Weed management in direct seeded rice: A review

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Abstract
Direct seeding is done by sowing of pre-germinated rice seeds under puddled condition either manually or by drum seeding methods. Direct seeded rice (DSR) cultivation needs only 34 per cent of the total labour requirement and saves 29 per cent of the total cost of the transplanted rice. Weed infestation and competition are severe in direct wet seeded rice as compared to transplanted rice, because of the simultaneous growth of both crops and weeds. Uncontrolled weeds decreased the yield by 96 per cent in dry DSR and 61 per cent in wet DSR. The yield loss due to weeds varies from 40 to 100 per cent in direct seeded rice. Any delay in weeding will lead to increased weed biomass which has a negative correlation with yield. Though manual weeding is considered to be the best, undependable labour availability and escalating labour cost in many cases have given impetus to the development and use of new chemicals for weed control. In contrast to this, chemical weed control offers economic and efficient weed control if applied at proper dose and stage. The combination of chemical, manual and mechanical weed control is an efficient integrated weed management strategy for effective weed control in direct seeded rice.

Keywords: Direct seeded rice, crop-weed competition, crop establishment, weed control methods, economics

Introduction
In Tamil Nadu, rice is being cultivated under different ecosystems viz., transplanted puddled lowland rice, direct seeded lowland rice (Wet seeded rice in puddled soil and Dry seeded rice in un-puddled soil), dry seeded upland rice and deep water rice. Most of the farmers in the intensive cropping areas are shifting from conventional transplanting to System of Rice Intensification (SRI) and direct seeded rice due to shortage of labour and scarcity of water (Rathika and Ramesh, 2018) [70]. Additionally, late onset of monsoon, unpredictable rainfall pattern and delayed release of canal (Cauvery) water favour to go in for dry or wet seeding under puddled condition. In direct seeded rice (DSR) under puddled condition, grasses cause maximum yield reduction followed by sedges and broad leaved weeds. Nowadays, chemical weed control in DSR has gained importance because of the intensity of weed problems coupled with the scarcity of labour for weeding and its accelerated cost. The use of herbicides either singly or in combination with manual or mechanical weeding in puddled direct seeded rice has been highlighted by several workers (Sangeetha et al., 2009) [75]. However, evaluation of herbicides in crops is a continuous process as newer herbicide molecules are being released for use. Several new herbicides molecule are launched for transplanted rice but their efficiency for direct seeded rice is not well known and need to be investigated. Use of alternative herbicides with wide spectrum control of the weeds in direct seeded puddled rice is the need of the present time (Nath et al., 2014) [52]. In this situation, use of herbicides is becoming more popular in DSR because saves on labour and less cost of cultivation (Vikram Singh et al., 2016; Rathika and Ramesh, 2019)[50, 71].

Weed flora in direct seeded rice field
Changes in crop establishment, from transplanting to direct seeding also resulted in marked changes in the composition of weed flora (Singh, 2008) [84, 93]. Adoption of direct seeding technology may result in weed flora shifts towards more difficult to control and competitive grasses and sedges (Kumar and Ladha, 2011). The weed flora of wet seeded rice crop is sowing and shallow depths of water up to 3 weeks after sowing.
As weeds emerge almost at the same time as that of the crop in direct wet seeded rice and weed competition with rice crop is greater, hence weed management by herbicide is more crucial (Singh and Singh, 2010) [80]. The major weeds associated with the direct seeded rice (DSR) were Cyperus rotundus, C. iria, C. difformis, Eclipta prostrata and Portulaca oleracea (Riaz et al., 2007) [73]. Maity and Mukherjee (2011) [46] observed that the weed flora in DSR consisted of grasses like Cynodon dactylon and Echinochloa colona, sedges like Cyperus rotundus, Cyperus iria and Fimbristylis miliacea and broad leaved weeds like Ludwigia parviflora, Ageratum conyzoides, Spilanthes paniculata, Eclipta alba and Enhydra fluctans. Raghavendra et al. (2015) [64] found that Echinochloa colona, Echinochloa crus-galli, Fimbristylis miliacea, Eclipta alba, Ammania baccifera, Ludwigia parviflora, Marsilea quadrifoliata and Monochoria vaginalis were the major weed species in direct wet seeded rice. Ajay Singh et al. (2017) [3] observed that the weed flora in DSR was mainly dominated by Cyperus difformis, Cyperus rotundus, Leptochloa chinensis, Echinochloa glabrescens, Eclipta alba and Ammania spp. In direct wet seeded rice, the major grass weeds were Echinochloa crusgalli (L.), Echinochloa colona (L.), Leptochloa chinensis (L.) and Panicum repens (L.) and the common sedges included Cyperus difformis (L.), Cyperus iria (L.) and Fimbrystylis miliacea (L.). Among the broad leaved weeds, Eclipta alba (L.), Ammania baccifera (L.) and Ludwigia parviflora Roxb. were the dominant species (Rathika and Ramesh, 2019) [71]. Suryakanta et al. (2019) [96] found that major weeds in the dry direct seeded rice under irrigated ecosystem were Echinochloa crus-galli, Echinochloa colona and Leptochloa chinensis among grasses; Cyperus iria and Cyperus difformis among sedges; Ammania baccifera and Alternanthera sessilis among broadleaf weeds.

Crop-weed competition

Productivity of rice in India is declining due to an array of biotic and abiotic factors. Weeds are the prime yield-limiting biotic constraint that competes with rice for moisture, nutrients and light. The problem of weed interference is more in direct seeded than transplanted rice (Rathika and Ramesh, 2018) [80]. Weeds in direct seeded rice adversely affect the yield, quality and cost of production as a result of competition for various growth factors. The yield loss may vary from 10 per cent to complete failure of the crop depending upon the situation. The yield decrease in direct seeded rice increases with the increase in weed competition duration during the initial period. But, at later stages or after a certain stage, the rate of decrease may not change because maximum damage has already occurred (Johnson, 1996). Yield loss depends on several factors such as associated weed flora, degree of infestation, rice ecosystem, growing season, cultivar raised, cultural and management practices followed. Because of wide adaptability and faster growth, weeds dominate the crops habitat and reduce the yield potential (Rao, 2011). Bhatt and Kukal (2011) reported that uncontrolled weeds in direct wet seeded rice can reduce yields to the tune of 53 per cent and losses were reported even up to 90 per cent. Raj et al. (2013) reported that, season long weed competition in wet seeded rice caused 69.71 and 67.40 per cent reduction in grain yield during kharif and rabi season, respectively. Reduction in yield to the tune of 34 per cent in transplanted rice, 45 per cent in direct seeded low land rice and 67 per cent in upland rice due to weeds were reported in India (Muthukrishnan et al., 2010). In Tamil Nadu, the yield loss of rice is around 111.81 thousand tonnes per year due to weeds alone (Chinnusamy et al., 2012) [39]. Vikram Kumar (2015) [99] showed that the loss in grain yield of rice due to unchecked weed growth throughout the crop growth period was estimated to be 30 to 75 per cent in DSR. Direct seeded rice was more vulnerable for loss of grain yield due to the presence of weeds compared to transplanted rice and it adversely affects not only the grain yield and crop quality (Arunbabu and Jena, 2018) [5]. In India, yearly loss of rice grain production is around 15 million tonnes due to heavy weed infestation (Singh et al., 2018) [82]. Chaudhary et al. (2018) [32] found that shorter panicle length was recorded on weedy check plot of dry DSR which might be due to draining of nutrients by weeds and lowest thousand grain weight because of the unfavorable environment created by weeds throughout the crop cycle. Karthika et al. (2019) [16] reported that in the unweeded check, the yield reduction was noticed upto 67 per cent.

