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Efficacy of New-Era Combined Herbicides on Weed Dynamics, Productivity and Economics of Summer Green Gram (*Vigna radiata* L.)

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***Abstract*— *A field experiment titled "Efficacy of new-era combined herbicides on weed dynamics, productivity and economics of summer green gram (Vigna radiata L.)" was carried out during the summer season of 2018 at the Instructional Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari, Gujarat. The study comprised ten weed management treatments, evaluated in a RBD (Randomized block design) with three replications. The treatments included: (T_1): pendimethalin at 900 g ha⁻¹ as pre-emergence followed by one hand weeding at 30 DAS, (T_2): sodium acifluorfen + clodinafop-propargyl (ready-mix) at 250 g ha⁻¹ as post-emergence applied at 20 DAS, (T_3): imazethapyr + pendimethalin (ready-mix) at 750 g ha⁻¹ as pre-emergence, (T_4): imazethapyr + imazamox (ready-mix) at 70 g ha⁻¹ as pre-emergence, (T_5): imazethapyr + propaquizafop (ready-mix) at 125 g ha⁻¹ as post-emergence at 20 DAS (T_6): quizalofop-p-ethyl at 100 g ha⁻¹ as post-emergence at 20 DAS, (T_7): fenoxaprop-p-ethyl at 100 g ha⁻¹ as post-emergence at 20 DAS, (T_8): two hand weedings at 20 and 40 DAS, (T_9): unweeded control and (T_{10}): weed-free check. From the results of experiment observed that significantly highest value of growth parameters yield attributes and yield of green gram seed yield, straw yield and harvest index were observed under weed free (T_{10}) treatment, which was statistically at par with the treatment pendimethalin 900 g /haas pre-emergence + 1 HW at 30 DAS (T_1) and followed by sodium acifluorfen + clodinafop-propargyl $_{(RM)}$ 250 g /haas post-emergence at 20 DAS and 2 HW at 20 and 40 DAS (T_2).*

***Keywords*— Weed, Green gram, Herbicides, Yield attributes and Yield.**

I. INTRODUCTION

Green gram (*Vigna radiata* L.), commonly known as mung bean, is a short-duration, protein-rich pulse crop of significant agronomic and nutritional importance in India. As a legume, it contributes to soil fertility through biological nitrogen fixation, making it integral to sustainable farming systems and crop rotations with cereals such as rice and wheat (Agricultural Market Intelligence Centre, PJTAU, 2025). India accounts for more than 70 per cent of the world's green gram production, positioning itself as the largest global producer and consumer of this pulse crop (Agricultural Market Intelligence Centre, PJTAU, 2025).

At the national level, green gram area and production have shown an upward trend in recent seasons. According to the third advance estimates of the Ministry of

Agriculture and Farmers Welfare, the total area under green gram in India during the 2024–25 crop year was approximately 35.27 lakh hectares, with production estimated at 3.82 million tonnes (Agricultural Market Intelligence Centre, PJTAU, 2025). The expansion in cultivated area and output reflects both increased farmer interest and supportive policy measures aimed at enhancing pulse production under India's broader agricultural development agenda. In the western Indian state of Gujarat, green gram (locally referred to as moong) constitutes an emerging but comparatively smaller component of the overall pulse production. Recent state data indicates that during the 2024–25 season, the area under moong cultivation in Gujarat reached about 1.38 lakh hectares with a production of approximately 1.26 lakh tonnes, indicating both area expansion and yield stabilization among growers (Gujarat Agriculture Department, as reported in *Pulses Production Doubles in Gujarat in Six Years*, 2026). These green gram figures are part of a broader pattern of growth in the state's pulse sector, where total pulse cultivation area expanded from 9 lakh hectares in 2019–20 to 14.39 lakh hectares in 2024–25, with total pulse output doubling over the same period (Times of India, 2026).

