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Evaluation of various ready mix and tank-mixed herbicides for weed control in Moong bean (*Vigna radiate* L.).

Ravikesh Kumar Pal, Durgesh Maurya, Sarvesh Kumar and Raghvendara Singh
[6]Faculty of Agriculture Science and Allied Industries, Rama University, Kanpur-209217

Abstract

An experiment was conducted involving ten different treatments in a randomized block design with three replications at the Research Farm of the Rama University Mandhana Kanpur, focusing on Moong bean during the Kharif season of 2022. The treatments included Imazethapyr at 70 g ha-1 applied pre-emergence (PRE), Imazethapyr at 70 g ha-1 applied post-emergence (POE) at the 3-4 leaf weeds stage, Imazethapyr + imazamox (RM) at 70 g ha-1 POE (3-4 leaf weeds stage), Imazethapyr + imazamox (RM) at 80 g ha-1 POE (3-4 leaf weeds stage), Pendimethalin at 1000 g ha-1 applied PRE, Imazethapyr + Pendimethalin (RM) at 1000 g ha-1 PRE, Topramezone at 25.80 g ha-1 as POE (3-4 leaf weeds stage), and Hoeing (20 & 40 DAS), along with a weedy check. A diverse range of weed flora, including *Echinochloa colona, Cynodon dactylon, Solanum nigrum, Trinthema monogyna, Celosia argentea, Cyperus rotundus, Digera arvensis, Phyllanthus niruri, and Commelina benghalensis,* was observed. The combination of pendimethalin at 1000 g ha-1 (pre-emergence) and imazethapyr at 70 g ha-1 (post-emergence at 3-4 leafy stage of weeds) proved to be the most effective in minimizing weed density and maximizing weed control efficiency, yield, and its contributing traits. This dual application strategy demonstrated its effectiveness in achieving the highest grain yield (12.60 q ha-1), revenue generation (net return Rs. 57587 ha-1), and a beneficial B: C ratio of 2.05 in Moong bean cultivation during the *Kharif* season.

Keywords: Moong bean, pre emergence, post emergence, herbicides, weed management

Introduction- Moong (Vigna mungo L.), a significant short-duration pulse crop, is cultivated in tropical and subtropical regions worldwide. Primarily grown during Kharif, occasionally during Rabi, and in the summer season with sufficient water availability, Moong serves as a sequential, catch, mixed, or sole crop. It is often planted when moisture persists after rice harvesting and before or after the harvest of other summer crops in diverse conditions. With seeds rich in minerals, vitamins, carbohydrates, and protein (25–26%), Moong bean is cultivated across approximately 4.8 million hectares, yielding a total of 25.6 lakh tonnes with a productivity of 533 kg/ha (Kushwaha et al. 2023, Agricoop.nic.in, 2020-21,). Despite its widespread cultivation, particularly in Uttar Pradesh, India, Moong bean exhibits remarkably low productivity due to various biotic and abiotic factors, with weed infestation being a significant concern. Fields of Moong bean often witness a substantial rise in weed population, with grassy weeds posing the most threat, followed by sedges and broad-leaved weeds (BLWS). Beyond direct competition with the crop, weeds also serve as a refuge for numerous pests and pathogens. The critical period for crop-weed competition is typically between 15 and 45 days after sowing, though in some cases, it may extend to 25–35 days after sowing according to Randhawa et al. (2002). Weeds can inflict considerable damage, accounting for up to 50% to 60% of the total harm. Effective weed control is essential during this period to enhance Moong bean yield. Various techniques, including cultural, mechanical, biological, and chemical methods, are employed for weed control, as highlighted by Fand et al. (2013). However, manual weeding, as suggested by Chand et al. (2004), is laborious, time-consuming, expensive, and often challenging due to the unavailability of laborers during critical crop-weed competition phases, as noted by Dheer and Yadav (2021). In pursuit of an alternative, chemical herbicides such as pendimethalin and fluchloralin have been extensively studied and are now recommended for weed control in Moong bean due to their proven efficiency.

The pre-emergence application of both these herbicides led to issues with weeds that emerged later, affecting the crop. In light of this, new-generation herbicides like imazamox and imazethapyr, known for their effectiveness when used independently or in pre-formulated combinations, have been evaluated across various pulse crops, showing promising results. Against this backdrop, an experiment was formulated to standardize the application of imazamox and imazethapyr, both individually and in pre and post emergence, in conjunction with previously recommended and commonly used herbicides for effective weed management in Moong bean.

