*Plant Archives* Vol. 26, Supplement 2, 2026 pp. 523-529 e-ISSN:2581-6063 (online), ISSN:0972-5210

Plant Archives

Journal homepage: http://www.plantarchives.org
DOI Url : https://doi.org/10.51470/PLANTARCHIVES.2026.v26.supplement-2.056

# EFFECT OF MECHANICAL AND CULTURAL WEED MANAGEMENT PRACTICES ON WEED DYNAMICS, YIELD AND ECONOMICS OF DIRECT-SEEDED RICE (*Oryza sativa* L.)

**Neha Singh[1], Rajneesh Kumar[2], Amit Kumar[3], Ankita Giri[3] and Ashutosh Shukla[3]**
[1]Department of Agronomy, Phonics Group of Institution, Roorkee, Uttarakhand- 247667, India
[2]Division of Genetic, ICAR- Indian Agricultural Research Institute, New Delhi- 110012, India
[3]Sri Dev Suman Uttarakhand Vishwavidyalaya, Badshahi Thaul, Tehri Garhwal, Uttarakhand- 249 199, India
*Corresponding author E-mail: ns7071998@gmail.com
(Date of Receiving : 02-05-2026; Date of Revision : 15-06-2026; Date of Acceptance : 06-07-2026)

**ABSTRACT**

Direct-seeded rice (DSR) offers a promising resource-efficient alternative to traditional puddled transplanted rice, yet severe weed competition during early crop growth stages continues to limit its productivity. The study was laid out in a randomized block design with nine treatments and three replications. Treatments comprised weedy check, weed-free condition, hand weeding (20 and 40 DAS), mechanical weeding (20 and 40 DAS), brown manuring terminated with bispyribac-sodium, brown manuring terminated with 2,4-D, rice straw mulching, stale seedbed, and stale seedbed + rice straw mulching. Weed-free plots maintained the lowest weed density and highest weed control efficiency throughout the crop growth period. Among the practical treatments, mechanical weeding at 20 and 40 DAS proved most effective, recording 90.8% weed control efficiency at 60 DAS and grain yield of 59.0 q $ha^{-1}$. The highest grain yield (64.7 q $ha^{-1}$) was recorded under weed-free conditions, while the weedy check yielded the lowest (25.3 q $ha^{-1}$). Mechanical weeding also registered the highest net return (Rs. 1,35,456 $ha^{-1}$) and Net benefit-cost ratio (2.53). The results demonstrate that mechanical weeding performed twice at 20 and 40 days after sowing is an effective, economical, and environmentally sustainable option for weed management in direct-seeded rice.
***Keywords*** **:** Direct-seeded rice, mechanical weeding, brown manuring, stale seedbed, weed control efficiency

## Introduction

Rice (*Oryza sativa* L.) is one of the most important cereal crops and plays a central role in food and livelihood security, particularly in Asia (Atri *et al*., 2025; Parray *et al*., 2026). In many rice-growing regions, conventional puddled transplanted rice is becoming less sustainable because it requires large quantities of irrigation water, labour and energy. Direct-seeded rice (DSR) has emerged as a resource-conserving alternative because it avoids nursery raising, puddling and transplanting, and allows faster crop establishment under suitable field conditions (Kumar and Ladha, 2011).

The adoption of DSR is increasing because it can reduce labour demand and improve water-use efficiency compared with conventional transplanted rice. The improved crop management under DSR can support higher productivity while reducing dependence on labour-intensive transplanting operations. However, the success of DSR largely depends on effective early-season weed management (Sandhu *et al*., 2021).

Weed infestation is one of the most serious biological constraints in DSR. Unlike transplanted rice, where standing water and older seedlings suppress early weed emergence, rice and weeds in DSR germinate almost at the same time and compete strongly for light, nutrients, moisture and space. Chauhan and Johnson (2009) reported that simultaneous emergence of rice and weeds is a major reason for severe weed competition in direct-seeded rice.

