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Effect of integrated weed management on growth and yield of rainfed pigeonpea *Cajanus cajan* (L.) Millsp.

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Abstract
A field experiment was conducted during *kharif* 2025-26 at College of Agriculture, Kalaburagi, Karnataka, to evaluate integrated weed management practices in rainfed pigeonpea. Eleven treatments were tested in a Randomized Complete Block Design (RCBD) with three replications. Among the treatments tested, pre-emergence spray of diclosulam 84 % WDG at 30 g ha^{-1} *fb.* post-emergence application of quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25-30 days after sowing (DAS), supplemented with intercultivation at 45 DAS, recorded plant height (189.17 cm), primary branches (21.02 plant^{-1}), secondary branches (27.45 plant^{-1}) and total dry matter production (216.96 g plant^{-1}) at harvest, leaf area (34.93 dm^2 plant^{-1}) and leaf area index (1.29) at 135 DAS. The same treatment produced a greater number of pods (148.81 plant^{-1}), pod yield (52.69 g plant^{-1}), grain yield (1280 kg ha^{-1}), stover yield (4637 kg ha^{-1}) and biological yield (5917 kg ha^{-1}). These parameters were statistically on par with the weed-free check, which produced grain yield (1328 kg ha^{-1}) and stover yield (4733 kg ha^{-1}), and were significantly higher than those of the weedy check. Economically, it recorded gross returns (₹ 95,975 ha^{-1}), net returns (₹ 62,648 ha^{-1}) and benefit ratio (2.88). The weed-free check maintained complete weed control (100 %) and recorded greater gross returns (₹ 99,600 ha^{-1}); however, its cultivation cost (₹ 42,194 ha^{-1}) resulted in lower net returns (₹ 57,406 ha^{-1}) and benefit ratio (2.36). Gross and net returns of the sequential treatment remained statistically on par with the weed-free check. The weedy check recorded lower net returns (₹ 34,856 ha^{-1}) and benefit ratio (2.19). Thus, sequential application of diclosulam *fb.* quizalofop ethyl + imazethapyr integrated with intercultivation supported improved growth and productivity of rainfed pigeonpea under the experimental conditions.

Keywords: Pigeonpea, integrated weed management, growth, yield

Introduction

Pigeonpea {*Cajanus cajan* (L.) Millsp.} commonly known as redgram, tur or arhar, is an important pulse crop belonging to the family *Fabaceae*. It contributes to food and nutritional security by supplying vegetable protein and forms an essential component of cereal-based diets. Its seeds contain approximately 20-22 % protein, together with carbohydrates, essential amino acids and minerals (Saxena *et. al.*, 2002) [9]. Besides grain, pigeonpea provides fodder, fuelwood and livestock feed through its foliage, stems and milling by-products. Its capacity for biological nitrogen fixation also contributes to soil fertility, making it valuable in diversified farming systems under rainfed conditions. Pigeonpea occupies a substantial area in India and contributes considerably to domestic pulse production. According to Agricultural Statistics at a Glance 2024 [1]-25 (Anonymous, 2026), the crop was cultivated over 4.34 million hectares in India during 2024 [1]-25, with a production of 3.62 million tonnes and an average productivity of 836 kg ha^{-1}. During the same period, Karnataka accounted for 1.75 million hectares, producing 1.00 million tonnes with an average productivity of 572 kg ha^{-1}. The state contributed 40.3 % of the national pigeonpea area and 27.5 % of production. The lower average productivity in Karnataka compared with the national average highlights the importance of improving crop-management practices that support crop establishment, growth and yield formation.

