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Effect of different weed management practices on growth, yield, weed dynamics, and economics of transplanted basmati rice (*Oryza sativa* L.)

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Abstract

A field experiment was conducted during the Kharif season 2025-26 at Rama University, Kanpur (Uttar Pradesh) to evaluate the impact of various weed management practices on growth, yield, weed dynamics, and economics of transplanted Basmati rice (cv. Pusa Basmati 1121). The experiment was laid out in a randomized block design with six treatments and three replications. Treatments: T₁: Weedy check (no weed control), T₂: Two hand weedings at 20 and 40 DAT, T₃: Pendimethalin @ 1.0 kg a.i. ha⁻¹ (pre-emergence, applied within 3 DAT), T₄: Bispyribac-sodium @ 25 g a.i. ha⁻¹ (post-emergence, applied at 20–25 DAT), T₅: Pendimethalin @ 1.0 kg a.i. ha⁻¹ (PE) + one hand weeding at 30 DAT, T₆: Pendimethalin @ 1.0 kg a.i. ha⁻¹ (PE) + Bispyribac-sodium @ 25 g a.i. ha⁻¹ (PoE). Results revealed that the sequential application of pendimethalin followed by bispyribac-sodium (T₆) recorded significantly superior performance. It produced the highest plant height (110.8 cm), number of tillers (428 m⁻²), leaf area index (5.35), and dry matter accumulation (952 g m⁻²) at 60 DAT. This treatment also gave the maximum grain yield (52.6 q ha⁻¹) — an increase of 123.8% over the weedy check — along with the highest weed control efficiency (92.1%). Economically, T₆ recorded the highest net returns (₹1,68,450 ha⁻¹) and benefit-cost ratio (2.75). The study concludes that integrated pre- and post-emergence herbicide application is the most effective, sustainable, and profitable weed management strategy for transplanted Basmati rice.

Keywords: Basmati rice, integrated weed management, pendimethalin, bispyribac-sodium, weed control efficiency, economics

Introduction

Basmati rice (*Oryza sativa* L.) is a premium aromatic rice variety highly valued in domestic and international markets for its exceptional grain quality, delightful aroma, extra-long slender grains, and superior cooking characteristics. India is the largest producer and exporter of Basmati rice in the world, contributing more than 70% of global Basmati trade. During 2024-25, India exported about 6.065 million metric tonnes of Basmati rice, generating revenue of approximately ₹50,312 crore. Uttar Pradesh has emerged as one of the major Basmati-producing states in the country after Punjab and Haryana. However, the average productivity of Basmati rice in India typically ranges between 3.0 to 4.5 tonnes per hectare, which is significantly lower than that of high-yielding non-aromatic rice varieties. Its productivity is often constrained by slow initial growth, longer crop duration (135–150 days), tall stature, lodging tendency, and severe weed competition. Weeds can cause yield losses ranging from 15 to 85% in Basmati rice by competing aggressively for light, water, nutrients, and space, particularly during the critical period of crop-weed competition (20–45 DAT). Traditional manual weeding is labour-intensive and becoming increasingly uneconomical due to rising labour costs and shortages. On the other hand, continuous reliance on a single herbicide may lead to weed resistance and environmental concerns. Therefore, Integrated Weed Management (IWM) combining chemical, mechanical, and cultural methods has gained considerable importance. The present investigation was carried out to identify the most effective, economically viable, and sustainable weed management practice for transplanted Basmati rice in the Central Plain Zone of Uttar Pradesh.

Materials and Methods

The field experiment was conducted during the Kharif season 2025-26 at the Research Farm, Department of Agronomy, Rama University, Kanpur. The soil was sandy loam with pH 7.85, organic carbon 0.52%, available N 178.4 kg ha⁻¹, P 21.6 kg ha⁻¹,

and K 282.5 kg ha⁻¹. Experimental Design: Randomized Block Design (RBD) with 6 treatments and 3 replications. Variety: Pusa Basmati 1121 Spacing: 20 cm × 15 cm Transplanting: 30-day-old seedlings on 20 July 2025.

