International Journal of Chemical Studies

**P-ISSN: 2349–8528**
**E-ISSN: 2321–4902**
IJCS 2019; 7(2): 2099-2105

Received: 26-01-2019
Accepted: 27-02-2019

**Himanshu Verma**
Ph.D. Scholar, Agronomy Department of Agronomy, College of Agriculture, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

**SP Singh**
Senior research officer, Agronomy Department of Agronomy, College of Agriculture, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

**Correspondence**
**Himanshu Verma**
Ph.D. Scholar, Agronomy Department of Agronomy, College of Agriculture, Govind Ballabh Pant University of Agriculture & Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

# Weeds in direct seeded rice and their sustainable management through non-chemical approach: A review

**Himanshu Verma and SP Singh**

## Abstract
Weed infestation in direct seeded rice remains the single largest constraint limiting their productivity. A direct seeded rice crop generally lacks a "head start" over weeds due to dry tillage, absence of flooding and alternate wetting & drying conditions making it particularly vulnerable to weed competition during early period of crop growth therefore a key to success of direct-seeded rice is efficient weed control techniques that are economically and ecologically viable. Chemical weed management, the most popular method of weed control in direct seeded rice due to its feasibility and applicability is driving the ecosystems towards environmental pollution therefore non-chemical methods of weed control are also in use not only to increase yield and productivity but to improve soil health with sustainability also.

**Keywords:** Direct seeded rice, weed, sustainable, non-chemical

## Introduction
Rice feeds more than 50 per cent of the world population. Asia accounts for about 90per cent and 91 per cent of world's rice area and production, respectively. Among the rice growing countries, India having the largest area of 43.19 million hectare under rice in the world and in case of production (110.15 million tons), it is next to China. However, productivity of India is 2.55 tons per hectare. Rice is generally transplanted in the first fortnight of July in puddled soil, which leads destruction of macro pores and reduction in permeability; degrade the soil and water resources, and thereby, threatening the sustainability of the system.

Direct seeding of rice, a common practice before green revolution in India, is becoming popular once again because of its potential to save water and labour as it avoids three basic operations, namely puddling (a process where soil is compacted to reduce water seepage), transplanting and maintaining standing water. In addition to higher economic returns, direct seeded rice crops are faster and easier to plant, having shorter duration, less labour intensive, consume less water conducive to mechanization, have less methane emissions and hence offer an opportunity for farmers to earn from carbon credits than transplanted rice system.

Weeds pose a serious threat to the direct- seeded rice crop by competing for nutrients, light, space and moisture throughout the growing season. High weed infestation is a major constraint for broader adoption of direct seeded rice (Rao *et al.*, 2007) [49]. Yield reduction due to weeds is more critical in direct- seeded rice than in transplanted rice (Karim *et al.*, 2004) [29]. The competitive advantage of transplanted rice over direct seeded rice is due to the use of 4-5 weeks old seedlings (20-30 cm tall) in transplanted rice and also that the weeds emerging after rice transplanting are controlled by flooding after transplanting in transplanted rice compared to direct seeded rice and more than 50 weed species infest direct-seeded rice, causing severe competition in rice production worldwide (Caton *et al.*, 2003; Rao *et al.*, 2007) [7, 49].

Herbicide-based weed management is becoming the most popular method of weed control in direct seeded rice and is likely to increase further in response to labour scarcity, rising wages and increased adoption of direct seeding. Unfortunately, indiscriminate use of herbicides is driving the agro-ecosystems towards declining species diversity and, in many situations to herbicide resistance, weed shift and environmental pollution. Therefore adoption of non-chemical weed management approaches also play an important role for controlling weeds, increasing productivity without causing harm to the ecosystem.

**Major weeds in direct seeded rice**

Infestation of weeds in direct seeded rice depends upon many factors like intensity of weeds, species and prevailing environmental conditions. In general grassy weeds, broadleaf weeds and sedges are predominantly found in direct seeded rice. Grassy weeds are heavy competitors with rice crop followed by sedges and broad leaved weeds. Direct seeded rice fields are more species rich with greater diversity in weed flora than transplanted rice field.

**Table 1:** Per cent distribution of grasses, sedges and broad leaf weeds (BLWs) in weedy check at various stages of direct seeded rice

| Crop growth stage | Grasses (per cent) | Sedges (per cent) | BLWs (per cent) |
|---|---|---|---|
| 25 days after sowing (DAS) | 68.8 | 22.2 | 9.1 |
| 50 days after sowing (DAS) | 90.5 | 2.3 | 7.2 |
| 75 days after sowing (DAS) | 78.1 | 5.4 | 16.5 |
| 100 days after sowing (DAS) | 46.9 | 6.5 | 46.6 |
| maturity/harvest stage | 46.9 | 5.7 | 47.4 |

(Verma, 2015) [72]

