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**Review Article**

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# Understanding Strategic Weed Management in Direct Seeded Rice - A Review

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## ABSTRACT

Transplanting in puddled soils (intensive tillage in ponded conditions) with continuous flooding is the most common method of rice crop establishment in Asia. However, the most important problem associated with transplanted rice is that change in soil aggregates and development of hardpan below the soil surface caused due to flooding and puddling, which is not desirable for following wheat crop. Although, this is advantageous for effective weed control in the transplanted rice field. The technique of flooding the field with water is not only very laborious, tidy, and cumbersome but also very expensive, and time-consuming. The direct seeding of rice seems to be the only viable alternative to liberate farmers. However, weeds are the main biological constraint in DSR. Weed problems associated with DSR (direct seeded rice) have been explained in this review paper and also the strategies to develop for weed management in DSR. In this effort the chapter has been covered by elaborating the techniques of prevention, land preparation, effect of sowing time on weed dynamics, impact of planting density on weed dynamics, impact of row spacing, mechanical weed control, nutrient management, water management, chemical weed control and integrated weed management in context to DSR with a view to achieve enhanced rice yield similar to that under transplant condition.
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**Keywords:** DRS, Weed management, Weed dynamics, Integrated Weed management

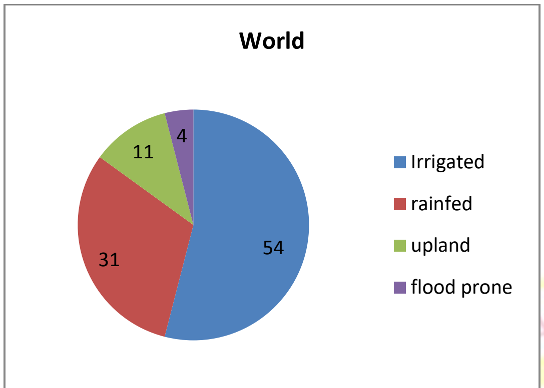
## INTRODUCTION

Rice (*Oryza sativa L.*) is one of the world's most important staple food crops. It is the primary source of income and employment for the majority of the population in Asia in general and India in particular. Rice has wider climatic adaptability, under both the lower and upper limits of climatic variables with average growing temperature (17–33 ºC), annual rainfall (100–5100 mm), and solar radiation (25–95% of potential) during the main rice season (Zhao, 2006) grows well all over the world ranging from the flood plains of Bangladesh to the Himalayan foothills of Nepal, and from the rain forests of Indonesia to the desert plains of Australia (IRRI, 1995; Maclean *et al*., 2002; Kumar and Ladha, 2011) covering nearly 161 million hectares (m ha) in 114 countries. Asia alone contributes more than 90% of global production (143 m ha area; 612 m tons production) and consumption (FAO,2009) as it is the principal cereal food of the main diet of 3.5 billion people, and due to burgeoning population, there is still need of about 70% additional rice by 2025 (Kim and Krishnan, 2002).

**Methods of Rice cultivation:**

Transplanting in puddled soils (intensive tillage in ponded conditions) with continuous flooding is the most common method of rice crop establishment in Asia (Singh *et al*., 2006; Kumar and Ladha, 2011). However, the most important problem associated with transplanted rice is that flooding and puddling bring about change in soil aggregates and develop hardpan below the soil surface which is not desirable for following wheat crop. Although this situation is advantageous for effective weed control in the transplanted rice field (Bhagat *et al*., 1999; Kumar *et al*., 2008). The technique of flooding the field with water is not only very laborious, tidy, and cumbersome but also very expensive, and time-consuming (Timsina and Connor, 2001; Rajkumara *et al*., 2003; Soomro,2004; Sahrawat *et al*., 2010). Manual transplanting of the seedling is often delayed because all fields are not transplanted simultaneously, thus the seedling age surpasses that of optimum age of 21 to 25 days thus fewer tillers develop reducing the crop yield. (Khaliq and Matloob, 2011) Many times it has been observed that hired laborers are not committed to fair and good transplanting of seedlings, this way the average number of plants population (<250,000 plants ha_l) per unit area is reduced (Baloch *et al*., 2000). The timely availability of skilled labor for transplanting is a big problem due to escalating wages. Moreover, due to the shortage of laborers, many of them are engaged in transplanting work in the villages and farmers wait for their turn after relieving of preoccupied laborers.