Critical period of competition

In the crop growth period, there exists a critical period during which the crop is very sensitive to weed competition. The presence of weed beyond a certain period of time will cause significant yield reduction. According to Ladu and Singh (2006) [42] direct seeded rice kept weed free for the first 30 DAS produced grain yield similar to that of weed free period up to harvest. The effective control of weeds at initial stages of rice growth (0 to 40 DAS) could help in improving the productivity of DSR (Maity and Mukherjee, 2008) [45]. Singh (2008) [84, 93] opined that a weed free situation for first 60 or 70 DAS produced yield comparable with weed free situation until harvesting. The critical period of weed competition is longer for direct seeded rice (15 to 45 DAS) as indicated by Singh et al. (2008) [84, 93]. The period within 20 to 50 DAS appeared to be an important factor in crop-weed competition in dry DSR (Khalqi Abdul and Matloob Amar, 2011).

Table 1: Loss of grain yield in different methods of rice establishment in India (Ladu and Singh, 2006; Singh et al., 2011) [42, 93].

| S. No | Methods of rice establishment | Reduction in yield due to weeds (%) |
|-------|-------------------------------|-----------------------------------|
| 1     | Upland rice                   | 97                                |
| 2     | Upland dry seeded rice        | 94                                |
| 3     | Dry seeded rice               | 17-73                             |
| 4     | Wet seeded rice               | 85                                |

Table 2: Critical period of crop weed competition in rice is influenced by different rice establishment methods (Arunbabu and Jena, 2018) [5].

| S. No | Rice establishment method | Critical period of crop-weed competition |
|-------|---------------------------|----------------------------------------|
| 1     | Transplanted rice          | 20-40 DAT                              |
| 2     | Wet seeded rice            | 15-60 DAT                              |
| 3     | Dry seeded rice            | 15-60 DAT                              |
| 4     | Rainfed direct seeded rice | 0-90 DAT                               |
| 5     | Upland direct seeded rice  | 30 DAT                                 |

*DAT: Days after transplanting; DAS: Days after sowing

Effect of crop establishment methods on weed management

System of rice cultivation in various rice growing regions varies largely due to soil and climatic condition as well as irrigation system of the region. Transplanting is the most dominant and traditional method of crop establishment in
irrigated lowland rice. Ramamoorthy and Subbaiah (1999) [67] observed that wet seeded rice culture by drum seeder could be a viable alternative to transplanted rice in irrigated areas of India. Direct seeded rice is a resource-conserving technology relative to transplanted rice, but it is subjected to heavy weed infestation (Awan et al., 2015; Mahajan and Chauhan, 2015) [7, 43].

**Transplanted rice vs Direct seeded rice**

Farmers had achieved a breakthrough in raising the productivity of rice through transplanting (Singh and Bhattacharyya, 1989) [85]. Transplanting is the most dominant method of crop establishment in irrigated lowland rice (Biswa et al., 1991) [17]. According to Chandra (1992) [21], line transplanting increased plant height and grain yield due to more uniform distribution of sun light within the canopy compared to direct seeding method. Govindarasu et al. (1998) [30] stated that for wet seeding, the field is puddled and properly levelled and sprouted seeds are sown uniformly by broadcasting or in lines by using seed drill. Direct seeding offers certain advantages i.e. saves labour, faster and easier planting helps in timely sowing, less drudgery, early crop maturity by 7-10 days, less water requirement, tolerance to water deficit, often higher yield, low production cost and more profit, better soil physical conditions for following crops and less methane emission (Balasubramanian and Hill, 2002) [9]. The risks of crop yield loss due to competition from weeds in direct seeded rice was greater than in transplanted rice because the weeds and rice emerge together and farmers are not usually able to use standing water to suppress weeds at the early growth stage of rice (Chauhan and Johnson, 2010) [23]. Direct seeding involves dry and wet seeding in which seeds are sown directly in the main field rather than transplanting. In dry direct seeding, it is sown by either broadcasting or dibbling and in wet seeding, pre germinated seeds are sown under puddled conditions (Kaur and Singh, 2017) [37]. However, the direct seeded rice is considered as the best alternative for transplanting, heavy weed infestation is one of the major constraints for its adaptation (Karthika et al., 2019) [36].

Direct sowing over the puddled field by drum seeder can be successfully adopted in irrigated lands. Success of DSR depends largely on weed control especially with chemical methods of weed management. Various herbicides have been used for controlling weeds in DSR but efficiency of chemical methods based on single herbicide treatment may be unsatisfactory because of their narrow spectrum of weed control. Application of different pre emergence herbicides including thiobencarb, pendimethalin, butachlor, oxadiazon and nitrofen has found to control weed satisfactorily in DSR. Among the different post emergence herbicides, ethoxy sulfuron, bispyribac sodium, cyhalofop-butyl, petrilachlor, chlorimuron, metsulfuron and penoxsulam were found effective against complex weed flora in DSR (Singh et al., 2007; Mahajan et al., 2009) [87, 91]. Therefore, application of several herbicides in sequence could be more useful (Chauhan and Albugo, 2013) [24]. The trend for an increase in herbicide use has been reinforced by the spread of DSR (Suryakanta et al., 2019) [96].

