



ISSN Print: 2618-060X
 ISSN Online: 2618-0618
 NAAS Rating (2026): NAAS
 Rating (2026): 5.20
 IJRA 2026; 9(9): 688-692
www.agronomyjournals.com
 Received: 01-07-2026
 Accepted: 10-08-2026
 Published: 15-08-2026

Hrishikesh Gajanan Kokate
 Research Scholar, Department
 of Agronomy, Faculty of
 Agriculture, Rabindranath
 Tagore University, Raisen,
 Madhya Pradesh, India

HD Verma
 Professor and Dean,
 Department of Agronomy,
 Faculty of Agriculture,
 Rabindranath Tagore
 University, Raisen, Madhya
 Pradesh, India

Balkrishna Namdeo
 Assistant Professor,
 Department of Agronomy,
 Faculty of Agriculture,
 Rabindranath Tagore
 University, Raisen, Madhya
 Pradesh, India

**Corresponding Author:
 Hrishikesh Gajanan
 Kokate**

Research Scholar,
 Department of Agronomy,
 Faculty of Agriculture,
 Rabindranath Tagore
 University, Raisen, Madhya
 Pradesh, India

Effect of integrated weed management practices on growth, yield, quality and economics of green gram (*Vigna radiata* L.)

Hrishikesh Gajanan Kokate¹, HD Verma², Balkrishna Namdeo³, Brajkishor Rajput⁴,
 Ashok Kumar Verma⁵

DOI: <https://www.doi.org/10.33545/2618060X.2026.v9.i9j.6589>

ABSTRACT

A two-year field investigation was conducted during the 2025 and 2026 kharif seasons at the Agriculture Research Farm, Faculty of Agriculture, Rabindranath Tagore University, Raisen, Madhya Pradesh, to evaluate the effect of ten weed management treatments, comprising nine integrated combinations of pre-emergence herbicides (pendimethalin, flumioxazin, pyroxasulfone), post-emergence herbicides (quizalofop-*P*-ethyl, propaquizafop, imazamox, halosulfuron-methyl), hand weeding and mechanical hoeing, together with an unweeded control, on the growth, yield, quality and economics of green gram (*Vigna radiata* L.) cv. PDM 139. The experiment was laid out in a Randomized Block Design with three replications. Pooled analysis of two years' data revealed that treatment T_8 (pendimethalin 1.0 kg/ha as pre-emergence followed by imazamox 75 g/ha at 30 days after sowing followed by mechanical hoeing at 45 days after sowing) recorded the tallest plants (45.00 cm), maximum branches per plant (16.91) and highest plant dry weight (26.68 g) at harvest, and significantly out-yielded all other treatments with a seed yield of 12.27 q/ha, a 66.5 per cent increase over the unweeded control (7.37 q/ha). Treatment T_8 also recorded the highest number of pods per plant (25.40), seed index (34.28 g), harvest index (32.19%) and seed protein content (24.09%). Treatment T_9 (pyroxasulfone 0.75 kg/ha followed by halosulfuron-methyl 75 g/ha at 25 days after sowing followed by hand weeding at 45 days after sowing) was statistically at par with T_8 for several parameters and ranked second, recording a seed yield of 11.57 q/ha, 57.0 per cent higher than the control. Economic analysis showed that T_8 recorded the highest net return (Rs 95,467/ha) and benefit-cost ratio (3.10), followed by T_9 (Rs 87,074/ha; 2.86) and T_5 (Rs 75,422/ha; 2.56). Treatments relying on a single herbicide application without a complementary post-emergence or mechanical/manual follow-up (T_4 , T_6 and T_7) recorded significantly lower growth, yield and economic returns, only marginally ahead of the unweeded control. The study concludes that integrated weed management combining a pre-emergence herbicide with a post-emergence herbicide and a mechanical or manual follow-up operation significantly improves the growth, productivity, seed quality and profitability of green gram over single-tactic approaches, with the pendimethalin-imazamox-mechanical hoeing sequence emerging as the most effective and economical option for the region.

