Madras Agric.J.,2026; https://doi.org/10.29321/MAJ.10.261301

RESEARCH ARTICLE

Optimizing Weed Management and Yield in Pearl Millet (*Pennisetum glaucum* L.) through Sequential Application of Herbicides

J. Sivanantha[1*], S. Manimaran[1], P. Sudhakar[1] and D. Venkatakrishnan[2]

[1]Department of Agronomy, [2]Department of Soil Science and Agricultural Chemistry, Faculty of Agriculture, Annamalai University, Chidambaram – 608002, Tamil Nadu, India.

Received: 29 Dec 2025

Revised: 09 Mar 2026

Accepted: 11 Mar 2026

ABSTRACT

Pearl millet (*Pennisetum glaucum* L.) is a vital nutrient-rich crop belonging to the family Poaceae, capable of thriving in adverse climatic conditions. However, weed competition for moisture, nutrients, space, and light remains a primary barrier to productivity, particularly during the critical early growth stages. To identify effective chemical management strategies, a field experiment was conducted during the *Kharif* season (June-September) of 2023 at the Experimental Farm, Department of Agronomy, Annamalai University. The experiment was laid out in a Randomized Block Design with three replications and eleven treatments. The treatments consisted of various herbicides, including pre-emergence applications of Atrazine (Atrataf), Pretilachlor (Delete), and Pendimethalin (Pendamil), and post-emergence applications of 2,4-D (Pakar) and Tembotrione (Laudis), tested alone and in combination, alongside twice-hand weeding and an untreated control. The experimental field was predominantly infested with *Brachiaria reptans*, *Cyperus rotundus,* and *Trianthema portulacastrum*. Among the herbicidal treatments, the application of Pendimethalin followed by Tembotrione (Pendamil + Laudis) was found to be the most effective in suppressing the density and growth of these dominant weed species. This treatment significantly reduced weed competition and yielded more grain than other chemical treatments. The study concludes that the combination of Pendimethalin and Tembotrione offers superior weed control efficiency and enhances crop productivity. Therefore, this treatment can be recommended to farmers for effective and economic weed management in pearl millet cultivation.

Keywords: *Herbicides, Laudis, Pearl millet, Pendamil, Weed management*

INTRODUCTION

Millets are small-seeded grasses cultivated worldwide as cereal crops, and among them, pearl millet is a key variety thriving in hot, dry regions. India is the top producer of millet, contributing approximately 80 percent of global production (FAO, 2015). Pearl millet (*Pennisetum glaucum*) belongs to the Poaceae family and is notable for its nutritional value and ability to withstand harsh climates.

*Corresponding author mail: sivajayapandian@gmail.com

It ranks as the sixth most important cereal globally. It is the fourth most significant food grain in India, following rice, wheat, and sorghum. In India, it occupies an area of 9.50 million hectares and produces 13.50 million tonnes with a productivity of 1.4 t ha^{-1} (USDA, 2024). In Tamil Nadu, it occupies an area of 0.46 lakh ha with a production of 1.19 lakh tonnes and productivity of 2578 kg ha^{-1} (Anonymous, 2024). Pearl millet is cultivated in Tamil Nadu's Northeastern Zone and Cauvery delta Zone, with Cuddalore district being a major producer, covering 4031 ha and yielding 14,126 metric tonnes (1.5 tonnes ha^{-1}) (ICAR-CRIDA, 2020). Additionally, pearl millet is nutritionally rich, offering a good source of protein and essential micronutrients. As a leading nutritional source of millet, enhancing its zinc and iron content through agronomic biofortification is an effective strategy that helps to tackle issues of food insecurity and malnutrition. The area under pearl millet cultivation is steadily decreasing due to its low demand and low producer prices.