**Table 2:** Common weed flora found in direct seeded rice

| Scientific name | Source |
|---|---|
| *Echinochloa crus-galli* | Verma *et al.*, (2017 a) [73]; Ravishankar and Chandrashekharan (2003); Saini and Angiras (2002) [53]; Mahajan *et al.* (2003) [34]; Bahar and Singh (2004) [3]; (Saini, 2005) [55]; (Dhyani *et al.*, 2009) [18]. |
| *Echinochloa colona* | Verma *et al.*, (2017 a) [73]; Ravishankar and Chandrashekharan (2003); Moorthy and Saha (2003) [39]; Tomar *et al.* (2002) [70]; Ram *et al.* (2004) [47]; Bahar and Singh (2004) [3]; (Saini, 2005) [55]; Shekhar and Mankotia, (2005) [59]; Dhyani *et al.*, 2009 [18]. |
| *Leptochloa chinensis* | Verma *et al.*, (2017 a) [73]; Ravishankar and Chandrashekharan (2003); Dhyani *et al.*, (2009) [18]. |
| *Commelina diffusa* | Dhyani *et al.*, (2009) [18]; Bahar and Singh (2004) [3] |
| *Commelina benghalensis* | Shekhar and Mankotia, (2005) [59]; Saini, (2005) [55]; Singh and Namdeo, (2004) [61]; Ram *et al.*, (2004) [47]; Mahajan *et al.*, (2003) [34]; Saini and Angiras (2002) [53]; |
| *Cyperus rotundus* | Verma *et al.*, (2017a) [73]; Moorthy and Saha, (2003) [39]; Mahajan *et al.*, (2003) [34]; Ram *et al.*, (2004) [47]; Bahar and Singh (2004) [3]; Dhyani *et al.*, (2009) [18]. |
| *Cyperus iria* | Verma *et al.*, (2017 a) [73]; Ravishankar and Chandrashekharan, (2003); Moorthy and Saha, (2003) [39]; Saini and Angiras (2002) [53]; Tomar *et al.*, (2002) [70]; Mahajan *et al.*, (2003) [34]; Ram *et al.*, (2004) [47]; Shekhar and Mankotia, (2005) [59]; Dhyani *et al.*, (2009) [18]. |
| *Cyperus difformis* | Verma *et al.*, (2017 a) [73]; Ravishankar and Chandrashekharan, (2003); Saini and Angiras, (2002) [53]; Tomar *et al.*, (2002) [70]; Mahajan *et al.*, (2003) [34]; Ram *et al.*, 2004) [47]; Shekhar and Mankotia, (2005) [59]. |
| *Fimbristylis milliacea* | Verma *et al.*, (2017 a) [73]; Mahajan *et al.*, (2003) [34]; Shekhar and Mankotia, (2005) [59]; Dhyani *et al.*, (2009) [18]. |
| *Eclipta alba* | Ravishankar and Chandrashekharan, (2003); Ram *et al.*, (2004) [47] |
| *Ammania baccifera* | Ravishankar and Chandrashekharan, (2003). |
| *Ludwigia parriflora* | Ravishankar and Chandrashekharan, (2003); Moorthy and Saha, (2003) [39]. |
| *Caesulia axillaris* | Mahajan *et al.*, (2003) [34]; Bahar and Singh, (2004) [3]; Ram *et al.*, (2004) [47] |
| *Trianthema monogyna* | Tomar *et al.*, (2002) [70] |
| *Euphorbia spp* | Ram *et al.* (2004) [47]; Singh and Namdeo, (2004) [61] |
| *Digitaria sanguinalis* | Moorthy and Saha, (2003) [39]; Saini, (2005) [55] |

**Table 3:** Common name, botanical name, family and place of origin of different weeds associated with direct seeded rice

| Weed type | Botanical name | Common Name | Family | Place of origin |
|---|---|---|---|---|
| Grass | *Echinochloa crus-galli* | Banyard Grass | Poaceae | Europe and India |
| | *Echinochloa colona* | Jungle Rice | Poaceae | India |
| | *Leptochloa chinensis* | Red Sprangle Top | Poaceae | Tropical Asia |
| | *Commelina banghalensis* | Wandering Jaw | commelinaceae | Tropical Asia and Africa |
| | *Commelina cummunis* | Day Flower | commelinaceae | East Asia and Northern parts of Southeast Asia |
| | *Panicum maxicum* | Guinea Grass | Poaceae | East Africa |
| | *Paspalum conjugatum* | Sour Paspalum | Poaceae | Tropical America |
| | *Monochoria vaginalis* | Monochoria | Pontederiaceae | Asia |
| | *Elusine indica* | Goose Grass | Poaceae | China, Japan, India |
| | *Cynodon dactylon* | bermuda Grass | Poaceae | Tropical Africa |
| | *Sorghum helepense* | Johnson Grass | Poaceae | Mediterranean region |
| | *Imperata cylindrical* | Cogon Grass | Poaceae | Old world tropics |
| | *Brachiaria eruciformis* | Para Grass | Poaceae | Mexico, west indies |
| sedge | *Cyperus rotundus* | Purple Nut Sedge | Cyperaceae | Africa, southern and central Europe |
| | *Cyperus iria* | Flate Sedge | Cyperaceae | Old world tropics |
| | *Cyperus difformis* | Umbrella Nut Sedge | Cyperaceae | Old world tropics |
| | *Fimbristylis milliacea* | Globe Fingerrush | Cyperaceae | Coastal tropical Asia |
| | *Cyperus esculentus* | Yellow Nut Sedge | Cyperaceae | Tropical Africa, India |
| Broad leaf | *Trianthema portulacastrum* | Horse Purslane | Aizoaceae | Africa, North and South America |
| | *Trianthema monogyna* | Purslane | Aizozceae | Africa, North and South America |
| | *Celosia argentea* | White Cockscomb | Amaranthaceae | Tropical Africa and America |
| | *Amaranthus viridis* | Slender Pigweed | Amaranthaceae | Asia |
| | *Amaranthus spinosus* | Spiny Pigweed | Amaranthaceae | Asia |
| | *Physalis minima* | Wild Goose Berry | Solanaceae | America |

| | | | | |
|---|---|---|---|---|
| | *Phyllanthus niruri* | Niruri | Solanaceae | China, India and South/Central America |
| | *Ludwigia parviflora* | Perennial Water Primerose | Onagraceae | South America |
| | *Ludwigia octovalvis* | Water Primerose | Onagraceae | South America |
| | *Eclipta alba* | False Daisy | Asteraceae | India |
| | *Ammania baccifera* | Red Stem | Lythraceae | Tropical Asia |
| | *Ipomoea repens* | Morning Glory | Convolvulaceae | Mexico and Central America |