Treatment	Treatment Details	Characteristics
T ₁	Weedy check	No weed control (control plot)
T ₂	Two hand weeding at 20 and 40 DAT	Manual weeding
T ₃	Pendimethalin @ 1.0 kg a.i. ha ⁻¹ (PE)	Pre-emergence herbicide
T ₄	Bispyribac-sodium @ 25 g a.i. ha ⁻¹ (PoE)	Post-emergence herbicide
T ₅	Pendimethalin @ 1.0 kg a.i. ha ⁻¹ (PE) + one hand weeding at 30 DAT	Integrated (chemical + mechanical)
T ₆	Pendimethalin @ 1.0 kg a.i. ha ⁻¹ (PE) + Bispyribac-sodium @ 25 g a.i. ha ⁻¹ (PoE)	Sequential herbicide application (IWM)

Recommended dose of fertilizers (120:60:40 kg N:P₂O₅:K₂O ha⁻¹) and standard agronomic practices were followed uniformly. Observations on growth, yield attributes, yield, weed parameters, soil properties, and economics were recorded using standard procedures. Data were statistically analyzed by ANOVA for RBD and treatment means were compared using CD at 5% level of significance.

Results and Discussion

Effect of Weed Management Practices on Crop Growth

Growth is one of the most sensitive indicators of crop response to weed competition. Weed management treatments significantly ($P \leq 0.05$) influenced plant height and tiller production of transplanted Basmati rice (Table 1). Effective suppression of weeds during the critical crop–weed competition period improved

crop access to nutrients, moisture, light, and growing space, thereby enhancing vegetative growth and biomass production.

Table 1: Effect of weed management practices on plant height and tiller production of transplanted Basmati rice

Treatment	Plant height (cm) at harvest	Tillers m ⁻² at 60 DAT
T ₁	85.4	225
T ₂	106.2	382
T ₃	97.5	325
T ₄	99.8	342
T ₅	108.5	412
T ₆	110.8	428
Sem±	1.01	2.23
CD (P=0.05)	3.35	6.8

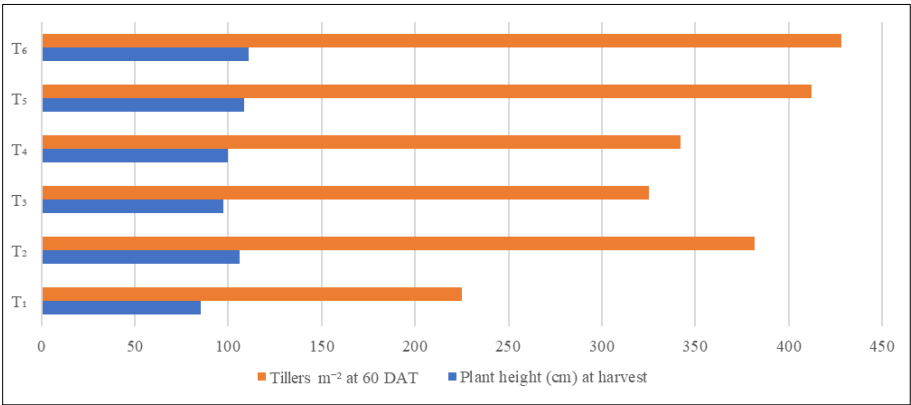


Fig 1: Effect of weed management practices on plant height and tiller production.

