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# Assessment of critical period for weeding and yield loss in direct seeded rice (*Oryza sativa*)

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ABSTRACT

A field experiment was conducted at research farm of Regional Rainfed Lowland Rice Research Station, ICAR-National Rice Research Institute, Gerua, Assam during two consecutive *boro* seasons of 2014–15 and 2015–16 to assess yield losses in direct seeded rice (DSR) under weeding times. There were two DSR establishment techniques (dry and sprouted seeding) in main plots and four weeding times (15, 30, 45 and 60 DAS) in sub plots. It was found that *Scirpus juncoides*, *Echinochloa colona*, *Cyperus difformis*, *Cyperus iria*, *Monochoria vaginalis* and *Ludwigia octovalvis* were the dominant weed species in shallow lowlands. DSR establishment techniques had non-significant effect on weed characteristics as well as growth, yield attributes and productivity of rice. Weed density of individual weed group and dry matter were significantly influenced by weeding times. Weeding at 15 DAS resulted in significantly low weed density and biomass as compared to weeding at 45 and 60 DAS. Growth and yield attributes, viz. plant height, panicles/m$^2$, filled grains/panicle and fertility percentage were significantly higher and subsequently resulted in higher grain and straw yield under early weeding at 15 DAS. The highest grain yield losses due to weeds were calculated with weeding at 60 DAS (20.4%) followed by 45 DAS (15.8%) in DSR. Thus, early weeding in DSR plays an important role to obtain higher productivity of rice and minimise yield loss due to weeds.

**Keywords**: Direct seeded rice, Shallow lowlands, Sprouted seeds, Weed density, Yield loss

Rice (*Oryza sativa* L.) is the principal cereal crop and major source of food for more than half of the world population. Rice is cultivated through transplanting of seedlings in puddled soil which negatively affects soil physical properties and incurs higher cost of production and more energy (Chauhan 2012), whereas, direct seeded rice (DSR) is a less labour intensive option for establishment of rice (Misra *et al.* 2005). In India, dry-seeding is extensively practiced in rainfed lowlands, uplands, and flood prone areas over 12 Mha (28%), while wet seeding remains a common practice in irrigated areas (Misra *et al.* 2005). DSR occupies a major area in eastern zone comprising Assam, Bihar, Eastern Madhya Pradesh, Orissa, Eastern Uttar Pradesh, West Bengal and North-Eastern Hill region in India. DSR is a major opportunity to change production practices to attain optimal plant density and high water productivity in water scarce areas. However, DSR has many biotic and abiotic challenges like drought, weed infestation, insect-pests and diseases. Among the major biotic constraints, weeds are considered most harmful to DSR as they compete with the crop for resources, shelter insect-pests, interfere with water management, reduce the yield and quality, and subsequently increase the cost of production (Zimdahl 2013). Potential yield losses due to weeds in DSR are observed to be higher (16–80%) than transplanted rice (45–51%) (Jabran *et al.* 2012, Singh *et al.* 2017 and Gharde *et al.* 2018). Weed management in DSR is more critical as weeds emerge at the same time or before the rice plants resulting in more competition. The practice of shallow flooding, necessary to enable good establishment of the rice seedlings, also favours weed growth. Weeds are responsible for higher yield losses in DSR, to the extent of complete crop failure under severe infestation. Thus, weed control at right time is very important to get comparative yield from DSR. Keeping these facts in view, a field experiment was conducted to assess the growth and yield losses in DSR by weeds under shallow lowlands of Assam.

## MATERIALS AND METHODS

A field experiment was conducted during two consecutive *boro* seasons of 2014–15 and 2015–16 at research farm of Regional Rainfed Lowland Rice Research Station, ICAR-National Rice Research Institute, Gerua, Assam located at 28°14'59" N latitude, 91°33'44" E