The sustained improvements in area, production and yield at both national and state levels underline the dynamic nature of green gram cultivation in India. Detailed analysis of spatial and temporal trends in green gram production is essential for identifying agronomic constraints and opportunities, guiding policy interventions and fostering enhanced productivity within diversified cropping systems. Weed competition is recognized as one of the major constraints in mung bean (*Vigna radiata* L.) production, particularly during the early stages of crop growth. Yield losses due to weed infestation in mung bean have been reported to range from 65.4 to 79.0 per cent, indicating the severity of this constraint under uncontrolled conditions (Dungarwal *et al*., 2003). The extent of yield reduction largely depends on the composition of the weed flora, duration of crop–weed competition and the intensity of weed infestation. Effective weed management plays a crucial role in enhancing green gram productivity, as weeds compete aggressively with crop plants for essential growth resources such as nutrients, moisture, light and space, especially during the critical early growth period of the crop. Failure to control weeds during this phase often results in irreversible yield losses. Herbicide combinations or mixtures, consisting of two or more herbicides, are increasingly used for effective and economical weed control. No single herbicide can provide complete control of diverse weed species without posing a risk of crop injury, as higher doses are often required to broaden the spectrum of weed control. In contrast, herbicide mixtures help broaden the spectrum of herbicidal activity, enabling effective control of both grassy and broad-leaved weeds while reducing the likelihood of phytotoxicity. Therefore, minimizing weed growth during the critical period of crop–weed competition is essential, as it can result in crop yields comparable to those obtained under weed-free conditions.

II. MATERIALS AND METHODS

A field experiment was carried out during the summer season of the year 2018 at College Farm, N. M. College of Agriculture, Navsari Agricultural University, Navsari (Gujarat). The experimental field was clayey in texture and showed low, medium and high rating for available N, P_2O_5 and K_2O, respectively. The soil was found slightly alkaline (P^H 8.1) with normal electrical conductivity. Green gram (*Vigna radiata* L.) variety Meha was used for the experiment. Prior to sowing, the seeds were treated with ceresan at 3.0 g kg^{-1}seed to protect against seed-borne fungal diseases. Subsequently, the seeds were inoculated with rhizobium culture to enhance biological nitrogen fixation. After treatment, the seeds were shade-dried before sowing. Sowing was carried out on 5th February 2018 using the line sowing method, maintaining a spacing of 30 cm × 10 cm between rows and plants, respectively. A seed rate of 20 kg ha^{-1} was used to ensure optimum plant population. A basal dose of fertilizers, comprising 20 kg N ha^{-1} and 40 kg P_2O_5 ha^{-1}, was applied just before sowing in the form of urea and single superphosphate (SSP), respectively. No potassium fertilizer was applied.

Herbicides evaluated in the study included pendimethalin, imazethapyr + pendimethalin (RM), imazethapyr + imazamox (RM), sodium acifluorfen + clodinafop-propargyl (RM), imazethapyr + propaquizafop (RM), quizalofop-p-ethyl, and fenoxaprop-p-ethyl. The required quantities of each herbicide were measured using a graduated measuring cylinder at the time of application, as per the respective treatment requirements. Herbicide spraying was carried out using a knapsack sprayer fitted with a flat-fan nozzle, applying 500 L of water ha^{-1} to ensure uniform coverage. Pendimethalin, imazethapyr + pendimethalin (RM), and imazethapyr + imazamox (RM) were applied as pre-emergence (PE) herbicides, whereas sodium acifluorfen + clodinafop-propargyl (RM), imazethapyr + propaquizafop (RM), quizalofop-p-ethyl, and fenoxaprop-p-ethyl were applied as post-emergence (PoE) herbicides.

Pre-emergence herbicide application was carried out on the second day after sowing, one day after irrigation. The quantity of commercial formulation required for each treatment was calculated based on the active ingredient content using the following formula:

$$Rh = \frac{Ai \times At}{Ci} \times 100$$

where,

Rh=Required quantity of trade formulation of herbicide (ha^{-1}),

Ai=Quantity of active ingredient to be applied (kg),

At=Area to be treated (ha), and

Ci = concentration of active ingredient (%) in the commercial formulation.

III. RESULTS AND DISCUSSION

Growth Attributes

Plant height recorded at 30 and 60 DAS as well as at harvest was significantly influenced by different weed management treatments. Significantly higher plant height at 30 DAS (22.43 cm), 60 DAS (41.70 cm) and at harvest (52.40 cm), along with a higher number of branches per plant (22.67), was observed under the weed-free treatment (T_{10}). This treatment remained statistically at par with T_1 (pendimethalin 900 g ha^{-1} as pre-emergence + one hand weeding at 30 DAS), T_2 (sodium acifluorfen + clodinafop-propargyl [RM] 250 g ha^{-1} as post-emergence at 20 DAS) and T_8 (two hand weddings at 20 and 40 DAS).

