
**E-ISSN:** 2618-0618
**P-ISSN:** 2618-060X

NAAS Rating (2025): 5.20
www.agronomyjournals.com
2025; 8(8): 880-885
Received: 05-05-2025
Accepted: 07-06-2025

**Nivetha K**
Post-Graduate Researcher, Department of Agronomy, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India

**Anandan P**
Assistant Professor, Department of Agronomy, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India

**Natarajan S**
Professor, Department of Agronomy, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India

**Pooja K**
Ph.D. Research Scholar, Department of Agronomy, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India

**Corresponding Author:**
**Nivetha K**
Post-Graduate Researcher, Department of Agronomy, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India

# Performance and efficacy of non-chemical weed management in drum seeded rice cultivation under the Cauvery delta zone

**Nivetha K, Anandan P, Natarajan S and Pooja K**

**DOI:** https://www.doi.org/10.33545/2618060X.2025.v8.i8m.3658

**Abstract**
Weeds are the primary biological limitation in direct-seeded rice production. To address this, a field experiment was conducted in September 2024 at Annamalai University, Chidambaram, Tamil Nadu, India, using a split-plot design with three replications. The study aimed to evaluate the performance of different rice cultivars in conjunction with integrated weed management practices. The treatments included three main plot cultivars: TKM 13, BPT 5204 and ADT 54. Sub-plot treatments involved four weed management practices: incorporation of *Sesbania aculeata*, followed by cono-weeding at 30 DAS, incorporation of *Crotalaria juncea* followed by cono-weeding at 30 DAS, hand weeding twice at 20 and 40 DAS and an un-weeded control. Results indicated that the rice cultivar ADT 54 with *Sesbania aculeata* incorporation followed by cono-weeding at 30 DAS which is effectively reduced weed density and weed dry weight and higher weed control efficiency while simultaneously increasing growth, yield attributes and rice grain yield. The un-weeded control treatment consistently resulted in the lowest growth, yield attributes and overall yield of rice in DSR under the Cauvery delta zone.

**Keywords:** Drum seeded rice, direct-seeded rice, weed management

## 1. Introduction
Rice (*Oryza sativa* L.) is a major source of food and nutrition for a significant part of the human population by providing nourishment for ~3.5 billion globally (Alam *et al.*, 2024) [1]. Worldwide, rice is cultivated across approximately 168.58 million hectares, resulting in a total production of 532.87 million tonnes and an average productivity of 4.72 t $ha^{-1}$. In India, rice cultivation covers about 50 million hectares, producing 145 million tonnes with an average productivity of 4.35 t $ha^{-1}$ (USDA, 2024-2025) [23]. Specifically in the state of Tamil Nadu, rice is grown on approximately 20.20 lakh hectares, with the production of 81.81 lakh tonnes and achieving an average productivity of around 4.0 t $ha^{-1}$ (Department of Economics and Statistics, 2024) [7].

Direct-seeded rice (DSR) cultivation is increasingly adopted in many Asian countries as an alternative to traditional transplanting, primarily due to rising labour costs and water scarcity concerns. This method involves sowing rice seeds directly into the field rather than transplanting seedlings from a nursery, offering advantages such as reduced water consumption and earlier maturity (Saravanane, 2020) [19]. However, DSR systems face significant challenges, with weed infestation being the most critical biological constraint. The absence of standing water at crop emergence, which typically suppresses weed growth in transplanted rice and the lack of an initial seedling size advantage, make DSR highly susceptible to weed competition, often leading to substantial yield losses ranging from 20% to 100% (Singh *et al.*, 2016) [22]. To address this challenge, integrated weed management (IWM) approaches are becoming essential for sustainable rice production in DSR systems (Shrestha *et al.*, 2020) [21]. While chemical herbicides are widely used and can provide effective weed control, their long-term sustainability is questionable due to environmental concerns, the evolution of herbicide-resistant weeds and a desire for more ecological farming practices (Matzrafi *et al.*, 2025). [13] Consequently, there is a growing emphasis on non-chemical weed management (NCWM) methods, which encompass all practices that influence weeds without relying on herbicides (Melander *et al.*, 2017) [14]. Incorporation of green manure crops like *Sesbania aculeata* (dhaincha) and sunhemp (*Crotalaria juncea*) offers promising alternatives for sustainable weed control in rice (Kumari *et al.*, 2023) [12]. These practices help suppress weed populations while providing essential nutrients and improving soil health, offering an eco-friendly and cost-effective approach compared to sole reliance on chemical herbicides or manual labour (Biswas and Das, 2024) [5]. Mechanical methods such as hand weeding and cono-weeding are effective, though often labour-intensive (Kalaimathi *et al.*, 2023) [9]. The performance of different rice cultivars also plays a significant role, as some varieties exhibit greater early vigour and competitiveness against weeds due to their genetic makeup and morphological characteristics (Selvaraj and Hussainy, 2020) [20]. Evaluating the efficacy of these non-chemical weed management practices in drum-seeded rice is vital for developing robust and economically viable weed control strategies in drum-seeded rice, especially in the face of labour shortages and increasing environmental pressures. The aim is to create sustainable solutions that reduce reliance on herbicides while maintaining high productivity and protecting agroecosystems.