**Losses caused by weeds in direct seeded rice**

Crop yield losses due to weeds mainly depend upon their intensity, type of weed flora and prevailing climatic condition. There is a linear correlation between yield loss and population of weeds, however, above certain population limits, yield reductions becomes nearly constant due to self-competition among weed plants. Axiomatically, the weed growth in direct-seeded rice is severe and is one of the serious limiting factors in realizing the yield potential of direct-seeded rice (Rao *et al.*, 2007; Rao and Nagamani, 2007) [49, 49]. The greatest loss caused by the weeds resulted from their competition with crop for growth factors *viz.*, nutrients, soil moisture, light, space, etc. (Walia, 2006). Weeds pose a serious threat to the direct seeded rice crop by competing for nutrients, light, space and moisture throughout the growing season (Hussain *et al.*, 2008) [25]. Globally, actual yield losses due to pests have been estimated about 40 per cent, of which weeds caused the highest loss (32 per cent) (Rao *et al.*, 2007) [49].

Uncontrolled weeds reduce the grain yield by 96 per cent in dry direct-seeded rice and 61 per cent in wet direct seeded rice (Maity and Mukerjee, 2008) [35] which is one of the major factors responsible for low yield of rice. Competition offered by weeds is most important and reduces the grain yield up to the extent of 32 per cent (Singh *et al.*, 2007) [61]. The yield loss due to weeds varied from 40 to 100 per cent in case of direct seeded rice (Choubey *et al.*, 2001) [15]. On an average, yield loss in direct seeded rice due to weed ranges from 15 to 20 per cent, but in severe cases the yield loss may exceed 50 per cent (Hasanuzzaman *et al.*, 2009) [24] or even 100 per cent (Mishra and Singh, 2007; Jayadeva *et al.*, 2011) [61, 55]. The yield losses due to *Echinochloa crus-galli* and *Echinochloa colonum*, major grassy weeds ranges from 50-60 per cent in direct-seeded (Dixit and Bhan, 2001) [19]. Estimated losses from weeds in rice are around 10 per cent of total grain yield; however, can be in the range of 30 to 90 per cent, reduces grain quality and enhances the cost of production (Rao *et al.*, 2007; Singh *et al.*, 2009) [61, 49]. Weedy check recorded lowest yield (1925 kilograms per hectare) with a yield reduction of 59.4 per cent due to severe weed competition (Rao *et al.*, 2008) [50].

Bindra *et al.* (2002) [6] observed that the average yield loss in direct-seeded rice due to weed infestation accounts for 35.5 per cent which is mainly attributed to reduction in number of panicles per square meter, grain weight per panicle and 1000 grain weight. Saini (2003) [54] from Palampur (Himanchal Pradesh) also found that loss in grain yield of direct-seeded rice due to unchecked weed competition was 39-42 per cent. Bahar and Singh (2004) [3] at Pantnagar also reported that the uncontrolled weed control cause 98.6 per cent reduction in grain yield of direct seeded rice. Rice plots without such competition recorded higher number of productive tillers over control because of the greater space capture by rice plants. The canopy closure occurred earlier due to better competitive ability and nutrient efficiency (Baloch *et al.*, 2005) [5]. Weeds also remove nutrients (N, P and K) eight times higher under direct seeded rice compared to that of puddled transplanted rice (Singh *et al.*, 2002) [32]. Sudhalakshmi *et al.* (2005) [68] also reported that nutrient uptake by weeds was 30 kilogram N, 10 kilogram P and 17 kilogram K per hectare in direct seeded rice in clay loam soil of Coimbatore.

**Critical period of crop-weed competition**

The principle behind critical period of crop–weed competition (minimum time span of crop growth cycle measured empirically during which yield is severely reduced due to weed competition, Zimdahl, 1999) [75]. Introduced by Nieto *et al.* (1968) [41]. Draws attention to the critical time period when weeding should done. In general critical period of crop- weed competition in upland direct seeded rice ranges from 15- 30 days after sowing (Shelke *et al.*, 1985) [60]. And 15- 45 days after sowing (Saraswat, 1989) [56]. In a field trial of direct seeded irrigated rice, 95 per cent of a weed free rice yield was obtained when controlled until 32 days after sowing during wet season while until 83 days after sowing during the dry season in the Senegal River delta (Johnson *et al.*, 2004) [28].

**Non chemical weed management in direct seeded rice**

Presently available rice herbicides have narrow spectrum activity and limited efficacy when used alone, and hence rarely provide season long weed control in direct seeded rice. Variation in weed flora composition and their pattern of emergence during growing season is the key factor influencing level of weed control achieved with herbicides (Khalique *et al.*, 2013 and Kumar *et al.*, 2002) [32]. Despite known limitations and hazards, herbicides pose to individuals in particular, and biosphere at large, their usage still seems indispensable in direct seeded rice. Nonetheless, associated hazards can be lessened to a certain extent through their judicious use in conjunction with other control measures, thus key to success of direct-seeded rice so as to increase productivity is availability of efficient weed control techniques that are economically and ecologically viable. The increased use of herbicides, risk of herbicide resistance, rising costs of production, and concerns about environmental pollution are creating an interest among researchers in exploring non-chemical methods of weed control (Chauhan, 2012) [12].

