



# Enhancing Summer Black Gram Productivity through Combined Herbicide Application: A Growth, Yield and Economic Analysis

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**Abstract**— A field experiment was conducted during the summer season of 2019 at the Hill Millet Research Station, Rajendrapur Farm, N. A. U., Waghai to study the efficacy of combined herbicides in summer black gram (*Vigna mungo* L.). The soil was characterized as clayey, low in available nitrogen, medium in available phosphorus, and fairly rich in available potassium. The study comprised ten weed management treatments:  $T_1$ : Pendimethalin 900 g ha<sup>-1</sup> as pre-emergence + one hand weeding (HW) at 30 days after sowing (DAS);  $T_2$ : Sodium acifluorfen + clodinafop-propargyl (ready-mix) 250 g ha<sup>-1</sup> as post-emergence at 20 DAS;  $T_3$ : Imazethapyr + pendimethalin (RM) 750 g ha<sup>-1</sup> as pre-emergence;  $T_4$ : Imazethapyr + imazamox (RM) 70 g ha<sup>-1</sup> as pre-emergence;  $T_5$ : Imazethapyr + propaquizafop (RM) 125 g ha<sup>-1</sup> as post-emergence at 20 DAS;  $T_6$ : Quizalofop-p-ethyl 100 g ha<sup>-1</sup> post-emergence at 20 DAS;  $T_7$ : Fenoxaprop-p-ethyl 100 g ha<sup>-1</sup> post-emergence at 20 DAS;  $T_8$ : Two hand weedings at 20 and 40 DAS;  $T_9$ : Unweeded control;  $T_{10}$ : Weed-free treatment. These treatments were evaluated on black gram cv. GU-1, arranged in a Randomized Block Design (RBD) with three replications.

The results indicated that plant population was unaffected by the treatments; however, growth parameters were significantly influenced.  $T_{10}$  (weed-free treatment) recorded the tallest plants and highest number of branches, followed by  $T_1$  and  $T_2$ . Yield attributes such as number of pods per plant and pod length showed significant variation, whereas seeds per pod, test weight, and harvest index were not significantly affected. The highest seed yield (1083.33 kg ha<sup>-1</sup>) and haulm yield (2456.79 kg ha<sup>-1</sup>) were recorded under  $T_{10}$ , closely followed by  $T_1$ ,  $T_2$  and  $T_8$ . Economic analysis revealed that although the highest gross returns were obtained under weed-free conditions, the maximum net returns (₹54,812 ha<sup>-1</sup>) and benefit-cost ratio (1:2.86) were achieved with  $T_2$  treatment. Thus, sodium acifluorfen + clodinafop-propargyl applied at 20 DAS proved to be the most economically viable and efficient weed management practice for summer black gram under South Gujarat conditions.

**Keywords**— Black gram, Herbicides, Growth, Yield, Economics.

## I. INTRODUCTION

Pulses are an integral part of the Indian agricultural economy, ranking after cereals and oilseeds in terms of acreage, production, and economic value. They are a rich source of protein and energy; however, in India, these crops are largely cultivated under resource-poor conditions, resulting in low productivity. This is mainly due to the unavailability of quality seed at the proper

time, cultivation on marginal and sub-marginal lands, imbalanced fertilizer use, and non-adoption of improved crop management practices (Choudhary, 2009; Pooniya et al., 2015).

Among the pulse crops, black gram [*Vigna mungo* (L.) Hepper], commonly known as urd bean or mash, is an important short-duration legume crop cultivated extensively in India. The crop is highly valued for its high protein and phosphoric acid content and forms an integral component of diversified cropping systems due to its adaptability to varied agro-climatic conditions. India is the largest producer of black gram, contributing more than 70 percent of global production, followed by Myanmar and Pakistan. During 2023–24, black gram occupied nearly 4 million ha with a production of approximately 2 million tonnes and an average productivity of 598 kg ha<sup>-1</sup> (Anonymous, 2023–24a). Among the major black gram-growing states, Madhya Pradesh ranks first in area and production, followed by Uttar Pradesh and Maharashtra (Anonymous, 2025). In Gujarat, summer black gram was cultivated over an area of 21,354 ha, with a production of 30,368 metric tonnes and an average productivity of 1422.10 kg ha<sup>-1</sup> during 2023–24 (Anonymous, 2023–24b).