## 2. Materials and Methods

A field experiment was carried out at the experimental farm, plot GL 9AB, within the Garden Land Block of the Department of Agronomy, Faculty of Agriculture, Annamalai University, Chidambaram, Cuddalore district, during the late *Samba* season (September 2024 to January 2025). The study aimed to evaluate different rice cultivars and weed management practices specifically for drum-seeded rice in the Cauvery delta zone. The experimental site is located at 11° 24' North latitude and 79° 44' East longitude of + 5.79 m above the mean sea level. The experimental field soil was characterized as a clay loam soil had a pH of 7.2, low available nitrogen at 214.12 kg $ha^{-1}$, high available phosphorus at 14.62 kg $ha^{-1}$ and medium available potassium at 290.35 kg $ha^{-1}$. The experiment was designed using a Split-Plot design with three replications, consisting of three main plots and four sub-plots. The experiment utilized three cultivars - TKM 13, BPT 5204 and ADT 54, which were assigned to the main plots. The sub-plots were assigned four distinct weed management practices: *Sesbania aculeata* incorporation followed by con-weeding at 30 DAS, *Crotalaria juncea* incorporation followed by cono-weeding at 30 DAS, hand weeding twice at 20 and 40 DAS and un-weeded control. The recommended seed rate of 40 kg $ha^{-1}$ at a spacing of 20 × 10 cm. The data on various characters studied during the course of investigation were statistically analysed as suggested by Gomez and Gomez (2010) [8]. Data on weed density showed high variation and hence the data are subjected to a square root transformation $\sqrt{x} + 0.5$ and analysed statistically. Wherever statistical significance was observed, a critical difference (CD) at the 0.05 level of probability was worked out for comparison.

Among grasses, *Echinochloa colonum* was the most predominant weed species, followed by *Leptochloa chinensis*. In sedges, *Cyperus rotundus*, *Cyperus iria* and *Cyperus difformis*. For broad-leaved weeds, *Bergia capensis*, *Eclipta alba* and *Sphenoclea zeylanica* were also observed in the experimental field is depicted in Fig. 1.

*Cyperus iria*

*Eclipta alba*

*Echinochloa colonum*

*Leptochloa chinensis*

*Cyperus rotandus* | *Sphenoclea zeylanica* | *Cyperus difformis* | *Bergia capensis*

**Fig 1:** Major weeds of the experimental field

## 3. Results

The data on total weed density, weed dry weight and weed control efficiency recorded at 30, 60 DAS of the cropping season 2024-25 are presented in Table 1, 2 and 3.

Among the various cultivars, the lowest total weed density, weed dry weight and highest weed control efficiency was recorded by the cultivar $M_3$ (ADT 54) and it was followed by $M_1$ (TKM 13). The highest total weed density, weed dry weight and lowest weed control efficiency was recorded in $M_2$ (BPT 5204).

At 30 DAS, among the different weed management practices, lowest total weed density, weed dry weight and highest weed control efficiency was registered with $S_1$ (*Sesbania aculeata* incorporation followed by cono-weeding at 30 DAS) which was on par with $S_3$ (hand weeding twice at 20 and 40 DAS). The highest total weed density, weed dry weight and lowest weed control efficiency was registered in $S_4$ (un-weeded control).