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longitude and an altitude of 49 m amsl. The climate of the experimental site was subtropical monsoon type with 1500 mm annual average rainfall. The soil was clay loam in texture with *p*H 6.2, high in organic carbon (1.08%), medium in available nitrogen (290 kg/ha) and phosphorous (16.15 kg/ha), and high in potash (320 kg/ha). Crop received 1094 mm and 821 mm rainfall with varying intensity at the time of reproductive phase during both the years. Average bright sunshine hours were 4.9 h/day and 5.5 h/day and mean evaporation was 3.9 mm/day and 2.9 mm/day during both years (Fig 1). The experiment was conducted in split plot design with two DSR techniques, viz. dry seed direct seeded rice (DSDSR) and wet sprouted seed direct seeded rice (SSDSR) in main plots and four weeding periods (weeding at 15, 30, 45 and 60 days after sowing (DAS) in sub plots, replicated thrice. All treatments remained weed free for rest of growing period once weeding was completed. Dry and germinated seeds were carefully sown in well puddled soil on 8$^{th}$ January during both the years according to the treatments with 20 cm × 15 cm spacing. A fertilizer dose of 60–30–30 kg/ha N-P-K was applied as urea, di-ammonium phosphate (DAP) and muriate of potash (MOP) in the field. One-third urea, and full doses of DAP and three-fourths of MOP were applied as basal dose at the time of final land preparation and incorporated well into the soil. Remaining two-thirds of urea was applied in two equal splits at 50 days and 80 days after sowing (DAS) while one fourth MOP was applied before panicle emergence (80 DAS).

Random sampling from each plot was done before weeding at 15, 30, 45 and 60 DAS. Sampling was done by placing three quadrats of 0.25 m$^2$ randomly in each plot to determine the weed density and biomass. From each quadrat, weeds were separated by species and the number counted and sorted into three categories: grasses, sedges and broadleaved weeds. For recording dry weight, weed samples were sun-dried for 2–3 days then oven-dried at 66°C until constant weight recorded. At maturity, plant height, dead hearts and yield attributes were recorded. After harvesting and threshing, grain yield was determined and adjusted to moisture content of 14%. Potential yield losses were calculated using formulae given by Galon and Agostinetto (2009) and Soltani *et al.* (2016).

$$\text{Potential yield losses due to weeds} = \frac{(WFy - WCy)}{WFy} \times 100$$

Where, WFy is crop yield in weed free situation and WCy is crop yield in weedy check plot.

Data were analysed following analysis of variance (ANOVA) and means were compared based on the least significant difference (LSD) test at 0.05 probability level.

## RESULTS AND DISCUSSION

*Weed flora, density and biomass:* Ten major weed species were identified in the experiment during crop growth period. Six weed species were dominant, viz. *Scirpus juncoides* Roxb., *Echinochloa colona* (L.) Link, *Cyperus difformis* L., *Cyperus iria* L., *Monochoria vaginalis* (Burm. f.) C. Presl ex Kunth and *Ludwigia octovalvis* L. Other four weed species were *Leptochloa chinensis* (L.) Nees, *Echinochloa crusgalli* (L.) P. Beauv, *Fimbristylis miliacea* (L.) Vahl and *Marsilia minuta* L. Weed species were not distributed uniformly in plots. Results revealed that grasses were the predominant weed group in DSR irrespective of the treatment followed by sedges in shallow lowlands. DSDSR and SSDSR techniques had non-significant effect on weed densities, dry matter accumulation and dead heart (Table 1). This might be due to similar microclimate in both the establishment techniques which hardly differ with 5 days in their seedling emergence to establishment in the field. However, grass and sedge density was higher in SSDSR as compared to