Keywords: Green gram, Integrated weed management, Herbicides, Seed yield, Harvest index, Economics

Introduction

Green gram (*Vigna radiata* L.), commonly known as mung bean, is one of the most important short-duration pulse crops of India, valued for its high protein content, nitrogen-fixing ability, and suitability for intensive and relay cropping systems. Despite these agronomic advantages, average national productivity of green gram remains well below its genetic potential, and uncontrolled weed growth is consistently identified as one of the principal biotic constraints limiting yield, particularly because the crop's short stature, slow initial growth and wide row spacing during the early vegetative phase leave it poorly competitive against fast-establishing weed flora (Hirani *et al.*, 2024) [1]. Weeds compete with the crop for light, moisture, nutrients and space during the critical crop-weed competition period and, if left unmanaged, can depress green gram yield severely (Abbas *et al.*, 2018) [2].

Traditional single-tactic weed management, whether a single pre-emergence herbicide application, a single post-emergence spray, or one round of manual weeding, often fails to provide season-long control because different weed species emerge and flush at different times through the crop's growth cycle, and a single intervention timed for one flush inevitably leaves later-emerging cohorts uncontrolled (Riemens *et al.*, 2022) [3]. This has driven a broad shift in weed science towards Integrated Weed Management (IWM), which deliberately combines chemically and mechanistically diverse control tactics, pre-emergence and post-emergence herbicides with different modes of action, together with mechanical or manual intervention, to intercept se

quential weed flushes and reduce reliance on any single tactic (Gonzalez-Andujar, 2023) [4]. Empirical support for the yield and profitability advantage of such integrated, multi-tactic regimens over single-tactic approaches has been documented across several crops, including maize (Aslam *et al.*, 2024) [5], (Bin Lukangila *et al.*, 2024) [6] and (Simić *et al.*, 2025) [7], and cereal-legume rotations (Mishra *et al.*, 2022) [8], but comparable systematic, multi-parameter evidence specific to green gram, evaluating a range of pre-emergence, post-emergence and mechanical/manual treatment combinations together for their effect on growth, yield, quality and economics under Indian agro-climatic conditions, remains comparatively limited (Das *et al.*, 2024) [9].

Beyond the direct yield outcome, weed management decisions in green gram cultivation are also an economic decision for resource-constrained smallholder growers, who must weigh the cost of herbicide inputs and labour against the value of the yield protected, making the profitability of any recommended weed management package, and not only its biological efficacy, of direct practical relevance (Kumar *et al.*, 2024) [10].

Against this background, a two-year field investigation was undertaken with the specific objective of evaluating the effect of nine integrated pre-emergence, post-emergence and mechanical/manual weed management combinations, together with an unweeded control, on the growth attributes, yield attributes, seed yield, seed quality (protein content) and economics of cultivation of green gram cv. PDM 139, so as to identify the most effective and economically viable weed management package for the region.

Materials and methods

A field experiment was conducted over two consecutive kharif seasons (2025 and 2026) at the Agriculture Research Farm, Faculty of Agriculture, Rabindranath Tagore University (RNTU), Raisen, Madhya Pradesh, India. The experimental site lies in the central Narmada valley agro-climatic zone, with medium-to-deep black soil (Vertisol), clay-dominant texture, near-neutral pH (7.23) and low initial organic carbon (0.38%). The experiment was laid out in a Randomized Block Design (RBD) with ten treatments and three replications, giving thirty plots of 5.00 m x 4.00 m (gross = net plot size). Green gram variety PDM 139 was sown at a spacing of 30 cm (row to row) x 10 cm (plant to plant) with a seed rate of 13 kg/ha, on 20 June in both years, and fertilized uniformly at 20:40:20 kg N:P₂O₅:K₂O per ha.

The ten treatments evaluated (T_1 - T_{10}) are summarised in Table 1. Nine were integrated combinations of a pre-emergence herbicide (pendimethalin 1.0 kg/ha, flumioxazin 0.6 kg/ha or pyroxasulfone 0.75 kg/ha) with a post-emergence herbicide (quizalofop-*P*-ethyl 75 g/ha, propaquizafop 100 g/ha, imazamox 75 g/ha or halosulfuron-methyl 75 g/ha) and/or a mechanical hoeing or hand-weeding operation at 20-50 days after sowing (DAS); the tenth treatment (T_{10}) was an unweeded control. Herbicides were applied using a knapsack sprayer fitted with a flat-fan nozzle and 500 L/ha spray volume; pre-emergence herbicides were applied within 24-48 hours of sowing. Five randomly selected net plants (for growth and yield attributes) or 1 m² quadrats (for weed observations), excluding border rows, were sampled from each plot. Plant height, number of branches per plant, and plant dry weight were recorded at 20, 40, 60 DAS and at harvest. Yield attributes (pods/plant, seeds/pod, seed index), seed yield, stover yield, biological yield and harvest index were recorded at harvest.