Weed competition is an important constraint to pigeonpea productivity, particularly during the initial stages of crop growth. Slow early growth and wider row spacing delay canopy development, allowing weeds to establish and compete for moisture, nutrients, light and space. Successive weed flushes during the *kharif* season can prolong this competition and restrict crop development. Vivek *et al.* (2003) [12] identified 30-60 days after sowing as a critical period of crop-weed competition and reported better yield attributes and grain yield when the crop remained weed-free. Similarly, Singh and Sekhon (2013) reported grain-yield reductions of 31.0–52.8 % under uncontrolled weed infestation across different years. These findings demonstrate the importance of timely weed management in protecting pigeonpea productivity. Hand weeding and intercultivation can reduce weed competition when undertaken at appropriate stages. However, rainfall, unsuitable soil conditions and labour availability can delay these operations under rainfed cultivation. Such delays allow weeds to compete during sensitive stages of crop establishment and vegetative development. Integration of herbicide application with manual or mechanical operations offers an opportunity to maintain weed suppression across successive growth stages. Singh and Sekhon (2013)

demonstrated that application of pendimethalin integrated with hand weeding or ridging improved weed control and grain yield compared with uncontrolled weed infestation.

Pre-emergence application of herbicides suppresses the initial weed flush, whereas post-emergence application controls susceptible weeds that escape early treatment or emerge subsequently. Sequential application can therefore extend weed suppression during crop establishment and active growth. Nath *et al.* (2023) [7] reported effective reduction in weed growth and dry matter through pre-emergence application of pendimethalin followed by post-emergence application of imazethapyr in pigeonpea. Crop responses to weed-management practices can vary with weed flora, rainfall distribution, soil conditions and the timing of field operations. Comparative evaluation under local conditions is therefore necessary to identify practices that sustain growth and improve yield. Accordingly, the present investigation was undertaken during *kharif* 2025-26 at College of Agriculture, Kalaburagi, Karnataka, to evaluate pre and post emergence application of weedicides for improving growth and productivity of rainfed pigeonpea.

Materials and Methods

The field experiment was conducted during *kharif* 2025-26 at the H-14 block of the College of Agriculture, Kalaburagi, University of Agricultural Sciences, Raichur, Karnataka. The soil was medium-deep black clay, with pH (8.02), electrical conductivity (0.59 dS m^{-1}), organic carbon (0.49 %) and available nitrogen, phosphorus and potassium (229, 49 and 374 kg ha^{-1}, respectively). Eleven treatments were evaluated in a randomized complete block design with three replications. Gross and net plot sizes were 5.4 m × 4.2 m and 3.6 m × 3.6 m, respectively.

Treatments and crop management

The treatments comprised pre-emergence application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (T1) or diclosulam 84 % WDG at 30 g ha^{-1} (T2); post-emergence application of propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} (T3) or quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} (T4); and the four sequential combinations T1 *fb.* T3 (T5), T2 *fb.* T3 (T6), T1 *fb.* T4 (T7) and T2 *fb.* T4 (T8). The remaining treatments were one hand weeding at 30 DAS *fb.* intercultivation at 45 DAS (T9), a weedy check (T10) and a weed-free check (T11). Post-emergence application was undertaken at 25–30 DAS, and treatments T3–T8 received one intercultivation at 45 DAS. The weed-free check was maintained through three hand weedings and two intercultivations.

Pigeonpea variety TS-3R was sown on 4 July 2025 at a spacing of 90 cm × 30 cm using a seed rate of 12.5 kg ha^{-1}. Recommended crop husbandry and plant-protection practices were followed uniformly. Pre-emergence application of herbicides was undertaken on the day after sowing. A knapsack sprayer fitted with a flat-fan nozzle was used, with spray volumes of 750 and 500 l ha^{-1} for pre- and post-emergence application, respectively.

Growth observations

Growth observations were recorded at 45, 90 and 135 DAS and at harvest. This paper presents plant height and branching at harvest, leaf area and leaf area index at 135 DAS, and total dry matter production at all four observation stages. Plant height was measured from ground level to the base of the last opened leaf on five randomly selected and tagged plants per plot and expressed in centimetres. Primary and secondary branches were counted separately and expressed as number $plant^{-1}$.