Additionally, weeds are a significant obstacle to pearl millet production, as they compete with the crop for moisture, nutrients, space, and light. Dhayal *et al*., (2020) found that unrestricted growth of weeds in weedy plots led to a 48.50 per cent reduction in grain yield compared to plots with two hand weeding at 20 DAS and 40 DAS. Effective weed management during the early growth stages of pearl millet is crucial. Using herbicides saves time and money and enables more extensive, timely weeding. The combined application of pre- and post-emergence herbicides has reduced weed populations, decreased weed biomass, and improved various yield components and overall grain yield. This study aims to evaluate the effectiveness of different herbicides in controlling weeds in pearl millet cultivation.

MATERIALS AND METHODS

The field experiment was conducted in the Experimental Farm, Department of Agronomy, Faculty of Agriculture, Annamalai University, Annamalai Nagar, Tamil Nadu, during June-September 2023 (*Kharif*). There are eleven weed management treatments, viz., Atrataf (Atrazine), Delete (Pretilachlor), Pendamil (Pendimethalin), a Combination of pre-emergence herbicides with post-emergence herbicides (viz., Pakar (2,4-D), Laudis (Tembotrione)), twice-hand weeding, and an untreated control. The experiment was laid out in a randomized block design with three replications.

Almost all types of weeds, viz., grassy, sedge, and broad-leaved weeds, infested the pearl millet field. The herbicides were sprayed as pre-emergence at 3 DAS on the soil with optimum moisture, and post-emergence herbicides were sprayed at 20 DAS. The pearl millet crop was fertilized with 80:40:40 kg ha^{-1} of NPK. Biometric observations of weed count, weed dry weight, and weed control efficiency were recorded at 20 DAS and 45 DAS. Weed control efficiency (Eqn. 1) was calculated using the following formula from Kabir *et al.,* (2008).

$$WCE\ (\%) = \frac{\text{Dry weight in untreated control plot - Dry weight in treated plot}}{\text{Dry weight in untreated control plot}} \times 100$$

(Eqn. 1)

RESULTS AND DISCUSSION

Weed flora

Divergent weed flora like *Brachiaria reptans, Cynodon dactylon, Echinochloa colonum, Leptochloa chinensis* of grassy weeds; *Cyperus iria, Cyperus rotundus* of sedges, and *Amaranthus viridis, Corchorus trilocularis, Cleome viscosa, Cleome gynandra, Cyanotis axillaris, Phyllanthus maderaspatensis, Trianthema portulacastrum* of broad-leaved weeds were observed. Among the diverse weed flora, the predominant weed species found in the experimental field were *Brachiaria reptans, Cyperus rotundus,* and *Trianthema portulacastrum*, which cause heavy losses in pearl millet production.

Effect on Brachiaria reptans

The *Brachiaria reptans* weed count (No. m^{-2}), dry matter (g m^{-2}), and weed control efficiency (per cent) at 20 DAS and 45 DAS have been significantly affected by weed management treatments as presented in Table 1.

Among the various herbicidal treatments, Pendamil + Laudis (T_8) recorded the lowest weed count (8.42 m^{-2} and 13.14 m^{-2}) and dry matter (2.34 g m^{-2} and 3.65 g m^{-2}) of *Brachiaria reptans* at 20 DAS and 45 DAS, respectively. The highest weed control efficiency of 81.71 per cent and 76.37 per cent was found in the treatment Pendamil + Laudis (T_8) at 20 DAS and 45 DAS, respectively. It was followed by Pendamil + Pakar (T_5). The reason behind the low weed count, dry matter, and higher weed control efficiency might be due to the effective control of the first flush of weeds by pre-

Table 1. Brachiaria reptans - weed count (No. m^{-2}), dry matter (g m^{-2}), and WCE (per cent) at 20 DAS and 45 DAS