**Crop establishment methods on weed dynamics**

A major problem encountered in direct seeding of rice is weed control. In direct seeded rice, weed emergence occurs almost at the same time as that of rice plants and thereafter competition is severe at early stages of the rice (Balyan, 1982; Reddy et al., 1994) [10, 72]. Prasad et al. (2001) [61] stated that the lowest weed density and weed dry weight were recorded under transplanting method followed by puddled sowing of sprouted seeds and dry drilling. Singh et al. (2005) [99] reported that the weed density was higher in DSR (dry direct seeding unpuddled) and least in WSR (wet seeding in puddled soil) and TPR (transplanted) establishment methods. Uphoff (2006) [98] emphasized that when puddy fields are not kept flooded, weed problems will become more severe and require more weeding. Hassan et al. (2010) [52] found that transplanted rice reduced the weed population as well as dry matter with higher weed control efficiency resulting in higher grain yield than WSR. Parmeshwari et al. (2015) [56] observed that the crop establishment methods influenced the weed management practices and improved the weed control efficiency. The highest weed control efficiency of 90.4 and 88.1 per cent were recorded under transplanted and direct seeded rice, respectively. Suryakanta et al. (2019) [96] reported that the highest weed control efficiency was recorded in weed free condition and lowest in weedy check condition dry direct seeded rice under irrigated ecosystem.

**Crop establishment methods on growth attributes**

In direct seeded rice, leaf area growth starts two weeks earlier and leaf area index (LAI) is higher than that in transplanted rice (Schnier et al., 1990) [77]. Bharathi (1996) [13] noted that number of tillers per unit area and LAI were more in row sown rice than those in broadcast and transplanted rice. Increased plant height was recorded with direct sown rice than transplanted rice (Prabhakar and Reddy, 1997) [60]. Pal et al. (1999) [84] studied the different methods of rice establishment and revealed that line planting produced higher LAI, dry matter accumulation and consequently higher crop growth rate. Ni et al. (2000) from IRRI observed that in direct seeded puddled rice, the crop growth rate, LAI and dry matter production at tillering were associated with their competitiveness against weeds, whereas, relative crop growth rate, net assimilation rate and tillering capacity of the crop did not show such association. Singh et al. (2004) [89] found that plant height was more under non-puddled direct seeded rice at 30 and 60 DAS. However, tillers m<sup>2</sup> and dry matter accumulation were higher under puddled rice using rotavator. According to Kumar et al. (2008) direct seeding of sprouted seeds under puddled condition recorded higher growth attributes than other systems of cultivation. Parmeshwari et al. (2015) [56] observed that the crop establishment methods significantly influenced the plant height at harvest. The taller plants were observed under transplanted rice and it was comparable with SRI. However, it was significantly higher than that of direct seeded rice under puddled condition. Karthika et al. (2019) [96] reported that weed free upo panicle initiation stage had recorded the tallest panicle and higher yield among the different weed management practices in direct seeded rice under puddled and unpuddled rice conditions.

**Crop establishment methods on yield attributes and yield**

Wet seeded rice producing similar or higher yield than transplanted rice was well documented by several workers in Philippines (Khan et al., 1990 and Moody, 1993), [49, 40] in India (Ramasamy et al., 1994, Rachel and Martin, 1995) [68, 63] and in Pakistan (Majid et al., 1996) [47]. Prasad et al. (2001) [61] stated that between two direct seeding methods (dry drill seeding at 15 cm distance, broadcasting sprouted seeds under puddled condition); puddled sowing of sprouted seeds...
resulted in significantly higher yield attributes than dry drilling. Grain and straw yields were also higher under puddled sowing condition than dry drilling. Budhar and Tamil Selvan (2002) [19] revealed that wet seeding by broadcasting (57.2 q/ha) and wet seeding by drum seeder (56.6 q/ha) has recorded higher yield than transplanting (55.8 q/ha) but drum seeding method did not give significantly higher yield over transplanting.

The maximum grain yield was observed in direct seeded and transplanted plots treated with two hand weeding and higher fertilizer dose of 120: 60: 60 kg N, P₂O₅ and K₂O/ha (Singh et al., 2006) [94]. Yadav et al. (2006) [101] stated that almost equal grain yield of rice under transplanted (55 q/ha) and drum seeding (53 q/ha) methods. Bisht et al. (2007) [106] reported that all the tested agro techniques of crop establishment (SRI, drum seeding, dry seeding and broadcasting of sprouted seeds) were found to produce grain yield statistically on par to that of conventional method of transplanting. Aslam et al. (2008) [6] revealed that highest number of productive tillers per unit area (232) was noted in direct seeding followed by double zero tillage (219), bed planting (207) and conventional planting (200), respectively. Prasad et al. (2010) [62] found that grain yields in transplanted (4367 kg/ha) and drum seeded rice (3933 kg/ha) were on par with each other but significantly superior over direct seeded rice (2992 kg/ha) as a result of reduced weed competition measured in terms of low weed density and dry weight. Rice yield was maximum in mechanized transplanting but it was statistically on par with direct seeded rice. The highest rice yield was obtained in farmer conventional transplanting. It was further revealed that although transplanting methods produced higher filled grains panicle⁻¹, 1000 grain weight but it was statistically similar to DSR methods (Ali et al., 2014) [3]. Parameshwari et al. (2015) [56] observed that no significant differences among different crop establishment methods were noticed in number of grains panicle⁻¹, panicle length and test weight. Iqbal et al. (2017) [32] found that maximum 1000 grain weight was recorded in direct seeded rice followed by transplanted rice.

**Crop establishment methods on economics**

Transplanting gave the highest gross and net returns and showed superiority to direct seeding. However, benefit cost ratio (BCR) was almost alike under direct seeding and transplanting (Thakur, 1993) [97]. A study at Tamil Nadu reported the maximum net returns and energy use efficiency in direct seeding with drum seeder over random or line transplanting of seedlings (Bhuvaneshwari, 1998) [15]. Whereas Prasad et al. (2001) [61] obtained the highest gross return, net returns and BCR under transplanting compared to other methods of cultivation. Similarly, economic advantages of transplanting over drum seeding have also been reported by Sanjay et al. (2006) [76]. In contrary, Budhar and Tamil Selvan (2002) [19] claimed that direct seeding practices viz., wet seeding by manual broadcasting and drum seeding recorded higher net income (Rs.21551 and 21214/ha) and BCR (2.51 and 2.48, respectively) against traditional transplanting (Rs.18666/ha and 2.10). Economic factors and technology development in rice production are the major drivers that have led to the adoption of direct seeding methods for rice establishment in place of transplanting in Asia (Pandey and Valasco, 2002) [55].