Leaf area was estimated by the leaf-disc method on a dry-weight basis following Vivekanandan *et al.* (1972) [13]. It was calculated as $LA = (W_a/Wd) \times A$, where LA is leaf area (dm^2 $plant^{-1}$), W_a is the oven-dry weight of all leaves, including the ten sampled discs, Wd is the oven-dry weight of the ten discs, and A is their total area (dm^2). Leaf area index was calculated as LAI = LA/P, where P is the ground area occupied by one plant, following Sestak *et al.* (1971) [10]. At the adopted spacing, P was 27 dm^2 (2700 cm^2).

For dry matter estimation, five plants were randomly sampled at each stage, air-dried and subsequently oven-dried at 65–70 °C to constant weight. Dry weights of leaves and stems were recorded at all stages, while pod dry weight was recorded at 135 DAS and at harvest. Total dry matter production was calculated by summing the dry weights of leaves, stems and pods, wherever present, and expressed as g $plant^{-1}$.

Yield observations and statistical analysis

Yield attributes were recorded from five representative plants harvested separately at physiological maturity. Pods were counted and expressed as number $plant^{-1}$. Seeds from these plants were separated by threshing, cleaned and weighed to determine yield per plant. One hundred seeds from the produce of each plot were counted and weighed to determine 100-seed weight. Plants from the net plot were harvested and threshed, and cleaned grain weight was converted to grain yield in kg ha^{-1}. The remaining plant material was dried and weighed to determine stover yield. Biological yield was calculated as the sum of grain and stover yields. Harvest index was calculated as grain yield divided by biological yield and expressed as a dimensionless fraction, following Donald (1962) [4].

Data were subjected to analysis of variance appropriate to a randomized complete block design following Gomez and Gomez (1984) [5]. Treatment means were compared using the critical difference (CD) at the 5 % significance level wherever the F-test was significant. Standard error of the mean (SEm ±) and CD values are presented with the treatment means.

Results and Discussion

Growth parameters

Plant height

Weed management practices significantly influenced plant height at harvest (Table 1). Pre-emergence application of diclosulam *fb.* post-emergence application of quizalofop ethyl + imazethapyr integrated with intercultivation (T8) recorded plant height (189.17 cm), which was statistically on par with the weed-free check (193.68 cm) and significantly higher than the weedy check (159.96 cm). The four sequential treatments (T5–T8) were statistically on par with the weed-free check. Reduced competition during establishment and subsequent growth may have improved the availability of moisture, nutrients and light for crop development. Narolia *et al.* (2024) [6] likewise reported improved plant height following sequential application of herbicides supplemented with intercultivation in pigeonpea.

Table 1: Plant height and branching of pigeonpea at harvest as influenced by weed management practices

Treatment	Plant height (cm)	Primary branches (no. plant^{-1})	Secondary branches (no. plant^{-1})
T1: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE)	169.27	14.22	20.57
T2: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE)	170.28	13.41	22.25
T3: Application of propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	167.27	12.38	18.27
T4: Application of quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	170.23	12.70	19.45
T5: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE) *fb.* propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	181.03	17.68	23.59
T6: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE) *fb.* propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	184.86	19.55	26.32
T7: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE) *fb.* quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	183.13	18.92	25.07
T8: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE) *fb.* quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	189.17	21.02	27.45
T9: One hand weeding at 30 DAS *fb.* IC at 45 DAS	173.64	16.52	23.41
T10: Weedy check	159.96	10.94	17.15
T11: Weed-free check	193.68	21.54	28.45
SEm ±	4.71	1.36	1.66
CD at 5 %	13.89	4.03	4.89

Note: One intercultivation at 30 DAS was common to T3–T8. DAS: days after sowing; PE: pre-emergence; PoE: post-emergence; IC: intercultivation; *fb.*: followed by; *a.i.*: active ingredient; CS: capsule suspension; WDG: water-dispersible granules; EC: emulsifiable concentrate; ME: microemulsion; SEm: standard error of the mean; CD: critical difference.

