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Corresponding Author

Teekam Singh

e-mail: teekam.singh@icar.gov.in

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Author's Address

ICAR-Indian Agricultural Research Institute, New Delhi (110 012), India

Weed Management Options for Successful Dry Direct Seeded Rice in Conservation Agriculture

Ayan Sarkar, Abhijit Mandal and Teekam Singh*

Abstract

Conservation agriculture emerged as a potential resource conservation technology against conventional puddled transplanting rice. In DDSR, the absence of standing water and conventional tillage, seedling size differentiation gives weed a prolific advantage over rice plants. Sometimes weeds could cause loss up to 100%. Preventive approaches like pure seeds, weed free bunds and irrigation channels, seed quarantine aimed to minimize weed seed entry in to a field. Hand weeding, stale seed bed and non-selective herbicides like paraquat or diquat are the most important components in IWM of DDSR in CA based system. Some cultural practices like high seed rate, early sowing, mulching, brown manuring and cover crops are found beneficial against weeds. The varieties like- 'PR 120', 'PR 108', 'PI 312777' having vigorous early growth, vertical leaf orientation and more tillering potential are found suitable in Indian condition for DDSR.

1. Introduction

Conservation agriculture (CA) is a holistic production system approach which is being used as a vital tool to deal with the problems arising from modern intensive chemical and tractor-based conventional agricultural practice. Declining factor productivity, soil organic carbon, ground water table, deterioration of soil fertility and bio diversity etc. are suitably addressed by CA based systems through its three pillars i.e., continuous minimum mechanical soil disturbance, permanent crop residue/soil organic cover and diversification of crop species grown in sequence/or associations. Soil disturbance i.e., tillage is completely eliminated and clean cultivation is prohibited which might be responsible for weed problem in conservation agriculture during initial years till weed seed bank exhausted from upper soil layer. Weeds are well known as the major biotic constraints in successful crop production which can reduce more than one third of the crop yield. In crop like direct seeded rice (DSR), which is a fouling crop, the yield loss due to weeds may be as high as 100% of the total produce. In the present days, when the importance of non-puddled non transplanted rice



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is increasing mainly due to its less water requirement, however, weeds are the major hindrance. So, we have to find out what are the possible weed management options we have in our hand to tackle this problem.

2. Brief History of CA

The term “conservation agriculture” was first coined in the 1990s but its origins is way back in the 1930s, during the ‘Dust Bowl’ in the mid-western United States of America. Tillage, the age-old practice was first time questioned by Edward H. Faulkner in his manuscript “Plowman’s folly”. With time, the concept of protecting soil, by reducing tillage and keeping the soil covered with residue along with crop diversification, gained importance. This system named as conservation tillage (Friedrich et al., 2012). Today this practice is performed in millions of hectares in various parts of world including India.

3. What is Dry DSR?

Dry direct seeded rice is a crop establishment strategy of rice crop where pre germinated rice seeds are sown on a non-puddled, non-transplanted condition either in broadcasting method or dibbling method or drilling method. In case of later two methods, implements like power tiller operated seeder or seed cum fertilizer drills can be used. It differs from wet DSR, where pre germinated seeds are sown on puddle soil. It can be

followed under both conventional condition as well as zero till or CA based system. Under reduced tillage based dry DSR, power tiller operated seeder tills the soil at a shallow depth of 4-5cm and drills rice seeds at a 20 cm row spacing in a single operation. The soil condition is aerobic and sowing depth is 2-3 cm. In case of zero till dry DSR, fields are flush irrigated and weeds are allowed to germinate. After about 14 days, they are killed using any non-selective herbicide then seeds are either broadcasted in moist soil, followed by a light irrigation or drill sown using a zero till drill seeder with row spacing of 20 cm, followed by a light irrigation. Here also depth of sowing is 2-3 cm. In dry DSR, land preparation is usually done before onset of monsoon and seeds are sown before start of the wet season so as to take the advantage of pre monsoon rainfall. (Kumar and Ladha, 2011).