The weed flora in DSR usually consists of grasses, sedges and broad-leaved weeds. Common weeds include *Echinochloa colona*, *Echinochloa crus-galli*, *Cyperus iria*, *Cyperus difformis*, *Eclipta alba* and *Alternanthera sessilis*. If weeds are not managed during the critical crop growth period, they can reduce tillering, panicle formation and grain yield. The uncontrolled weed growth may cause severe yield loss in direct-seeded rice (Rao *et al*., 2017).

Chemical weed control is commonly used in DSR because it is fast and less labour-demanding. However, repeated and continuous use of herbicides may lead to weed shifts, herbicide resistance, crop injury and environmental concerns. Navi *et al*. (2024) and Nagargade *et al*. (2024) emphasised on overreliance of herbicides in rice-based systems, which can create long-term weed management problems. Therefore, non-chemical and integrated weed management options need greater attention for sustainable DSR cultivation.

The integrated weed management is essential to achieve long-term, sustainable and economic management of weeds in direct-seeded rice systems (Hashim *et al*., 2024). Mechanical weeding is one of the practical options for reducing weed competition in DSR, especially where labour availability and herbicide dependence are major concerns. Mechanical weeding at the critical crop growth stages removes weeds physically and also disturbs the soil surface, which can reduce further weed establishment. The timely mechanical weeding can effectively reduce weed density in direct-seeded rice (Mahajan and Chauhan, 2013).

Cultural practices such as stale seedbed preparation, rice straw mulching and brown manuring can also contribute to weed suppression in DSR. A stale seedbed encourages weed seed germination before sowing, while rice straw mulch limits weed emergence by reducing light availability at the soil surface. Shekhawat *et al*. (2020) observed that cultural weed management practices can reduce weed pressure and improve the sustainability of dry direct-seeded rice systems.

Although several weed management practices have been studied in DSR, their relative performance under specific agro-climatic conditions still needs systematic evaluation. Information on the combined effects of mechanical and cultural practices on weed dynamics, yield attributes, grain yield and economic profitability is especially important for small and marginal farmers. Therefore, the present study was undertaken to evaluate the effects of different mechanical and cultural weed management practices on weed dynamics, yield and profitability of direct-seeded rice.

## Materials and Methods

### Experimental site and soil characteristics

The field experiment was conducted during the Kharif season of 2025 at the Post Graduate Research Farm, Phonics Group of Institutions, Roorkee, Uttarakhand (29.85°N, 77.88°E, 268 m amsl). The soil was clay loam in texture with pH 7.75, EC 0.28 dS $m^{-1}$, organic carbon 0.46%, available N 163 kg $ha^{-1}$, $P_2O_5$ 23.9 kg $ha^{-1}$ and $K_2O$ 250 kg $ha^{-1}$.

### Experimental design and treatment details

The experiment was laid out in a randomized block design (RBD) with nine treatments and three replications. Details of treatments are presented in Table 1. Rice variety NDR-2064 was sown directly at 60 kg $ha^{-1}$ with 20 cm row spacing. Recommended fertilizer dose of 120:80:60 kg N: $P_2O_5$: $K_2O$ $ha^{-1}$ was applied, with full P and K plus half N as basal and remaining N in two equal splits at tillering and panicle initiation stages.

**Table 1 :** The details of Treatment and their description

| Code | Treatment | Description |
|---|---|---|
| **$T_1$** | Weedy check | No weeding |
| **$T_2$** | Weed-free | Manual weeding at all stages |
| **$T_3$** | Hand weeding | Hand weeding at 20 and 40 DAS |
| **$T_4$** | Mechanical weeding | Mechanical weeding (khurpi/grubber) at 20 and 40 days after sowing (DAS) |
| **$T_5$** | Brown manuring (Bispyribac) | Bispyribac sodium @20 g $ha^{-1}$ at 25 DAS |
| **$T_6$** | Brown manuring (2,4-D) | 2,4-D @1 kg a.i. $ha^{-1}$ at 25 DAS |
| **$T_7$** | Mulching | Rice straw mulch @5 t $ha^{-1}$ |
| **$T_8$** | Stale seedbed | Two tillage + irrigation cycles before sowing |
| **$T_9$** | Stale seedbed + mulch | Combination of $T_8$ and $T_7$ |

### Crop establishment and agronomic practices

The rice variety NDR-2064 was used for the experiment. Seeds were sown directly in the field at a seed rate of 60 kg $ha^{-1}$ with a row spacing of 20 cm. All recommended agronomic practices, including irrigation and plant protection measures, were followed uniformly in all treatments except the imposed weed management practices.