Primary and secondary branches

Application of diclosulam *fb.* quizalofop ethyl + imazethapyr integrated with intercultivation (T8) recorded primary branches (21.02 plant^{-1}) and secondary branches (27.45 plant^{-1}) at harvest (Table 1). These values were statistically on par with the weed-free check (21.54 and 28.45 plant^{-1}, respectively) and significantly higher than the weedy check (10.94 and 17.15 plant^{-1}, respectively). All four sequential treatments were statistically on par with the weed-free check for both branching parameters. Improved resource availability under these treatments may have favoured the initiation and retention of branches, providing more sites for reproductive development. The response is consistent with the benefits of sustained weed management reported by Singh and Sekhon (2013) and Narolia *et al.* (2024) [6].

Leaf area and leaf area index

At 135 DAS, application of diclosulam *fb.* quizalofop ethyl + imazethapyr integrated with intercultivation (T8) recorded leaf area (34.93 dm² plant^{-1}) and leaf area index (1.29). These were statistically on par with the weed-free check (36.00 dm² plant^{-1} and 1.33) and significantly higher than the weedy check (24.31 dm² plant^{-1} and 0.90; Table 2). Treatments T5–T8 were statistically on par with the weed-free check for both parameters. Reduced weed interference may have supported leaf expansion and retention, allowing the crop to develop a larger photosynthetic canopy. The correspondence between leaf area, branching and dry matter production suggests that improved canopy development contributed to the biomass response. These observations are consistent with the favourable growth conditions associated with integrated weed management described by Badvel *et al.* (2024) [3].

Table 2: Leaf area and leaf area index at 135 DAS, and yield attributes of pigeonpea as influenced by weed management practices

Treatment	Leaf area (dm² plant^{-1})	Leaf area index	Pods (no. plant^{-1})	Pod yield (g plant^{-1})
T1: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE)	26.97	1.00	130.58	36.20
T2: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE)	27.83	1.03	131.51	36.07
T3: Application of propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	24.73	0.92	126.09	36.18
T4: Application of quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	25.47	0.94	128.46	40.50
T5: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE) *fb.* propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	30.96	1.15	139.12	44.92
T6: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE) *fb.* propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	33.73	1.25	143.25	48.41
T7: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE) *fb.* quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	31.51	1.17	141.14	46.68
T8: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE) *fb.* quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	34.93	1.29	148.81	52.69
T9: One hand weeding at 30 DAS *fb.* IC at 45 DAS	28.43	1.05	135.20	43.13
T10: Weedy check	24.31	0.90	119.44	38.04

T11: Weed-free check	36.00	1.33	156.69	55.03
SEm ±	1.77	0.07	6.70	3.20
CD at 5 %	5.22	0.19	19.72	9.37

Note: One intercultivation at 30 DAS was common to T3–T8. DAS: days after sowing; PE: pre-emergence; PoE: post-emergence; IC: intercultivation; *fb.*: followed by; *a.i.*: active ingredient; CS: capsule suspension; WDG: water-dispersible granules; EC: emulsifiable concentrate; ME: microemulsion; SEm: standard error of the mean; CD: critical difference.