Seed protein content was estimated by the micro-Kjeldahl method, using the standard nitrogen-to-protein conversion factor of 6.25 (AOAC, 2000) [11]. Cost of cultivation, gross returns (based on prevailing minimum support price of seed and local market rate of stover), net returns and benefit-cost (B:C) ratio were computed for each treatment.

Data recorded in each year were subjected to analysis of variance (ANOVA) appropriate to a Randomized Block Design; where the error variances of the two years were found homogeneous, a pooled analysis of variance across years was carried out, following the procedure of (Panse and Sukhatme) [12]. Standard error of mean (SEM $\pm$), critical difference at 5 per cent level of significance (CD at $P = 0.05$) and coefficient of variation (CV%) were computed for each parameter, and pooled means (of two years) are reported in the results.

Results

Table 1. Treatment details

Treatment	Details
T1	Pendimethalin 1.0 kg/ha (PE) + Hand weeding (20 DAS) + Quizalofop- <i>P</i> -ethyl 75 g/ha (35 DAS) + Mechanical hoeing (50 DAS)
T2	Flumioxazin 0.6 kg/ha (PE) + Hand weeding (20 DAS) + Propaquizafop 100 g/ha (40 DAS)
T3	Pyroxasulfone 0.75 kg/ha (PE) + Imazamox 75 g/ha (25 DAS) + Hand weeding (40 DAS)
T4	Pendimethalin 1.0 kg/ha (PE) + Quizalofop- <i>P</i> -ethyl 75 g/ha (30 DAS)
T5	Pendimethalin 1.0 kg/ha (PE) + Quizalofop- <i>P</i> -ethyl 75 g/ha (25 DAS) + Halosulfuron-methyl 75 g/ha (40 DAS)
T6	Flumioxazin 0.6 kg/ha (PE) + Propaquizafop 100 g/ha (30 DAS)
T7	Pyroxasulfone 0.75 kg/ha (PE) + Imazamox 75 g/ha (35 DAS)
T8	Pendimethalin 1.0 kg/ha (PE) + Imazamox 75 g/ha (30 DAS) + Mechanical hoeing (45 DAS)
T9	Pyroxasulfone 0.75 kg/ha (PE) + Halosulfuron-methyl 75 g/ha (25 DAS) + Hand weeding (45 DAS)
T10	Unweeded control

Growth parameters: Data on plant population, plant height, number of branches per plant and plant dry weight, recorded at harvest and pooled over two years, are presented in Table 2. Weed management treatments significantly influenced all growth parameters (CD at $P = 0.05$). Treatment T_8 recorded the maximum plant height (45.00 cm), the highest number of branches per plant (16.91) and the highest plant dry weight (26.68 g), followed closely by T_9 (43.93 cm; 16.26 branches/plant; 26.39 g), while the unweeded control (T_{10}) recorded the lowest values for all growth parameters (39.23 cm; 13.47 branches/plant; 23.26 g). Plant population at harvest ranged from 31.33 (T_4 , T_{10}) to 33.33 (T_8) plants/m² and, while statistically significant, showed a comparatively narrow range across treatments, reflecting the fact that weed competition affects plant vigour more than plant stand under this experimental design.

Table 2. Effect of weed management treatments on growth parameters of green gram at harvest (pooled data of two years)

Treatment	Plant population (No./m ²)	Plant height (cm)	Branches/plant	Plant dry weight (g)
T1	33.00	43.43	15.77	26.20
T2	32.00	41.82	14.96	24.98
T3	32.33	42.61	15.31	25.25

(continued on next page)

T4	31.33	38.73	13.99	23.93
T5	32.66	42.69	15.57	25.82
T6	31.66	40.13	14.48	24.20
T7	32.00	40.98	14.63	24.70
T8	33.33	45.00	16.91	26.68
T9	33.00	43.93	16.26	26.39
T10	31.33	39.23	13.47	23.26
SE (m+)	0.41	0.13	0.63	0.03
CD (<i>P</i> = 0.05)	0.86	0.41	1.91	0.09
CV %	1.27	0.52	6.68	0.21