Among the various weed management treatments, T₆ (Pendimethalin PE followed by Bispyribac-sodium PoE) produced the tallest plants (110.8 cm) and the highest tiller density (428 m⁻²), which remained statistically at par with T₅, but significantly superior to the remaining treatments. In contrast, the weedy check (T₁) recorded the lowest plant height (85.4 cm) and tiller population (225 m⁻²), indicating severe suppression of crop growth due to continuous weed interference. The improvement in plant height under T₆ was 29.7% over the weedy check, while tiller production increased by 90.2%, demonstrating the effectiveness of sequential herbicide application in minimizing weed competition throughout the crop growth period. The superior crop growth under integrated herbicide application can be attributed to the reduced depletion of nutrients, soil moisture, and solar radiation by weeds during the early vegetative stage. Weed-free conditions also promoted greater leaf area development, chlorophyll synthesis, dry matter accumulation, and photosynthetic efficiency, which ultimately enhanced tiller initiation and plant vigour. These findings corroborate those

reported by Rao (2000) [16], who emphasized that timely weed control during the first 30–45 days after transplanting is essential for maximizing rice growth. Similar observations were also reported by Chauhan and Johnson (2011) [2], Mahajan *et al.* (2012) [12], Singh *et al.* (2017) [19], and Kumar *et al.* (2022) [10], who observed significantly greater plant height and tillering under integrated herbicide programmes compared with single herbicide applications or manual weeding.

Effect of Weed Management Practices on Yield Attributes and Yield of Transplanted Basmati Rice

Crop yield is ultimately determined by the successful development of yield attributes, which are highly sensitive to weed competition during the critical stages of crop growth. Effective weed management not only minimizes competition for nutrients, moisture, light, and space but also improves photosynthetic efficiency, dry matter accumulation, and assimilate translocation towards reproductive organs. Consequently, the present investigation revealed significant ($P \leq$

0.05) differences among weed management treatments with respect to productive tillers, panicle length, grains per panicle,

grain yield, and straw yield (Table 2).

Table 2: Effect of weed management practices on yield attributes and yield of transplanted Basmati rice

Treatment	Productive tillers (m ⁻²)	Panicle length (cm)	Grains panicle ⁻¹	Grain yield (q ha ⁻¹)	Straw yield (q ha ⁻¹)
T ₁	195	18.2	82	23.5	35.2
T ₂	355	24.5	142	47.5	68.4
T ₃	290	22.1	118	39.8	57.5
T ₄	310	22.8	125	42.3	60.8
T ₅	365	25.1	146	49.2	71.5
T ₆	385	25.6	152	52.6	74.8
Sem±	0.45	0.34	3.2	1.34	2.24
CD (P=0.05)	1.21	1.35	9.6	3.60	5.35

The marked increase in yield under T₆ was due to better tillering, improved panicle characters, and efficient assimilate partitioning resulting from excellent weed control during the critical period.