Gaire et al. (2013) [28] reported that in direct seeded rice three hand weeding gave the highest gross return, net return and BCR. Shelar (2014) found that maximum net returns (Rs.16878.66 /ha) and B:C ratio (1.37) was recorded in the treatment of pre emergence application of oxadiargyl at 120 g/ha + post emergence application of bispyrribac sodium at 25 g/ha direct seeded rice. Iqbal et al. (2017) [32] reported that the highest BCR was recorded in direct seeded rice followed by transplanted rice and concluded that direct seeded rice is a site specific technology for sowing of rice which save labor and energy. Karthika et al. (2019) [36] reported that higher net return and B:C ratio was observed with the application of Bensulfuron methyl (0.6%) + Pretichlor (6% GR) (10 kg/ha) fb 2,4-D (1.25 kg/ha) + one hand weeding at 45 DAS in direct seeded rice ecosystems.

**Weed control strategies**

**Hand weeding**

In India, manual weeding is the most prevalent practices in different cultures of rice but this practice is effective only when weeds attain certain stature to provide better grip for uprooting (Bhan, 1980) [11]. Hand weeding (20 and 40 DAS) twice performed the best in enhancing all the growth and yield parameters (Singh and Namdeo, 2004) [89]. Hand weeding twice resulted in significantly higher panicle number and grain yield (Suganthi et al., 2005) [95]. The highest weed control efficiency of 66 per cent was recorded with two hand weeding at 30 and 45 DAS as reported by Payman and Singh (2008) [84, 91].

The lowest weed count and weed dry weight was recorded under twice hand weeding in DSR (Roy et al., 2010) [74]. Nadeem Akbar et al. (2011) [51] reported that hand weeding was more effective in decreasing weed density and dry weight and increasing weed control efficiency and rice yield than the mechanical hoeing and chemical weed control method in direct seeded rice. Hand weeding at 20 and 45 DAS recorded significantly taller plant height and higher dry matter production in DSR (Sheeja et al., 2013). Nath et al. (2014) [52] found that among different weed control treatments, two hand weeding at 20 and 40 DAS had highest weed control efficiency (75.7%) in DSR. Kankal (2015) reported that maximum height, numbers of tillers/0.25 m² and dry matter accumulation in rice crop was recorded by hand weeding thrice (20, 40 and 60 DAS) in drilled rice. Chaudhary et al. (2018) [22] found that two hand weeding produced the highest thousand grain weight in dry DSR. Devi and Singh (2018) [82] reported that two hand weedings at 20 and 40 DAS recorded maximum yield, NPK content in grain and straw in direct seeded rice.

**Mechanical weeding**

Increasing demand for labour and escalating cost of agrochemicals together with phytotoxicity effects necessitated the farmers to think of mechanical measures of controlling weeds. Mechanical weeding had the advantage of economical, non-polluting without residual problems and it is relatively safe to the operator (Mishra and Sahoo, 1971) [48]. Senthilkumar et al. (2003) [78] reported that rotary weeder weeding had the advantage of 10.9 per cent of increased crop yield/ha rather than using hand weeding. Rajendran et al. (2005) showed that 22 to 24 per cent yield increase due to the use of mechanical weeder. The highest weed suppression and increase in rice yield by 25 per cent over unweeded check under mechanical hoeing and it was statistically on par with hand weeding treatment (Nadeem Akbar et al., 2011) [51]. Hand weeding is very easy and environment-friendly but tedious and highly labour intensive and thus is not an economical for the farmers (Juraimi et al., 2013) [35]. Mechanical weeding resulted 72 per cent reduction in the total
weed density compared with the control. Mechanical weed management followed by chemical application led to higher efficacy in weed control over the control (Arunbabu and Jena, 2018) [5].

**Chemical weed control**

In rice, the conventional method of weed control i.e. hand weeding is very laborious, expensive and inefficient. Use of chemical to control weeds has been found effective and economical. Chemical weeding is easier, time saving and economical as compared to hand weeding alone (Brar and Mishra, 1989) [18]. Chemical weed control can be considered as a better alternative (Singh et al., 1998) [88]. Herbicidal weed control methods offer an advantage to save labour and money, as a result, regarded as cost effective method of weed control (Ahmed et al., 2000) [1]. Herbicides provide superior weed control and are more labour efficient than manual or mechanical methods of weed management (Chauhan et al., 2014) [25]. Jacob et al. (2014) [53] reported that the major advantage in going for herbicidal control of weeds in DSR is the reduction in the cost of cultivation.

Pre-emergence application of herbicides is not possible always because of unfavorable climate and sowing pressure (Porwal, 1999) [59]. Continuous use of pre-emergence herbicides in high dose causes shift in weed flora from grasses to non-grassy weeds (Singh et al., 2009) [91] and development of herbicide resistance in weed due to long persistence in the soil. This necessitates use of post emergence herbicides for weed control in DSR, which provides broad spectrum, weed control and tackle the problem of herbicide resistance. Paswan et al. (2012) [83] opined that herbicides with different mode of action when mixed together, bind to different target sites in weeds and prevent the probability of target site resistance in susceptible species. Herbicides may be considered to be a viable alternative to hand weeding (Chauhan and Johnson, 2010; Anwar et al., 2012) [23, 4]. Singh et al. (2017) [83] found that sequential application of pendimethalin fb penoxsulam produced the lowest weed density and total weed biomass over weedy check, and consistently produced higher growth, yield attributes and yield of DSR. Devi and Singh (2018) [82] reported that the application of bispripyrac at 25 g a.i./ha + azimsulfuron at 17.5 g a.i./ha + NIS (0.25%) at 15-20 DAS recorded maximum yield (grain and straw) in direct seeded rice. Rathika and Ramesh (2019) [71] reported that application of PE pretilachlor + safener at 0.45 kg/ha + EPOE metsulfuron methyl + chlorimuron ethyl at 4 g/ha on 25 DAS recorded higher grain yield (4.91 t/ha), maximum net returns and BCR (Rs.42371/ha and 2.23) in direct wet seeded rice.

A list of commonly used herbicides in direct seeded rice field with their active ingredients, application time and target weed groups has been presented in Table 3.