### Weed, Growth and Yield Observations

Weed density and dry matter were recorded at 30, 60, 90 DAS and at harvest using a 0.5 m × 0.5 m quadrat. Weed control efficiency (WCE) and weed index were calculated using standard formulas.

**WCE** (%) = [(Weed dry matter in weedy check – Weed dry matter in treated plot) / Weed dry matter in weedy check] × 100

**Weed index** (%) = [(Grain yield in weed-free treatment – Grain yield in treatment) / Grain yield in weed-free treatment] × 100

Plant height, tillers $m^{-2}$, dry matter accumulation, panicles $m^{-2}$, grains per $panicle^{-1}$, test weight, grain yield and straw yield were recorded using standard procedures. Grain and straw yields were expressed in q $ha^{-1}$.

### Economic analysis

Cost of cultivation, gross return, net return and net benefit-cost ratio were calculated using prevailing market prices of inputs and produce. Gross return was calculated from grain and straw yields using the market prices of Rs. 2320 $q^{-1}$ for grain and Rs. 600 $q^{-1}$ for straw. Net return was calculated by subtracting the cost of cultivation from gross return. The net benefit-cost ratio was calculated as:

Net B: C ratio = Net return / Cost of cultivation

### Statistical analysis

Data were analyzed using analysis of variance (ANOVA) for RBD, and treatment means were compared using the least significant difference (LSD) at $p \leq 0.05$.

## Results and Discussion

### Weed flora and weed dynamics

The experimental field was infested with a mixed weed flora comprising grasses, sedges and broad-leaved weeds. The dominant grassy weeds were *Echinochloa colona*, *Echinochloa crus-galli* and *Cynodon dactylon*, while *Cyperus iria* and *Cyperus difformis* were the major sedges. Among broad-leaved weeds, *Eclipta alba* and *Alternanthera sessilis* were commonly observed. The presence of mixed weed flora indicates that direct-seeded rice provides favourable conditions for the emergence and growth of different weed groups during the early crop growth period. Similar dominance of grasses and sedges in direct-seeded rice was reported by Chauhan and Johnson (2009).

Weed density and weed dry matter were significantly influenced by different weed management practices (Table 2). The weed-free treatment recorded the lowest weed density throughout the crop season because weeds were removed regularly from the plots. Among the practical treatments, mechanical weeding at 20 and 40 days after sowing (DAS) recorded the lowest weed density of 42.0 $m^{-2}$ at 60 DAS, followed by hand weeding at 20 and 40 DAS with 48.0 $m^{-2}$. The weedy check recorded the highest weed density of 274.0 $m^{-2}$ at 60 DAS, showing severe weed infestation in the absence of weed control.

The lower weed density under mechanical weeding may be due to the physical uprooting and burial of weeds at the critical crop-weed competition period. Mechanical weeding also disturbs the soil surface and reduces the establishment of newly emerged weeds between crop rows. Mahajan and Chauhan (2013) also reported that timely mechanical weeding effectively reduces weed density in direct-seeded rice.

Stale seedbed followed by rice straw mulching also reduced weed density compared with brown manuring and mulching alone. This may be because stale seedbed encouraged weed seed germination before sowing, while subsequent mulching reduced further weed emergence by limiting light at the soil surface. Shekhawat *et al*. (2020) also observed that cultural practices such as stale seedbed and residue mulch can reduce weed pressure in dry direct-seeded rice.