4. Scope of Dry-DSR in CA

Reduced tillage or zero tillage based dry DSR is a potential resource conservation technology, which could replace the conventional puddled transplanting which is resource and labour-intensive system of rice cultivation. Including this in CA would also benefit the environment in many ways like reduced water requirement, methane emission, denitrification loss of nitrogen and global warming potential. Additionally, the benefits of CA can be harnessed like improved physical condition of soil, improved infiltration rate, reduced soil erosion, reduced evaporation, increasing organic matter content of soil etc. So reduced tillage or zero tillage based dry DSR with CA has a tremendous scope mainly rice based cropping systems where lots of energy and resources could be saved.

5. Major Hindrance in CA

Weeds are the major hindrance in dry direct seeded rice and especially under CA situations. The risk of greater crop yield losses due to weed competition in dry direct-seeded rice systems compared to transplanted rice is mainly because of the seedling size differentiation between rice and weeds (lack of head start of rice) and the absence of the suppressive effect of standing water on weed emergence and growth at crop emergence time, additionally absence of conventional tillage gives weed a prolific advantage over rice plants. Presence of previous crop residue also influence germination of weeds by either suppressing or increasing some of the weeds. In DDSR the weed flora shift is towards annual grasses and species diversity is seen more compared to transplanted rice.

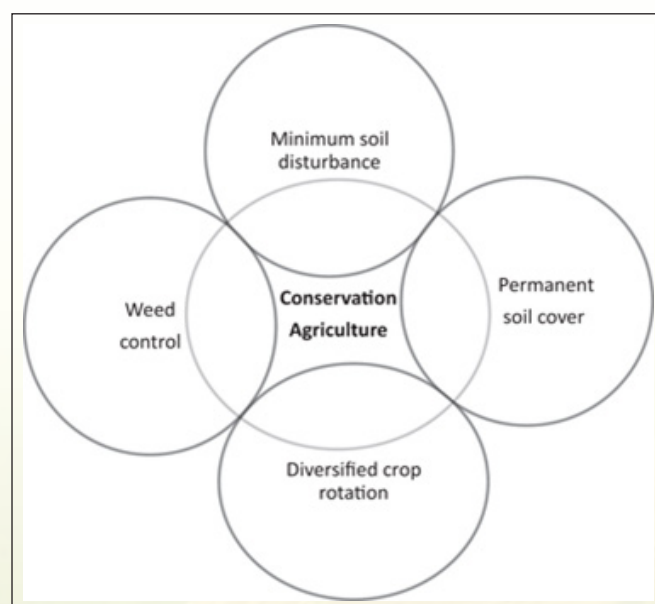


Figure 1: Elements of conservation agriculture (Farooq et al., 2015)

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Yield loss due to weeds in DDSR may range between 15-100% (Busi et al., 2017). The critical period of weed competition in DDSR remains up to 41

DAS (Chauhan and Johnson, 2011). Poor weed control has been reported as the second most important barrier in DDSR after inadequate water availability.

Weedy rice (*Oryza sativa* fsp. *Spontanea*) has emerged as one of the main weeds of DDSR over several places of world. Various morphological, chronological and genetic similarity, seed shattering and dormancy ability, high vigour, and aggressiveness, profuse tillering ability etc. trait made it a cumbersome weed in DDSR. Due to red endosperm, it is also called as red rice. Other than this there are various other weeds like *Echinochloa colona*, *Echinochloa crus-galli*, *Dactyloctenium aegyptium*, *Leptochloa chinensis*, *Cyperus rotundus*, *Cynodon dactylon*, *Digitaria sanguinalis*, *Elusine indica* etc.



Figure 2: Emergence of dry direct seeded rice seedlings under residue retention condition

6. Weed Management Options in DDSR in CA System

Traditional options like tillage or flooding or maintenance of standing water is not done in this case, so we have to rely on various other methods for managing weeds. Use of only chemical option is not good as it will bring herbicide resistance problem along with environmental constraints. So, 'Multi hammer approach' means use of various methods like preventive, cultural, mechanical, chemical, biological simultaneously or complementarily following integrated weed management (IWM) principle is the most useful strategy to tackle this barrier in CA based DDSR.