The interaction of cultivars and weed management practices significantly influenced on 30 DAS. With respect to interaction, the lowest total weed density, weed dry weight and highest weed control efficiency was recorded by $M_3S_1$ (ADT 54 with *Sesbania aculeata* incorporation followed by cono-weeding at 30 DAS), this was followed by $M_3S_3$ (ADT 54 with hand weeding twice at 20 and 40 DAS). The highest total weed density, weed dry weight and lowest weed control efficiency was noticed under $M_2S_4$ (BPT 5204 with un-weeded control).

## 4. Discussion

Significant differences in weed density and weed dry weight were observed among the cultivars at 30 DAS. BPT 5204 recorded the highest weed density and weed dry weight compared to the other two cultivars. In contrast, ADT 54 exhibited lower weed density and dry weight, likely due to reduced weed seed emergence and growth under its canopy. These findings are consistent with the results of Pooja *et al*. (2021) [16]. Kumar *et al*. (2017) [10] also reported that tall genotypes with drooping leaves were more competitive against weeds than shorter varieties with erect leaves. Similarly, Awan *et al*. (2018) [3] highlighted the superior weed-suppressing ability of certain rice cultivars.

Weed management practices such as the incorporation of *Sesbania aculeata* incorporation followed by cono-weeding at 30 DAS and hand weeding at 20 and 40 DAS, significantly reduced weed density and dry weight. This effectiveness can be attributed to *Sesbania aculeata*, a fast-growing leguminous green manure crop, which suppresses weed emergence and growth by creating a physical barrier, providing shade and competing for essential resources. According to Sah and Singh (2023) [18], co-cultivating *Sesbania aculeata* with rice reduces weed density and biomass by limiting light availability, a critical factor for weed development. Additionally, *Sesbania aculeata* enhances soil nitrogen through biological nitrogen fixation, improving nutrient availability and soil health, which supports vigorous rice growth that further outcompetes weeds. Incorporating of *Sesbania aculeata* (dhaincha) with rice partially smothers weed growth and reduces dependency on herbicides or labour-intensive weeding, as noted by Kumari *et al*. (2023) [12] and Bommayasamy *et al*. (2019) [4]. These studies reported that the smothering effect and reduced sunlight penetration inhibit the germination and photosynthesis of late-emerging weeds. Furthermore, cono-weeding mechanically removes weeds in inter-row spaces, targeting those that survive the initial suppression by *Sesbania aculeata*, thereby enhancing overall weed control effectiveness.

Cono-weeding at 30 DAS effectively reduces weed density, helping to maintain a weed-free environment during the crop's critical growth stages. This timing aligns with the peak period of weed emergence, making cono-weeding a highly efficient and environmentally safe alternative to chemical herbicides. When used alongside the initial weed suppression provided by *Sesbania aculeata* (dhaincha) incorporating cono-weeding further enhances weed control. The combination of *Sesbania aculeata* incorporating and cono-weeding significantly improves rice growth parameters by minimizing weed competition. This results in increased tiller production, higher dry matter accumulation and ultimately higher grain yield. Additionally, this integrated approach reduces the labour and costs associated with frequent hand weeding while promoting sustainable and eco-friendly weed management. According to Meyyappan *et al*. (2018) [15], the improved weed control may be attributed to the effective incorporation and disruption of weeds by cono-weeding. The highest total weed density and weed dry weight were recorded in un-weeded plot due to unchecked growth of weeds which compete for all the resources up to maturity with crop. Similar findings were noted by Kumar *et al*. (2017a) [11].

Weed Control Efficiency (WCE) measures the effectiveness of a weed control treatment relative to an untreated, weedy control. Among the cultivars studied, ADT 54 recorded the highest WCE, likely due to its genotypic traits and naturally lower weed infestation. The competitive ability of rice is strongly linked to traits that enhance light interception, such as plant height, leaf area index, specific leaf area, drooping leaves and early tiller formation (Rao *et al*., 2007) [17]. Similarly, Dass *et al*. (2017) [6] emphasized that weed-competitive rice cultivars typically possess favourable characteristics such as large seed size, strong seedling vigour, rapid early growth, optimal plant architecture, prolific tillering, deep and extensive root systems and resilience to both biotic and abiotic stresses. Early maturity and allelopathic potential also contribute significantly to a cultivar's ability to suppress weeds effectively. Weed management practices involving the incorporation of *Sesbania aculeata* followed by cono-weeding at 30 DAS which was on par with hand weeding twice at 20 & 40 DAS, recorded the highest weed control efficiency. This effectiveness can be attributed to the integrated approach, where *Sesbania aculeata* helps smother weed growth through shading and competition, while the cono-weeder incorporates emerging weeds during the critical weed competition period. This combination effectively suppresses weed emergence and growth throughout the early stages of crop development. Anitha and Mathew (2010) [2] also reported that the simultaneous cultivation of green manure crops significantly reduced weed population and biomass in dry-sown rice systems, highlighting the advantages of integrating green manure with mechanical and manual weeding strategies for improved weed control.