**Table 2 :** Effect of mechanical and cultural weed management practices on weed population and weed dry matter in direct-seeded rice

| Treatment | Weed population ($m^{-2}$) | | | | Weed dry matter ($g\ m^{-2}$) | | | |
|---|---|---|---|---|---|---|---|---|
| | 30 DAS | 60 DAS | 90 DAS | Harvest | 30 DAS | 60 DAS | 90 DAS | Harvest |
| $T_1$ | 209 | 274 | 268 | 248 | 70.0 | 266.3 | 295.7 | 318.7 |
| $T_2$ | 0 | 0 | 0 | 0 | 0.0 | 0.0 | 0.0 | 0.0 |
| $T_3$ | 53 | 48 | 45.3 | 41 | 17.0 | 28.3 | 32.3 | 37.3 |
| $T_4$ | 46 | 42 | 39 | 34 | 16.3 | 24.6 | 28.6 | 33.6 |
| $T_5$ | 137 | 132 | 128 | 123 | 32.7 | 53.7 | 57.7 | 62.7 |
| $T_6$ | 116 | 111 | 107 | 107 | 30.7 | 47.8 | 51.8 | 56.8 |
| $T_7$ | 106 | 101 | 97 | 93 | 24.4 | 38.8 | 42.8 | 47.8 |
| $T_8$ | 89 | 85 | 80 | 75 | 23.4 | 34.3 | 38.3 | 43.3 |
| $T_9$ | 84 | 80 | 78 | 73 | 19.8 | 30.2 | 37.9 | 42.9 |
| SEm± | 3.50 | 6.84 | 9.84 | 9.48 | 0.71 | 1.96 | 1.96 | 1.96 |
| CD at 5% | NS | 20.51 | 29.92 | 28.41 | 2.13 | 5.88 | 5.88 | 5.88 |

Note: DAS = days after sowing; NS = non-significant. Original weed population values are presented; data were square-root transformed before statistical analysis.

## Weed control efficiency and weed index

Weed control efficiency varied considerably among different treatments (Table 3). The weed-free treatment recorded the highest weed control efficiency because weeds were completely removed from the plots. Among the field-applicable treatments, mechanical weeding at 20 and 40 DAS recorded the highest weed control efficiency of 90.8% at 60 DAS. Hand weeding at 20 and 40 DAS recorded 89.4% weed control efficiency, showing that both manual and mechanical weed removal were highly effective during the critical period of weed competition.

The higher weed control efficiency under mechanical weeding was mainly associated with lower weed dry matter accumulation. Since weed control efficiency is calculated on the basis of weed dry matter reduction, treatments that suppressed weed growth more effectively showed higher WCE values. Dhanapal *et al.* (2018) also reported that effective weed management treatments reduce weed biomass and improve weed control efficiency in rice.

The weed index showed an opposite trend to weed control efficiency. The weed-free treatment recorded zero weed index, while mechanical weeding recorded the lowest weed index among practical treatments. This indicates that mechanical weeding minimized yield loss due to weeds and maintained crop performance close to weed-free conditions. Rao *et al.* (2017) reported that uncontrolled weeds can cause severe yield reduction in direct-seeded rice. The relationship between weed control efficiency at 60 DAS and weed index clearly showed that treatments with higher weed control efficiency recorded lower weed index, indicating reduced yield loss due to better weed suppression (Fig. 1).

**Table 3 :** Effect of mechanical and cultural weed management practices on weed control efficiency and weed index in direct-seeded rice

| Treatment | WCE 30 DAS (%) | WCE 60 DAS (%) | WCE 90 DAS (%) | WCE at harvest (%) | Weed index (%) |
|---|---|---|---|---|---|
| $T_1$ | – | – | – | – | 60.9 |
| $T_2$ | 100.0 | 100.0 | 100.0 | 100.0 | 0.0 |
| $T_3$ | 75.7 | 89.4 | 89.1 | 88.3 | 12.4 |
| $T_4$ | 76.7 | 90.8 | 90.3 | 89.5 | 8.8 |
| $T_5$ | 53.3 | 79.8 | 80.5 | 80.3 | 27.4 |
| $T_6$ | 56.1 | 82.1 | 82.5 | 82.2 | 25.8 |
| $T_7$ | 65.1 | 85.4 | 85.5 | 85.0 | 24.1 |
| $T_8$ | 66.6 | 87.1 | 87.0 | 86.4 | 22.3 |
| $T_9$ | 71.7 | 88.7 | 87.2 | 86.5 | 12.5 |

Note: WCE = weed control efficiency.