6.1. Preventive approach

There are various preventive approaches to be followed like use of weed seed contamination free seeds, sowing implements, weed free bunds, irrigation channels, seed quarantine etc. Preventive approach aims at minimizing the weed seed bank and minimizing entry of new weed seeds in to a field or area or country. It is used in complementing the other approaches. It helps in eliminating the chance of invasive weeds infestation by strict quarantine approach. In many countries weedy rice or red rice spreads as contaminated seeds along with rice seeds and now this weed has become a menace because of the non-availability of selective herbicides to control it. Contaminated weed seeds may also spread herbicide resistance besides introducing new species. So, considering 'Prevention is better than cure', preventive weed management practices are very much essential component in IWM particularly in DDSR. Additionally, inclusion of any short duration dual purpose crop like summer mung bean in the cropping system to eliminate the fallow period before rice may also serve as preventive approach by reducing the chance of seed rain during the fallow period, but in that moisture availability for successive rice crop is a concern.



Figure 3: Problematic weeds in DDSR (1. Weedy rice (*Oryza sativa* f. *spontanea*); 2. *Dactyloctenium aegyptium*, 3. *Echinochloa crus-galli*; 4. *Digitaria sanguinalis* 5. *Echinochloa colona*)

6.2. Physical approach

This approach is basically combination of mechanical and manual approach. It is also an important component of IWM. In CA based system, tillage or hoeing is not included in this approach and further it is DDSR, so flooding is also not included. Due to presence of previous crop residue in CA based system, there will be creation of air gaps under the polythene in soil solarisation, so it may not be an effective tool. The most important physical means of weed control here in this case is hand weeding. At least one hand weeding should be done during the

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critical period of crop weed competition in the IWM package of practice. The previous crop residue may also act as mulch which also may suppress germination of weed seeds, along with reducing evaporation of water, minimizing erosion and adding organic matter in soil. Crop residues like *Brassica sp.* also may release some allelopathic chemicals which may also play crucial role in weed seed survival, germination, emergence and development.

6.3. Cultural approach

It is also called ecological approach or crop competitive approach as all the cultural approach gives the crop a competitive advantage over weeds. It includes various methods like stale seed bed, use of weed competitive variety, time of sowing, seed rate, spacing, crop rotation, inclusion of cover crops or any break crop in the system etc. Stale seed bed using a non-selective total killer like paraquat or diquat is one of the most important components in IWM of DDSR in CA based system. Due to practice of ZT, most of the weed seeds are on the top few centimetres of soil layer, providing pre sowing light irrigation, weed seeds may get germinated. After germination, they are killed by paraquat and then, sowing operation is taken. Stale seed bed technique is a very effective weed management practice against weedy rice and reduces up to 53% of weedy rice over the control and 13–33% reductions in the viable seed bank have been recorded (Singh et al., 2018). Seeds with hard seed coat like *Commelina bengalensis*, *Cyperus diffusa* etc. is difficult to control with stale seed bed approach.



Figure 4: Brown manuring in rice

Rice cultivar having vigorous early growth, rapid ground cover or higher specific leaf area, more prolific root growth, vertical leaf orientation, more tillering potential are more competitive to weeds against other varieties. 'PR 120', 'PR 108', 'PI 312777', 'RH 257', 'Krishna hamsa', 'Prabhat' etc. are suitable as DDSR in Indian condition. Increasing in the germination process through seed priming also helps rice to establish faster and become more competitive towards weeds vis-a-vis providing resistance towards various abiotic stress. Use of higher seed rate also helps in suppressing the weeds and compensating the reduced germination under no till residue retention condition. Time of sowing is also important as late sowing will trigger more weed germination and the competitive ability of the crop will be less. Sowing timely with the onset of monsoon is recommended.

Brown manuring is a very important component in CA based DDSR. It is basically a no till version of green manuring where rice seeds are sown along with sesbania seeds at the time of sowing. After 25–30 DAS, a selective herbicide like 2,4-d ethyl ester @ 500g a.i./ ha or bispyribac-Na @ 20 g a.i./ ha is sprayed. This causes to desiccation of the sesbania leaves and turning them to brown and subsequently get decomposed *in-situ* in the field. This is very effective approach for managing weeds in DDSR along with service other purpose like addition of organic matter in soil. It is more effective in managing broad leaves and sedges compared to grasses. Proper crop rotation, use of cover crop during fallow period etc are also effective methods for managing weeds in DDSR based CA system.