The significant improvement in plant height and branching under these treatments may be attributed to effective weed control during the critical period of crop–weed competition, which minimized competition for nutrients, moisture, light and space. Consequently, enhanced availability of growth resources promoted better vegetative growth and development of summer green gram. Plant height at 60 DAS was particularly sensitive to weed management practices, indicating the importance of maintaining a weed-free environment during the mid-growth stage of the crop. Similar findings was observed by Bareek *et al.* (2024) and Shilurenla *et al*. (2025).

Table 1: Plant height (cm) and branches per plant of green gram as influenced by various weed management treatments

Treatments	Plant height (cm)			Branches/plant
	30 DAS	60 DAS	At Harvest	
T_1 = Pendimethalin 900 g /ha as pre emergence + 1 HW at 30 DAS	19.27	36.87	48.87	18.87
T_2 = Sodium acifluorfen +clodinafop-propargyl $_{(RM)}$ 250 g /ha as post emergence at 20 DAS	20.13	37.80	50.40	21.67
T_3 = Imazathapyr + pendimethalin $_{(RM)}$ 750 g /ha as pre emergence	18.60	34.20	45.67	18.53
T_4 = Imazathapyr + imazamox $_{(RM)}$ 70 g /ha as pre emergence	18.67	34.77	45.90	17.67
T_5 = Imazethapyr + propaquizafop$_{(RM)}$ 125 g /ha as post emergence at 20 DAS	16.93	33.70	45.47	18.07
T_6 = Quizalofop-p-ethyl 100 g /ha post emergence at 20 DAS	19.03	35.53	48.20	19.40
T_7 = Fenoxaprop-p-ethyl 100 g /ha post emergence at 20 DAS	19.00	34.87	47.80	18.60
T_8 = 2 HW at 20 and 40 DAS	19.33	37.27	50.60	19.87
T_9 = Unweeded control	14.93	28.73	40.73	14.80
T_{10} = Weed free	22.43	41.70	52.40	22.67
S.Em. ±	1.13	1.74	1.76	1.33
C.D at 5 %	3.34	5.16	5.22	3.96
C.V. %	10.35	8.46	6.39	12.13

Yield Attributes and Yield

Yield attributes of summer green gram were significantly influenced by different weed management treatments. The weed-free treatment (T_{10}) produced the highest number of pods per plant (34.63), seeds per pod (10.20) and pod length (7.54 cm) were highest under T_{10}, remaining comparable to several other effective weed control treatments, while the unweeded control (T_9) consistently recorded the lowest values for these parameters. The improved vegetative and reproductive growth under weed-free and effectively managed treatments may be attributed to reduced competition with weeds for nutrients, moisture, light and space, which allowed better resource allocation to both vegetative development and pod formation. However, 1000-seed weight was not significantly affected by weed management, suggesting that seed size in summer green gram is largely determined by genetic potential rather than external competition. The mean data on seed and straw yield of summer green gram, recorded at harvest indicated that weed management treatments significantly influenced both parameters. The weed-free treatment (T_{10}) resulted in the highest seed yield (1319 kg ha^{-1}) and straw yield (1632 kg ha^{-1}), which were statistically comparable to T, T_2, and T_8. In contrast, the lowest seed (687 kg ha^{-1}) and straw yields (932 kg ha^{-1}) were recorded under the unweeded control (T_9), reflecting a 92% increase in seed yield under the weed-free treatment over the unweeded control. The superior yields under weed-free and effectively managed treatments can be attributed to reduced competition from weeds for essential resources such as nutrients, moisture, light and space, which enhances crop growth, dry matter accumulation and reproductive success. (Parihar *et al.*, 2024; green gram yield losses due to weed competition range from 30–40% when not controlled. Similar findings were reported by Yadav *et al.* (2019), who observed significant increases in seed and straw yield with effective weed control in green gram, while harvest index remained unaffected by weed management or planting methods.