**Table 3:** Commonly used herbicides in direct seeded rice system (Azmi, 2012) [8].

| Herbicides          | Time of application (DAS) | Dose                        | Salient features                                                                 |
|---------------------|--------------------------|-----------------------------|----------------------------------------------------------------------------------|
| Benthocarb          | 5-7                      | 6 L product/ha              | Early post emergence herbicide, broad spectrum of weed control under saturated conditions |
| Bispyribac sodium   | 10-14                    | 20-40 g a.i./ha             | Contact herbicide for early post emergence application, broad spectrum of weed control except Leptochloa chinensis |
| Bensulfuron methyl  | 6-10                     | 300-500 g a.i./ha           | Effective against almost all annual and perennial broadleaved weeds and some sedges during pre-emergence and early post emergence under wet/standing water conditions |
| Cyhalofop butyl     | 10-14                    | 100 g a.i./ha               | Effective against E. crusgalli and L. chinensis until four leaf stage. Tank mixed with Sulfonyl urea gives wide spectrum of weed control |
| Fentrazamide        | 4-7                      | 60-70 g product/10L         | Early post emergence herbicide; effective against mostly grasses and some sedges, broadleaved weeds |
| Molinate + bensulfuron | 6-10              | 3.0 + 0.03 kg a.i./ha       | Wide spectrum of weed control under standing water Conditions |
| Molinate + 2.4-D    | 14-21                    | 3.0 + 0.5 kg a.i./ha        | Early post emergence herbicide for Echinichola spp., wide spectrum of weed control |
| Pretilachlor        | 1-4                      | 0.5 kg a.i./ha              | Pre-emergence herbicide, broad spectrum of weed control |
| Propanil            | 5-7                      | 6 L product/ha              | Early post emergence herbicide, broad spectrum of weed control under saturated conditions |
| Propanil + 2.4-D    | 6-10                     | 2-4 kg a.i./ha + 1 kg a.i./ha | Early post emergence herbicide for grassy weeds, effective under dry and saturated conditions |
| Penoxsulam + Cyhalofop butyl | 6-10 | 12.5 g + 62.5 g a.i./ha | Effective against E. crusgalli, L. chinensis, C. iria, F. miliacea and C. dfformis under saturated condition |

(DAS = Days after sowing; a.i = active ingredient; ha = hectare)

**Integrated weed management**

No single weed control method can combat multitude of weed problems in a given area and so it is necessary to use a combination of physical, chemical (time of application) and cultural (method of seeding and intercropping) management techniques to achieve higher benefits in wet seeded rice cultivation. Gogoi (1995) reported that cultural and chemical combination had the greatest weed control efficiency. The integration of cultural and mechanical control with safe herbicides can be recommended for pollution free weed management (Bhan and Sushil Kumar, 1996) [12]. Integration of diverse technologies is essential for weed management because weed communities are highly responsive to management practices and environmental conditions (Buhler et al., 2000). Chemical method of weed control should not be considered as a replacement for other weed control methods, however, should be integrated with them. Karthika et al. (2019) [30] reported that the application of Bensulfuron methyl + Pretilachlor (10 kg/ha) fb 2,4-D (1.25 kg/ha) + one hand weeding @ 45 DAS was found to be the ideal combination for managing the weeds by increasing weed control efficiency under direct seeded condition with higher grain yield.
Table 4: Influence of IWM on the rice grain and biological yield of the direct sown puddled rice (Sharma and Singh, 2008) [84, 93].

| S. No | Weed control measures                  | Grain yield (t/ha) | Biological yield (t/ha) |
|-------|---------------------------------------|--------------------|------------------------|
| 1     | Weedy                                 | 0.7                | 7.7                    |
| 2     | Two hand weedings                      | 5.0                | 12.0                   |
| 3     | Herbicide + one hand weeding           | 5.3                | 12.6                   |
| 4     | Criss cross sowing + one hand weeding  | 3.8                | 11.5                   |
| 5     | Criss cross sowing + one hand weeding  | 5.5                | 13.3                   |
|       | LSD at 5%                              | 0.1                | 2.8                    |

Conclusion

It is inferred that no single weed control method is adequate in checking weed population in rice cultivation. Judicious mix of more than one method is warranted to keep the weed under control for higher productivity in rice. Hence, integrated weed management packages comprising of suitable herbicides supplemented with hand/mechanical weeding should be given focus for effective control of weeds in direct seeded rice towards targeted yield.