Weed infestation is one of the major biological constraints limiting black gram production, particularly during the rainy season when favourable environmental conditions encourage rapid weed growth. Weeds compete aggressively with the crop for nutrients, moisture, sunlight, and space during the early stages of crop growth, resulting in poor plant development and substantial yield reduction. The critical period of crop–weed competition in black gram has been reported to occur between 25 and 35 days after sowing (Randhawa et al., 2002). Failure to control weeds during this period may result in yield losses ranging from 43.2 to 64.1 percent, depending on weed density, weed species, and duration of competition (Rathi et al., 2004). Therefore, timely and effective weed management is essential for achieving optimum crop growth and higher productivity.

Various weed management practices, including cultural, mechanical, manual, biological, and chemical methods, are employed in black gram cultivation. Among these, chemical weed control is considered one of the most effective and economical approaches when herbicides are applied at the appropriate dose and time (Dungarwal et al., 2003). However, a single herbicide may not effectively control diverse weed flora. Therefore, herbicide mixtures and sequential applications of pre- and post-emergence herbicides are gaining importance for achieving broad-spectrum weed control, reducing the risk of herbicide resistance, and improving black gram productivity.

## II. MATERIALS AND METHODS

A field experiment was conducted during the summer season of 2019 at the Hill Millet Research Station, Rajendrapur Farm, Navsari Agricultural University, to evaluate the efficacy of combined herbicides in summer black gram [*Vigna mungo* (L.) Hepper]. The experimental site was located in the Dang district of Gujarat under the South Gujarat Heavy Rainfall Zone-I (Agro-ecological Situation III). The soil of the experimental field was clayey in texture with near-neutral pH (6.9), EC 0.24 dS m<sup>-1</sup>, organic carbon 0.90%, medium available nitrogen (245 kg ha<sup>-1</sup>), medium available phosphorus (23 kg ha<sup>-1</sup>), and high available potassium (325 kg ha<sup>-1</sup>).

The experiment was laid out in a Randomized Block Design (RBD) with three replications comprising ten treatments:

- **T<sub>1</sub>**: Pendimethalin 900 g ha<sup>-1</sup> as pre-emergence (PE) + one hand weeding (HW) at 30 DAS
- **T<sub>2</sub>**: Sodium acifluorfen + clodinafop-propargyl (ready-mix) 250 g ha<sup>-1</sup> as post-emergence (PoE) at 20 DAS
- **T<sub>3</sub>**: Imazethapyr + pendimethalin (RM) 750 g ha<sup>-1</sup> as PE
- **T<sub>4</sub>**: Imazethapyr + imazamox (RM) 70 g ha<sup>-1</sup> as PE
- **T<sub>5</sub>**: Imazethapyr + propaquizafop (RM) 125 g ha<sup>-1</sup> as PoE at 20 DAS
- **T<sub>6</sub>**: Quizalofop-p-ethyl 100 g ha<sup>-1</sup> as PoE at 20 DAS
- **T<sub>7</sub>**: Fenoxaprop-p-ethyl 100 g ha<sup>-1</sup> as PoE at 20 DAS
- **T<sub>8</sub>**: Two hand weedings at 20 and 40 DAS
- **T<sub>9</sub>**: Unweeded control
- **T<sub>10</sub>**: Weed-free treatment

The black gram variety Gujarat Urad-1 (GU-1) was sown on 18 February 2019 at a spacing of 45 cm × 10 cm after seed treatment with fungicide and *Rhizobium* culture.