The concept behind non chemical weed management approach is to find ecological balance with improved yield of the direct seeded rice as during application of herbicide, a large portion of chemicals accumulates in the top layer of soil (0-15 centimeter) where most of the microbiological activities occur. Microorganisms degrade a variety of carbonaceous substances including the accumulated herbicides in soil to derive their energy and other nutrients for their cellular metabolism. Reports are also available on the adverse effect of herbicides on growth and activities of beneficial microorganism in soil. More over these deleterious effects of the herbicides on soil microorganisms and their associated transformations of plant nutrients vary depending upon the type of herbicides and microorganism (Das *et al.*, 2012) [16]. Jha (2009) [27] in a study observed that there was decrease in microbial biomass in soil due to herbicides application. Change in microbial parameters measured as microbial numbers and soil respiration, occurred only at herbicide concentration of much higher than that used for field application and side effects of these chemicals were probably of little ecological significance.

Non chemical weed management offer convenient edaphic conditions for microbe's proliferation in the soil. Higher population of rhizospheric soil microorganisms like bacteria, fungi and actinomycetes were also recorded in non- chemical weed management practices compared with chemical weed management. Non- chemical methods of weed control in direct seeded rice have lesser adverse impact on soil microbes than that of herbicidal application. (Verma *et al.*, 2017 b) [74].

### Application of wheat straw mulch

Mulches on the soil surface are known to suppress weed emergence. Spreading of mulch on soil surface reduces evaporation, saves water, protects from wind and water erosion, and suppresses weed growth. Singh *et al.*, 2007 [61]. reported that in northern India, under rice-wheat cropping system, spreading of wheat residue @ 4 tons per hectare reduced annual and broad-leaved weed densities in direct seeded rice compared with no residue. The phyto toxic nature of wheat straw leachates and possible involvement of other organic molecules in the inhibition of different weeds are well documented. Infestation and density of perennial rye grass was found lower when wheat straw was included in the system. (Hamdi *et al.*, 2001) [23].

A study conducted in India also found that spreading of wheat residue mulch over the soil surface of direct seeded rice @ 4 tons per hectare reduced the emergence of grassy weeds by 44–47 per cent and of broadleaf weeds by 56–72 per cent and resulted in 17–22 per cent higher grain yield (Chauhan and Johnson, 2010; Singh *et al.*, 2009; Singh *et al.*, 2007) [59, 61, 71]. The density of grassy weeds was low in the rice field mulched at all stages of crop growth (Teosdale and Mogler, 2000) [69]. Gurung (2006) [22] in a study also revealed that weed infestation was significantly higher in no mulch plot (56.95 gram per square meter) than in the mulched plot (38.59 gram per square meter). In comparison to the weedy check, mulch and *Sesbania* alone caused a 42.7–45.7 per cent reduction in total weed density and a 37.1–41.4 per cent reduction in total weed dry weight at 75 days after sowing. Thus, crop residue present on the soil surface can influence weed and crop growth (Chauhan, 2012; Chauhan and Mahajan, 2012; Chauhan and Abugho, 2013; Chauhan *et al.*, 2012; Deva Singh *et al.*, 2011) [12, 12, 13, 12, 17].

### Manual weeding

Maintaining weed free condition till maturity give significantly higher grain yield due to more panicle per square meter and lower density and dry matter accumulation of weeds (Singh *et al.* 2002) [32]. Manual weeding is an effective weed control practices in reducing weed count and biomass. This practice helps to eradicate weeds (Grasses, broadleaves and sedges) which will be further suppressed by shading effect of rice (Baloch *et al.*, 2005) [5] in the later stages of crop growth due to quick and dense canopy closure. It is the most effective method of weed control which in a study recorded 88 per cent suppression of weed density as compared with control plots (Khaliq *et al.*, 2012) [31].

Prasad *et al.*, 2001 [44] also revealed that hand weeding twice at 20 and 40 days after sowing was superior to the chemical weed control for all the growth and yield attributes of direct seeded rice, reflecting the higher grain yield of 2876 kilogram per hectare in silty loam and calcareous soil during *kharif* season. Chander and Pandey (2001) [8]. observed that hand weeding increases grain as well as straw yields compared to herbicides because of frequent elimination of weeds that results in the reduction of weed competition (Kumar, 2000) [33]. Twice hand weeding resulted in lower weed density compared to herbicidal application and untreated control. However, the highest paddy yield (4.17 tons per hectare) was recorded from hand weeding treatment. Manual weeding, although efficient in controlling weeds, has been restricted due to several economic and technological factors (Khaliq and Matloob, 2011) [30].

Timely hand weeding increases grain yield due to suppressing the weeds resulted in improved soil aeration and soil health and increased nutrient availability (Prasad and Pandey, 2005) [43]. (Dutta *et al.* (2005) [20]. in an experiment also found the similar findings that hand weeding twice at 21 and 42 days after sowing recorded the highest weed control efficiency and increased grain and straw yield of rice crop. Pal *et al.* (2009) [42]. opined that hand weeding on 20 and 40 days after sowing recorded highest grain yield of 5.08 tons per hectare in Gangetic alluvial soil because it gave very little scope to weeds to flourish and to compete with the crop preferably at the critical stage of crop weed competition. Highest thousand grain weight was recorded from the hand pulling treatment followed by mechanical hoeing (Akbar *et al.*, 2011) [1]. Hand pulling is more effective in decreasing weed density and dry weight and increasing rice yield than the mechanical hoeing.

Manual weeding is very effective but it is tedious, time consuming and expensive in large scale cultivation. Continuous rains in rainy season and unavailability of man power make manual weeding difficult (Puniya *et al.*, 2007) [45]. Hand weeding is laborious and generally more expensive. The weed control cost is maximum for hand weeding (two hand weeding at 30 and 45 days after sowing) and the lowest for chemical weed management (Hasanuzzaman *et al.*, 2009) [24]. It is time consuming and expensive practice, therefore, can be practiced on limited scale but not practicable on large scale (Hussain *et al.*, 2008) [25].