References

1. Ahmed GJU, Mamun AA, Hossain SMA, Mritha AJ, Hossain ST. Agro-economic study of weed control in direct seeded Aus rice in the farmer’s field. Annals of Bangladesh Agriculture, 2000; 8(2):111-118.
2. Ajay Singh, Nandal DP, Punia SS. Bio-Efficacy of sequential application of herbicides on weeds and yield in direct seeded rice (Oryza sativa). International Journal of Current Microbiology and Applied Sciences. 2017; 6(4):900-905.
3. Ali AM, Thind HS, Sharma S. Prediction of dry direct-seeded rice yields using chlorophyll meter, leaf color chart and Green Seeker optical sensor in North Western India. Field Crops Research, 2014; 161:11-15.
4. Anwar MP, Juraimi AS, Puthe A, Selamat A, Rahman MM, Samedani M et al. Seed priming influences weed competitiveness and productivity of aerobic rice. Acta Agriculturae Scandinavica. 2012; 62:499-509.
5. Arunbabu T, Jena SN. Weeds and progressive weed management techniques in rice (Oryza sativa, L.): A review. Bulletin of Environment, Pharmacology and Life Sciences. 2018; 7(2):108-117.
6. Aslam M, Hussain S, Ramzan M, Akhter M. Effect of different stand establishment techniques on rice yields and its attributes. Journal of Animal and Plant Sciences. 2008; 18(2-3):80-82.
7. Awan TH, Cruz PCS, Chauhan BS. Ecological significance of rice (Oryza sativa) planting density and nitrogen rates in managing the growth and competitive ability of itchgrass (Rottboellia cochinchinensis) in direct-seeded rice systems. Journal of Pest Science. 2015; 88:427-438.
8. Azmi M. Weed succession and management technologies in rice. Presented Research inaugural lecture, 17 May, 2012, MARDI, Serdang, Malaysia, 2012, 21.
9. Balasubramanian V, Hill JE. Direct seeding of rice in Asia: Emerging issues and strategic research needs for 21st century. In: Direct Seeding: Research Strategies and Opportunities, Pandey et al. (eds.). Proc. Int. Workshop on Direct Seeding in Asian Rice Systems: Strategic Research, Issues and Opportunities, Jan 25-28, Bankok, Thailand, 2002, 15-39.
10. Balyan RS. Paddy herbicides: Weed control and residual effect. Pesticide. 1982; 16(12):15-16.
11. Bhan VM. Effect of hydrology, soil moisture regimes and fertility management on weed populations and their control in rice. In: Weed control in rice, 1980, 47-56.
12. Bhan VM. Sushil Kumar. Pollution free weed management - an approach. Pestology. 1996; 20(4):25-35.
13. Bharathi T. Management options for seeding and weeding in wet-seeded rice. M.Sc., (Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, 1996.
14. Bhatt R, Kuikal SS. Direct seeded rice in South Asia. In: Sustainable Agriculture Reviews. Springer International Publishing, 2011, 217-252.
15. Bhuveneshwari P. Effect of establishment methods and weed control on productivity, energetic and economics of lowland rice. M.Sc., (Ag.) Thesis. Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India, 1998.
16. Bisht PS, Punia R, Pandey PC, Singh DK. Grain yield and yield components of rice as influenced by different crop establishment methods. Int. Rice Res. Notes. 2007; 32(2):33-34.
17. Biswas S, Sankaran S, Panaliappan SP. Direct seeding practices in India. In: Direct seeded flooded rice in the tropics. IRRI, Manila, Philippines, 1991, 55-63.
18. Brar LS, Mishra SP. Weed control in groundnut with pre and post emergence herbicides. Indian Journal of Weed Science. 1989; 21(1-2):16-21.
19. Budhar MN, Tamil Selvan N. Study on stand establishment techniques in lowland irrigated rice (Oryza sativa L.). Madras Agricultural Journal. 2002; 88(4-6):365-366.
20. Buhler DD, Liebman M, Obrycki JJ. Theoretical and practical challenges to an IPM approach to weed management. Weed Science. 2000; 48:274-280.
21. Chandra D. Effect of methods of establishment and levels of nitrogen on growth, yield and protein content of rice varieties. Oryza. 1992; 29:33-36.
22. Chaudhary SK, Marahatta S, Chaudhary M. Performance of dry direct seeded rice and weeds on Sesbania brown manuring as compared to farmers’ practice and chemical control method. International Journal of Applied Sciences and Biotechnology. 2018; 6(3):265-269.
23. Chauhan BS, Johnson DE. The role of seed ecology in improving weed management strategies in the tropics. Advances in Agronomy, 2010; 105:221-262.
24. Chauhan BS, Albugo SB. Effects of water regime, nitrogen fertilization and rice plant density on growth and reproduction of lowland weed Echinocloa crus-galli. Crop Protection. 2013; 54:142-147.
25. Chauhan BS, Kumar V, Mahajan G. Research needs for improving weed management in rice. Indian Journal of Weed Science. 2014; 46:1-13.
26. Chinunamy C, Nalini K, Nithya C. Major weeds and their management in Tamil Nadu, In: Proc. of Biennial Conference of Indian Society of Weed Science on “Weed
threat to agriculture, biodiversity and environment”, April 19-20, Kerala Agricultural University, Thrissur, Kerala, India, 2012, 4.

27. Devi RB, Singh Y. Nutrient uptake and yield of direct seeded rice as influenced by nitrogen and weed management practices. Indian Journal of Pure & Applied Biosciences. 2018; 6(5):34-40.

28. Gaire R, Dahal KR, Amgain LP. Effect of different mulching materials on weed dynamics and yield of direct seeded rice in Chitwan, Nepal. Agronomy Journal of Nepal. 2013; 3:73-81.

29. Gogoi AK. Weed management in transplanted low land rice (Oryza sativa). Indian Journal of Agronomy. 1995; 14(1):96-98.

30. Govindarasu R, Ramamohan J, Ramamoorthy N, Mohamed Hanif A. Direct seeding - a best suitable for transplanted rice cultivation in future. Kisan World. 1998; 25(11):20-21.

31. Hassan G, Tanveer S, Khan NU, Munir M. Integrating cultivars with reduced herbicide rates for weed management in maize. Pakistan Journal of Botany. 2010; 42(3):1923-1929.

32. Iqbal MZ, Hussain M, Rasheed A. Direct seeded rice: purely a site specific technology. International Journal of Advanced Research in Biological Sciences. 2017; 4(1):53-57.

33. Jacob G, Menon MV, Abraham CT. Comparative efficacy of new herbicides in direct seeded rice. Journal of Tropical Agriculture. 2014; 52:174-177.

34. Johnson DE. Weed management in small holder rice production in the tropics. National IPM Network, University of Minnesota, 1996, 1-8.

35. Juraimi AS, Anwar MP, Selamat A, Puteh A, Man A. The influence of seed priming on weed suppression in aerobic rice. Pakistan Journal of Weed Science Research. 2013; 18:257-264.

36. Kartihka R, Subramanian E, Ragavan T, Kumutha K. Studies on crop weed competition and weed management in direct seeded rice under puddled and unpuddled conditions. International Journal of Chemical Studies. 2019; 7(3):2769-2773.

37. Kaur J, Singh A. Direct seeded rice: Prospects, problems/constraints and researchable issues in India. Current Agriculture Research Journal. 2017; 5(1):13.

38. Khalilq Abdul, Matloob Amar. Weed-crop competition period in three fine rice cultivars under direct-seeded rice culture. Pakistan Journal of Weed Science Research. 2011; 17(3):229-243.

39. Khan C, Duff B, Erguiza A. Choice of rice crop establishment technique: transplanting vs wet seeding. IRRI research paper series, 1990, 139.

40. Kumar V, Ladha JK. Direct seeding of rice: recent developments and future research needs. Advances in Agronomy. 2011; 111:299-360.

41. Kumar V, Bellinder RR, Gupta RK, Malik RK, Brainard DC. Role of herbicide-resistant rice in promoting resource conservation technologies in rice–wheat cropping systems of India: a review. Crop Protection. 2008; 27(3):290-301.

42. Ladu M, Singh MK. Crop-weed competition in upland direct seeded rice under foot hill conditions of Nagaland. Indian Journal of Weed Science. 2006; 38:131-132.

43. Mahajan G, Chauhan BS. Weed control in dry direct-seeded rice using tank mixtures of herbicides in South Asia. Crop Protection. 2015; 72:90-96.

44. Mahajan GBS, Chauhan Johnson DE. Weed management in aerobic rice in north western Indo-Gangetic Plains. Journal of Crop Improvement. 2009; 23:366-82.

45. Maity SK, Mukherjee PK. Integrated weed management in dry direct-seeded rainy season rice (Oryza sativa). Indian Journal of Agronomy. 2008; 53(3-4):116-120.

46. Maity SK, Mukherjee PK. Effect of brown manuring on grain yield and nutrient use efficiency in dry direct seeded kharif rice (Oryza sativa L.). Indian Journal of Weed Science. 2011; 42(1&2):61-66.