Total dry matter production

Total dry matter production increased with crop age and differed significantly among treatments at each observation stage (Table 3). Application of diclosulam *fb.* quizalofop ethyl + imazethapyr integrated with intercultivation (T8) recorded dry matter production (12.64, 62.33, 163.49 and 216.96 g plant^{-1}) at 45, 90 and 135 DAS and harvest, respectively. Corresponding values under the weed-free check were 13.35, 63.62, 168.61 and 226.02 g plant^{-1}. These two treatments were statistically on par at all four stages, whereas the weedy check recorded significantly lower dry matter production (5.38, 44.90, 118.06 and 167.33 g plant^{-1}, respectively) than T8. The four sequential treatments (T5–T8) were statistically on par with the weed-free check at 45, 90 and 135 DAS. At harvest, T6, T7 and T8 remained statistically on par with the weed-free check. Higher dry matter production under these treatments may have resulted from reduced competition during successive growth stages, together with improved branching and canopy development. In contrast, continued weed interference in the weedy check may have restricted resource acquisition and assimilate production. Badvel *et al.* (2024) [3] reported improved dry matter production through integration of pre-emergence application of pendimethalin, mechanical weeding and post-emergence application of quizalofop ethyl. Nath *et al.* (2023) [7] also demonstrated the value of sequential application of herbicides in reducing weed growth in pigeonpea.

Table 3: Total dry matter production (g plant^{-1}) of pigeonpea at different growth stages as influenced by weed management practices

Treatment	45 DAS	90 DAS	135 DAS	At harvest
T1: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE)	7.40	51.03	134.33	184.93
T2: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE)	7.98	52.01	137.23	189.10
T3: Application of propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	6.07	47.12	126.15	178.94
T4: Application of quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	6.77	48.68	130.54	182.54
T5: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE) *fb.* propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	11.25	57.59	151.89	199.49
T6: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE) *fb.* propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	12.26	61.07	157.69	208.40
T7: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE) *fb.* quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	11.71	59.43	154.04	203.67
T8: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE) *fb.* quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	12.64	62.33	163.49	216.96
T9: One hand weeding at 30 DAS *fb.* IC at 45 DAS	9.10	53.26	139.93	192.04
T10: Weedy check	5.38	44.90	118.06	167.33
T11: Weed-free check	13.35	63.62	168.61	226.02
SEm ±	0.73	2.38	5.72	7.74
CD at 5 %	2.17	7.03	16.86	22.84

Note: One intercultivation at 30 DAS was common to T3–T8. DAS: days after sowing; PE: pre-emergence; PoE: post-emergence; IC: intercultivation; *fb.*: followed by; *a.i.*: active ingredient; CS: capsule suspension; WDG: water-dispersible granules; EC: emulsifiable concentrate; ME: microemulsion; SEm: standard error of the mean; CD: critical difference.

Yield attributes and yield

Pods per plant

Application of diclosulam *fb.* quizalofop ethyl + imazethapyr integrated with intercultivation (T8) produced pods (148.81 plant^{-1}), which were statistically on par with the weed-free check (156.69 plant^{-1}) and significantly higher than the weedy check (119.44 plant^{-1}; Table 2). Treatments T5–T8 were statistically on par with the weed-free check. Improved branching and dry matter production under sequential treatments may have supported pod initiation and retention. The relationship between improved crop growth and pod production agrees with the findings of Narolia *et al.* (2024) [6], who reported favourable yield-attribute responses to sequential application of herbicides integrated with intercultivation.

Pod yield per plant

Application of diclosulam *fb.* quizalofop ethyl + imazethapyr integrated with intercultivation (T8) recorded pod yield (52.69 g plant^{-1}), which was statistically on par with the weed-free check (55.03 g plant^{-1}) and significantly higher than the weedy check (38.04 g plant^{-1}; Table 2). Treatments T6 and T7, with pod yields of 48.41 and 46.68 g plant^{-1}, respectively, also remained statistically on par with the weed-free check. The higher yield per plant under T8 was associated with improved pod production and biomass accumulation. This response suggests that maintaining favourable conditions during vegetative and reproductive growth supported yield formation.

100-seed weight

Differences in 100-seed weight were non-significant among treatments. Application of diclosulam *fb.* quizalofop ethyl + imazethapyr integrated with intercultivation (T8) recorded 100-seed weight (10.94 g). The absence of a significant treatment effect indicates that the yield response was more clearly expressed through pod production and total crop

biomass than through individual seed weight under the experimental conditions.