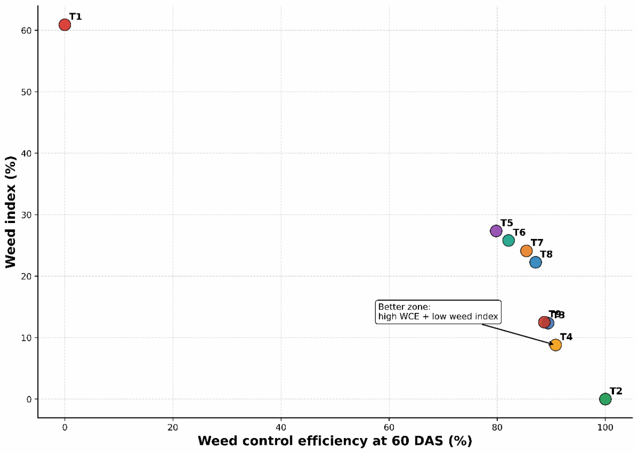


**Fig. 1 :** Relationship between weed control efficiency at 60 DAS and weed index under different weed management practices in direct-seeded rice.

## Crop growth and yield attributes

Crop growth was significantly affected by weed management treatments (Table 4). Plant height, tiller number and dry matter accumulation were higher under weed-free and mechanical weeding treatments than under the weedy check. The better crop growth in these treatments was due to reduced weed competition, which allowed rice plants to utilize available nutrients, moisture and light more efficiently.

Yield attributes also improved with effective weed control. The weed-free treatment recorded the highest number of panicles m$^{-2}$, grains panicle$^{-1}$ and test weight. Mechanical weeding at 20 and 40 DAS recorded 321 panicles m$^{-2}$, 163 grains panicle$^{-1}$ and 26.7 g test weight, which were close to hand weeding and clearly superior to the weedy check. Saravanane (2020) also observed that effective weed control improves yield attributes in dry direct-seeded rice.

The weedy check recorded the lowest values for yield attributes because weeds competed continuously with rice plants throughout the crop season. Continuous weed competition reduced tiller survival, panicle development and grain formation. Dhillon *et al.* (2021) reported that severe weed competition in direct-seeded rice reduces crop growth and yield-contributing characters.

**Table 4 :** Effect of mechanical and cultural weed management practices on yield attributes and yield of direct-seeded rice

| Treatment | Panicles (m$^{-2}$) | Grains panicle$^{-1}$ | Test weight (g) | Grain yield (q ha$^{-1}$) | Straw yield (q ha$^{-1}$) |
|---|---|---|---|---|---|
| $T_1$ | 213 | 126 | 21.1 | 25.3 | 40.3 |
| $T_2$ | 345 | 177 | 28.7 | 64.7 | 92.4 |
| $T_3$ | 317 | 158 | 25.7 | 56.7 | 82.7 |
| $T_4$ | 321 | 163 | 26.7 | 59.0 | 86.9 |
| $T_5$ | 222 | 131 | 22.8 | 47.0 | 63.6 |
| $T_6$ | 232 | 135 | 23.3 | 48.0 | 65.6 |
| $T_7$ | 256 | 137 | 24.2 | 49.1 | 69.1 |
| $T_8$ | 267 | 144 | 24.3 | 50.3 | 74.4 |
| $T_9$ | 300 | 151 | 25.0 | 56.6 | 81.0 |
| CD at 5% | 21.7 | 12.0 | 2.05 | 4.21 | 5.94 |

## Grain yield

Grain yield differed significantly among different weed management treatments (Table 4). The highest grain yield was recorded under the weed-free treatment (64.7 q ha$^{-1}$). Mechanical weeding at 20 and 40 DAS recorded the next highest grain yield of 59.0 q ha$^{-1}$, followed by hand weeding at 20 and 40 DAS with 56.7 q ha$^{-1}$ and stale seedbed with rice straw mulching with 56.6 q ha$^{-1}$. The weedy check produced the lowest grain yield of 25.3 q ha$^{-1}$.