47. Majid A, Khan AS, Ahmad SI, Zaidi MA. Water consumption of different rice production techniques. Agricultural Mechanization in Asia, Africa and Latin America. 1996; 27(1):37-40.

48. Mishra A, Sahoo BC. Cultivation of low land rice in Orissa. Oryza. 1971; 8:225-229.

49. Moody K. Weed control in wet seeded rice. Experimental Agriculture. 1993; 29:393-403.

50. Muthukrishnan P, Subbalakshmi L, Sathiya K. Weed distribution and management in rice. In: Proc. of National Conference on “Challenges in weed management in agroecosystems - Present status and future strategies”, Nov.30 and Dec.01, Tamil Nadu Agricultural University, Coimbatore, India, 2010, 15-20.

51. Nadeem Akbar K, Jabran, Ali MA. Weed management improves yield and quality of direct seeded rice. Australian Journal of Crop Science. 2011; 5(6):688.

52. Nath CP, Saha M, Pandey PC, Das TK, Meena RK, Paul T et al. Bioefficacy evaluation of different herbicides on weed population, grain yield and nutrient uptake in direct seeded puddled rice (Oryza sativa L.). Annals of Agricultural Research. 2014; 35(2):217-223.

53. Ni H, Moody K, Robles RP, Paller Jr EC, Lales JS. Oryza sativa plant traits conferring competitive ability against weeds. Weed Science. 2000; 48(2):200-204.

54. Pal SK, Singh KM, Thakur R, Verma VN, Singh MK. Growth and yield of rice (Oryza sativa L.) cultivars under different methods of planting in Bihar plateau. Journal of Research Birsa Agricultural University. 1999; 11(1):19-22.

55. Pandey S, Valasco L. Economics of direct seeding in Asia: pattern of adoption and research priorities. IRRN. 2002; 24:6-11.

56. Parameshwari YS, Srinivass A, Prakash TR, Narendar G. Effect of different crop establishment methods on rice (Oryza sativa L.) growth and yield: A review. Agricultural Reviews. 2015; 35(1):74-77.

57. Paswan A, Kumar R, Kumar P, Singh R. Influence of Metsulfuron-methyl and carfentrazone-ethyl either alone or in combination on weed flora, crop growth and yield in wheat (Triticum aestivum). Madras Agricultural Journal. 2012; 99:560-562.

58. Payman G, Singh S. Effect of seed rate, spacing and herbicide use on weed management in direct seeded rice (Oryza sativa). Indian Journal of Weed Science. 2008; 40(1-2):11-15.

59. Porwal MK. Weed management through herbicide in direct drilled upland rice in rainfed situations of southern Rajasthan. Indian Journal of Weed Science. 1999; 31:196-198.

60. Prabhakar SVRK, Reddy SN. Rice productivity as affected by dates of seeding and methods of planting. The Andhra Agricultural Journal. 1997; 44:30-32.

61. Prasad SM, Mishra SS Singh SJ. Effect of establishment methods, fertility levels and weed management practices
on rice (*Oryza sativa*). Indian Journal of Agronomy. 2001; 46(2):216-221.

62. Prasad TVR, Sanjay MT, Denesh GR, Kumar HSR, Ananda N, Lokesh DS et al. Influence of time of sowing and weed control methods on yield and economics of direct seeded rice. In: Proceeding of the Biennial Conference of Indian Society of Weed Science on “Recent Advances in Weed Science Research-2010” February, 2010, 25-26.

63. Rachel SA, Martin GJ. Comparative study on the methods of establishment of rice – ADT 36. Madras Agricultural Journal. 1995; 82(1):71-72.

64. Raghavendra B, Susheela R, Rao VP, Madhavi M. Efficacy of different weed management practices on growth and yield of direct wet seeded rice sown through drum seeder. The Bioscan. 2015; 10(1):97-101.

65. Raj SK, Mathew R, Jose N, Leenakumary S. Evaluation of early post emergence and post emergence herbicides on weed control and productivity of direct-seeded puddled rice in Kuttanad. Madras Agricultural Journal. 2013; 100:738-742.

66. Rajendran R, Ravi V, Ramanathan S, Chandrasekaran B, Jayaraj T, Balasubramanian V et al. Evaluation of selected crop management components for enhancing rice productivity and profitability in Tamil Nadu, India. In: TM. Thiyagarajan, Hengsdijk, H. and PS. Bindraban (eds). Transitions in Agriculture for Enhancing Water Productivity: Proceedings of an International Symposium held on September 23-25 at Killikulam, Tamil Nadu, India. Tamil Nadu Agricultural University, Coimbatore, and Plant Research International, Wageningen, Netherlands, 2005.

67. Ramamoorthy K, Subbaiah SV. Effect of butachlor + safener on drum seeded rice at DRR farm, Andhra Pradesh, India. In: 2nd IRRI-CREMNET Workshop cum Group Meeting, 24-27 August, Soil and Water Management Research Institute, Thanjavur, Tamil Nadu, India, 1999.

68. Ramasamy S, Premsekar M, Purushothaman S. Evaluation of rice varieties under different systems of crop establishment. Madras Agricultural Journal. 1994; 81(3):154.

69. Rao VS. Principles of weed science (2nd Ed.). Oxford and IBH Publishing Co. Pvt. Ltd., New Delhi, 2011, 277.

70. Rathika S, Ramesh T. Weed management effect in system of rice intensification. Indian Journal of Weed Science. 2018; 50(4):388-390.

71. Rathika S, Ramesh T. Weed management in direct wet seeded rice. Journal of Pharmacognosy and Phytochemistry, 2019; SP2:978-981.

72. Reddy MD, Reddy VN, Rao CPS. Puddle seeded rice technology and its prospects in Andhra Pradesh, India. In: International Workshop on Constraints, Opportunities and Innovations for Wet-seeded rice. 31st May - 3rd June 1994. Bangkok, Thailand. 1994.

73. Riaz A Mann, Shabbaz Ahmad, Gul Hassan, Mohammad Safdar Baloch. Weed management in direct seeded rice crop. Pakistan Journal of Weed Science Research. 2007; 13(3-4):219-226.

74. Roy DK, Singh D, Dharminder. Effect of crop establishment techniques and different weed management practices on growth, yield and quality of rice. In: Proc. of National Conference on “Challenges in weed management in agro-ecosystems - Present status and future strategies”, Nov.30 and Dec.1, TNAU, Coimbatore, 2010, 151.