Grain yield

Weed management significantly influenced grain yield (**Table 4**). Application of diclosulam *fb.* quizalofop ethyl + imazethapyr integrated with intercultivation (T8) produced grain yield (1280 kg ha^{-1}), which was statistically on par with the weed-free check (1328 kg ha^{-1}) and significantly higher than the weedy check (854 kg ha^{-1}). Application of diclosulam *fb.* propaquizafop + imazethapyr (T6) and application of pendimethalin *fb.* quizalofop ethyl + imazethapyr (T7), each supplemented with intercultivation, also remained statistically on par with the weed-free check, recording grain yields of 1214 and 1193 kg ha^{-1}, respectively. Grain yield under T8 was 49.9 % higher than under the weedy check.

The grain-yield response was associated with improved branching, canopy development, dry matter production and pod number. Sequential application of herbicides, together with intercultivation, may have reduced competition across successive weed flushes and enabled the crop to use available resources more effectively. The results agree with Nimbargi *et al.* (2021) and Ansari *et al.* (2022) [2, 8], who reported favourable pigeonpea yield responses to application of post-emergence herbicide combinations. Singh and Sekhon (2013) and Nath *et al.* (2023) [7] similarly demonstrated the importance of timely and sustained weed management for pigeonpea productivity.

Stover and biological yields

Application of diclosulam *fb.* quizalofop ethyl + imazethapyr integrated with intercultivation (T8) recorded stover yield (4637 kg ha^{-1}) and biological yield (5917 kg ha^{-1}), which were statistically on par with the weed-free check (4733 and 6061 kg ha^{-1}, respectively; Table 4). The weedy check recorded significantly lower stover yield (3724 kg ha^{-1}) and biological yield (4578 kg ha^{-1}) than T8. All four sequential treatments (T5–T8) were statistically on par with the weed-free check for these parameters. Higher stover and biological yields were consistent with the greater dry matter production measured during crop growth. Improved biomass production following integrated weed management was also reported by Badvel *et al.* (2024) [3].

Table 4: Grain, stover and biological yields of pigeonpea as influenced by weed management practices

Treatment	Grain yield (kg ha^{-1})	Stover yield (kg ha^{-1})	Biological yield (kg ha^{-1})
T1: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE) *fb.* IC at 30 DAS	1050	4036	5086
T2: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE) *fb.* IC at 30 DAS	1071	4091	5162
T3: Application of propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	990	3776	4766
T4: Application of quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	1010	3913	4923
T5: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE) *fb.* propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	1171	4372	5543
T6: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE) *fb.* propaquizafop 2.5 % + imazethapyr 3.7 % w/w ME at 100 g *a.i.* ha^{-1} at 25–30 DAS (PoE)	1214	4581	5795
T7: Application of pendimethalin 38.7 % CS at 0.75 kg ha^{-1} (PE) *fb.* quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	1193	4460	5653
T8: Application of diclosulam 84 % WDG at 30 g ha^{-1} (PE) *fb.* quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30 DAS (PoE)	1280	4637	5917
T9: One hand weeding at 30 DAS *fb.* IC at 45 DAS	1126	4257	5383
T10: Weedy check	854	3724	4578
T11: Weed-free check	1328	4733	6061
SEm ±	49	155	183
CD at 5 %	144	457	539

Note: One intercultivation at 30 DAS was common to T3–T8. DAS: days after sowing; PE: pre-emergence; PoE: post-emergence; IC: intercultivation; *fb.*: followed by; *a.i.*: active ingredient; CS: capsule suspension; WDG: water-dispersible granules; EC: emulsifiable concentrate; ME: microemulsion; SEm: standard error of the mean; CD: critical difference.