Nursery raising for transplanted rice cultivation is not only a risky matter but it also involves energy, is time-consuming, and is also expensive. The risky in sense, that many times after raising nursery, the main field doesn't get prepared due to delayed monsoon rain thus seedlings get overage. Decreasing rice yield due to reduced tillering (Ghosh and Singh, 1994). Transplanting also decreases rice plants' ability to withstand moisture stress.



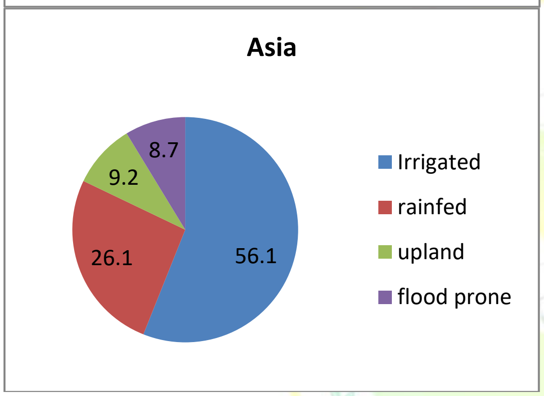




**Figure 1:** Area (% coverage) under different rice ecosystems in the world and Asia. Swain *et al*. (2005); IRRI (2001) based on FAO stat.

**Transplanted rice-wheat –**

**Problems associated with Transplanted rice:** conventionally, rice is transplanted after puddling in the rice-wheat system (Gupta and Seth, 2007), while the subsequent wheat crop requires well plowed pulverized soil. Rice soil under transplant conditions brings causes deleterious effects on the soil environment for the succeeding wheat due to soil particles dispersion, soil compactness, and difficulties in tillage operations (Chauhan *et al*., 2012) inviting more energy and time in field preparation for succeeding wheat crop. A sharp reduction in wheat productivity has also been reported by Mohanty *et al*., 2007 and exhaustive work of Fujisaka *et al*. (1994) in several rice-wheat areas who revealed that yield reduction was due to disturbance of the soil structure accompanied by the formation of subsurface hardpans. They further opined that poor wheat root growth due to soil compaction and hardpans is the principal cause of low productivity after transplanted rice in puddled conditions. Many times, due to the late arrival of monsoon rains, delayed transplanting leads to the late vacancy of field resulting in a late harvest of rice and compelling sowing of wheat beyond the optimum time (Farooq *et al*., 2006) hence reducing wheat yields enormously (Gangwar *et al*., 2006). Transplanted rice is a mammoth water user (Barker *et al*., 1998; Kumar and Ladha, 2011), as it utilizes almost three times more water consumption than usually that of other upland crops. Another problem associated with transplanted rice is that usually requires a huge quantity of water when the reservoirs and ponds are still filled low in the water. Unless and until these reservoirs are filled with sufficient water for puddling, the farmers are not able to prepare the field which subsequently delays rice transplanting. Tillage operations account for 15% of the total production cost in irrigated rice (AgStat, 2004). Thus it can be concluded that rice production through the traditional system of transplanting is becoming less profitable. Therefore, it is imperative to switch over from traditional transplanting for economic gain. The direct seeding of rice seems to be the only viable alternative to liberate farmers (Farooq *et al*., 2011; Kumar and Ladha, 2011; Nie *et al*., 2012). Dawe, (2005) emphasized that 5 persons –day per ha are required under DSR while it counts about 25-30 person-day per ha under conventional method of transplanting.