Treatment	Weed Count (No. m^{-2})		Weed dry matter (g m^{-2})		WCE (per cent)	
	20 DAS	45 DAS	20 DAS	45 DAS	20 DAS	45 DAS
T_1 - Atrataf	35.78	45.31	9.95	12.60	22.25	18.52
T_2 - Pendamil	33.74	37.93	9.38	10.55	26.67	31.78
T_3 - Delete	34.67	39.61	9.64	11.01	24.66	28.76
T_4 - Atrataf + Pakar	28.44	29.27	7.91	8.14	38.19	47.36
T_5 - Pendamil + Pakar	15.05	17.89	4.18	4.97	67.30	67.83
T_6 - Delete + Pakar	20.49	23.90	5.70	6.64	55.48	57.01
T_7 - Atrataf + Laudis	26.78	28.87	7.44	8.03	41.81	48.08
T_8 - Pendamil + Laudis	8.42	13.14	2.34	3.65	81.71	76.37
T_9 - Delete + Laudis	15.68	18.88	4.36	5.25	65.93	66.05
T_{10} - Twice-hand weeding	8.27	12.25	2.30	3.40	82.03	77.97
T_{11} - Unweeded control	46.02	55.60	12.79	15.46	0.00	0.00
SE(d)	0.38	0.13	0.17	0.07	-	-
CD (0.05)	0.74	0.25	0.32	0.14	-	-

emergence herbicide and subsequent flushes by post-emergence herbicide, which was found effective against all kinds of weeds, resulting in reduced particular weed count and dry matter, ultimately enhancing the weed control efficiency. Similar observations were made by Irungbam *et al*., (2024).

Pendimethalin is a systemic herbicide most widely used as a pre-emergent herbicide, very effective in controlling *Brachiaria reptans* by inhibiting cell division and elongation in plants. Tembotrione is a selective systemic herbicide; it works by inhibiting 4-hydroxyphenylpyruvate dioxygenase (HPPD) enzymes. This enzyme is responsible for the production of carotenoids, which are essential for plant photosynthesis. This herbicide is used as a post-emergence herbicide to control a wide range of broad-leaved and grassy weeds (Agrawal *et al.,* 2026).

The highest weed count (46.02 m^{-2} and 55.60 m^{-2}) and dry matter (12.79 g m^{-2} and 15.46 g m^{-2}) were recorded in the unweeded control at 20 DAS and 45 DAS, respectively. The lowest weed control efficiency was recorded in the sole application of Atrataf (T_1) at 20 DAS and 45 DAS. This might be due to the sole application of the atrazine herbicide, which may not be efficient in controlling *Brachiaria reptans* weed. However, the treatments with the sole application of herbicides showed reduced control of recently emerged weeds, resulting in higher weed counts, lower dry matter, and the lowest weed control efficiency for grassy weeds. These results were confirmed with the findings of Tugoo *et al.,* (2025).

Effect on Cyperus rotundus

All the weed management treatments have significantly influenced the *Cyperus rotundus* weed count (No. m^{-2}), dry matter (g m^{-2}), and weed control efficiency (per cent) at 20 DAS and 45 DAS, which were furnished in Table 2.

Among the herbicidal treatments, Pendamil + Laudis (T_8) recorded the lowest weed count (50.87 m^{-2} and 88.72 m^{-2}) and dry matter (16.94 g m^{-2} and 29.54 g m^{-2}) of *Cyperus rotundus* at 20 DAS and 45 DAS, respectively. The highest weed control efficiency of 80.31 per cent and 72.14 per cent was found in the treatment Pendamil + Laudis (T_8) at 20 DAS and 45 DAS, respectively. It was followed by Pendamil + Pakar (T_5). The reason for the effective control of *Cyperus rotundus* weed under these treatments might be the inhibition of weed germination and growth by arresting cell division and cell elongation, thereby causing weed mortality. It seems to be the most spectacular reason for the lower weed counts and dry weights, leading to higher weed control efficiency. The weeds caused sufficient damage

Table 2. *Cyperus rotundus* - weed count (No. m^{-2}), dry matter (g m^{-2}), and WCE (per cent) at 20 DAS and 45 DAS