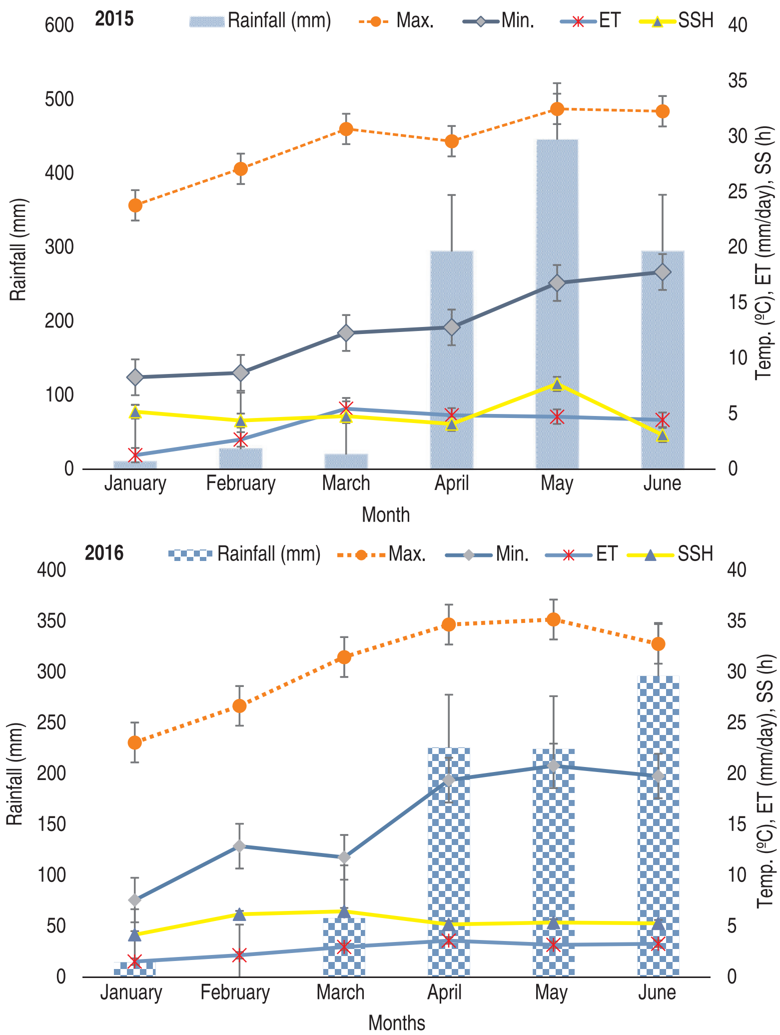


Fig 1 Weather parameters during crop growth period of rice during 2015 and 2016.

Table 1 Effect of DSR establishment techniques and weeding time on weed parameters, growth, yield attributes, productivity and yield losses to rice

| Treatment | Weed density (Nos/m$^2$) | | | Total weed dry matter (g/m$^2$) | Dead heart (/m$^2$) | Plant stands at 15 DAS (/m$^2$) | Plant height (cm) | Panicles (/m$^2$) | Panicle length (cm) | Panicle weight (g) | Filled grains/ panicle (No.) | Chaffy grains/ panicle (No.) | Fertility (%) | Test weight (g) | Harvest index | Straw yield (t/ha) | Grain yield (t/ha) | Yield loss by weeds (%) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Grasses | Sedges | BLW | | | | | | | | | | | | | | | |
| *Direct seeded rice* | | | | | | | | | | | | | | | | | | |
| DSDSR | 83.08 | 35.88 | 15.67 | 35.38 | 1.97 | 27.8 | 100.0 | 245.6 | 21.5 | 1.72 | 90.6 | 17.4 | 83.8 | 21.3 | 0.46 | 4.34 | 3.91 | |
| SSDSR | 91.58 | 37.63 | 8.67 | 33.71 | 2.19 | 27.7 | 96.0 | 245.2 | 21.8 | 1.75 | 88.3 | 17.5 | 83.1 | 21.5 | 0.46 | 4.29 | 3.93 | |
| SEm± | 6.62 | 5.79 | 2.59 | 1.49 | 0.10 | 0.63 | 0.56 | 5.54 | 0.61 | 0.10 | 3.35 | 2.07 | 1.53 | 0.25 | 0.01 | 0.16 | 0.13 | |
| CD (P = 0.05) | NS | NS | NS | NS | NS | NS | 2.42 | NS | NS | NS | NS | NS | NS | NS | NS | NS | NS | |
| *Weeding situations* | | | | | | | | | | | | | | | | | | |
| Weeding @15 DAS | 62.50 | 23.33 | 18.75 | 11.00 | 1.06 | 27.9 | 103.4 | 264.3 | 22.0 | 1.96 | 102.6 | 14.4 | 87.6 | 21.0 | 0.45 | 4.96 | 4.42 | |
| Weeding @30 DAS | 68.17 | 24.00 | 21.67 | 23.33 | 2.10 | 27.8 | 99.8 | 253.8 | 22.1 | 1.84 | 95.9 | 16.9 | 84.9 | 21.6 | 0.46 | 4.44 | 4.03 | 8.82 |
| Weeding @45 DAS | 115.25 | 45.58 | 3.50 | 34.58 | 2.31 | 27.7 | 95.0 | 238.8 | 21.2 | 1.63 | 83.7 | 17.9 | 82.3 | 21.4 | 0.46 | 4.07 | 3.72 | 15.84 |
| Weeding @60 DAS | 103.42 | 54.08 | 4.75 | 69.25 | 2.85 | 27.7 | 93.8 | 224.7 | 21.3 | 1.51 | 75.5 | 20.7 | 78.9 | 21.5 | 0.46 | 3.79 | 3.52 | 20.36 |
| SEm± | 9.52 | 6.99 | 2.60 | 4.33 | 0.35 | 2.18 | 2.07 | 5.26 | 0.74 | 0.11 | 3.79 | 1.87 | 1.58 | 0.37 | 0.01 | 0.20 | 0.19 | |
| CD (P = 0.05) | 20.74 | 15.22 | 5.67 | 9.42 | 0.77 | NS | 4.52 | 11.45 | NS | 0.23 | 8.26 | 4.07 | 3.45 | NS | NS | 0.45 | 0.41 | |