The field was prepared by ploughing, harrowing, and planking to obtain a fine tilth. A basal dose of 20 kg N ha<sup>-1</sup> and 40 kg P<sub>2</sub>O<sub>5</sub> ha<sup>-1</sup> was applied through urea and single super phosphate, respectively. Herbicides were applied using a knapsack sprayer fitted with a flat-fan nozzle calibrated to deliver 500 L water ha<sup>-1</sup>. Pendimethalin, imazethapyr + pendimethalin, and imazethapyr + imazamox were applied as pre-emergence herbicides, whereas sodium acifluorfen + clodinafop-propargyl, imazethapyr + propaquizafop, quizalofop-p-ethyl, and fenoxaprop-p-ethyl were applied as post-emergence treatments. Thinning and gap filling were carried out to maintain optimum plant population. Five irrigations were provided during the crop season as per crop requirement.

Observations recorded included growth and yield attributes such as plant population, plant height, branches per plant, days to 50% flowering, days to maturity, pods per plant, seeds per pod, pod length, test weight, seed yield, haulm yield, harvest index, protein content, and protein yield. Weed parameters including weed flora, weed population, weed dry weight, weed control efficiency (WCE), and weed index (WI) were also recorded.

The crop was harvested at physiological maturity during the fourth week of May 2019. The harvested produce was sun-dried, manually threshed, and cleaned seed yield was recorded treatment-wise. Economic analysis included computation of gross returns, net returns, and benefit:cost (B:C) ratio based on prevailing market prices and cost of cultivation.

The experimental data were statistically analyzed using analysis of variance (ANOVA) as outlined by Panse and Sukhatme (1985). Treatment means were compared using the critical difference (CD) test at the 5% level of significance. Weed population data were subjected to square-root transformation prior to statistical analysis following the procedure described by Steel and Torrie (1960).

### III. RESULTS AND DISCUSSION

#### 3.1 Growth and Growth Attributes

Significant differences in plant height and number of branches per plant were observed among the weed management treatments, whereas plant population at 20 DAS and at harvest, days to 50% flowering, and days to maturity remained non-significant.

Plant height at harvest was significantly influenced by weed management practices. Treatment T<sub>10</sub> recorded the highest plant height (51.47 cm), which remained statistically comparable with T<sub>1</sub>, T<sub>2</sub>, T<sub>6</sub>, and T<sub>8</sub>, while the lowest plant height (41.40 cm) was observed under T<sub>9</sub>. The increased plant height under T<sub>10</sub> may be attributed to effective weed control up to 45 DAS, corresponding to the critical crop–weed competition period, which minimized crop–weed competition and provided favourable conditions for crop growth.

The highest number of branches per plant at harvest was also recorded under T<sub>10</sub> (6.67), which was statistically comparable with T<sub>2</sub> (5.87), whereas the lowest value (4.07) was observed under T<sub>9</sub>. Improved soil physical conditions and a weed-free environment throughout the crop growth period under these treatments might have promoted better crop growth and branching. These results are in agreement with the findings of Kumar and Kundra (2001) and Mishra (2006). The data further indicated that weed management treatments did not exert any significant effect on days to 50% flowering and days to maturity of summer black gram.

**TABLE 1**  
**INFLUENCE OF VARIOUS WEED MANAGEMENT TREATMENTS ON GROWTH ATTRIBUTES OF SUMMER BLACK GRAM (*VIGNA MUNGO* L.)**