The higher grain yield under mechanical weeding was mainly due to effective weed suppression during the early and active growth stages of rice. Reduced weed competition improved tiller production, panicle formation and grain filling. Patel *et al.* (2025) also reported that mechanical weeding improves rice productivity by reducing weed competition at critical growth stages.

Although weed-free treatment recorded the maximum grain yield, it may not always be the most practical option for farmers because it requires repeated labour-intensive weeding. Mechanical weeding produced yield close to the weed-free treatment with comparatively lower cost. This makes mechanical weeding a more practical option under field conditions.

Stale seedbed combined with rice straw mulching also produced comparatively higher yield than stale seedbed or mulching alone. The better performance of this treatment may be due to combined weed suppression before and after crop establishment. Gogoi and Deka (2023) also found that integrated weed management practices improved growth and yield of direct-seeded rice.

### Economics

Economic analysis showed that the highest grain yield did not necessarily result in the highest profitability (Table 5). The weed-free treatment recorded the highest cost of cultivation because of repeated manual weed removal. Mechanical weeding at 20 and 40 DAS recorded the highest net return of Rs. 1,35,456 ha$^{-1}$ and the highest net benefit-cost ratio of 2.53. This indicates that mechanical weeding provided the best balance between weed control, grain yield and cost of cultivation. The comparative economic performance of different weed management treatments in terms of net return and net benefit-cost ratio is presented in Fig. 2.

The higher profitability under mechanical weeding was due to its comparatively lower cost than weed-free and hand weeding treatments, along with high grain yield. Patel *et al.* (2025) also reported that mechanical weeding using a grubber improved the economic returns in rice.

The weedy check recorded the lowest economic performance because poor weed control resulted in very low grain yield. Brown manuring and mulching treatments improved net returns over the weedy check, but their profitability remained lower than mechanical weeding. Therefore, mechanical weeding at 20 and 40 DAS emerged as the most economical and practical weed management practice for direct-seeded rice.

**Table 5 :** Economics of different mechanical and cultural weed management practices in direct-seeded rice

| Treatment | Cost of cultivation (Rs. ha$^{-1}$) | Gross return (Rs. ha$^{-1}$) | Net return (Rs. ha$^{-1}$) | Net B: C ratio |
|---|---|---|---|---|
| $T_1$ | 44,116 | 82,876 | 38,760 | 0.88 |
| $T_2$ | 72,556 | 2,05,544 | 1,32,988 | 1.83 |
| $T_3$ | 58,336 | 1,81,164 | 1,22,828 | 2.11 |
| $T_4$ | 53,564 | 1,89,020 | 1,35,456 | 2.53 |
| $T_5$ | 46,077 | 1,47,200 | 1,01,123 | 2.19 |
| $T_6$ | 46,102 | 1,50,720 | 1,04,618 | 2.27 |
| $T_7$ | 49,827 | 1,55,372 | 1,05,545 | 2.12 |
| $T_8$ | 47,390 | 1,61,336 | 1,13,946 | 2.40 |
| $T_9$ | 53,102 | 1,79,912 | 1,26,810 | 2.39 |

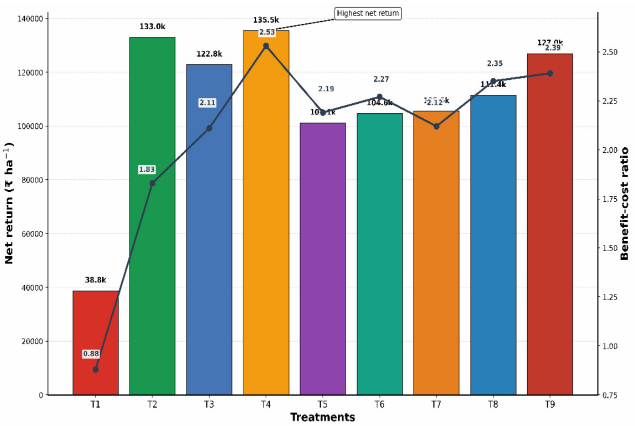


**Fig. 2 :** Net return and net benefit-cost ratio of direct-seeded rice as influenced by different weed management practices.