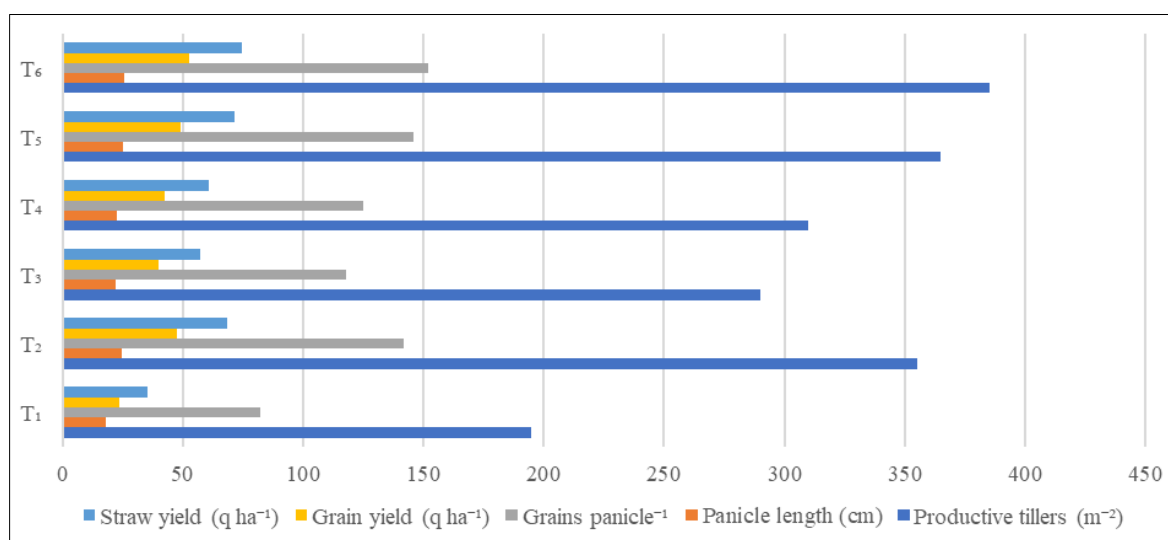


Fig 2: Effect of weed management practices on yield attributes and yield of transplanted Basmati rice

The data presented in Table 2 clearly indicate that all yield-attributing characters were significantly influenced by different weed management practices. Among the evaluated treatments, T₆ (Pendimethalin @ 1.0 kg a.i. ha⁻¹ as pre-emergence followed by Bispyribac-sodium @ 25 g a.i. ha⁻¹ as post-emergence) produced the highest number of productive tillers (385 m⁻²), longest panicle (25.6 cm), maximum grains per panicle (152), highest grain yield (52.6 q ha⁻¹), and straw yield (74.8 q ha⁻¹). However, these values remained statistically at par with T₅ (Pendimethalin followed by one hand weeding at 30 DAT), which recorded 365 productive tillers m⁻², 25.1 cm panicle length, 146 grains panicle⁻¹, grain yield of 49.2 q ha⁻¹, and straw yield of 71.5 q ha⁻¹. In contrast, the untreated weedy check (T₁) recorded the lowest values for all yield attributes, producing only 195 productive tillers m⁻², 18.2 cm panicle length, 82 grains panicle⁻¹, grain yield of 23.5 q ha⁻¹, and straw yield of 35.2 q ha⁻¹. The grain yield obtained under T₆ was approximately 123.8% higher than that of the weedy check, highlighting the severe adverse impact of uncontrolled weed infestation on crop productivity. The substantial increase in productive tillers under T₆ can be attributed to effective weed suppression throughout the crop growth period, particularly during the critical competition phase between 20 and 45 DAT. Reduced weed interference allowed the rice plants to utilize available soil nutrients, moisture, and solar radiation more efficiently, resulting in vigorous vegetative growth and increased tiller survival. Greater assimilate production during the vegetative stage subsequently contributed to enhanced panicle initiation,

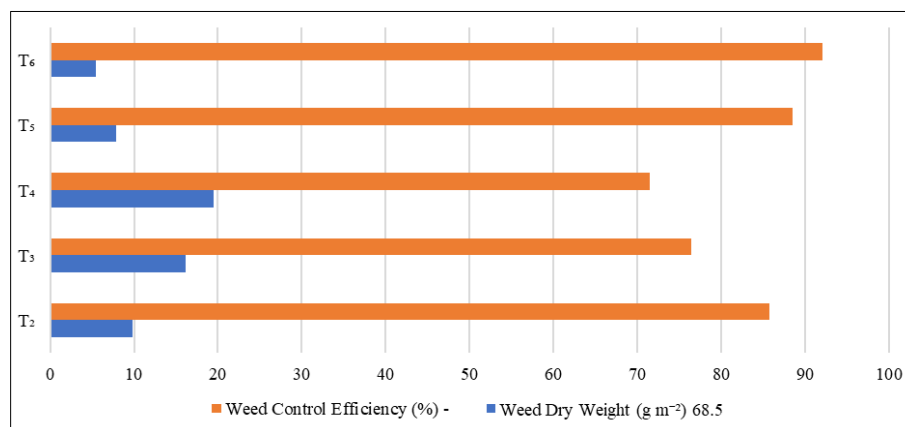
spikelet differentiation, and grain filling. The present findings are in close agreement with those reported by Moody (1982) ^[14], who concluded that prolonged weed-free conditions substantially improve rice yield components. Likewise, Rao (2000) ^[16] observed that effective weed management during the early crop growth stages significantly enhances productive tillers and grain yield. Similar improvements in panicle length, grains per panicle, and grain yield following integrated herbicide application have also been reported by Chauhan and Johnson (2011) ^[2], Mahajan *et al.* (2012) ^[12], Singh *et al.* (2017) ^[19], Yadav *et al.* (2019) ^[22], Kumar *et al.* (2022) ^[10], and FAO (2023) ^[4].