Treatments	Plant height (cm)	Branches per plant	Days to 50% flowering	Days to maturity
T <sub>1</sub> : Pendimethalin 900 g/ha as PE + 1 HW at 30 DAS	45.53	5.33	40.17	81.13
T <sub>2</sub> : Sodium acifluorfen + clodinafop-propargyl (RM) 250 g/ha as PoE at 20 DAS	50.6	5.87	39.6	80.6
T <sub>3</sub> : Imazethapyr + pendimethalin (RM) 750 g/ha as PE	42.93	5.07	40.53	81.53
T <sub>4</sub> : Imazethapyr + imazamox (RM) 70 g/ha as PE	43.4	4.93	39.2	80.2
T <sub>5</sub> : Imazethapyr + propaquizafop (RM) 125 g/ha as PoE at 20 DAS	42.47	5	39.6	80.2
T <sub>6</sub> : Quizalofop-p-ethyl 100 g/ha PoE at 20 DAS	45.53	5.4	40.67	81.67
T <sub>7</sub> : Fenoxaprop-p-ethyl 100 g/ha PoE at 20 DAS	44.27	5.13	40.17	80.93
T <sub>8</sub> : Two HW at 20 and 40 DAS	47.27	5.73	40.67	81.67
T <sub>9</sub> : Unweeded control	41.4	4.07	39	80
T <sub>10</sub> : Weed free	51.47	6.67	40.73	81.73
<b>SEm ±</b>	2.11	0.3	1.13	1.65
<b>CD at 5%</b>	6.27	0.91	NS	NS
<b>CV %</b>	8.04	10.02	4.87	3.54

### 3.2 Yield and Yield Attributes

The mean data on yield attributes and yield of black gram recorded at harvest revealed a significant effect of different weed management treatments on the number of pods per plant and pod length. T<sub>10</sub> recorded the highest number of pods per plant (50.53), which remained statistically comparable with T<sub>2</sub>, T<sub>6</sub>, and T<sub>8</sub>, whereas the lowest number of pods per plant (25.13) was observed under the unweeded control (T<sub>9</sub>).

Pod length was also significantly influenced by weed management treatments. The maximum pod length (4.93 cm) was recorded under T<sub>10</sub>, which was statistically comparable with T<sub>1</sub>, T<sub>2</sub>, T<sub>6</sub>, T<sub>7</sub>, and T<sub>8</sub>, while the minimum pod length (3.33 cm) was observed under T<sub>9</sub>. The improvement in these yield attributes may be attributed to effective weed control, which reduced crop–weed competition and ensured better availability of moisture, nutrients, light, and space for crop growth. Similar findings were reported by Chin and Pandey (1991) and Gogoi et al. (1992). However, the number of seeds per pod and test weight were not significantly affected by the weed management treatments.

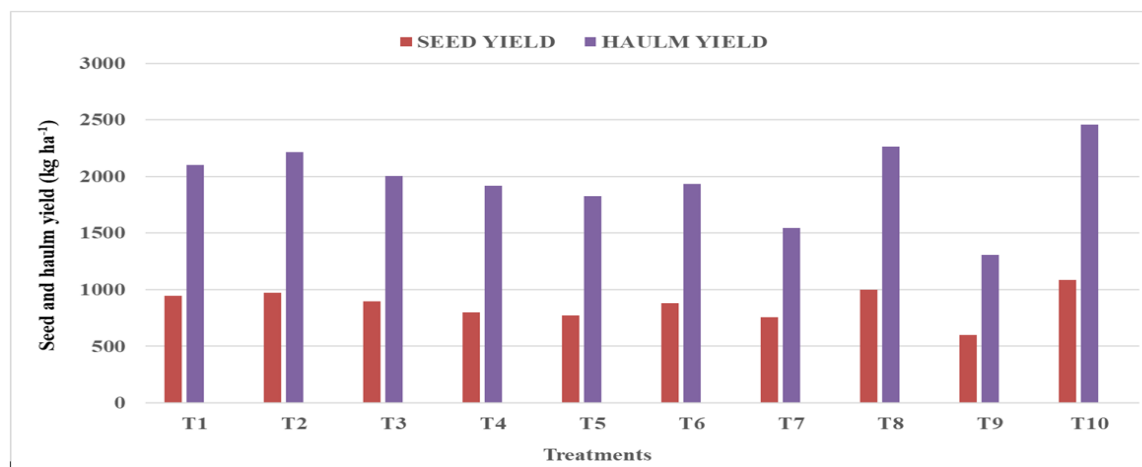
All weed management treatments produced significantly higher seed yield compared to the unweeded control (T<sub>9</sub>). The highest seed yield (1083.33 kg ha<sup>-1</sup>) was recorded under T<sub>10</sub>, which remained statistically comparable with T<sub>1</sub> (947.53 kg ha<sup>-1</sup>), T<sub>2</sub> (972.22 kg ha<sup>-1</sup>), and T<sub>8</sub> (996.91 kg ha<sup>-1</sup>). The lowest seed yield (601.85 kg ha<sup>-1</sup>) was observed under T<sub>9</sub>, possibly due to severe weed infestation causing intense competition for growth resources such as moisture, nutrients, light, and space. These results are in agreement with the findings of Bhandari et al. (2004), Angiras et al. (2006), and Vivek et al. (2008). The post-emergence herbicide applications evaluated in the study effectively controlled weeds and suppressed secondary weed emergence, resulting in lower weed biomass and higher weed control efficiency, which ultimately enhanced the yield potential of black gram.