Table 5: Economics of Pigeonpea cultivation as influenced by different weed management practices

Treatments	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T_1: Pendimethalin 38.7 % CS @ 0.75 kg ha^{-1} (PE)	31694	78750	47056	2.48
T_2: Dichlosulam 84 % WDG @ 30 g ha^{-1} (PE)	31452	80325	48873	2.55
T_3: Propaquizafop 2.5 % + Imazethapyr 3.7 % w/w ME @ 100 g *a.i.* ha^{-1} at 25-30 DAS (PoE)	32444	74225	41781	2.29
T_4: Quizalofop ethyl 7.5 % + Imazethapyr 15 % w/w EC @ 438 ml ha^{-1} at 25-30 DAS (PoE)	32069	75750	43681	2.36
T_5: Pendimethalin 38.7 % CS @ 0.75 kg ha^{-1} (PE) *fb.* Propaquizafop 2.5 % + Imazethapyr 3.7 % w/w ME @ 100 g *a.i.* ha^{-1} at 25-30 DAS (PoE)	33944	87800	53856	2.59
T_6: Dichlosulam 84 % WDG @ 30 g ha^{-1} (PE) *fb.* Propaquizafop 2.5 % + Imazethapyr 3.7 % w/w ME @ 100 g *a.i.* ha^{-1} at 25-30 DAS (PoE)	33702	91050	57348	2.70

T_7: Pendimethalin 38.7 % CS @ 0.75 kg ha^{-1} (PE) *fb*. Quizalofop ethyl 7.5 % + Imazethapyr 15 % w/w EC @ 438 ml ha^{-1} at 25-30 DAS (PoE)	33569	89450	55881	2.66
T_8: Dichlosulam 84 % WDG @ 30 g ha^{-1} (PE) *fb*. Quizalofop ethyl 7.5 % + Imazethapyr 15 % w/w EC @ 438 ml ha^{-1} at 25-30 DAS (PoE)	33327	95975	62648	2.88
T_9: One hand weeding at 30 DAS *fb*. IC at 45 DAS	36194	84450	48256	2.33
T_{10}: Weedy check	29194	64050	34856	2.19
T_{11}: Weed free check	42194	99600	57406	2.36
S.Em. ±	-	3649.5	3649.5	0.107
C. D. at 5%	-	13170	10765.91	0.32

Note: One IC is common for T_3 to T_8 DAS: Days After Sowing*a.i.*: Active Ingredient *fb*: Followed by CS: Capsule Suspension WDG: Water Dispersible Granules EC: Emulsifiable Concentrate IC: Intercultivation ME: Microemulsion PE: Pre-emergence PoE: Post-emergence

Harvest index

Harvest index did not differ significantly among treatments. Application of diclosulam *fb*. quizalofop ethyl + imazethapyr integrated with intercultivation (T8) recorded harvest index (0.22). Although weed management affected grain and biological yields, there was no significant evidence of a change in the proportion of total above-ground biomass allocated to grain. The productivity response was therefore associated primarily with improved biomass production and yield formation under the experimental conditions.

Economics of pigeonpea cultivation as influenced by different weed management practices

Significant variation was observed among the weed management practices with respect to gross returns, net returns and B ratio, while the cost of cultivation varied according to the inputs and field operations involved.

Cost of cultivation (₹ ha^{-1})

The cost of cultivation was higher under the weed-free check (₹ 42,194 ha^{-1}), followed by one hand weeding at 30 DAS *fb*. intercultivation at 45 DAS (₹ 36,194 ha^{-1}). Among the herbicidal treatments, the cost ranged from ₹ 31,452 to ₹ 33,944 ha^{-1}, whereas the weedy check recorded a lower cost of ₹ 29,194 ha^{-1}.

The higher cost under the weed-free treatment could be attributed to the greater labour requirement for repeated manual weed removal. In contrast, herbicide-based treatments involved comparatively lower expenditure on labour and intercultural operations, resulting in a moderate cost of cultivation.