Table 2: Yield attributes and yield of green gram as influenced by various weed management treatments

Treatments	Pods/plant	Seeds/pod	Pod length (cm)	Yield (kg/ha)		Harvest index (HI)
				Seed	Stover	
T_1 = Pendimethalin 900 g /ha as pre emergence + 1 HW at 30 DAS	29.33	9.30	7.05	1121	1367	44.05
T_2 = Sodium acifluorfen +clodinafop-propargyl $_{(RM)}$ 250 g /ha as post emergence at 20 DAS	32.87	10.07	6.85	1099	1376	44.36
T_3 = Imazathapyr + pendimethalin $_{(RM)}$ 750 g /ha as pre emergence	26.20	9.47	6.53	1030	1314	43.86
T_4 = Imazathapyr + imazamox $_{(RM)}$ 70 g /ha as pre emergence	25.17	8.67	6.41	976	1198	44.93
T_5 = Imazethapyr + propaquizafop$_{(RM)}$ 125 g /ha as post emergence at 20 DAS	24.83	8.40	6.38	932	1144	44.82
T_6 = Quizalofop-p-ethyl 100 g /ha post emergence at 20 DAS	29.53	8.97	7.48	995	1256	44.27
T_7 = Fenoxaprop-p-ethyl 100 g /ha post emergence at 20 DAS	26.77	9.67	7.05	882	1113	44.21
T_8 = 2 HW at 20 and 40 DAS	32.67	9.83	7.34	1184	1453	44.94
T_9 = Unweeded control	17.83	7.20	5.93	687	932	42.09
T_{10} = Weed free	34.63	10.20	7.54	1319	1632	44.72
S.Em. ±	1.74	0.44	0.25	77.24	90.26	0.89
C.D at 5 %	5.17	1.32	0.75	229.48	268.18	NS
C.V. %	10.76	8.37	6.35	13.08	12.23	3.49

Weed Studies

The predominant weed flora observed in the experimental field is presented in Table 3. The major monocot weeds were samo, bermuda grass and crab grass, while pig weed, amaranthus and field bindweed were the dominant dicot weeds. Nut sedge was the only sedge weed recorded during the experiment.

Weed population: Presented data revealed that weed population of monocot, dicot and sedge weeds at 30, 60 DAS and at harvest was significantly influenced by different weed management treatments. Treatment T_{10} (weed-free) recorded almost nil weed population throughout the crop growth period. Among the remaining treatments, T_8 (two hand weedings at 20 and 40 DAS) registered the lowest population of monocot, dicot and sedge weeds at 30, 60 DAS and at harvest, which was statistically at par with T_1 and T_2, while T_6 was at par in case of monocot weeds.

Table 3: Weeds population at harvest as influenced by various weed management treatments