**Table 1:** Effect of cultivars and weed management practices on total weed density (nos. $m^{-2}$) on 30 and 60 DAS of drum seeded rice

| 30 DAS | | | | | 60 DAS | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Treatment** | **$M_1$** | **$M_2$** | **$M_3$** | **Mean** | **Treatment** | **$M_1$** | **$M_2$** | **$M_3$** | **Mean** |
| $S_1$ | 6.21 (38.07) | 6.60 (43.20) | 5.54 (30.26) | 6.12 (37.17) | $S_1$ | 7.10 (50.11) | 7.56 (56.63) | 6.83 (46.50) | 7.16 (51.08) |
| $S_2$ | 6.42 (40.84) | 6.77 (45.34) | 5.79 (33.01) | 6.32 (39.73) | $S_2$ | 7.56 (56.68) | 7.93 (62.30) | 7.30 (52.99) | 7.60 (57.32) |
| $S_3$ | 6.35 (39.86) | 6.67 (44.03) | 5.69 (31.93) | 6.23 (38.61) | $S_3$ | 7.43 (54.73) | 7.86 (61.69) | 7.13 (50.43) | 7.47 (55.62) |
| $S_4$ | 9.52 (90.20) | 9.82 (95.87) | 9.33 (86.61) | 9.55 (90.87) | $S_4$ | 11.27 (127.01) | 11.67 (135.27) | 11.00 (120.93) | 11.31 (127.73) |
| Mean | 7.12 (52.24) | 7.46 (57.11) | 6.58 (45.45) | | Mean | 8.34 (72.13) | 8.75 (78.97) | 8.06 (67.71) | |
| | M | S | M x S | S x M | | M | S | M x S | S x M |
| S. Ed | 0.04 | 0.06 | 0.10 | 0.10 | S. Ed | 0.02 | 0.07 | 0.11 | 0.12 |
| CD(p=0.05) | 0.11 | 0.13 | 0.22 | 0.22 | CD(p=0.05) | 0.07 | 0.15 | NS | NS |

*Figures in parentheses indicate original values and the others are square root transformed x+0.5 values. Transformed values were statistically analysed. DAS: Days after sowing

**$M_1$** – TKM 13 **$S_1$** - *Sesbania aculeata* incorporation *fb* cono-weeding on 30 DAS
**$M_2$** – BPT 5204 **$S_2$** – *Crotalaria juncea* incorporation *fb* cono-weeding on 30 DAS
**$M_3$** – ADT 54 **$S_3$** – Hand weeding twice on 20 & 40 DAS
**$S_4$** – Un-weeded control

**Table 2:** Effect of cultivars and weed management practices on total weed dry weight (g $m^{-2}$) on 30 and 60 DAS of drum seeded rice

| 30 DAS | | | | | 60 DAS | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | $M_1$ | $M_2$ | $M_3$ | Mean | Treatment | $M_1$ | $M_2$ | $M_3$ | Mean |
| $S_1$ | 7.38 (54.05) | 7.88 (61.77) | 6.56 (42.67) | 7.28 (52.83) | $S_1$ | 9.12 (82.69) | 9.71 (94.00) | 8.72 (75.79) | 9.18 (84.16) |
| $S_2$ | 7.69 (58.81) | 8.14 (65.75) | 6.90 (47.20) | 7.58 (57.25) | $S_2$ | 9.75 (94.66) | 10.25 (104.66) | 9.33 (86.66) | 9.77 (95.32) |
| $S_3$ | 7.58 (57.00) | 7.99 (63.40) | 6.77 (45.35) | 7.44 (55.25) | $S_3$ | 9.55 (90.85) | 10.15 (102.63) | 9.10 (82.49) | 9.60 (91.99) |
| $S_4$ | 11.46 (130.79) | 11.85 (139.97) | 11.19 (124.72) | 11.49 (131.82) | $S_4$ | 14.62 (213.37) | 15.14 (228.60) | 14.17 (200.31) | 14.64 (214.09) |
| Mean | 8.53 (75.16) | 8.96 (82.72) | 7.85 (64.98) | | Mean | 10.76 (120.39) | 11.31 (132.47) | 10.33 (111.31) | |
| | M | S | M x S | S x M | | M | S | M x S | S x M |
| S. Ed | 0.04 | 0.07 | 0.12 | 0.13 | S. Ed | 0.09 | 0.12 | 0.20 | 0.21 |
| CD(p=0.05) | 0.13 | 0.15 | 0.27 | 0.27 | CD(p=0.05) | 0.25 | 0.25 | NS | NS |