DSDSR, Dry seed direct seeded rice; SSDSR, Sprouted seed direct seeded rice; DAS, Days after sowing; BLW, Broad leaf weeds.
Pooled Data of 2 years.

DSDSR. Water-seeding (pregerminated seeding) provides favourable conditions for better germination of sedges and grassy weeds (Rao *et al.* 2007).

Weed density of grasses showed increasing trend up to weeding at 45 DAS, thereafter it started declining. There was significant increment in grass density between weeding at 30 and 45 DAS. Grass and sedge density at 45 and 60 DAS was significantly higher over 15 and 30 DAS. Sedge density went on increasing as long as weeds were allowed to grow in the field which might be due to secondary propagation of sedges from tubers. However, broad leaf weeds (BLW) were recorded highest at 30 DAS, thereafter drastic reduction in BLW density was observed which might be due to continuous stagnation of water from advancing premonsoon rainfall in shallow lowlands of Assam. However, total weed density at 45 and 60 DAS remained non-significant with each other but significantly higher over that at 15 and 30 DAS. Singh *et al.* (2005) also reported that weeding at 30 DAS led to increased sedges and grasses in DSR.

Weed dry matter accumulation was non-significant between DSDSR and SSDSR techniques. However, slightly higher dry matter accumulation of weeds was recorded in DSDSR. Among the weed management situations, weed dry matter accumulation was significantly increased up to 60 DAS which was mainly due to increase in weed density and weeds became more vigorous and healthier as they remained in field for a longer duration. The maximum weed dry matter was obtained at 60 DAS which was also significant over rest of the treatments. Dead hearts in both DSR techniques were found non-significant, whereas delayed weeding in DSR resulted in significantly higher number of dead hearts due to infestation of stem borer. Thus, weed infestation provided alternate host to stem borer. Mondal *et al.* (2017) also observed that weed density and biomass gradually increased up to 70 days after transplanting and declined in summer rice.

*Growth and yield attributes:* Direct seeded rice techniques had non-significant effect on the growth and yield attributes which indicated that both DSDSR and SSDSR had almost similar seedling establishment in the field (Table 1). Weeding situations significantly affected plant growth and yield attributes. Early weeding at 15 DAS resulted in significantly higher values for plant height, panicles/m$^2$, filled grains/panicle, panicle length and weight over weeding at 45 and 60 DAS, however, remained statistically at par with weeding at 30 DAS. Harvest index and 1000-grain weight remained unaffected with weed management conditions. This showed that early weeding is highly critical for weed management for successful DSR. Mola and Belachew (2015) and Alam *et al.* (2015) reported that early weeding was the most important practice to obtain higher growth and yield.

*Productivity and yield losses due to weeds:* Grain and straw yield remained unaffected with both the DSR techniques (Table 1). However, weeding conditions significantly affected the grain and straw yield. The maximum grain and straw yield were obtained when weeding