Treatments	Weed population at 30 DAS (No. m^{-2})			Weed population at 60 DAS (No. m^{-2})			Weed population at harvest (No. m^{-2})		
	Monocot	Dicot	Sedge	Monocot	Dicot	Sedge	Monocot	Dicot	Sedge
T_1 = Pendimethalin 900 g ha^{-1} as pre emergence + 1 HW at 30 DAS	3.18 (9.67)	3.33 (10.67)	2.46 (5.67)	3.72 (13.33)	4.02 (15.67)	3.07 (9.00)	4.05 (16.00)	4.37 (18.67)	3.34 (10.67)
T_2 = Sodium acifluorfen + clodinafop-propargyl $_{(RM)}$ 250 g ha^{-1} as post emergence at 20 DAS	3.32 (10.67)	3.53 (12.00)	2.60 (6.33)	3.80 (14.00)	3.89 (14.67)	3.23 (10.00)	4.13 (16.67)	4.33 (18.33)	3.44 (11.33)
T_3 = Imazathapyr + pendimethalin $_{(RM)}$ 750 g ha^{-1} as pre emergence	3.89 (14.67)	4.09 (16.33)	2.67 (6.67)	4.60 (20.67)	4.64 (21.00)	4.29 (10.33)	4.70 (21.67)	4.84 (23.00)	3.53 (12.00)
T_4 = Imazathapyr + imazamox $_{(RM)}$ 70 g ha^{-1} as pre emergence	3.92 (15.00)	4.14 (17.00)	2.85 (7.67)	4.56 (20.33)	4.86 (23.33)	3.49 (11.67)	4.81 (22.67)	5.14 (26.00)	3.76 (13.67)
T_5 = Imazethapyr + propaquizafop$_{(RM)}$ 125 g ha^{-1} as post emergence at 20 DAS	3.47 (11.67)	4.01 (15.67)	2.72 (7.00)	4.23 (17.67)	4.66 (21.33)	3.48 (11.67)	4.40 (19.00)	5.01 (24.67)	3.80 (14.00)
T_6 = Quizalofop-p-ethyl 100 g ha^{-1} post emergence at 20 DAS	3.12 (9.33)	4.45 (19.33)	2.75 (7.33)	4.04 (16.00)	4.58 (20.67)	3.38 (11.00)	4.24 (17.67)	5.11 (25.67)	3.63 (12.67)
T_7 = Fenoxaprop-p-ethyl 100 g ha^{-1} post emergence at 20 DAS	3.43 (11.33)	4.49 (19.67)	2.90 (8.00)	4.22 (17.33)	4.70 (21.67)	3.53 (12.00)	4.44 (19.33)	5.24 (27.00)	3.89 (14.67)
T_8 = 2 HW at 20 and 40 DAS	2.79 (7.33)	3.02 (8.67)	2.11 (4.00)	3.34 (10.67)	3.48 (11.67)	2.86 (7.67)	3.66 (13.00)	3.96 (15.33)	3.13 (9.33)
T_9 = Unweeded control	6.33 (39.67)	7.34 (53.33)	2.96 (8.33)	7.25 (52.00)	8.11 (65.33)	3.62 (12.67)	7.49 (55.67)	8.19 (66.67)	3.93 (15.00)
T_{10} = Weed free	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)	0.70 (0.0)
S.Em. ±	0.19	0.18	0.20	0.18	0.20	0.13	0.17	0.16	0.11
C.D at 5 %	0.56	0.54	0.60	0.53	0.58	0.37	0.52	0.48	0.33
C.V. %	9.55	8.00	14.13	7.58	7.76	7.11	7.09	5.94	5.88

*Data in parenthesis indicate square root transformation $\sqrt{(X+0.5)}$ value and out side parenthesis indicate actual value.

The unweeded control (T_9) recorded the highest population of monocot, dicot, and sedge weeds. The superior performance of T_8 may be attributed to timely removal of weeds during the critical crop–weed competition period, which prevented weed establishment, reduced regrowth, and minimized soil seed bank replenishment. Repeated hand weeding also disrupted weed root systems, resulting in lower weed emergence at later growth stages. Similar findings related to Chaudhary *et al*. (2011) and Singh and Yadav (2014).

Dry weed weight (kg ha^{-1}): Data presented in Table 4 indicated that dry weed weight at harvest was significantly influenced by weed management treatments. The unweeded control (T_9) recorded the highest dry weed biomass (2062 kg ha^{-1}). Among the weed management practices, T_8 (two hand weedings at 20 and 40 DAS) resulted in the lowest dry weed weight (315 kg ha^{-1}), which was statistically at par with T_1 (437 kg ha^{-1}). The reduced weed biomass under T_8 may be attributed to effective and timely removal of weeds during the critical competition period, leading to reduced weed growth, suppression of regrowth, and depletion of assimilate accumulation in weeds.

Table 4: Dry weed weight, weed control efficiency and weed index as influenced by various weed management treatments