**WHY DSR:**

Many Asian countries are practicing DSR (Direct seeded rice) as it has emerged a popular method of rice cultivation. As compared to transplant method, DSR requires about 11 to 75% less labour depending upon extent of weed infestation, season and location. However, weeds are the main biological constraint in DSR. A worldwide survey in several rice producing countries revealed that weed infestation was the serious biological constraint limiting the productivity of rice fields (Johnson, 1996). According to Tomita *et al*., 2003a,b; Rao *et al*., 2007, the diverse weed flora are found under DSR which has been identified in severe reduction in rice yield under DSR. While the rice seedlings under transplant condition suppress early emerging weeds due to anaerobic condition developed by water logged condition which is absent under DSR. Hence weed control in DSR is a cumbersome practice as they compete with rice seedlings right from beginning as emerging simultaneously with rice seedlings.

**Weed Dynamics in DSR:** As mentioned earlier, weeds are dynamic in nature, and the composition of weed communities in rice fields is influenced by cultural, mechanical, chemical, and environmental factors. Weeds not only compete with DSR for space, water, nutrients, and sunlight but they are also site for insect pests, damaging rice crop as well as affect the quality of produce. As the weeds in DSR, emerge simultaneously with germination of rice seedlings, invite tough competition, stating from very early in the life of the crop and hence require early weed control. Thus, it can be inferred that there is enough room left for developing strategies for effective weed management to harness good rice yield.

**How to develop strategies for weed management in DSR:**

**1. Prevention:**

Prevention of weed introduction and spread is the most important strategy in managing weeds regardless of crop, establishment method, and ecosystem.

The machines used for tillage, planting, harvesting, and threshing should be clean (free from weed seeds) before moving them from one field to another.

The most important preventive measure is the use of clean rice seeds. Managing weeds on bunds or levees and roads can also help in preventing invasion of weeds in rice fields.

Managing weeds on bunds and roads can also help in preventing invasion of weeds in rice fields.

**2. Land Preparation:**

The composition, extent, and occurrence of weed species are greatly influenced by tillage performance.

It has been reported that in DSR, the composition of weed communities is more pronounced on the topsoil surface layer (0-15 cm) as under no-till condition seasonal weeds seeds lie undisturbed on soil surface than under conventional tillage (Barberi and Lo Cascio, 2001). Composition of weeds, their density, and persistence in soil are influenced by the method of cultivation, its depth, and frequency of tillage (Mohler and Galford, 1997). Seeds of weeds deposited near the soil surface rapidly destroy due to germination and mortality (Mohler, 1993).

One should have enough knowledge of the weed emergence pattern of different weed species under different tillage systems for satisfactory management and prediction in DSR fields.

Regular monitoring and study of weed flora of DSR under zero tilled or prepared field can be a preventive measure for efficient weed management.

It has been observed that without weed control measures yield loss to the tune of 85–96% in conventional tillage and up to 98% in zero tillage has been reported by Singh *et al*., 2011; Chauhan and Johnson, 2011b.

Significant replacement of weed species has been observed by Hobbs *et al*., (2002) and Tuong *et al*. (2005) by a change in tillage from wet to dry seeding of rice which resulted in the dominance of grassy weeds density.

Tillage also influences the vertical distribution of weed species in the different soil profile, like an infestation of Ipomea wright was suppressed by conventional tillage but zero tillage promoted the same (Gealy, 1998). Chauhan and Johnson, 2009; Chauhan and Ope~na, 2012a have reported that *Ludwigia parviflora*, *Portulaca oleracea* L., *Digitaria ciliaris* (Retz.) Koel., *Eclipta prostrata* (L.) L, *E. colona*, *Ageratum conyzoides* L., and E. indica, infested DSR in next season of zero tillage.

Deposition of live weed seeds are found more abundantly on 0 to 5 cm surface layer of soil under zero tillage compared to conventionally tilled soil.

Chauhan and Johnson, 2009, observed that under zero tillage, 77% of the seeds were found in the topsoil surface (2 cm) and 62% of the seeds were buried to a depth of 2–5 cm. May this be possibly due to obstruction created by soil mass on smaller-sized weed seeds occurring in deeper soil layer restricting them to emerge out. While under the conventional method of tillage soil mass is friable and deeper-seated weeds seeds come up due to soil turning which facilitates them to germinate receiving essential resources like suitable moisture, and lights.