Treatment	Weed Count (No. m^{-2})		Weed dry matter (g m^{-2})		WCE (per cent)	
	20 DAS	45 DAS	20 DAS	45 DAS	20 DAS	45 DAS
T_1 - Atrataf	183.94	232.01	61.25	77.26	28.82	27.16
T_2 - Pendamil	162.07	183.71	53.97	61.18	37.28	42.32
T_3 - Delete	171.82	197.99	57.22	65.93	33.51	37.84
T_4 - Atrataf + Pakar	133.72	168.42	44.53	56.08	48.25	47.12
T_5 - Pendamil + Pakar	75.17	112.81	25.03	37.57	70.91	64.58
T_6 - Delete + Pakar	102.87	135.47	34.26	45.11	60.19	57.47
T_7 - Atrataf + Laudis	127.91	163.84	42.59	54.56	50.50	48.56
T_8 - Pendamil + Laudis	50.87	88.72	16.94	29.54	80.31	72.14
T_9 - Delete + Laudis	79.00	118.93	26.31	39.60	69.43	62.66
T_{10} – Twice-hand weeding	45.84	85.16	15.26	28.36	82.26	73.26
T_{11} - Unweeded control	258.41	318.50	86.05	106.06	0.00	0.00
SE(d)	6.01	7.64	2.00	2.54	-	-
CD (0.05)	11.60	14.74	3.86	4.91	-	-

to crop growth, which was effectively controlled by the application of the post-emergence herbicide tembotrione. Almost similar findings were reported by Devi (2024).

The highest weed count (258.41 m^{-2} and 318.50 m^{-2}) and dry matter (86.05 g m^{-2} and 106.06 g m^{-2}) were recorded in the unweeded control at 20 DAS and 45 DAS, respectively. The lowest weed control efficiency of 28.82 per cent and 27.16 per cent was recorded in the sole application of Atrataf (T_1) at 20 DAS and 45 DAS, respectively. This might be due to the sole application of atrazine herbicide; it may not be efficient in controlling *Cyperus rotundus* weed, as the fast-growing nature of this weed was higher during the initial stages of crop growth, and the growth of pearl millet was very slow at early stages. However, the treatments with the sole application of herbicides showed reduced control of recently emerged weeds, resulting in higher weed counts, lower dry matter, and lower weed control efficiency of sedges. These results are supported by those of Dokala *et al.,* (2025).

Effect on Trianthema portulacastrum

The weed *Trianthema portulacastrum* individual count (No. m^{-2}), dry matter (g m^{-2}), and weed control efficiency (per cent) at 20 DAS and 45 DAS have been significantly affected by weed management treatments as displayed in Table 3.

Among the herbicidal treatments, Pendamil + Laudis (T_8) recorded the lowest weed count (2.80 m^{-2} and 5.58 m^{-2}) and dry matter (0.70 g m^{-2} and 1.40 g m^{-2}) of *Trianthema portulacastrum* at 20 DAS and 45 DAS, respectively. The highest weed control efficiency of 87.04 per cent and 79.64 per cent was found in the treatment Pendamil + Laudis (T_8) at 20 DAS and 45 DAS, respectively. It was followed by Pendamil + Pakar (T_5). The drastic reduction in weed dry matter production under these treatments might be directly associated with the corresponding reduction in weed count, resulting from effective control of the complex weed flora and suppression of *Trianthema portulacastrum*, thereby enhancing weed control efficiency. This result was consistent with the findings of Chinyo *et al*., (2023).