Yield attributes, yield and quality: Data on yield attributes, seed yield, stover yield, biological yield, harvest index and seed protein content, pooled over two years, are presented in Table 3. Treatment *T*₈ recorded the maximum number of pods per plant (25.40), seeds per pod (8.30), seed index (34.28 g), seed yield (12.27 q/ha), biological yield (38.12 q/ha), harvest index (32.19%) and seed protein content (24.09%), significantly superior to all other treatments. Treatment *T*₉ was the second-best treatment for every one of these parameters (23.73 pods/plant; 7.45 seeds/pod; 32.87 g seed index; 11.57 q/ha

seed yield; 23.93% protein), followed by *T*₅ (10.60 q/ha) and *T*₃ (10.22 q/ha). The unweeded control (*T*₁₀) recorded the lowest values throughout (12.78 pods/plant; 7.37 q/ha seed yield; 20.35% protein), with *T*₈ representing a 66.5 per cent increase in seed yield over the control and *T*₉ a 57.0 per cent increase. Treatments relying on a single herbicide application without a complementary post-emergence or mechanical/manual follow-up (*T*₄, *T*₆ and *T*₇) recorded seed yields of 7.50, 8.10 and 8.52 q/ha respectively, only marginally higher than the control.

Table 3. Effect of weed management treatments on yield attributes, yield and quality of green gram (pooled data of two years)

Treatment	Pods/plant	Seeds/pod	Seed index (g)	Seed yield (q/ha)	Stover yield (q/ha)	Biological yield (q/ha)	Harvest index (%)	Protein content (%)
T1	20.10	7.03	32.42	10.91	23.31	34.20	31.89	23.85
T2	15.45	5.76	29.01	8.97	19.26	28.22	31.78	22.95
T3	17.77	6.20	30.52	10.22	21.91	32.11	31.74	23.23
T4	14.10	4.72	26.30	7.50	16.54	24.02	31.23	21.39
T5	19.42	6.83	31.24	10.60	22.71	33.28	31.83	23.54
T6	14.77	4.97	26.90	8.10	17.77	25.85	31.33	21.91
T7	15.10	5.27	28.51	8.52	18.63	27.15	31.47	22.22
T8	25.40	8.30	34.28	12.27	25.86	38.12	32.19	24.09
T9	23.73	7.45	32.87	11.57	24.41	35.98	32.17	23.93
T10	12.78	4.14	24.15	7.37	14.98	28.34	21.57	20.35
SE (m+)	1.61	0.42	0.08	0.02	0.04	0.04	0.05	0.05
CD (<i>P</i> = 0.05)	2.20	0.20	0.21	0.05	0.08	0.13	0.13	0.14
CV %	6.65	1.12	0.60	0.30	0.15	0.28	0.34	0.39

Economics: Data on cost of cultivation, gross returns, net returns and benefit-cost (B:C) ratio, pooled over two years, are presented in Table 4. Treatment *T*₈ recorded the highest gross returns (Rs 1,40,915/ha), net returns (Rs 95,467/ha) and B:C ratio (3.10), despite a lower cost of cultivation (Rs 45,448/ha) than *T*₁, *T*₃ or *T*₅. Treatment *T*₉ ranked second (Rs 87,074/ha net returns; B:C 2.86), followed by *T*₅ (Rs

75,422/ha; B:C 2.56), which achieved a favourable B:C ratio through a simpler two-herbicide regimen without a separate mechanical or hand-weeding operation. The unweeded control (*T*₁₀), despite the lowest cost of cultivation (Rs 39,598/ha), recorded the lowest net returns (Rs 51,710/ha) among all treatments on account of severe yield loss to weed competition.