6.4. Chemical approach

Chemical approach using herbicide is one of the most important components of IWM despite its environmental concerns, resistance development problem, effect on living organisms etc. There are a number of options to manage weeds in CA based DDSR system. Pre-emergence (PRE) herbicides like pendimethalin 30%EC @ 1–1.5kg a.i./ ha, oxyflourfen 23.5% EC @ 150–240g a.i./ ha, oxadiazon @ 0.5–0.75kg a.i./ ha etc. can be used followed by some post-emergence (POST) herbicides like bispyribac-Na 10%SC @ 20g a.i./ ha at 20 DAS, cyhalofop butyl 10%EC @ 75–80g a.i./ ha, azimsulfuron 50%DF @ 35g a.i./ ha, fenoxaprop-P-ethyl 6.7%w/w EC @ 56–60 g a.i./ ha etc. are used for complete weed control in DDSR. Herbicide mixtures offer more broad-spectrum activity compared to a single herbicide application. Herbicide mixtures like metsulfuron methyl+ chlorimuron ethyl (Almix 20WP)

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can be used 20–35 DAS @40g a.i./ ha, fentrazamide + propanil (Lecspiro) 4–8 DAS @ 1.5kg/ ha, butachlor + propanil (Advance) @1.5–2.0 l/ ha at 6–10 DAS etc. are some effective mixture herbicides for DDSR. For sequential application, pendimethalin fb bispyribac sodium, oxadiargyl fb bispyribac-sodium, pendimethalin fb azimsulfuron, oxadiargyl fb azimsulfuron etc. are some of the combinations that can be used successfully in DDSR (Singh et al., 2016). To prevent resistance development, some steps should be followed like don't use same herbicide or herbicide with similar mode of action repeatedly; use only recommended dose of herbicide at the right time; in a mixture of herbicide, component of mixture should have different mode of action so that it can delay resistance development.

Before sowing of DDSR, the existing weed flora that comes out after harvest of preceding crop, should be killed by chemical ploughing like using of paraquat. Pre emergence application in granule formulation may have edge over liquid-based formulation under residue retention condition. So, after the weed flora settles and crop emerges properly, POST herbicide may be preferable as they are more efficient than PRE.

6.5. Herbicide tolerant rice

Herbicide tolerant (HT) rice is a genetically modified (GM) or non-GM crop which is tolerant to a specific herbicide genetically. So, this gives us an opportunity to use any specific herbicide or any non-selective herbicide and manage various problematic weeds like weedy rice in case of rice. This concept may provide an economical and long-term solution for managing weeds in DDSR system. Recently IARI has developed countries first ever non-GM herbicide tolerant basmati rice varieties i.e., 'Pusa Basmati 1979' and 'Pusa Basmati 1985' which are tolerant to herbicide Imazathapyr, a broad spectrum herbicide, inhibiting ALS enzyme, which in turn inhibits production of 3 amino acids namely leucine, isoleucine and valine. Similarly, rice cultivars 'Clearfield 121' and 'Clearfield 141' in the United States and 'IRGA 422 CL' in Brazil are some other examples of HT rice (Raso et al., 2010).

6.6. Integrated weed management

Considering the diversity of weed problems in different rice cultures, no single method of control, whether cultural, manual, mechanical, or chemical, would be sufficient to provide season-long weed control under all situations. Manual weeding is not only labour intensive

but their timely availability is also a problem. Chemical weed control on the other hand may lead to environmental pollution. Herbicides are used to control weeds in DSR, but because of concerns about the evolution of herbicide resistance and a scarcity of new and effective herbicides, there is a need to integrate other weed management strategies with herbicide use. In addition, because of the variability in the growth habit of weeds, any single method of weed control cannot provide effective and season-long control in DSR. Various weed management approaches need to be integrated to achieve effective, sustainable, and long-term weed control in DDSR.



Figure 5: IARI Director Dr. A.K. Singh with India's first herbicide tolerant non-GM rice variety (Indian Express)

7. Conclusion

Considering the negative effects of traditional puddle transplanted rice (TPR), DDSR is a very important alternative resource saving technique. Comparable yield could be harvested with DDSR through adoption of right agronomic weed management tactics viz., preventive measures, timely agronomic operations, herbicides, competitive varieties etc. The proper monitoring of weed flora and their distribution is also help in managing weeds to ensure long term economic viability as well as sustainability of DDSR based CA system.

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