The highest weed count (21.56 m^{-2} and 27.41 m^{-2}) and dry matter (5.39 g m^{-2} and 6.85 g m^{-2}) were recorded in the unweeded control at 20 DAS and 45 DAS, respectively. The lowest weed control efficiency on *Trianthema portulacastrum* (26.17 per cent and 22.00 per cent) was recorded in the sole application of Delete (T_3) at 20 DAS and 45 DAS, respectively. This might be due to the sole application of pretilachlor herbicide. This herbicide was effective in controlling grassy weeds but may not be competent

Table 3. Trianthema portulacastrum - weed count (No. m^{-2}), dry matter (g m^{-2}), and WCE (per cent) at 20 DAS and 45 DAS

Treatment	Weed Count (No. m^{-2})		Weed dry matter (g m^{-2})		WCE (per cent)	
	20 DAS	45 DAS	20 DAS	45 DAS	20 DAS	45 DAS
T_1 - Atrataf	12.79	18.01	3.20	4.50	40.68	34.29
T_2 - Pendamil	15.12	20.62	3.78	5.16	29.88	24.76
T_3 - Delete	15.92	21.38	3.98	5.34	26.17	22.00
T_4 - Atrataf + Pakar	11.83	16.55	2.96	4.14	45.15	39.63
T_5 - Pendamil + Pakar	5.12	9.25	1.28	2.31	76.27	66.27
T_6 - Delete + Pakar	8.49	12.77	2.12	3.19	60.63	53.40
T_7 - Atrataf + Laudis	11.54	17.30	2.89	4.33	46.47	36.87
T_8 - Pendamil + Laudis	2.80	5.58	0.70	1.40	87.04	79.64
T_9 - Delete + Laudis	5.14	10.18	1.29	2.55	76.15	62.85
T_{10} - Twice-hand weeding	2.23	5.34	0.56	1.34	89.67	80.51
T_{11} - Unweeded control	21.56	27.41	5.39	6.85	0.00	0.00
SE(d)	0.51	0.73	0.13	0.18	-	-
CD (0.05)	0.99	1.42	0.25	0.35	-	-

in controlling broad-leaved weeds, leading to higher weed counts, lower dry matter, and the lowest weed control efficiency for *Trianthema portulacastrum* weeds. The results were consistent with the findings of Dubey *et al.,* (2023) and Mahapatra *et al.,* (2023).

Grain and stover yield

The results of the field study on pearl millet revealed that grain and stover yields were significantly influenced by weed management treatments, as shown in Figure 1. Among the herbicidal treatments, Pendamil + Laudis (T_8) recorded the maximum grain yield (3347 kg ha^{-1}) and stover yield (5155 kg ha^{-1}). It was followed by the treatment Pendamil + Pakar (T_5). This might be due to the simultaneous application of pendimethalin as a pre-emergence herbicide and tembotrione as a post-emergence herbicide; it was significantly found to be better than the application of pre-emergence herbicides alone. This difference may be attributed to the subsequent use of post-emergence herbicides, which effectively controlled the annual grasses and a wide range of broadleaf weeds.

The unweeded control resulted in noticeably lower grain and stover yields. By enhancing the source-sink connections, higher grain yield may most likely be the result of higher yield attribute values combined with increased dry matter observed under this treatment. This result was similar to that of Irungbam *et al*., (2022).

CONCLUSION

From the field experiment, the predominant weed species of *Brachiaria reptans*, *Cyperus rotundus,* and *Trianthema portulacastrum* in the pearl millet field were effectively controlled by the application of Pendamil + Laudis. It may be concluded that applying Pendamil + Laudis was the most effective herbicide for weed control and enhanced the yield in pearl millet cultivation compared to the other herbicidal treatments. It could be recommended for the farmer to enhance pearl millet productivity.

FUNDING AND ACKNOWLEDGMENT

The research leading to these results was funded by the Tamil Nadu State Council for Science and Technology (TNSCST) under project code AS-0058 of the TNSCST Student Project Scheme 2023-24 (TNSCST-SPS).