Similarly, the highest haulm yield (2456.79 kg ha<sup>-1</sup>) was recorded under T<sub>10</sub>, which remained statistically comparable with T<sub>1</sub> (2101.85 kg ha<sup>-1</sup>), T<sub>2</sub> (2212.96 kg ha<sup>-1</sup>), and T<sub>8</sub> (2262.35 kg ha<sup>-1</sup>), whereas the lowest haulm yield (1305.56 kg ha<sup>-1</sup>) was observed under T<sub>9</sub>. Effective weed control under these treatments likely reduced crop–weed competition and promoted greater dry matter accumulation and better crop growth. The harvest index ranged from 29.77 to 32.92% across the treatments.

**TABLE 2**  
**EFFECT OF VARIOUS WEED MANAGEMENT TREATMENTS ON THE YIELD ATTRIBUTES OF SUMMER BLACK GRAM (*VIGNA MUNGO* L.)**

Treatments	Pods per plant	Seeds per pod	Pod length (cm)	Test weight (g)	Harvest Index (%)
T <sub>1</sub> : Pendimethalin 900 g/ha as PE + 1 HW at 30 DAS	44.1	4.56	4.73	4.04	30.99
T <sub>2</sub> : Sodium acifluorfen + clodinafop-propargyl (RM) 250 g/ha as PoE at 20 DAS	46.53	4.79	4.7	4.11	30.53
T <sub>3</sub> : Imazethapyr + pendimethalin (RM) 750 g/ha as PE	33.4	4.67	4.6	4.01	30.86
T <sub>4</sub> : Imazethapyr + imazamox (RM) 70 g/ha as PE	32	4.31	4.47	3.96	29.77
T <sub>5</sub> : Imazethapyr + propaquizafop (RM) 125 g/ha as PoE at 20 DAS	30.67	4.24	4.03	4	29.85
T <sub>6</sub> : Quizalofop-p-ethyl 100 g/ha PoE at 20 DAS	45.93	4.48	4.87	4.06	31.29
T <sub>7</sub> : Fenoxaprop-p-ethyl 100 g/ha PoE at 20 DAS	34.93	4.68	4.73	3.99	32.92
T <sub>8</sub> : Two HW at 20 and 40 DAS	46.13	4.73	4.8	4.12	30.68
T <sub>9</sub> : Unweeded control	25.13	4.15	3.33	3.92	31.73
T <sub>10</sub> : Weed free	50.53	5.01	4.93	4.23	30.65
<b>SEm ±</b>	1.65	0.17	0.1	0.13	1.69
<b>CD at 5%</b>	4.91	NS	0.29	NS	NS
<b>CV %</b>	7.35	6.52	3.77	5.43	9.48