### Inclusion of *Sesbania* in the system

Legumes generally find a place in intercropping systems because of their capacity to fix atmospheric nitrogen and to contribute nitrogen to the associated non-legume crops (Balasubramaniyan & Palaniappan, 2001). Chaudhary and Kennedy during 2004 also reported that cultivation of green manure crops like *Sesbania rostrata* along with cereal crop can fix considerable amounts of atmospheric N. It has highest atmospheric $N_2$ fixing potential to substitute urea N completely in rice cultivation. Rajkumar *et al.* (2004) [46]. also observed in a study that the application of *dhaincha* increased recovery of applied nitrogen by 38 per cent over no *dhaincha* application. Sharma and Ghosh (2000) [58]. reported that green manuring of rice with dhaincha (*Sesbania aculeata*) improve the rice yield by adding 80-86 N kilogram per hectare in the pure stand and 58-79 N kilogram per hectare when intercropped with direct seeded rice in alternate rows at 50 days of growth as well as improved rice growth after *dhaincha* was uprooted manually and buried in situ between the rice rows at the of depth 10-20 cm in the field. Angadi (1997) [2]. Reported that, effectiveness of *Sesbania aculeata* in smoothening weeds was reported when grown as intercrop with rice. Ravisankar *et al.* (2007) [52]. Reported that dhaincha incorporation effectively reduced the total weed density. The dual cropping of *Sesbania* with direct seeded rice had marked depression in total weed density and weed dry matter accumulation at all the stages of crop growth over other method of seeding. This might be due to dual *cropping* of green manure as smother intercrop in rice to reduce weed growth as earlier reported by Ravisankar, 2002).

Sriramachandrashekharan and Ravichnadra (2004) conducted field experiments during *kharif* and *rabi* seasons to study the effect of green manure crops on growth of rice and found that *Sesbania aculeata* released N at higher rate as compared to *Sesbania speciora* and *Crotolaria juncea* in both the seasons over the respective controls. *Sesbania* might have supplied sufficient nutrients in soil after decomposition coupled with smothering effect on weeds during the crop period which resulted in increased crop growth and yield. This confirmed the findings of Sardana *et al.* (2004) [57].

**Maintaining water in field**

Submergence is considered as the best herbicide in direct seeded rice. Every weed species habituating with rice crop has an optimum soil moisture level, below or above which, growth of the weed plants is hampered and their survival rate become very low, therefore time, depth and duration of giving flood irrigation could play an important role in suppressing the weeds associated with direct seeded rice. Submergence as a result of giving flood irrigation in the field of direct seeded rice hinders not only weed germination but suppresses population of most germinated weeds also. Early and continuous flooding to a shallow depth of approximately 2-4 centimeter helps to control the weed population by influencing their germination, emergence and growth. Some weeds like *Leptochloa chinensis* and *Cyperus iria, Fimbristylis miliaceae, Ludwigia hyssopifolia*. (Chauhan and Johnson, 2010) [12]. are successfully controlled by proving flood irrigation in the field of direct seeded rice.

**Mechanical weeding**

Rotary weeder is effective in controlling the weeds present in inter row space, but fails to control the weeds in intra row space or those in the vicinity of the crop. Uphoff (2002) [71]. Reported that the mechanical hand weeder pruned some of the upper roots and encouraged deeper root growth. Randriamiharisoa (2002) [48]. noticed that the mechanical weeding using rotating hoe with small toothed wheels increased the soil pores so that roots and microbes could more easily gain access to oxygen and also significantly increase the tiller production. Weeding by mechanical devices reduces the cost of labor and also saves time (Subudhi, 2004) [67]. The impact of conoweeding in increasing the ammonical and nitrate nitrogen content of the rhizosphere soils was evident only at harvest (37.9 ppm) and grain filling stages (49.6 ppm) respectively while at the rest of the stages conoweeding had not set any notable impact on the nitrogen fractions of the rhizosphere soil (Sudhalakshmi *et al.*, 2005) [68].

In a study, it has been noticed that use of conoweeder resulted in 10 per cent grain yield increase during wet season while the yield increase was only three per cent higher in dry season than conventional method of weeding (Thiyagarajan *et al.*, 2002) [68]. Conoweeding alone was found to contribute 17.43 per cent for grain yield when the average grain yield under the conoweeding treatments 3376 kilogram per hectare was compared against the average grain yield under hand weeding treatments 2875 kilogram per hectare (Sridevi, 2006) [65]. Minimum percentage (8.54 per cent) of sterile spikelets was recorded in the mechanical hoeing. Different weed control practices showed a significant effect on straw yield per ha. Significantly higher (10.46 tons per hectare) straw yield was recorded for mechanical hoeing which was statistically at par with other weed control treatments against the minimum in the weedy check (Akbar *et al.*, 2011) [1]. Mrunalini and Ganesh (2008) [40]. opined that the implements like conoweeder helps to save labour, time and reduce man - days required for weeding from 30 to 10 as they become more experienced in handling the cono weeder implement.

**Conclusion**

Weeds are the major constraint in direct seeded rice production systems in terms of lowering the yield and productivity level; thus efficient weed management is a primary concern in direct seeded rice cropping. However, use of herbicidal weed management practices has damaged sustainability of the ecosystem to a greater extent. In this article, we discussed several non-chemical methods *viz.*, hand weeding, cono weeding, mulching with wheat straw, maintaining water and intercropping with *sesbania* for controlling and managing the prominent weed species found in direct seeded rice. The use of any of this approach however, would not provide season long weed control but can provide sustainable weed control in long run without deteriorating the natural ecosystem.