ETHICS STATEMENT

The authors affirm that this work was conducted in accordance with the highest ethical standards. All research methods and data collection practices complied with relevant institutional guidelines. This

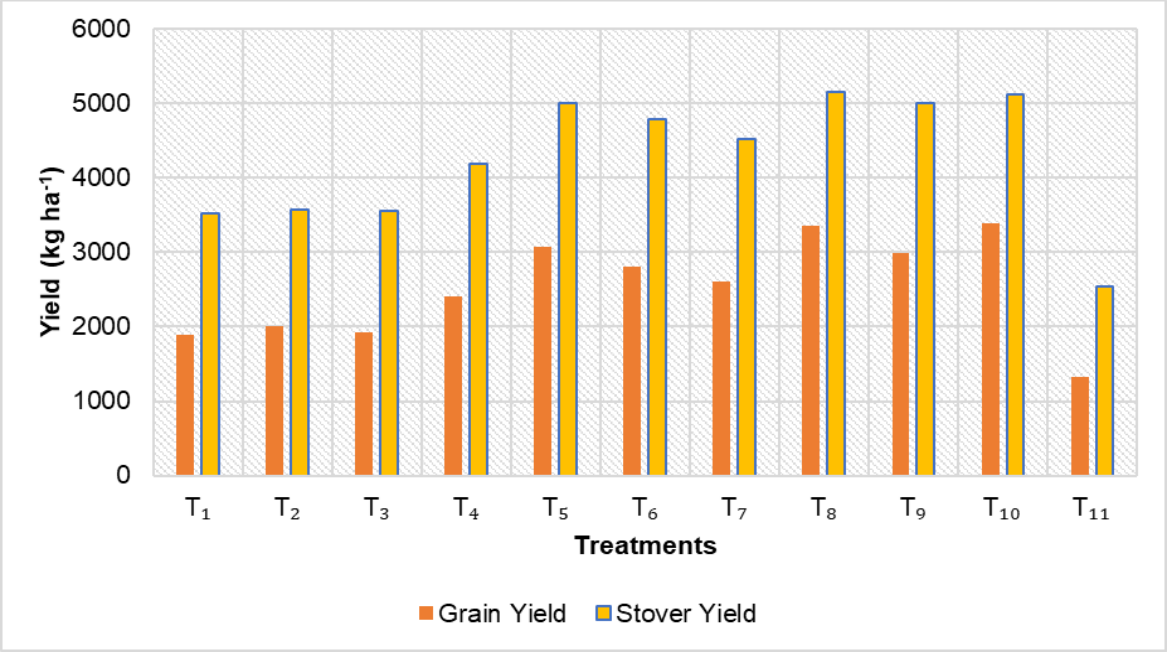

Fig. 1. Effect of weed management practices on grain and stover yield of pearl millet

article adheres to principles of honesty, transparency, and respect for intellectual property.

ORIGINALITY AND PLAGIARISM

This article represents the original work of the authors and has not been submitted elsewhere for publication. All information, data, and ideas that are not the authors' own have been properly cited and referenced in accordance with academic standards. The authors affirm that no part of this manuscript has been plagiarized or copied from previous works without proper acknowledgment.

CONSENT FOR PUBLICATION

All authors have reviewed and approved the content of this article and consent to its submission and publication in the journal.

COMPETING INTERESTS

The author(s) declare that there are no competing interests. This article was completed as part of academic coursework and was not influenced by any external funding, commercial interests, or personal relationships that could affect the objectivity of the work.

The data supporting the findings of this study are available from the corresponding author upon reasonable request. All data were collected and analyzed as part of the research conducted for academic purposes. No proprietary or confidential data were used in this study.

AUTHOR CONTRIBUTIONS

JS: Conceptualization, Resources, Data curation, Writing - original draft. SM: Conceptualization, Supervision, Funding acquisition. PS: Writing - review & editing, Methodology, Validation, Visualization. DV: Methodology, Validation, Visualization.