Effect of Weed Management Practices on Weed Dynamics, Weed Dry Matter Accumulation and Weed Control Efficiency

The success of any weed management programme largely depends on its ability to suppress weed emergence, reduce weed biomass, and minimize crop–weed competition during the critical stages of crop growth. Weed density and weed dry matter are reliable indicators of the effectiveness of a weed control strategy, whereas weed control efficiency (WCE) provides a quantitative measure of the extent of weed suppression achieved by a particular treatment. In the present investigation, weed management practices significantly ($P \leq 0.05$) influenced weed dry weight and weed control efficiency at 60 DAT (Table 3), indicating marked differences in their ability to manage the weed flora under transplanted Basmati rice.

Table 3: Weed dry weight and Weed Control Efficiency at 60 DAT

Treatment	Weed Dry Weight (g m ⁻²)	Weed Control Efficiency (%)
T ₁	68.5	-
T ₂	9.8	85.7
T ₃	16.2	76.4
T ₄	19.5	71.5
T ₅	7.9	88.5
T ₆	5.4	92.1
Sem±	2.56	2.21
CD (P=0.05)	5.04	6.34

**Fig 3:** Effect of weed management practices on weed dry weight and weed control efficiency of transplanted Basmati rice at 60 DAT

The results revealed that T₆ (Pendimethalin @ 1.0 kg a.i. ha⁻¹ as pre-emergence followed by Bispyribac-sodium @ 25 g a.i. ha⁻¹ as post-emergence) was the most effective weed management practice, recording the lowest weed dry weight (5.4 g m⁻²) and the highest weed control efficiency (92.1%). The treatment was statistically at par with T₅ (Pendimethalin followed by one hand weeding at 30 DAT), which recorded 7.9 g m⁻² weed dry weight and 88.5% weed control efficiency. Both treatments were significantly superior to the individual herbicide applications and manual weeding. On the other hand, the weedy check (T₁) registered the maximum weed dry weight (68.5 g m⁻²), indicating unrestricted weed growth throughout the crop season. Continuous weed infestation under untreated plots resulted in intense competition for essential growth resources, thereby adversely affecting crop growth and yield. Compared with the weedy check, sequential herbicide application under T₆ reduced weed biomass by approximately 92%, demonstrating its excellent weed suppressive ability. The superior weed control achieved under T₆ can be attributed to the complementary action of two herbicides with different modes of action and periods of activity. Pendimethalin, applied as a pre-emergence herbicide, effectively inhibited germination and establishment of the first flush of annual grasses and broad-leaved weeds by interfering with cell division and root development. Subsequently, Bispyribac-sodium, applied as a post-emergence herbicide, controlled weeds that escaped the initial herbicide treatment, particularly grasses, sedges, and several broad-leaved species, by inhibiting the acetolactate synthase (ALS) enzyme responsible for the synthesis of essential branched-chain amino acids. The sequential use of these herbicides ensured season-long weed suppression and prevented reinfestation during the critical crop growth period. Among the individual herbicide treatments, Pendimethalin alone (T₃) proved more effective than Bispyribac-sodium alone (T₄), indicating that early-season weed suppression plays a crucial role in minimizing crop-weed competition in transplanted rice.

Nevertheless, neither herbicide alone provided satisfactory control throughout the crop season because later-emerging weeds escaped treatment, leading to increased weed biomass and reduced weed control efficiency.