Table 4. Economics of weed management treatments in green gram (pooled data of two years)

Treatment	Cost of cultivation (Rs/ha)	Gross returns (Rs/ha)	Net returns (Rs/ha)	B:C ratio
T1	51,848	1,29,913	78,065	2.51
T2	47,048	1,10,948	63,900	2.36
T3	49,548	1,22,270	72,722	2.47
T4	44,398	98,165	53,767	2.21
T5	48,398	1,23,820	75,422	2.56
T6	44,898	1,02,850	57,952	2.29
T7	46,198	1,07,133	60,935	2.32
T8	45,448	1,40,915	95,467	3.10
T9	46,748	1,33,820	87,074	2.86
T10	39,598	91,808	51,710	2.32

Discussion

The consistently superior growth and yield performance of T_8 (pendimethalin fb imazamox fb mechanical hoeing) and T_9 (pyroxasulfone fb halosulfuron-methyl fb hand weeding) over the remaining treatments is attributable to their three-tier structure: an effective pre-emergence herbicide controlling the first flush of germinating weeds, a post-emergence herbicide with a complementary mode of action controlling weeds escaping the pre-emergence layer, and a physical (mechanical or manual) intervention giving a final, non-chemical pass ahead of the crop's critical reproductive stages. This is consistent with reports that integrated, multi-tactic weed management outperforms single-tactic approaches by intercepting sequential weed flushes that a single intervention cannot (Riemens *et al.*, 2022) [3], (Aslam *et al.*, 2024) [5], (Bin Lukangila *et al.*, 2024) [6] and (Simić *et al.*, 2025) [7], and mirrors similar findings in a rice-wheat-mungbean rotation, where integrated tillage and weed management improved crop stand and yield relative to conventional single-pass practice (Mishra *et al.*, 2022) [8].

The marked improvement in growth parameters (plant height, branches/plant and dry weight) under T_8 and T_9 reflects reduced weed competition for light, moisture, space and nutrients during the crop's early vegetative phase, when green gram, with its short stature and slow initial growth, is otherwise poorly competitive against faster-establishing weed flora (Hirani *et al.*, 2024) [1]. This growth advantage translated directly into yield attributes: the higher number of pods per plant, seeds per pod and seed index recorded under T_8 and T_9 indicate that effective early-season weed suppression allowed greater assimilate partitioning to reproductive sink development, consistent with the general principle that weed-free conditions during the critical crop-weed competition window disproportionately benefit yield-determining, rather than purely vegetative, growth (Abbas *et al.*, 2018) [2].

The higher seed protein content recorded under T_8 and T_9 is consistent with improved nitrogen availability to the crop under effective weed control, since weeds otherwise compete directly with the crop for available soil nitrogen; this nutritional dimension of weed management, beyond the yield outcome itself, adds to the case for integrated weed management as a quality-protecting, and not merely yield-protecting, practice.

From an economic standpoint, T_8 's combination of the highest net returns with a moderate cost of cultivation, lower than T_1 , T_3 or T_5 , confirms that the most profitable treatment need not be the most input-intensive one; its advantage rests on effectively timed, complementary interventions rather than on additional spray or labour cost. This finding reinforces the importance of evaluating weed management packages on profitability, and not on biological efficacy alone, particularly for resource-constrained smallholder growers (Kumar *et al.*, 2024) [10] and (Das *et al.*, 2024) [9]. T_5 's favourable B:C ratio, achieved through a simpler two-herbicide regimen without a mechanical or hand-weeding pass, further suggests that where labour availability or machinery access is a constraint, a well-timed two-tactic herbicide sequence remains a practically attractive alternative to the top-ranked three-tactic treatments, consistent with reports that herbicide-only integrated regimens can approach the profitability of more input-intensive combinations under favourable conditions (Gonzalez-Andujar, 2023) [4].

Treatments relying on a single herbicide application without a complementary post-emergence or mechanical/manual follow-up (T_4 , T_6 and T_7) consistently ranked in the lower half of the treatment set, only marginally outperforming the unweeded control. This confirms that a single herbicide application, however well chosen, is generally insufficient for season-long weed management in green gram, and that combining it with a second, differently timed or differently acting intervention is necessary to realise the crop's full growth and yield potential.

Conclusion

Integrated weed management combining a pre-emergence herbicide with a post-emergence herbicide and a mechanical or manual follow-up operation significantly improved the growth, yield attributes, seed yield, seed quality and profitability of green gram over single-tactic weed management approaches. Among the ten treatments evaluated, pendimethalin 1.0 kg/ha (PE) followed by imazamox 75 g/ha (30 DAS) followed by mechanical hoeing (45 DAS) (T_8) recorded the highest seed yield (12.27 q/ha, 66.5% over control), seed protein content (24.09%), net return (Rs 95,467/ha) and benefit-cost ratio (3.10), and is recommended as the most effective and economical weed management package for green gram cultivation in the central Narmada valley agro-climatic zone of Madhya Pradesh and comparable regions. Pyroxasulfone 0.75 kg/ha (PE) followed by halosulfuron-methyl 75 g/ha (25 DAS) followed by hand weeding (45 DAS) (T_9) is recommended as an equally effective alternative where labour is preferred over mechanical operations.