Treatments	Dry weed weight (kg ha^{-1})	WCE (%)	WI (%)
T_1 = Pendimethalin 900 g ha^{-1} as pre emergence + 1 HW at 30 DAS	437	78.83	15.22
T_2 = Sodium acifluorfen + clodinafop-propargyl $_{(RM)}$ 250 g ha^{-1} as post emergence at 20 DAS	493	76.07	16.14
T_3 = Imazathapyr + pendimethalin $_{(RM)}$ 750 g ha^{-1} as pre emergence	501	75.72	22.09
T_4 = Imazathapyr + imazamox $_{(RM)}$ 70 g ha^{-1} as pre emergence	556	73.03	26.10
T_5 = Imazethapyr + propaquizafop$_{(RM)}$ 125 g ha^{-1} as post emergence at 20 DAS	569	72.41	29.48
T_6 = Quizalofop-p-ethyl 100 g ha^{-1} post emergence at 20 DAS	539	73.76	24.28
T_7 = Fenoxaprop-p-ethyl 100 g ha^{-1} post emergence at 20 DAS	603	70.81	33.21
T_8 = 2 HW at 20 and 40 DAS	315	84.69	10.07
T_9 = Unweeded control	2062	0.00	48.28
T_{10} = Weed free	-	100	0.00
S.Em. ±	51.68	-	-
C.D at 5 %	153.54	-	-
C.V. %	14.72	-	-

Weed control efficiency (%): Weed control efficiency (WCE) at harvest varied significantly among treatments. The weed-free treatment (T_{10}) recorded the highest WCE (100%), followed by T_8 (82.87%). The overall trend of WCE was:

$T_{10} > T_8 > T_1 > T_2 > T_3 > T_6 > T_4 > T_5 > T_7 > T_9$. Higher WCE under T_{10} and T_8 was due to complete or repeated elimination of weeds, which restricted weed establishment and growth throughout the crop period.

Weed index (%): Weed index (WI), which indicates yield reduction due to weed competition, was lowest under T_{10}, followed by T_8 (10.07%). The trend of WI among treatments was: $T_{10} < T_8 < T_1 < T_2 < T_3 < T_6 < T_4 < T_5 < T_7 < T_9$. Lower WI under T_8 can be attributed to effective weed suppression during early and mid-crop growth stages, resulting in reduced crop–weed competition and better utilization of nutrients, moisture and light by the crop.

Table 5: Economics as influenced by different weed management treatments in green gram

Treatments	Yield (kg ha^{-1})		Income (₹ ha^{-1})		Gross return (₹ ha^{-1})	Total cost of Cultivation (₹ ha^{-1})	Net return (₹ ha^{-1})	B: C Ratio
	Seeds	Straw	Seeds	Straw				
T_1	1083	1367	64982	4786	69768	23756	46012	1.94
T_2	1099	1376	65922	4815	70737	19190	51547	2.69
T_3	1031	1314	61856	4600	66456	18912	47544	2.51
T_4	977	1199	58608	4195	62803	18773	44030	2.35
T_5	932	1144	55946	4005	59951	18679	41272	2.21
T_6	996	1256	59740	4396	64136	20546	43590	2.12
T_7	883	1114	52964	3899	56863	19595	37268	1.90

T_8	1184	1453	71062	5085	76147	26406	49741	1.88
T_9	687	932	41248	3261	44509	17506	27003	1.54
T10	1319	1632	79166	5712	84878	33348	51530	1.55

Selling price of green gram Seed = ₹ 60 kg^{-1}

Straw = ₹ 3.5 kg^{-1}

Economics: Among different treatment of weed management, the highest net return ₹ 51,547 was obtained with treatment T_2 (Sodium acifluorfen + clodinafop-propargyl $_{(RM)}$ 250 g ha^{-1} as post em. at 20 DAS) followed by treatment T_{10}, T_8, T_3 and T_1 where as in case of benefit cost ratio the highest BCR value of 2.69 recorded with treatment T_2, while it was followed by T_3, T_4, T_5, T_6, T_1 and T_7. Similar, results were also reported by Khot *et al.* (2012) and Patel and Thanki (2004).

IV. CONCLUSION

Based on the results of the present field investigation, it can be concluded that sodium acifluorfen + clodinafop-propargyl (RM) @ 250 g ha^{-1} applied as post-emergence at 20 DAS proved most effective in achieving efficient weed control, higher productivity and improved economic returns in summer green gram compared to other individual and combined herbicidal treatments. The superior performance of this treatment may be attributed to its broad-spectrum control of monocot, dicot and sedge weeds during the critical crop–weed competition period, resulting in reduced weed biomass, higher weed control efficiency and lower weed index. However, under conditions of adequate labour availability, manual weeding at critical stages was found to be an equally effective alternative for maintaining weed-free conditions and ensuring potential and profitable green gram production.

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