Similar findings have also been reported by Barberi and Lo Cascio (2001) who emphasized that weed composition in the 0- to 15-cm soil layer, is influenced to a greater extent by tillage than crop rotation. They further opined that in a tilled soil layer under conventional tillage, weed seeds are believed to be uniformly distributed (Ball, 1992).

Zero tillage also induces weed flora shift to annual grasses (Tuong *et al*., 2005). According to Mishra and Singh (2012) by the adoption of zero tillage, there was a reduction of the density of Chenopodium album L. and Avena ludoviciana in wheat crop, however, the densities of weeds like E. colona and C. iria increased significantly in rice.

This has been observed that reduced tillage often discourages broad-leaved weeds while encouraging annual grassy weeds species (Froud-Williams *et al*., 1981; Gill and Arshad, 1995).

Stale bed methods in which weeds are allowed to emerge before preparation of final seedbed, and are destroyed chemically or mechanically, the suppression of weeds was found to be the extent of 56% (Singh *et al*., 2009). Effective weed suppression under DSR was also demonstrated by Renu *et al*., (2000) by combining stale bed method and application of nonselective herbicides than mechanical weeding.

A stale seedbed technique combined with the application of a nonselective herbicide was found more efficient in suppressing weeds in DSR than mechanical weeding (Renu *et al*., 2000).

**3. Effect of sowing time on weed dynamics:**

Weed dynamics are also influenced by sowing time. Planting/sowing time can be altered to manage the composition of weeds in rice.

It has been observed that weeds species emerge only at a specific time and late planting can escape the period of peak weed germination.

It has also been reported that more yield losses occur when weeds emerge earlier or at the same time when crop seeds germinate (Aldrich, 1987). While the reduction in weed pressure was observed more by late planting than early in crops (Buhler and Gunsolus, 1996) for crops such as barley and oat (Lég_ere, 1997), faba bean (Grenz *et al*., 2005), corn (Williams, 2006), soybean (Buhler and Gunsolus, 1996), and wheat (Zafar, 2012).

**4. Impact of planting density on weed dynamics:**

Crop planting density has also an impact on weed dynamics (Mahajan *et al*., 2010). Enhanced seed rate provides weed suppression.

The yield loss is often proportional to the duration of late planting time beyond the optimum.

Report of the dominance of cyperus rotundus under dry season tillage and dominance of grasses such as Digitaria sanguinalis and Echinochloa colona after tillage at the start of the rainy season was suggested by (Castin and Moody, 1980).

Tillage in the dry season resulted in increased dominance of Cyperus rotundus, whereas grasses such as Digitaria spp. and E. indica dominated after tillage at the beginning of the rainy season

Delayed planting reduced the yield loss associated with weeds in soybean (Buhler and Gunsolus, 1996) and corn (Gower *et al*., 2002) due to increased weed seedling mortality.

Weeds in plots seeded at 50 kg ha_1 had higher survival and growth as indicated by higher weed biomass, resulting in a more competitive weed community (Phoung *et al*., 2005).

Conducive environment for the growth of weeds in DSR results from a reduced density of crops and enhanced rice yield coupled with reduced weed biomass was found in weedy plots when seeding rate increased from 100 to 300 seeds per m2 Zhao *et al*. (2007)

A competitive advantage to crop was observed in weedy plots when it was sown with a higher seed rate (Chauhan *et al*., 2011).

A reduction in weed biomass under weedy check was observed by Khaliq *et al*. (2012b), who suggested a reduction in weed biomass to the extent of 22–43% when seed rate was increased from 50 to 75% while the weed biomass reduced further when seed rate was increased to 100 kg/ha in DSR.

**5. Impact of row Spacing:**

The row spacing affects the light interception which is utilized for photosynthesis by crop plants. However, hindrance in a proper interception by weeds will affect crop productivity. The appropriate manipulation of in-row spacing and its orientation will reduce light interception by weeds. It has been suggested by Kristensen *et al*., 2008; Mashingaidze *et al*., 2009; Chauhan and Johnson, 2010b that narrow spacing reduced weed infestation compared to 30 cm spacing as a result of rapid canopy formation. For direct-seeded rice, a narrow spacing is desirable for having a competitive edge by a crop over weeds. Chauhan and Johnson, 2010 observed reduced weed biomass and density of E. colona and E. crusgalli when rice was sown at narrow spacing than a wider one.