**References**


1. Akbar N, Jawran E, Khawar K, Muhammad AA. Weed Management Improves Yield and Quality of Direct Seeded Rice. Australian journal of crop science. 2011; 5(6):688-694.
2. Angadi VV. IRRN. 1997; 22(1): 47-48.
3. Bahar FA, Singh G. Effect of Herbicides on Dry Seeded Rice and Associated Weeds. Indian J. Weed Science. 2004; 36(3-4):269-270.
4. Balasbramaniyan P, Palaniappan SP. Principles and practices of agronomy: Integrated farming system. Agrobios (India). 2001, 486-489.
5. Baloch MS, Hassan G, Morimoto T. Weeding techniques in transplanted and wet seeded rice in Pakistan. Weed Biolog. Mang. 2005; (5):190-196.
6. Bindra AD, Kalia BD, Shekhar J. Bio-Efficacy of Promising Herbicidal Molecules in Direct-Seeded Sprouted Puddle Rice. Indian J. Weed Sci. 2002; 34(1-2):39-41.
7. Caton BP, Cope AE, Martin M. Growth traits of diverse rice cultivars under severe competition: implications for screening for competitiveness. Field Crops Res. 2003; 83:157–172.
8. Chander S, Pandey J. Effect of rice (*Oryza sativa*) culture, nitrogen and weed control on nitrogen competition between scented rice and weeds. Indian J. Agron. 2001; 46 (1):68-74.
9. Chaudhury ATMA, Kennedy IR. Prospects and Potentials for Systems of Biological Nitrogen Fixation in Sustainable Rice Production. Biology and Fertility of Soils. 2004; 39(4):219-227.
10. Chauhan BS. Weed ecology and weed management strategies for dry seeded rice in Asia. Weed Technology. 2012; 26:1-13.
11. Chauhan BS, Abugho SB. Effect of crop residue on seedling emergence and growth of selected weed species in a sprinkler- irrigated zero-till dry-seeded rice system. Weed Science. 2013; 61:403-409.
12. Chauhan BS, Johnson DE. Relative importance of shoot and root competition in dry seeded rice growing with jungle rice and Ludwigia. Weed science. 2010; 58:295-299.