REFERENCES

Agrawal, R.K., Soni, J.K., Jha, S.K., Kale, R.V., Kumar, R., Kumar, B., Thomas, U.C., Chand, S., Roy, A.K., Jha, A.K. and V.K. Yadav. 2026. Weed Management in Fodder Maize Using Herbicides Under Diverse Agro-Climates of India. *Int. J. Plant Prod.*, **20(2)**. https://doi.org/10.1007/s42106-025-00389-5

Anonymous. 2024. 2nd advance estimates 2023–24. Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Government of India.

Chinyo, M., Singh, R. and M. Gautam. 2023. Conservation-agriculture practices and weed-management effects on productivity, water and energy-use efficiency of rainfed pearl millet (*Pennisetum glaucum*). *Ind. J. Agron.*, **68(1)**: 110-114. https://doi.org/10.59797/ija.v68i1.214

Devi, R., 2024. Effect of herbicidal weed management practices on growth characters of finger millet (*Eleusine coracana* L.). *Int. J.*

Res. Agron., **7(8S)**: 262-266. https://doi.org/10.33545/2618060X.2024.v7.i8Sd.1295

Dhayal, B.C., Yadav, S.S., Jat, M.L. and L. Dhayal. 2020. Efficacy of herbicides for weed control in pearl millet [*Pennisetum glaucum* (L.) R. Br. Emend Stuntz]. *Environ. Eco.*, **38(3B)**: 651-656.

Dokala, M., Rajput, P., Swaroop Naik, B.R.S., Kanaujiya, P.K. and S.K. Gautam. 2025. Effect of Weed Management Practices on Weed Prevalence, Crop Productivity and Profitability in pearl millet (*Pennisetum glaucum* L.). *Eco. Environ. Conser.*, **31:** S250-253. http://doi.org/10.53550/EEC.2025.v31i01s.042

Dubey, R.P., Chethan, C.R., Choudhary, V.K. and Mishra, J.S., 2023. A review on weed management in millets. *Indian J. Weed. Sci.*, **55(2):** 141-148. http://dx.doi.org/10.5958/0974-8164.2023.00025.4

FAO (Food and Agriculture Organization). 2015. FAOSTAT. Food and Agriculture Organization of the United Nations, Rome, Italy.

ICAR-CRIDA. 2020. State wise plans - Cuddalore: 2019-20. ICAR - The Central Research Institute for Dryland Agriculture. https://www.icar-crida.res.in

Irungbam, P., Singh, T.B., Malemnganbi, T., Heisnam, P. and Goudar, P., 2024. Performance of Direct Seeded Rice under Integrated Weed and Nutrient Management Practices and Residual Effect on Succeeding Rapeseed under Zero Tillage. *Indian J. Eco.*, **51(1):** 181-186. https://doi.org/10.55362/IJE/2024/4213

Kabir, M.H., Bari, M.N., Haque, M.M., Ahmed, G.J.U. and J.M.S. Islam. 2008. Effect of water management and weed control treatments on the performance of transplanted aman rice. *The Bangladesh J. Agricul. Res.*, **33(3)**: 399-408. https://doi.org/10.3329/bjar.v33i3.1599

Mahapatra, A., Kalasare, R.S., Palai, J.B., Duary, S., Sahu, C. and Rout, D.S., 2023. Review and outlook of weed management in millets. *J Appl Biol Biotechnol.*, **11:** 1-10. http://dx.doi.org/10.7324/JABB.2023.118222

Tugoo, M.Z., Kumar, V., Parray, S.A., Ramalingam, A.P., Vara Prasad, P.V. and R. Perumal. 2025. Pearl millet hybrid tolerance and weed control with preemergence herbicides. *Weed Tech.*, **39**: 78. https://doi.org/10.1017/wet.2025.10028

USDA. 2024. World agricultural production. Foreign Agricultural Services. https://ipad.fas.usda.gov/countrysummary/Default.aspx?id=IN&crop=Millet