PE = Pre-emergence; PoE = Post-emergence; HW = Hand weeding; RM = Ready-mix; NS = Non-significant



**FIGURE 1: Effect of different treatments on seed and haulm yield of Black Gram**

### 3.3 Economics

The highest net return (₹54,812 ha<sup>-1</sup>) was recorded under treatment T<sub>2</sub> [Sodium acifluorfen + clodinafop-propargyl (RM) at 250 g ha<sup>-1</sup> applied as post-emergence at 20 DAS], followed by T<sub>8</sub> (₹50,516 ha<sup>-1</sup>), T<sub>10</sub> (₹49,251 ha<sup>-1</sup>), and T<sub>3</sub> (₹49,080 ha<sup>-1</sup>). The lowest net return (₹28,051 ha<sup>-1</sup>) was observed under the unweeded control treatment (T<sub>9</sub>).

The B:C ratio varied considerably across treatments. The highest B:C ratio (1:2.86) was recorded under treatment T<sub>2</sub>, followed by T<sub>3</sub> (1:2.60), T<sub>4</sub> (1:2.26), and T<sub>6</sub> (1:2.25). The lowest B:C ratio (1:1.49) was observed under the weed-free treatment (T<sub>10</sub>), primarily due to higher cultivation costs associated with manual weed control.

**TABLE 3**  
**ECONOMICS AS INFLUENCED BY DIFFERENT WEED MANAGEMENT TREATMENTS IN BLACK GRAM**

Treatments	Seed income (₹ ha <sup>-1</sup> )	Haulm income (₹ ha <sup>-1</sup> )	Gross return (₹ ha <sup>-1</sup> )	Total cost of cultivation (₹ ha <sup>-1</sup> )	Net return (₹ ha <sup>-1</sup> )	B:C ratio
T <sub>1</sub>	63,485	8,407	71,892	23,211	48,681	2.1
T <sub>2</sub>	65,139	8,852	73,991	19,179	54,812	2.86
T <sub>3</sub>	59,969	8,012	67,981	18,901	49,080	2.6
T <sub>4</sub>	53,559	7,679	61,238	18,762	42,476	2.26
T <sub>5</sub>	51,698	7,296	58,994	18,668	40,326	2.16
T <sub>6</sub>	58,935	7,741	66,676	20,535	46,141	2.25
T <sub>7</sub>	50,664	6,173	56,837	19,584	37,252	1.9
T <sub>8</sub>	66,793	9,049	75,842	25,327	50,515	1.99
T <sub>9</sub>	40,324	5,222	45,546	17,495	28,051	1.6
T <sub>10</sub>	72,583	9,827	82,410	33,159	49,251	1.49

Note: T<sub>1</sub> to T<sub>10</sub> as described in Table 1 and Table 2.

#### IV. CONCLUSION

Based on one year of field experimentation, it can be concluded that post-emergence application of sodium acifluorfen + clodinafop-propargyl (ready-mix) at 250 g ha<sup>-1</sup> at 20 DAS was the most effective weed management practice for summer black gram under South Gujarat conditions. The treatment provided effective control of grassy and broad-leaved weeds, resulting in higher yield attributes, seed yield, and economic returns compared to other herbicidal treatments.

Under conditions of adequate labour availability, maintaining a weed-free crop through regular manual weeding (T<sub>10</sub>) was found equally effective in achieving higher productivity; however, the high cost of manual weeding reduced its economic viability. Therefore, application of sodium acifluorfen + clodinafop-propargyl (ready-mix) at 250 g ha<sup>-1</sup> at 20 DAS may be recommended as an efficient and economically viable weed management strategy for summer black gram in South Gujarat.

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#### CONFLICT OF INTEREST

The authors declare that there is no conflict of interest regarding the publication of this paper.

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