13. Chauhan BS, Mahajan G. Role of integrated weed management strategies in sustaining conservation agriculture systems. Current Science. 2012; 103:135-136.
14. Chauhan BS, Mahajan G, Sardana V, Timsina J, Jat ML. Productivity and sustainability of the rice-wheat cropping system in the Indo-Gangetic Plains of the Indian subcontinent: problems, opportunities, and strategies. Advances in Agronomy. 2012; 117:315-369.
15. Choubey NK, Kolhe SS, Tripathi RS. Relative performance of cyhalofop-butyl for weed control in direct seeded rice. Indian Journal of Weed Science. 2001; 33(3&4):132-135.
16. Das AC, Nayek H, Devi SN. Effect of pendimethalin and quizalofop on $N_2$ fixing bacteria in relation to availability of nitrogen in a typic Haplustept soil of West Bengal, India. Environmental monitoring and Assessment. 2012; 184(4):1985-1989.
17. Devasingh DAUD, Premarathne KP, Sangakkara UR. Weed management by rice straw mulching in direct seeded low land rice (*Oryza sativa*). Tropical Agrical research. 2011; 22(3):263-272.
18. Dhyani VC, Singh VP, Singh SP, Kumar A Tripathi N. Impact of *Sesbania* brown manuring on weeds and performance of direct seeded rice. Indian Journal of Weed Science. 2009; 41(3-4):157-159.
19. Dixit A, Bhan VM. Weed Management in Cereals". Pesticides Information. 2001; 27:4-8.
20. Dutta A, Patra BC, Jana P, Mandal N. Effect of fertility levels and weed management practices on growth, yield attributes and yield of direct seeded rice in the rainfed and lateritic belt of West Bengal: 69. In First International weed science seminar on innovative approaches for eco safety weed management, Kolkata, India, 2005, 21-24.
21. Gopal R, Jat RK, Malik RK, Kumar V, Alam MM, *et al*. Direct Dry Seeded Rice Production Technology and Weed Management in Rice Based Systems. Technical Bulletin. International Maize and Wheat Improvement Center, New Delhi, India, 2010, 28.
22. Gurung DB. Performance of rice as influenced by planting method, mulch and nitrogen management using leaf color chart (LCC). M.Sc. Thesis submitted to Tribhuvan University, Institute of Agriculture and Animal Science, Rampur, Chitwan, 2006.
23. Hamdi BA, Inderjit Olofdotter M, Streibig JC. Laboratory bioassay of phytotoxicity. Agron. J. 2001; 93:43–48
24. Hasanuzzaman M, Ali MH, Akther M, Alam KF. Evaluation of pre-emergence herbicide and hand weeding on the weed control efficiency and performance of transplanted Aus rice. Eurasian J Agron. 2009; 2(3):138-143
25. Hussain S, Ramzan M, Akhter M, Aslam M. Weed management in direct seeded rice. J. Anim. Pl. Sci. 2008; 18:2-3.
26. Jayadeva HM, Bhairappanavar ST, Hugar AY, Rangaswamy BR, Mallikarjun GB, Malleshappa C *et al*. Integrated Weed management in Aerobic Rice (*Oryza sativa* L.). Agric Sci Digest. 2011; 31(1):58-61.
27. Jha BK. Effect of herbicide application in soybean on productivity and soil health. Master thesis (Soil science) submitted to gbpuat, Pantnagar udham singh nagar, Uttarakhand. 2009, 23-31.
28. Johnson DE, Wopereis MCS, Mbodj D, Diallo S, Powers, S, Haefele SM. Timing of weed management and yield losses due to weeds in irrigated rice in the Sahel. Field Crops Res. 2004; 85:31-42.
29. Karim SMR, Man AB, Sahid IB.Weed problems and their management in rice fields of Malaysia: An overview. Weed Biol. Manag. 2004; 4:177-186.
30. Khaliq A, A Matloob. Weed crop competition period in three fine rice cultivars under direct seeded rice culture. Pakistan J. Weed Sci. Res. 2011; 17(3):229-243.
31. Khaliq A, Matloob A, Ahmad N, Rasul F, Awan IU. Post emergence chemical weed control in direct seeded fine rice. The Journal of Animal & Plant Sciences. 2012; 22(4):2012. Page: 1101-1106, ISSN: 1018-7081
32. Kumar PD, Jha A, Kumar MK, Chaudhary RK, Grover RK, Singh A *et al*. Economic analysis of total factor productivity of crop sector in Indo-Gangetic Plain of India by district and region. Agricultural Economics Research Report 2. New Delhi, India: Indian Agricultural Research Institute, 2002.
33. Kumar S. Weed Management in Transplanted Rice (*Oryza sativa* L.)". M.Sc. Ag. (Agronomy), thesis, G.B. Pant University of Agriculture and Technology, Pantnagar, 2000, 95.
34. Mahajan G, Boparai BS, Brar LS, Sardana. Effect of Pretilachlor on Weeds in Direct Seeded Puddled Rice. Indian J. of Weed Science. 2003; 35(1):128-130.
35. Maity SK, Mukerjee PK. Integrated weed management in dry direct seeded rainy seaso rice. Indian J. Agron. 2008; 53(2):116-120.
36. Maity SK, Mukherjee PK. Effect of brown manuring on grain yield and partial factor productivity of nutrients in dry direct seeded summer rice (*Oryza sativa* L.) under *Terai* agro-ecological region of West Bengal. Journal of Crop and Weed. 2009; 5(2):31-35.
37. Ministry of Agriculture. 4th Advance Estimates. Annual Report 2017-18. Department of Agriculture, Cooperation and Farmer welfare, 2018.
38. Mohan KS, Muniyappa TV, Murthy KNK, Ramesha YM, Savitha HR. Effect of chemical weed control on growth and yield of direct seeded puddle rice (*Oryza sativa* L.) International Journal of Agricultural Sciences. 2010; 6(2):471-474.
39. Moorthy BTS, Saha S. Studies on crop weed competition in rainfed direct seeded lowland rice (*Oryza sativa* L.). Indian J. Weed Sci. 2003; 40(3-4):112-116.
40. Mrunalini A, Ganesh M. Work load on woman using cono weeder in SRI method of paddy cultivation. *Oryza*. 2008; 45(1):58-61.
41. Nieto JH, Brondo MA, Gonzalez JT. Critical periods of the crop growth cycle for competition from weeds. PANS. 1968; 14:159–166.
42. Pal D, Ghosh RK, Sounda G, Dolai AK, Pramanick M, Mallick S. Bio efficacy of some promising herbicides in transplanted kharif rice and their influence on soil micro flora. Indian Agric. 2009; 53(3&4):193-198.
43. Prasad R, Pandey J. Text book of field crops production" Directorate of information and publication of agriculture, ICAR, Krishi anusandhan bhawan, PUSA, New Delhi, 2005, 33.
44. Prasad SS, Mishra S, Singh SJ. Effect of establishment methods, fertility levels and weed management practices on rice (*Oryza sativa*). Indian J Agron. 2001; 46(2):216-221.

