispyribac	Post emergence	17+12.5 (500)	12-20 DAS	***	***	***	For rice, effective on <i>Cyperus rotundus</i>
Propanil + Triclopyr	Post emergence	3000+500 (500)	15-25 DAS	**	**	*	For rice, temporary phyto toxicity problem
Intercropping systems							
Pendimethalin (Stomp 30 EC/Stomp xtra 37% CS)	Pre emergence	1000-1500 (500)	2-3 DAS	***	*	*	For wide range of crops
Oxyflurofen	Pre emergence	62-80 (500)	2-3 DAS	**	**	*	Sugarcane inter cropping system, garlic/onion, transplanted vegetables
Other crops							
Metribuzin (Sencor)	Pre/early post emergence	250-400 (500)	2-3 DAS	**	***		Potato, tomato, chillies and also as early post in peas
Oxyflurofen	Pre emergence	62-80 (500)	2-3 DAS	**	**	*	Transplanted vegetables, garlic onion
Chlorimurian (Cloban 25 WP)	Post emergence	9 (500)	10-20 DAS		***	***	Soybean
Imazethapyr (Persuit/Lagam 10 SL)	Post emergence	65 (500)	10-20 DAS	***	***	***	For Soyabean, groundnut, summer legumes

*Butachlor + Topstar sprays in DSR immediately after seeding can also be tried with some good results (although affects germination)

6.0. Soil cover management in rice based systems

6.1. Surface mulching with crop residues

Crop residues, when retained on the soil surface, serve as physical barrier to emergence of weeds, moderate the soil temperature, conserve soil moisture, and build soil organic matter. The new generation zero-till drills like the turbo seeder and disc opener planters allow seeding in presence of loose residues, but work best when residues are evenly spread across the field. In recent years, five advances in machinery have been developed or are under development for seeding crops into surface residues:



Turbo seeder

- **Turbo Seeder:** The Turbo Seeder is an improved version of the Happy Seeder. It shreds the residues in narrow strip in front of the tyne openers and places seed and fertiliser. This machine is capable of seeding into anchored or loose residue loads up to 8-10 t ha⁻¹.
- **PCR Planter:** The PCR planter is an advanced version of the Turbo Seeder having multi-crop precise seed

metering system “vertical plates” and adjustable row arrangements. Like turbo seeder, it shreds the residues in narrow strip in front of the tyne openers and places seed and fertiliser using inverted T-type openers. This machine is capable of seeding into anchored or loose residue loads up to 8-10 t ha⁻¹.



PCR Planter

- **Rotary disk drill:** This machine is based on a rotary till mechanism. The rotary disk drill is mounted on the three point linkage system and is powered through the power take-off (PTO) shaft of tractor. The rotating discs cut the residue and simultaneously make a narrow slit into the soil to facilitate placement of seed and fertilizer. The machine can be used for seeding under conditions of loose and anchored residues as well as residue-free conditions. This machine is capable of seeding into the loose residue load of up to 7-8 t ha⁻¹.
- **Double disc coulters:** Double disc coulters are fitted in front of seeding tynes to cut through loose residues. The problem being faced with this machine is that being lightweight it does not cut the loose residues and the seed and fertiliser is dropped on the



Rotary disc drill

top of it, part of which reaches the soil surface. Irrigation is required immediately after seeding in order to facilitate germination. This machine may work up to a residue load of about 3 to 4 t ha⁻¹.

- **Star wheel:** This mechanism is being used around the world under non-rice situations but its utility under rice wheat system with a residue load of 6 to 10 t ha⁻¹ is still to be proved. The initial results indicate that it may work under low residue load of up to 3 t ha⁻¹. At present, this machine drops the fertiliser on the surface in front of the moving star wheels, which is not the proper method of placing the fertiliser.

6.2. *Sesbania* Co-culture (Brown manuring) and cover crops

Traditionally, farmers grow green manure crops before rice culture and incorporate

it by puddling before transplanting rice seedlings. This means an additional need for irrigation water and fuel costs for incorporation. Since there is little water in the reservoirs during peak summers, farmers have not been able to take full advantage of green manuring in rice. In “Brown Manuring” practice, rice and *Sesbania* crops are planted together (as discussed in weed management). *Sesbania* surface mulch conserves soil moisture and supplies 10-15kg N/ha on decomposition. In areas where soil crusting is a problem, germinating *Sesbania* helps break it and facilitates emergence of rice seedlings. Rice and *Sesbania* can be planted with the same drill. *Sesbania* surface mulch decomposes very fast to supply N. The other way of planting cover crops (*Sesbania*, mungbean etc) is through relay cropping in wheat at last irrigation. In the DSR-wheat/maize rotation, the possibility of fitting summer legume is through relay cropping of these crops coinciding with last irrigation water application in winter crops (wheat, maize etc) so that the DSR crop can be planted in time after knocking down of the relay legumes using 2,4-D herbicide. This will also help in meeting early N requirement of the DSR crop and avoid early nitrogen and moisture stresses in DSR.



Rice and Sesbania co-culture at 20 days stage

Major Weeds of Rice (Kharif season)



Echinochloa crus-galli



Cyperus rotundus



Echinochloa colonum



Leptochloa spp.



Cyperus difformis



Cyperus compressus



Cyperus iria

Major Weeds of Wheat (*Rabi* season)



Phalaris minor



Avena ludoviciana



Rumex



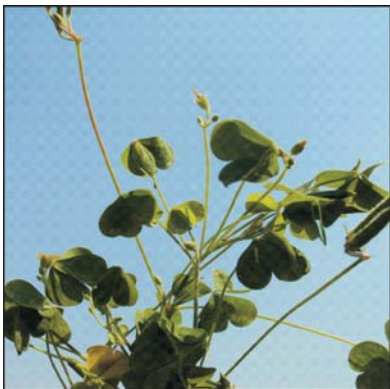
Poa annua



Anagallis arvensis



Malva parviflora



Oxalis corniculata



Fumaria parviflora



Chenopodium album



Solanum nigrum



Coronopus didymus



Cannabis sativa



International Maize and Wheat Improvement Center (CIMMYT)

**CG Block, National Agriculture Science Centre (NASC) Complex,
DPS Marg, Pusa Campus, New Delhi 110 012, India**

Telephone + 91 (11) 65441938, 25842940, Fax + 91 (11) 25842938

Visit our World Wide Web site at <http://www.cimmyt.org>