**6. Mechanical Weed Control:**

Usually mechanical weeding in DSR is not desirable owing following reasons:

Due to weather conditions when continuous rain makes the soil not fit for mechanical weeding by wheel hoe, grubber, and hand hoe due to wet soil condition.

Many times, rice seeds are sown as a broadcast method which does not allow weeding mechanically due to scattered seedling population.

Many times, mechanical weeding hampers the satisfactory result of herbicide application due to soil disturbance by exposing weeds to conducive germinating environment seeds located under deeper layer of soil surface.

**7. Nutrient Management:**

There is a direct relationship of weed dynamics with the nutrient status of the soil. Weeds being nutrifillic, utilize nutrients more compared to crop plants, thus posing a competitive edge over crop plants in absence of good weed control measures (Mahajan and Timsina, 2011). Among nutrients, nitrogen induces a weed population more than any other nutrients. Thus, proper manipulation of fertilizer levels is a desirable factor to suppress weed infestation for better crop production.

**8. Water Management:**

Water plays a vital role in deciding the quantum of weed population and weed biomass in rice crops. Already discussed that in transplanted rice weed density and biomass is reduced owing to continuous submergence with water compared to DSR. Under DSR, it is very difficult to maintain submerged conditions for the want of hardpan below the soil surface to retain the water as in the case of transplanted puddle rice condition. However, flooding in DSR is done immediately after the emergence of rice seeds as rice seeds do not germinate under flooded conditions. However, as soon as we start flooding, there is enough opportunity to weeds to germinate and compete with emerging rice crop seeds.

**9. Chemical Weed Control:**

The chemical method of weed control has become synonyms of each other with DSR in recent years. The hand pulling of weeds like E. colona, and E. crusgalli is very difficult to be uprooted by hand due to smaller in size as well as they mimic with rice seedlings to be separated for identification. The use of chemical herbicides in DSR is going on increasing due to escalating labour wages accompanied with no availability of labour for hand as well as for mechanical weeding.

Under DSR a gap of nearly 4 to 6 weeks to make field permanently flooded, give rise ample opportunity to weeds to emerge and infest the field. Thus, to have a good rice yield, pre- and post-application of appropriate herbicides should be applied. For control of grassy and broad-leaved weeds pendimethalin, benthiocarb, and quinclorac can be having residual activity in soil can be applied at 0-3 DAS before rice and weed emergence and also field has sufficient moisture in field. Bisparibac – sodium has been found effective post emergence herbicide @25 g a.i./ha. It has been observed that application of pendimethalin is effective for 3 to 4 weeks and poor in controlling some grassy species like *Dacteloctanium aiegiptium* and *Leptochloa chinensis* and also sedges weeds while application of bisparibac sodium also take over to manage late emerged grassy and broad-leaved weeds also. Although application of herbicide is a viable tool for effective weed control in DSR, but due to associated problem of side effects and inviting herbicide resistance weed biotypes, it is suggested that it should be used in conjunction with other cultural methods to maintain long term broad spectrum weed management strategy.

**10. Integrated weed management:**

For satisfactory and effective weed control in DSR, single method of weed control is not sufficient unless and until it is combined with other methods. As suggested along with application of herbicides some preventive measures and cultural methods as mentioned above should be integrated for long term suppression of weeds.

## CONCLUSION

Based on above facts it can be concluded that DSR is becoming popular among farmers, however the weed management is a big issue which rests primarily upon herbicide application but associated side effects, other associated problems of prolonged use of single herbicide on same land will call other problem of development of herbicide resistance in weeds. Hence integrated approach is best option to follow in addition to adopt all preventive and appropriate cultural methods like maintain time of sowing, seed rate, stale bed methods, crop residue management, minimum or zero tillage in order to put weed population at minimum level.

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