Gross returns (₹ ha^{-1})

The weed-free check recorded significantly higher gross returns (₹ 99,600 ha^{-1}) and was statistically on par with application of dichlosulam *fb*. quizalofop ethyl + imazethapyr (₹ 95,975 ha^{-1}), application of dichlosulam *fb*. propaquizafop + imazethapyr (₹ 91,050 ha^{-1}), application of pendimethalin *fb*. quizalofop ethyl + imazethapyr (₹ 89,450 ha^{-1}) and application of pendimethalin *fb*. propaquizafop + imazethapyr (₹ 87,800 ha^{-1}). The weedy check recorded lower gross returns (₹ 64,050 ha^{-1}).

The improvement in gross returns under effective weed management practices was mainly due to better weed suppression, reduced crop-weed competition and consequent improvement in seed yield. Poor weed control in the weedy check resulted in greater competition for moisture, nutrients, light and space, which reduced crop productivity and gross returns.

Net returns (₹ ha^{-1})

Significantly higher net returns were recorded with application of dichlosulam *fb*. quizalofop ethyl + imazethapyr (₹ 62,648 ha^{-1}). It remained statistically on par with the weed-free check (₹ 57,406 ha^{-1}), application of dichlosulam *fb*. propaquizafop + imazethapyr (₹ 57,348 ha^{-1}), application of pendimethalin *fb*. quizalofop ethyl + imazethapyr (₹ 55,881 ha^{-1}) and application of pendimethalin *fb*. propaquizafop + imazethapyr (₹ 53,856 ha^{-1}). The weedy check recorded lower net returns (₹ 34,856 ha^{-1}).

The higher net returns with sequential application of dichlosulam *fb*. quizalofop ethyl + imazethapyr could be attributed to the favourable balance between increased seed yield and comparatively lower weed-management cost. Although the weed-free treatment produced higher gross returns, the additional labour expenditure reduced its net monetary advantage.

BC ratio

A higher BC ratio was obtained with application of dichlosulam *fb*. quizalofop ethyl + imazethapyr (2.88), which was statistically on par with application of dichlosulam *fb*. propaquizafop + imazethapyr (2.70), application of pendimethalin *fb*. quizalofop ethyl + imazethapyr (2.66) and application of pendimethalin *fb*. propaquizafop + imazethapyr (2.59). The weedy check recorded a lower B ratio of 2.19.

The higher BC ratio under sequential herbicide application indicated greater economic efficiency due to effective weed control, higher crop yield and reasonable expenditure on weed management. Thus, the treatment producing higher yield did not necessarily result in the higher B ratio, as profitability was also influenced by the cost incurred for weed control.

These findings were in conformity with Rai *et al*. (2016) [14], who reported improved weed control with sequential use of pre- and post-emergence herbicides in pigeonpea. Panda *et al.* (2018) [15] also observed higher economic returns under integrated herbicide-based weed management and emphasized that higher yield or gross returns did not always correspond to a higher B ratio because of variation in weed-control costs. Similar economic benefits of effective herbicide combinations in pigeonpea were also reported by Singh and Kushwaha (2023) [16].

Conclusion

Pre-emergence application of diclosulam 84 % WDG at 30 g ha^{-1} *fb*. post-emergence application of quizalofop ethyl 7.5 % + imazethapyr 15 % w/w EC at 438 ml ha^{-1} at 25–30

DAS, supplemented with intercultivation at 30 DAS, improved growth and yield of rainfed pigeonpea during kharif 2025 at Kalaburagi. The treatment produced grain yield (1280 kg ha^{-1}), stover yield (4637 kg ha^{-1}) and biological yield (5917 kg ha^{-1}), statistically on par with the weed-free check. Grain yield was 49.9 % higher than under the weedy check. Differences in 100-seed weight and harvest index were non-significant. The treatment was an effective weed-management option under the experimental conditions; evaluation across additional seasons and locations would help establish the consistency of its performance.

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