75. Sangeetha SP, Balakrishnan A, Sathy Priya R, Maheswari J. Influence of seeding methods and weed management practices on direct seeded rice. Indian Journal of Weed Science. 2009; 41(3-4):210-212.

76. Sanjay MT, Shetty PTK, Nanjappa HV. Influence of weed management practices on nutrient uptake and productivity of rice under different methods of crop establishment. Crop Research. 2006; 32:131-136.

77. Schnier HF, Dingkuhn M, De Data SK, Mengal K, Wijangco E, Javellona C et al. Nitrogen economy and canopy carbon-dioxide assimilation of tropical lowland rice. Agronomy journal. 1990; 82:431-459.

78. Senthil Kumar K, Bindraban PS, Thiyagarajan TM, De Ridders N, Giller KE. Modified rice cultivation in Tamil Nadu, India: yield gains and farmers (lack of) acceptance. Agricultural Systems. 2003; 98(2):82-94.

79. Sharma SK, Singh KK. Production potential of the direct-seeded rice-wheat cropping system. In: Singh Y, Singh VP, Chauhan B, Orr A, Mortimer AM, Johnson DE, Hardy B (eds) Direct seeding of rice and weed management in irrigated rice wheat cropping system of the Indo Gangetic Plains. Los Banos (Philippines): International Rice Research Institute and Pantnagar (India): Directorate of Experiment Station, G B Pant University of Agriculture and Technology, 2008, 61-73.

80. Sheeja KR, Nimmy Jose, Reena Mathew, Sandhyadevi CD, Leenakumary S. Evaluation of broad spectrum herbicide- bispiribac sodiu + metamifop on weed control and productivity of direct-seeded rice in Kuttanad. In: Proc. 24th Asian –Pacific Weed Science Society Conference. October 22-25. Bandung, Indonesia, 2013.

81. Shelar SK. Effect of methods of sowing and weed control on the performance of direct seeded rice in Konkan region. M.Sc. (Agr.) Thesis, Konkan Krishi Vidyaapeeth, Dapoli, India, 2014.

82. Singh P, Shrivastava GK, Verma AK, Singh I. Effect of different doses of herbicides and mechanical weeding on yield attributes and grain yield of direct seeded rice (*Oryza sativa* L.) as influenced by nitrogen rates and herbicide sequence. Bangladesh Journal of Botany. 2017; 46(2):751-759.

83. Singh G. Integrated weed management in direct- seeded rice. In: Singh, Y., Singh, V.P., Chauhan, B., Orr, A., Mortimer, A.M., Johnson, D. E. and Hardy, B (eds), Direct seeding of rice and weed management in the irrigated rice-wheat cropping system of the Indo-Gangetic plains, IRRI, Los Banos, Philippines, 2008, 161-175.

84. Singh KN, Bhattacharyya HC. Direct seeded rice. Oxford and IBH publishing Co. Pvt. Ltd., New Delhi, 1989.

85. Singh M, Singh PR. Influence of crop establishment methods and weed management practices on yield and economics of direct-seeded rice (*Oryza sativa*). Indian Journal of Agronomy. 2010; 55(3):224-229.

86. Singh P, Singh P, Singh SS. Response of aromatic rice to establishment methods, fertility levels and weed
management practices. Indian Journal of Weed Science. 2007; 39(1-2):32-35.
88. Singh R, Mukhopadhyay SK, Patel CS. Economic evaluation of integrated weed management practices in upland rice. Indian Journal of Weed Science. 1998; 30(1-2):79-80.
89. Singh RK, Namdeo KN. Effect of fertility levels and herbicides on growth, yield and nutrient uptake of direct seeded rice (*Oryza sativa*). Indian Journal of Agronomy. 2004; 49(1):34-36.
90. Singh S, Singh G, Singh VP, Singh AP. Effect of establishment methods and weed management practices on weeds and rice in rice-wheat cropping system. Indian Journal of Weed Science. 2005; 37(1&2):51-57.
91. 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. Integrated Crop and Resource Management in the Rice–Wheat System of South Asia. Los Banos, International Rice Research Institute, Philippines, 2009, 261-278.
92. Singh Y, Singh VP, Singh G, Yadav DS, Sinha RKP, Johnson DE *et al*. The implications of land preparation, crop establishment method and weed management on rice yield variation in the rice-wheat system in the Indo-Gangetic plains. Field Crops Research. 2011; 121:64-74.
93. Singh S, Ladha JK, Gupta RK, Lav Bhushan, Rao AN. Weed management in aerobic rice systems under varying establishment methods. Crop Protection. 2008; 27:660-671.
94. Singh S, Lav Bhushan, Ladha JK, Gupta RK, Rao AN, Sivaprasad B *et al*. Weed management in dry seeded rice (*Oryza sativa*) cultivated in the furrow - irrigated raised-bed planting system. Crop Protection. 2006; 25:487-495.
95. Suganthi M, Kandasamy OS, Subbian P, Jayakumar R. Relative efficacy of pretilachlor 50 EC for weed control in lowland transplanted rice-rice cropping system. Indian Journal of Weed Science. 2005; 37(1-2):105-106.
96. Suryakanta Kashyap, Singh, Guru VP, Tej Pratap SK, Singh SP, Subhashisa Praharaj. Integrated weed control option for dry direct seeded rice under irrigated ecosystem. International Journal of Current Microbiology and Applied Sciences. 2019; 8(2):315-323.
97. Thakur RB. Effect of sowing method and seed rate on the performance of high yielding varieties of rice (*Oryza sativa*). Indian Journal of Agronomy. 1993; 38(4):547-550.
98. Uphoff N. The System of Rice Intensification (SRI) as a methodology for reducing water requirements in irrigated rice production. Cornell International Institute for Food, Agriculture and Development, Ithaca, NY, USA, In: International Dialogue on Rice and Water: Exploring option for Food security and Sustainable Environments, March 7-8, IRRI, Los Banos, Philippines, 2006.
99. Vikram Kumar. Performance of basmati rice under different transplanting date and weed management practices (Doctoral dissertation), CCSHAU, Hisar, Haryana, 2015.
100. Vikram Singh, Jat ML, Ganie ZA, Chauhan BS, Gupta RK. Herbicide options for effective weed management in dry direct-seeded rice under scented rice-wheat rotation of western Indo-Gangetic Plains. Crop Protection 2016; 81:168-176.
101. Yadav Vivek, Singh Bhagwan. Effect of crop establishment method and weed management practice on rice (*Oryza sativa*) and associated weeds. Indian Journal of Agronomy. 2006; 51(4):301-303.