Table 2 Correlation coefficients between weed parameters, growth, yield attributes and yield of summer rice

| Trait | Density of Grasses (m$^2$) | Density of Sedges (m$^2$) | Density of BLW (m$^2$) | Total weed density (m$^2$) | Weed dry matter (m$^2$) | Plant height (cm) | Panicles (m$^2$) | Panicle Length (cm) | Panicle Weight (g) | Filled grains/ panicle | Fertility (%) | Harvest index | Straw yield (t/ha) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Density of Grasses (m$^2$) | | | | | | | | | | | | | |
| Density of Sedge (m$^2$) | 0.417* | | | | | | | | | | | | |
| Density of BLW (m$^2$ | -0.638** | -0.646** | | | | | | | | | | | |
| Total weed density (m$^2$) | 0.910** | 0.705** | -0.594** | | | | | | | | | | |
| Weed dry matter (m$^2$) | 0.526** | 0.781** | -0.504* | 0.728** | | | | | | | | | |
| Plant height (cm) | -0.455* | -0.657** | 0.670** | -0.541** | -0.594** | | | | | | | | |
| Panicles (m$^2$) | -0.582** | -0.662** | 0.443* | -0.732** | -0.809** | 0.710** | | | | | | | |
| Panicle Length (cm) | -0.120 | -0.197 | 0.254 | -0.127 | -0.213 | 0.481* | 0.373 | | | | | | |
| Panicle Weight (g) | -0.596** | -0.505* | 0.623** | -0.600** | -0.671** | 0.616** | 0.665** | 0.617** | | | | | |
| Filled grains/panicle | -0.582** | -0.577** | 0.687** | -0.607** | -0.726** | 0.656** | 0.658** | 0.396 | 0.772* | | | | |
| Fertility (%) | -0.510* | -0.614** | 0.603** | -0.593** | -0.748** | 0.458* | 0.499* | -0.007 | 0.532** | 0.794** | | | |
| Harvest index | 0.070 | 0.366 | -0.023 | 0.258 | 0.209 | -0.265 | -0.212 | 0.215 | 0.164 | -0.103 | -0.143 | | |
| Straw yield (t/ha) | -0.526** | -0.617** | 0.412* | -0.665** | -0.710** | 0.640** | 0.750** | 0.296 | 0.445* | 0.680** | 0.505* | -0.544** | |
| Grain yield (t/ha) | -0.462* | -0.604** | 0.399 | -0.604** | -0.6803** | 0.582** | 0.684** | 0.246 | 0.389 | 0.633** | 0.480* | -0.498* | 0.967** |

Pooled Data of 2 years.

was done at 15 DAS and found significantly superior over weeding done at 45 and 60 DAS. However, grain and straw yield remained statistically at par in weeding at 15 and 30 DAS. This is mainly due to lesser weed competition because of early weeding at 15 DAS resulting in higher values for growth and yield attributes. Significantly lower grain and straw yield was obtained with weeding at 60 DAS. Harvest index remained non-significant in DSR techniques as well as weeding management treatments. Mola and Belachew (2015) and Alam *et al.* (2015) also reported that early weeding at 15 DAS resulted in significantly higher grain and straw yield of rice. Grain yield losses kept on increasing as weeds were allowed to grow for longer duration in the field. The highest yield losses were calculated in weeding at 60 (20.4%) DAS followed by 45 (15.8%) and 30 (8.8%) DAS which indicated that early weeding is vital for good rice crop in DSR. Gharde *et al.* (2018) also reported that yield losses might vary from 15–66% in DSR depending upon weeding situations.

*Correlation study:* Correlation effects were studied among weed parameters with growth, yield attributes and yield (Table 2) which revealed that almost all weed parameters had registered a strong significantly negative correlation with major crop growth and yield attributes of summer rice. This might be due to tough competition for resources in the respective critical weed infestation period. The strongest negative correlation for grain and straw yield was recorded with sedges (r = -0.604**) and grasses (r = -0.462*). However, broad leaf weeds (0.399) recorded positive correlation with grain yield of rice which might be due to lowest weed density and drastic reduction at 30 DAS. All the measured crop growth and yield attributes positively correlated with grain and straw yield of rice. The strongest positive relationship of grain yield was recorded with plant height (r = 0.582**), number of panicles/m$^2$ (r = 0.684**), filled grains/panicle (r = 0.633**) and straw yield (r = 0.967**). Mondal *et al.*(2017) also mentioned that rice grain yield is the function of number of filled grains/panicle while Iftekharuddaula *et al.*(2002) reported about number of effective tillers/m$^2$.

Based on the above results, it could be concluded that different weeding times affected grain yield and yield components of DSR significantly, and early weeding at 15 DAS was appropriate for DSR. However, DSR establishment techniques of dry and sprouted seeding were non-significant.

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