*Figures in parentheses indicate original values and the others are square root transformed x+0.5 values. Transformed values were statistically analysed.
DAS: Days after sowing
**$M_1$** – TKM 13 **$S_1$** - *Sesbania aculeata* incorporation *fb* cono-weeding on 30 DAS
**$M_2$** – BPT 5204 **$S_2$** – *Crotalaria juncea* incorporation *fb* cono-weeding on 30 DAS
**$M_3$** – ADT 54 **$S_3$** – Hand weeding twice on 20 & 40 DAS
**$S_4$** – Un-weeded control

**Table 3:** Effect of cultivars and weed management practices on weed control efficiency on 30 and 60 DAS of drum seeded rice

| 30 DAS | | | | | 60 DAS | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Treatment | $M_1$ | $M_2$ | $M_3$ | Mean | Treatment | $M_1$ | $M_2$ | $M_3$ | Mean |
| $S_1$ | 57.74 | 54.90 | 65.07 | 59.24 | $S_1$ | 60.50 | 58.14 | 61.57 | 60.07 |
| $S_2$ | 54.66 | 52.72 | 61.91 | 56.43 | $S_2$ | 55.31 | 53.93 | 56.17 | 55.13 |
| $S_3$ | 55.74 | 54.08 | 63.16 | 57.66 | $S_3$ | 56.86 | 54.41 | 58.27 | 56.52 |
| $S_4$ | 0.00 | 0.00 | 0.00 | 0 | $S_4$ | 0.00 | 0.00 | 0.00 | 0 |
| Mean | 42.03 | 40.42 | 47.53 | | Mean | 43.17 | 41.62 | 44.00 | |

*Data were not statistically analyzed
DAS: Days after sowing
**$M_1$** – TKM 13 **$S_1$** - *Sesbania aculeata* incorporation *fb* cono-weeding on 30 DAS
**$M_2$** – BPT 5204 **$S_2$** – *Crotalaria juncea* incorporation *fb* cono-weeding on 30 DAS
**$M_3$** – ADT 54 **$S_3$** – Hand weeding twice on 20 & 40 DAS
**$S_4$** – Un-weeded control

## 5. Conclusion

The comprehensive evaluation of drum seeded rice parameters revealed that the cultivar ADT 54 along with *Sesbania aculeata* as green manure, followed by cono-weeding at 30 DAS, significantly enhanced both rice productivity and profitability. The superior genetic traits of ADT 54 contributed to higher yield and improved agronomic performance, while *Sesbania aculeata*, through its nitrogen-fixing ability its improved soil fertility, reducing the reliance on synthetic fertilizers. The timely incorporation enhances nutrient availability, soil structure and root development. Cono-weeding at 30 DAS effectively suppresses weed competition during the critical growth stage, further promoting optimal crop development and yield formation. This integrated approach combining varietal selection and effective weed control maximizes yield and economic return. Thus, adopting the ADT 54 along with *Sesbania aculeata* incorporation and timely cono-weeding offers a sustainable and cost-effective strategy for improving the productivity and profitability of drum seeded rice cultivation.