Material and Methods

The current experiment involved ten treatments designated as follows: T1 - Imazethapyr 70 g ha-1 applied pre-emergence (PRE), T2 - Imazethapyr 70 g ha-1 applied post-emergence (POE) at the 3-4 leaf weeds stage, T3 - Imazethapyr + imazamox (RM) 70 g ha-1 POE (3-4 leaf weeds stage), T4 - Imazethapyr + imazamox (RM) 80 g ha-1 POE (3-4 leaf weeds stage), T5 - Pendimethalin 1000 g ha-1 PRE, T6 - Imazethapyr + Pendimethalin (RM) 1000 g ha-1 PRE, T7 - Topramezone 25.80 g ha-1 as POE (3-4 leaf weeds stage), and T8 - Hoeing (20 & 40 DAS), in addition to a weedy check. These treatments were implemented in a randomized block design with three replications at the Research Farm of the University, using Moong bean cv. Shekhar 2 during the Kharif season of 2022. The crop was spaced at 45 cm x 15 cm, with a plot size of 4.50 m x 4.00 m.

The experimental site's geographical coordinates are approximately 26.57° North latitude, 80.21° East longitude, and an elevation of 126 m above mean sea level. The soil at the experimental site was sandy loam, with a pH of 7.4, EC of 0.46 dSm-1, 0.53% organic carbon, 138.2 kg ha-1 available nitrogen, 14.7 kg ha-1 available P2O5, and 225.7 kg ha-1 available K2O. The field was well-prepared for optimal germination, and fertilizers were applied at the rate of 20 kg N, 60 kg P2O5, and 40 kg K2O ha-1 before sowing. Herbicides were applied using a Knapsack sprayer equipped with a flat fan nozzle, with a water volume of 500 liters per hectare. Various agronomic and plant protection measures were implemented throughout the crop growth period. Weed samples were collected from three randomly selected locations in weedy plots, and the species were identified and documented. Weed density was determined using a quadrate (0.5 m x 0.5 m) from each plot's three randomly selected locations. Weed control efficiency (WCE) was calculated using the following formula: WCE (%) =W0-W1/ W0 X 100

Where,
W0 =Weed dry wten in weedy plot
W1= Weed dry wten in treated plot

To assess ancillary characteristics, ten plants were randomly chosen. Grain yield was determined by adjusting to a moisture content of 12% in q/ha based on the net plot area of each treatment replication. The harvest index was calculated using Donald's formula (1962), expressed as Economic yield divided by Biological yield multiplied by 100. Net return was computed by deducting cultivation expenses from the gross return of each specific treatment. Additionally, the Benefit: Cost ratio was derived by dividing the net return by the cultivation cost of each particular treatment. Finally, the data were analyzed using standard statistical methods.

Results and Discussion

Weed papulation

The documented weed flora from the study revealing the persistence of several weed species that inflicted damage on the experimental fields. Notably, grassy weeds such as *Echinochloa colona and Cynodon*

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dactylon were prevalent. Broadleaf weeds included *Solanum nigrum*, *Alternanthera spp.*, *Trinthema monogyna*, and *Celosia argentea. Cyperus rotundus* was identified as a sedge, while other weeds comprised *Digera arvensis*, *Phyllanthus niruri*, and *Commelina benghalensis*. The majority of the weeds exhibited an annual habitat, except for *Cynodon dactylon and Cyperus rotundus*, which were identified as perennial. These findings align with previous reports by Chand et al. (2004), Punia et al. (2009), and Fand et al. (2013) Kushwaha et al. 2023.

Plant height (cm)

Compared to the application of post-emergence herbicides, pre-emergence herbicide applications led to increased plant hten. A significantly greater plant hten was observed with the use of imazethapyr + pendimethalin (RM) at 1000 g ha-1 applied pre-emergence, in comparison to other weed control treatments. However, it was on par with treatments T5 and T1. Among post-emergence herbicide treatments, the application of imazethapyr + imazamox (RM) at 80 g ha-1 during the 3-4 leaf weed stages resulted in significantly taller plants than treatments T4, T7, and T1. In contrast to traditional weed management methods, hoeing performed at 20 and 40 days after sowing led to notably taller plants. This was attributed to the fact that narrow-leaved weeds were more effectively controlled, reducing crop competition and consequently increasing plant hten. The weedy check plot exhibited the lowest plant hten. These findings closely align with the results reported by Nandan et al. (2011) Kushwaha et al. 2023, and Meena et al. (2011).

Number of primary branches plant^{-1}

The data clearly indicated a substantial increase in the number of primary branches per plant with the application of various herbicide treatments. Specifically, the use of imazethapyr + pendimethalin (RM) at 1000 g ha-1 pre-emergence resulted in a significantly higher number of primary branches per plant compared to treatments T5 and T1. Regarding post-emergence herbicide treatments, the application of imazethapyr + imazamox (RM) at 80 g ha-1 demonstrated a significantly higher number of primary branches per plant than T5 and T1. Although the application of Imazethapyr + imazamox (RM) at 80 g ha-1 during the 3-4 leaf weed stage resulted in a greater number of primary branches per plant compared to Imazethapyr + imazamox (RM) at 70 g ha-1 during the same stage, the difference did not reach statistical significance.