45. Puniya R, Pandey PC, Bisht PS, Singh DK. Nutrient uptake by crop and weeds as influenced by Trisulfuron, Trisulfuron + Pretilachlor and Bensulfuron-methyl in transplanted rice (*Oryza sativa* L.). Indian J. Weed Sci. 2007; 39(3&4):239-240.
46. Rajkumar S, Singh OP, Chauhan RPS, Prasad K. Effect of Dhaicha on the Utilization of Nitrogen from Coated Urea materials in Alkali Soil under Rice-Wheat". Ann. Pl. Soil Res. 2004; 6(1):97-99.
47. Ram M, Om H, Kumar S, Dahiman SD. Chemical Weed Control in Direct Seeded Rice with or without Sequential Application of 2, 4-D (EE). Indian J. of Weed Science, 2004; 39(3):463-465.
48. Randriamiharisoa. Research results on the System of Rice Intensification in Madagascar. In Proc. Intl. Conf. on Assessments of the System of Rice Intensification (SRI), Sanya, China, 2002, 1-4.
49. Rao AN, Johnson DE, Sivaprasad B, Ladha JK, Mortimer AM. Weed management in direct-seeded rice. Adv Agron. 2007; 93:153–255.
50. Rao AS, Ratnam M, Reddy TY. Weed Management in Direct-seeded Semi Dry Rice. Indian J. Weed Sci. 2008; 40(3-4):153-156.
51. Ravisankar N, Chandrasekharan B. Effect of Seeding Methods, in situ Incorporation of Dhaincha (*Sesbania aculeata*) and Application Time of Pretilachlor Plus on Weed Growth and Yield of Wet Seeded Rice. Indian J. of Weed Science. 2003; 35(1-2):125-127.
52. Ravisankar N, Chandrasekran B, Raja R, Din M, Chaudhuri, Ghosal S. Influence of integrated weed management practices on productivity and profitability of wet seeded rice (*Oryza sativa*). Indian J. Agronm. 2007; 53(1):57-61
53. Saini JP, Angiras NN. Evolution of Ethoxysulfuron against Broad leaved weeds and sedges in direct –seeded puddle rice. Indian J. Weed Sci. 2002; 34(1&2):36-38.
54. Saini JP. Efficacy of Cyhalofop-Butyl against Weeds in Direct-Seeded Puddled Rice under Mid Hill Conditions of Himachal Pradesh. Indian J. Weed Sci. 2003; 35(3&4):205-207.
55. Saini JP. Efficacy of Cyhalofop-butyl alone and in Combination with 2,4-D against Mixed Weed Flora in Direct Seeded Upland Rice. Indian J. Agron. 2005; 50(1):38-40.
56. Saraswat VN. Project Coordinator's Report (01.01.1989-31.12.1989). All India Coordinated Research Programme on Weed Control. Jabalpur, India, 1989, 218.
57. Sardana V, Mahajan G, Grar AS, Gill MS. Agronomic manipulations for higher productivity of direct seeded rice (*Oryza sativa* L.). Hariyana Journal of Agronomy. 2004; 20(1/2):71-74.
58. Sharma AR, Ghosh A. Effect of green manuring with *Sesbania aculeata* and Nitrogen fertilization on the performance of direct seeded flood prone lowland rice. Nutrient Cycling of Agroecosystems. 2000; 57:141-153.
59. Shekhar J, Mankotia BS. Efficacy of some New Herbicide in Wet Seeded Rice (*Oryza sativa* L.). Indian J. of Weed Science. 2005; 37(1&2):58-60.
60. Shelke DK, Bhosle RH, Jadhav NS. Studies on crop weed competition in irrigated upland drilled rice (var. Prabhavati). In: Abstracts of papers, annual Conference, Indian Society of Weed Science, April 4-5, 83. B. A. College of Agriculture, Gujrat Agriculture Univ., Anand Campus, Anand, Gujrat, India, 1985, 116.
61. Singh RK, Namdeo KN. Effect of Fertility Levels and Herbicides on Growth, Yield and Nutrient Uptake of Direct-Seeded Rice. Indian J. Weed Sci. 2004; 49(1):34-36.
62. Singh RK, Sharma SN, Singh R, Pandey MD. Efficacy of method of planting and weed control measures on nutrient removal of rice (*Oryza sativa* L.) and associated weeds. Crop Res. 2002; 24(3):425-429.
63. Singh S, Chhokar RS, Gopal R, Ladha JK, Gupta RK, Kumar V *et al.* Integrated weed management: A key to success for direct-seeded rice in the Indo-Gangetic Plains. In "Integrated Crop and Resource Management in the Rice-Wheat System of South Asia" Ladha, J.K, Singh, Y., Erenstein, O. and Hardy, B. (eds.). International Rice Research Institute, Los Banos, Philippines, 2009, 261–278.
64. Singh S, Ladha JK, Gupta RK, Bhusan L, Rao AN, Sivaprasad B, Singh PP. Evaluation of mulching, intecropping with Sesbania and herbicide use for weed management in dry-seeded rice. Crop Protec. 2007; 26(4):518-524
65. Sridevi V. Relative contribution of individual components of System of Rice Intensification (SRI) to the yield of rice. M.Sc. (Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, 2006.
66. Sriramchandrasekharan MV, Ravichandran M. Influence of green manures and nitrogen on growth, yield and N uptake by rice – rice crop sequence. Ann. Pl. Soil. Res, 2004; 6 (1):59-61.
67. Subudhi CR. Evaluation of weeding devices for upland rice in the Eastern Ghats of Orissa, India. IRRN. 2004; 29:79-80.
68. Sudhalakshmi C, Velu V, Thiyagarajan TM. Weed Management Options on the Dynamics of Nitrogen Fractions in the Rhizosphere Soil of Rice Hybrids. Madras Agric. J. 2005; 92(7-9): 444-448.
69. Teosdale JR, Mohler CL. The quantitative relationship between weed emergence and the physical properties of mulches. Weed Sci. 2000; 48:385–392.
70. Tomar TPS, Rana NS, Kumar S, Singh R. Effect of integrated Weed Management on Upland Direct-Seeded Rice and Associated Weeds. Annals Agric Res. 2002; 23(3):423-429.
71. Uphoff N. System of Rice Intensification (SRI) for enhancing the productivity of land, labour and water. J. Agric. Resource management. 2002; 1:43-49.
72. Verma H. Chemical vs non-chemical weed management in aerobic rice (*Oryza sativa* L.) under irrigated ecosystem. M.Sc. Thesis submitted to G. B. Pant University of Agriculture & Technology, Pantnagar, Uttarakhand, 2015.
73. Verma H, Singh SP, Singh VP, Mahapatra BS, Sirazuddin, Joshi N. *et al.* Weed Dynamics of Aerobic Rice (*Oryza sativa* L.) under Chemical and Non-Chemical Weed Management Practices in Irrigated Ecosystem. Int. J Curr. Microbiol. App. Sci. 2017a; 6(12):3159-3165.
74. Verma H, Singh SP, Singh VP, Mahapatra BS, Sirazuddin, Joshi N, Nutrient Uptake and Soil Health under Chemical and Non-Chemical Weed Management Practices in Irrigated Rice Ecosystem. Int. J. Curr. Microbiol. App. Sci. 2017b; 6(12):3152-3158
75. Zimdahl RL. 'Fundamentals of Weed Science. Academic Press Inc, San Diego, CA, USA, 1999.