Acknowledgement

The authors gratefully acknowledge the Faculty of Agriculture, Rabindranath Tagore University, Raisen, Madhya Pradesh, for providing the experimental farm, laboratory facilities and technical support necessary to carry out this investigation, and the Department of Agronomy for its continued academic guidance throughout the study.

References

- Hirani AK, Korav S, Rajanna GA, Elansary HO, Mahmoud EA. Determination of critical crop-weed competition period: Impact on growth, nutrient dynamics and productivity of green gram (*Vigna radiata*). *Heliyon*. 2024;10(17):e36855.
- Abbas T, Zahir ZA, Naveed M, Kremer RJ. Limitations of Existing Weed Control Practices Necessitate Development of Alternative Techniques Based on Biological Approaches. *Adv Agron*. 2018;147:239-280.
- Riemens M, Sønderkov M, Moonen AC, Storkey J, Kudsk P. An Integrated Weed Management framework: A pan-European perspective. *Eur J Agron*. 2022;133:126443.
- Gonzalez-Andujar JL. Integrated Weed Management: A Shift towards More Sustainable and Holistic Practices. *Agronomy*. 2023;13(10):2646.
- Aslam MT, Maqbool R, Khan I, Chattha MU, Nawaz M, Shah AN *et al.* Efficacy of Different Pre and Post Emergence Herbicide Application on Late Sown Maize Crop Under Variable Planting Density. *Int J Plant Prod*. 2024;18(2):229-238.
- Bin Lukangila MA, Tabu HI, Mugisho DB, Lubobo AK, Mbuyi Wa Mbombo AK. Evaluating the effects of manual hoeing and selective herbicides on maize (*Zea mays* L.) productivity and profitability. *Heliyon*. 2024;10(13):e33294.
- Simić M, Dragičević V, Tataridas A, Krachunova T, Srdić J, Gazoulis I *et al.* Integrated effects of crop rotation and different herbicide rates in maize (*Zea mays* L.) production in central Serbia. *Crop Prot*. 2025;187:106913.
- Mishra JS, Kumar R, Mondal S, Poonia SP, Rao KK, Dubey R *et al.* Tillage and crop establishment effects on weeds and productivity of a rice-wheat-mungbean rotation. *Field Crops Res*. 2022;284:108577.
- Das TK, Behera B, Nath CP, Ghosh S, Sen S, Raj R *et al.* Herbicides use in crop production: An analysis of cost-benefit, non-target toxicities and environmental risks. *Crop Prot*. 2024;181:106691.
- Kumar S, Rana SS, Abdelrahman K, Uddin MG, Fnais MS, Abioui M. Impact of conservation agriculture and weed management on carbon footprint, energy efficiency, and sustainability in maize-wheat cropping systems. *Energy*. 2024;309:133131.
- AOAC. Official Methods of Analysis. Edn 17, Association of Official Analytical Chemists, Washington DC; 2000.

12. Panse VG, Sukhatme PV. Statistical Methods for Agricultural Workers. Edn 2, Indian Council of Agricultural Research, New Delhi; 1967.

How to cite this article: Kokate HG, Verma H, Namdeo B, Rajput B, Verma AK. Effect of integrated weed management practices on growth, yield, quality and economics of green gram (*Vigna radiata* L.). *International Journal of Research in Agronomy*. 2026;9(9):688-692. doi: <https://www.doi.org/10.33545/2618060X.2026.v9.i9j.6589>

Authors

Brajkishor Rajput

Assistant Professor, Department of Soil Science, Faculty of Agriculture, Rabindranath Tagore University, Raisen, Madhya Pradesh, India

Ashok Kumar Verma

Professor and HOD, Department of Agricultural Economics, Faculty of Agriculture, Rabindranath Tagore University, Raisen, Madhya Pradesh, India