Hoeing conducted at 20 and 40 days after sowing notably increased the number of primary branches per plant compared to other weed management methods. The weedy check plot exhibited the smallest number of primary branches per plant. This could be attributed to the treatments promoting a more extensive horizontal crop development, leading to a higher number of branches per plant and improved weed control efficacy. Similar findings were reported by Sharma (2009) Kushwaha et al. 2023, and Singh et al. (2004).

Number of secondary branches plant^{-1}

The use of imazethapyr + pendimethalin (RM) at 1000 g ha-1 resulted in a significantly higher number of secondary branches per plant compared to treatments T5 and T1. Regarding post-emergence herbicide treatments, the application of imazethapyr + imazamox (RM) at 80 g ha-1 led to a higher number of secondary branches per plant compared to T3, T7, and T2. In comparison to alternative weed control methods, hoeing at 20 and 40 days after sowing significantly increased the number of secondary branches per plant. Throughout the entire crop life cycle, the weedy check plot maintained the lowest number of primary branches per plant Kushwaha et al. 2023.

Number of pods plant^{-1}

Table 1 clearly illustrated the substantial influence of weed control methods on the number of pods per plant. The application of imazethapyr + pendimethalin (RM) at 1000 g ha-1 resulted in a significant increase in the number of pods per plant compared to the other treatments, specifically T5 and T1. In terms of post-emergence herbicide treatments, the application of imazethapyr + imazamox (RM) at 80 g ha-1 during the 3-4 leaf weed stages significantly produced more pods per plant than T4, T7, and T3. The highest number of pods per plant (34.21) was achieved with hoeing at 20 and 40 days after sowing, while the minimum was observed in the weedy check (26.07). Similar responses to weed control treatments were reported by Butter et al. (2008) and Rana (2013).

Number of grains pod^{-1}

The impact of various weed management measures on the number of grains per pod is evident. A significantly higher number of grains per pod (8.42) was observed with the application of imazethapyr + pendimethalin (RM) at 1000 g ha-1 compared to the other treatments. However, there were non-significant differences in the number of grains per pod between T5 and T1. Concerning post-emergence herbicide treatments, the application of imazethapyr + imazamox (RM) at 80 g ha-1 during the 3-4 leaf weed stages significantly produced more grains per pod (7.05) compared to T3 and T2, except T7. Hoeing at 20 and 40 days after planting resulted in the highest number of grains per pod (8.70), while the weedy check produced the lowest amount (5.42). Similar responses to weed management methods were also reported by Singh et al. (2003), Vaishya et al. (2005), and Butter et al. (2008).

Test weight (g)

The various weed control treatments did not exert a significant influence on the test weight Nevertheless, the highest test weight was observed with hoeing (37.77 g), followed by imazethapyr + pendimethalin (RM) at 1000 g ha-1 (37.60 g), imazethapyr + imazamox (RM) at 80 g ha-1 (36.91 g), and imazethapyr + imazamox (RM) at 70 g ha-1 (36.87 g). The lowest test weight (36.13 g) was recorded in the weedy check.

Grain yield (q/ ha)

The grain yield of Moong bean was significantly influenced by the various weed control treatments, as indicated in Table 2. Among these treatments, the application of imazethapyr + pendimethalin (RM) at 1000 g ha-1 resulted in a significantly higher grain yield (12.48 q ha-1) compared to other herbicide applications, except for T5 and T1. In terms of different post-emergence herbicides, the application of imazethapyr + imazamox (RM) at 80 g ha-1 during the 3-4 leaf weed stages yielded significantly more grain (9.66 q ha-1) compared to T3, but it was on par with T7 and T2. Hoeing at 20 and 40 days after sowing led to a substantial grain yield (12.06 q ha-1), while the weedy check exhibited the lowest yield (5.73 q ha-1). The increased grain output in response to various weed control measures in Moong bean may be attributed to enhanced plant growth and yield-promoting characteristics, coupled with a reduction in weed density and dry matter. These results align closely with findings from Jakhar et al. (2015), Shruthi et al. (2015), Dinesh et al. (2016), and Dheer and Yadav (2021).

Harvest index

The harvest index of the Moong bean crop was not significantly impacted by the various weed management methods. However, the application of imazethapyr + pendimethalin (RM) 1000 g ha-1, followed by pendimethalin, resulted in the maximum harvest index (30.15%) (Table 2).

Net return

The treatment of Imazethaypr + pendimethalin (RM) 1000 g ha-1 days after sowing produced the highest net return (Rs. 57586.40 ha-1), which was followed by hoeing (20 and 40 DAS) and Pendimethalin 1000 g ha-1 PRE (Rs. 43176.60 ha-1). In the weedy check, the lowest net return (Rs 14946.60 ha-1) was noted (Table 2). These results are consistent with those of Meena et al. (2011) and Jakhar et al. (2015).