The effectiveness of integrated weed management observed in the present study agrees well with the findings of Moody (1982) ^[14], who reported that maintaining a weed-free environment during the first 40–45 days after transplanting is essential for achieving maximum rice productivity. Similarly, Rao (2000) ^[16] emphasized that sequential weed management strategies provide broader-spectrum weed control than single herbicide applications and significantly improve crop performance. Comparable results have also been reported by Chauhan and Johnson (2011) ^[2], who observed that integration of pre- and post-emergence herbicides effectively controlled complex weed flora in transplanted rice and significantly reduced weed dry matter accumulation. Mahajan *et al.* (2012) ^[12] further demonstrated that sequential herbicide programmes consistently produced higher weed control efficiency and lower weed biomass than either manual weeding or single herbicide applications. Recent investigations by Singh *et al.* (2017) ^[19], Yadav *et al.* (2019) ^[22], Kumar *et al.* (2022) ^[10], and FAO (2023) ^[4] have also highlighted that integrated herbicide strategies provide more consistent and sustainable weed management under irrigated rice ecosystems. These studies reported weed control efficiencies ranging between 85 and 95%, which closely correspond with the values observed in the present investigation.

Economics of Weed Management Practices

Economic evaluation is an important criterion for assessing the practical feasibility of weed management practices. Significant differences were observed among treatments with respect to cost of cultivation, gross returns, net returns, and benefit–cost ratio (Table 4).

Table 4: Economics of different weed management practices in transplanted Basmati rice

Treatment	Treatment Details	Cost of Cultivation (₹ ha ⁻¹)	Gross Returns (₹ ha ⁻¹)	Net Returns (₹ ha ⁻¹)	B:C Ratio
T ₁	Weedy check	78,650	1,18,200	39,550	1.50
T ₂	Two hand weedings (20 & 40 DAT)	1,12,450	2,30,700	1,18,250	2.05
T ₃	Pendimethalin @ 1.0 kg a.i. ha ⁻¹ (PE)	86,750	1,98,500	1,11,750	2.29
T ₄	Bispyribac-sodium @ 25 g a.i. ha ⁻¹ (PoE)	88,200	2,11,800	1,23,600	2.40
T ₅	Pendimethalin (PE) + one hand weeding (30 DAT)	95,200	2,48,000	1,52,800	2.58
T ₆	Pendimethalin (PE) + Bispyribac-sodium (PoE)	96,350	2,64,800	1,68,450	2.75

**Fig 4:** Economics of different weed management practices in transplanted Basmati rice

Treatment T₆ recorded the highest gross returns (₹264800 ha⁻¹), net returns (₹168450 ha⁻¹), and benefit–cost ratio (2.75), followed by T₅ with a B:C ratio of 2.58. Although T₆ involved a slightly higher cultivation cost, the substantial increase in grain yield resulted in maximum economic returns. The lowest profitability was recorded under the weedy check (T₁), owing to poor crop performance caused by uncontrolled weed infestation. These findings corroborate the reports of Chauhan and Johnson (2011) [2], Mahajan *et al.* (2012) [12], Singh *et al.* (2017) [19], and Kumar *et al.* (2022) [10], who also reported that sequential herbicide application provides higher economic returns than individual herbicides or manual weeding.

Conclusion

The results of the present study indicate that Pendimethalin @ 1.0 kg a.i. ha⁻¹ (PE) followed by Bispyribac-sodium @ 25 g a.i. ha⁻¹ (PoE) (T₆) was the most effective weed management practice for transplanted Basmati rice. It produced superior growth, higher yield attributes, maximum grain yield (52.6 q ha⁻¹), minimum weed biomass (5.4 g m⁻²), highest weed control efficiency (92.1%), improved post-harvest soil fertility, and the greatest economic returns (B:C ratio 2.75). Therefore, sequential application of pre- and post-emergence herbicides can be recommended as an efficient, sustainable, and economically viable weed management strategy for enhancing productivity and profitability of transplanted Basmati rice under irrigated conditions.

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