## References


1. Alam M, Lou G, Abbas W, Osti R, Ahmad A, Bista S, He Y. Improving rice grain quality through ecotype breeding for enhancing food and nutritional security in Asia–Pacific region. *Rice*. 2024;17(1):47.
2. Anitha S, Mathew J, Abraham CT. Dual cropping of rice (*Oryza sativa* L.) and green manure crops a cost-effective management alternative for direct seeded semi-dry system of rice cultivation. Indian Journal of Agronomy. 2010;55(3):165-170.
3. Awan TH, Lim CA, Ahmed S, Safdar ME, Chauhan BS. Weed-competitive ability of a hybrid and an inbred rice cultivar in managing *Ischaemum rugosum* in dry-seeded rice. Pakistan Journal of Agricultural Sciences. 2018;55(4):739-748.
4. Bommayasamy N, Singh LB, Pandey VK, Nanda BK, Nayak H, Kundu A. Efficacy of rice cum dhaincha (*Sesbania aculeata*) intercropping on weed control, growth, yield and economics of rice. Journal of Pharmacognosy and Phytochemistry. 2019;8(3):3257-3260.
5. Das S, Biswas S, Ramakrishnan B, Das TK, Purakayastha TJ, Gawade BH, Sinha K. Biological soil health with conventional and qPCR based indicators under conservation agriculture-based rice-wheat cropping system in Indo-Gangetic Plain. Applied Soil Ecology. 2024;19(3):105-128.
6. Dass A, Shekhawat K, Choudhary AK, Sepat S, Rathore SS, Mahajan G, Chauhan BS. Weed management in rice using crop competition - a review. Crop Protection. 2017;95:45-52.
7. Department of Economics and Statistics. Agriculture-Farmers Welfare Department, Policy notes, Tamil Nadu. Published 2024-2025.
8. Gomez KA, Gomez AA. Statistical procedures for agricultural research. John wiley and sons; 2010.
9. Kalaimathi V, Sivakumar C, Parasuraman P, Sivakumar R, Ragunath KP, Rani MA. Effect of Chemical and Non-Chemical Weed Management Practices in Direct Seeded Rice. Int. J. Plant Soil Sci. 2023;35(18):1812-1820.
10. Kumar S, Kumar R, Mishra JS, Dwivedi SK, Prakash V, Bhakta N, Yadav A. Evaluation of rice (*Oryza sativa* L.) cultivars under different crop establishment methods to enhance productivity, profitability and energetics of rice in middle Indo-Gangetic Plains of India. Indian Journal of Agronomy. 2017;62(3):307-314.
11. Kumar VI, Kumar T, Singh G, Singh RA. Effect of

integrated nutrient management on yield of rice and its residual effect on wheat in rice-wheat system under lowland. Annals of Plant and Soil Research. 2017;19(4):360-365.

12. Kumari S, Singh MK, Dendukuri UL. Studies on Sesbania, rice residue mulching and post emergence herbicides on weed growth and yield in unpuddled transplanted hybrid rice. Weed Biology and Management. 2023;23(3-4):122-130.
13. Matzrafi M, Blank L, Lati RN. Selection and adaptation to weed management methods: implications for non-chemical and integrated weed management approaches. Pest Management Science. 2025;81(1):22-27.
14. Melander B, Liebman M, Davis AS, Gallandt ER, Barberi P, Moonen AC, Vidotto F. Non-chemical weed management. Weed research: Expanding horizons. 2017;245-270.
15. Meyyappan M, Ilango C, Natarajan S, Angayarkanni A. Effect of weed management practices on weeds, nutrient depletion and yield of rice (*Oryza sativa* L.). Indian Journal of Agronomy. 2018;63(4):453-456.
16. Pooja K, Saravanane P, Sridevi V, Nadaradjan S, Vijayakumar S. Effect of cultivars and weed management practices on productivity, profitability and energetics of dry direct-seeded rice. Oryza. 2021;58(3):442-447.
17. Rao NR, Garg PK, Ghosh SK. Development of an agricultural crops spectral library and classification of crops at cultivar level using hyperspectral data. Precision Agriculture. 2007;8:173-185.
18. Sah A, Singh DN. Effect of Sesbania aculeata as brown manure on grain yield and partial factor productivity of nutrients in dry direct seeded rice-wheat system. Israel Journal of Plant Sciences. 2023;70(1-2):57-64.
19. Saravanane P. Effect of different weed management options on weed flora, rice grain yield and economics in dry direct-seeded rice. Indian journal of weed science. 2020;52(2):102-106.
20. Selvaraj A, Hussainy SAH. Evaluating weed management practices for direct sown drum seeded rice (*Oryza sativa*): A review. Crop Research. 2020;55(3and4):139-151.
21. Shrestha S, Sharma G, Burgos NR, Tseng TM. Competitive ability of weedy rice: toward breeding weed-suppressive rice cultivars. Journal of Crop Improvement. 2020;34(4):455-469.
22. Singh V, 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.
23. USDA. World Agricultural Production. Foreign Agricultural Service, Washington, D.C. Published 2024-2025.