B: C ratio

Imazethapyr + imazamox (RM) 80 g ha-1 POE (3-4 leaf weeds stage) (1.44) and Imazethapyr + imazamox (RM) 70 g ha-1 POE (3-4 leaf weeds stage) (1.37) were the herbicide treatments that yielded the highest

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benefit when combined with pendimethalin 1000 g ha-1 (1.56) and hoeing done at 20 and 40 days after sowing (1.47). In Weedy Check, the lowest benefit:cost ratio (0.54) was noted (Table-2). Ram et al. (2014) and Ankita et al. (2014) have also published findings that are comparable.

Table 1: Effects of herbicides on yield and its contributing traits and net return in Moong bean

Treatment		Plant hten (cm)	Primary branch/plant	Secondary branch/plant	No. of pod/plant	No. of grain/pod	1000 seed wten (g)
T 1	Imazethapyr at 70 g ha-1 applied pre-emergence (PRE), weeds stage	36.14	4.42	13.01	30.01	6.97	36.89
T 2	Imazethapyr at 70 g ha-1 applied post-emergence (POE) at the 3-4 leaf weeds stage,	36.12	3.38	10.49	26.58	5.71	36.53
T 3	Imazethapyr + imazamox (RM) at 70 g ha-1 POE (3-4 leaf weeds stage),	38.14	3.95	12.3	29.48	6.95	36.87
T 4	Imazethapyr + imazamox (RM) at 80 g ha-1 POE (3-4 leaf	38.66	4.32	12.59	30.22	7.05	36.91
T 5	Pendimethalin at 1000 g ha-1 applied PRE	40.12	5.58	13.49	31.59	7.62	37.03
T 6	Imazethapyr + Pendimethalin (RM) at 1000 g ha-1 PRE	40.89	6.40	14.23	33.27	8.42	37.6
T 7	Topramezone at 25.80 g ha-1 as POE (3-4 leaf weeds stage),	39.32	3.78	11.09	28.62	6.43	36.87
T 8	Hoeing (20 & 40 DAS),	42.62	6.70	15	34.21	8.7	37.77
T 9	weedy check.	30.51	3.11	9.97	26.07	5.42	36.13
T 10	Imazethapyr at 50 g ha-1 applied pre-emergence (PRE), weeds stage	32.22	4.25	40.21	30.11	5.21	35.21
Sem (+)		1.66	0.15	0.34	0.81	0.06	1.23
CD (5%)		4.98	0.45	1.01	2.42	0.18	NS

Table 2: Effects of herbicides on yield and its contributing traits and net return in Moong bean.

Treatment		Grain yield ($q\ ha^{-1}$)	Biological Yield ($q\ ha^{-1}$)	Harvest index (%)	Net return (Rs. ha-1)	B: C ratio
T 1	Imazethapyr at 70 g ha-1 applied pre-emergence (PRE), weeds stage	9.2	33.98	27.07	36144.81	1.362
T 2	Imazethapyr at 70 g ha-1 applied post-emergence (POE) at the 3-4 leaf weeds stage,	7.92	31.54	25.11	27297.61	1.022
T 3	Imazethapyr + imazamox (RM) at 70 g ha-1 POE (3-4 leaf weeds stage),	9.43	35.91	26.26	37411.81	1.382
T 4	Imazethapyr + imazamox (RM) at 80 g ha-1 POE (3-4 leaf	9.78	36.55	26.76	39572.81	1.452
T 5	Pendimethalin at 1000 g ha-1 applied PRE	10.38	38.36	27.06	43176.81	1.562
T 6	Imazethapyr + Pendimethalin (RM) at 1000 g ha-1 PRE	12.6	41.52	30.35	57586.61	2.052
T 7	Topramezone at 25.80 g ha-1 as POE (3-4 leaf weeds stage),	8.24	32.21	25.58	24758.61	0.792
T 8	Hoeing (20 & 40 DAS),	12.14	41.62	29.17	49252.81	1.482
T 9	weedy check.	5.85	28.73	20.36	14946.81	0.542

T 10	Imazethapyr at 50 g ha-1 applied pre-emergence (PRE), weeds stage	7.97	30.35	26.26	16532.61	0.952
Sem (+)		0.23	1.17	-	-	-
CD (5%)		0.79	3.54	-	-	-

Conclusion

In considering the aforementioned findings, it is concluded that, in the cultivation of moong beans during the Kharif season, the application of pendimethalin 1000 g ha-1 (pre emergence) and imazethapyr 70 g ha-1 (post emergence at 3–4 leafy stage of weeds) could be utilised to harvest the maximum grain yield (12.6 q ha-1), revenue generation (net return Rs. 57587 ha-1), and (2.05) B:C ratio.

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