### Acknowledgement

The authors thank the Department of Agriculture, Phonics Group of Institution, Roorkee, and Sri Dev Suman Uttarakhand University for providing facilities and support for this research.

### Conflict of Interest

The authors declare that there is no conflict of interest.

## References

Atri, N., Singh, D. P., & Sharma, V. (2025). CRISPR to Climate Resilience-Breakthroughs in Agri-Biotech for Sustainable Farming. *Biomedical Journal of Scientific & Technical Research*, **62**(1), 54181-54184.

Chauhan, B.S. and Johnson, D.E. (2009). Influence of tillage systems on weed seedling emergence pattern in rainfed rice. *Soil and Tillage Research*, **106**, 15–21.

Dhanapal, G.N., Sanjay, M.T., Nagarjun, P. and Sandeep, A. (2018). Integrated weed management for control of complex weed flora in direct-seeded upland rice under Southern transition zone of Karnataka. *Indian Journal of Weed Science*, **50**(1), 33–36.

Dhillon, B.S., Bansal, T., Pardeep-Sagwal, Kumar, V., Bhullar, M.S. and Singh, S. (2021). Weed competitive cultivars as a component of integrated weed management in direct-seeded rice: A review. *Indian Journal of Weed Science*, **53**(3), 230–237.

Gogoi, B. and Deka, J. (2023). Effect of integrated weed-management practices in direct-seeded autumn rice (*Oryza sativa*) on growth, yield and soil microflora. *Indian Journal of Agronomy*, **68**(2), 140–146.

Hashim, M., Singh, V. K., Singh, K. K., Dhar, S., & Pandey, U. C. (2024). Weed Management Strategies in Direct Seeded Rice: A Review. *Agricultural Reviews*, **45**(2).

Kumar, V. and Ladha, J.K. (2011). Direct seeding of rice: Recent developments and future research needs. *Advances in Agronomy*, **111**, 297–413.

Mahajan, G. and Chauhan, B.S. (2013). The role of cultivars in managing weeds in dry-seeded rice production systems. *Crop Protection*, **49**, 52–57.

Nagargade, M., Singh, M. K., Tyagi, V., Govindasamy, P., Choudhary, A. K., Rajpoot, K., ... & Sarangi, D. (2024). Ecological weed management and square planting influenced the weed management, and crop productivity in direct-seeded rice. *Scientific reports*, **14**(1), 10356.

Navi, L., Mavarkar, N., Kushal, M., & Madhukar, M. (2024). Weed management strategies for conservation agriculture: A review. *International Journal of Research in Agronomy*, **7**(4), 313-321.

Parray, R., Singh, A. K., Singh, D. P., Amin, Z., Dulakakharia, B., Priya Kumari, G., ... & Singh, G. P. (2026). Harnessing omics and molecular breeding for developing drought-resilient rice varieties. *Cereal Research Communications*, 1-26.

Patel, D., Gami, M. R., & Patel, P. B. (2025). Weed Management in Aerobic Rice Cultivation in South Gujarat, India. *Journal of Experimental Agriculture International*, **47**(8), 66-72.

Rao, A.N., Brainard, D.C., Kumar, V., Ladha, J.K. and Johnson, D.E. (2017). Preventive weed management in direct-seeded rice: Targeting the weed seedbank. *Advances in Agronomy*, **144**, 45–142.

Sandhu, N., Yadav, S., Singh, V.K. and Kumar, A. (2021). Effective crop management and modern breeding strategies to ensure higher crop productivity under direct-seeded rice cultivation system: A review. Agronomy, **11**(7), 1264.

Saravanane, P. (2020). Effect of different weed management options on weed flora, rice grain yield and economics in dry direct-seeded rice. *Indian Journal of Weed Science,* **52**(2), 102–106.

Shekhawat, K., Rathore, S.S. and Chauhan, B.S. (2020). Weed management in dry direct-seeded rice: A review on challenges and opportunities for sustainable rice production. *Agronomy*, **10**(9), 1264.