AATCC Review

27 May 2025: Received
12 July 2025: Revised
23 July 2025: Accepted
23 August 2025: Available Online

https://aatcc.peerjournals.net/

Original Research Article

Open Access

# Efficacy, crop safety, and implications of premix herbicide combination (metamifop 8%, imazethapyr 4%, and imazamox 3% ME) in groundnut and its residual effect on succeeding green gram

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## ABSTRACT

*Timely weed management, through the use of pre and post-emergence herbicide, is crucial for maximizing economic yield and oil content in groundnut cultivation. However, the limited availability of effective herbicides, coupled with increasing weed resistance and concerns of crop phytotoxicity, continues to challenge sustainable weed management in groundnut. To address this issue, a two-year field trial (2021 and 2022) was conducted to evaluate the impact of post-emergence herbicides on the bio-efficacy, phytotoxicity, and profitability of groundnut cultivation. Results revealed that treatment Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 1250 mlha$^{-1}$ ($T_6$) has significantly reduced the weed density (79-95, 78-86 and 80-90%), weed dry weight (79-86, 87-93 and 77-93%) andweed control efficiency(79-90, 77-93, 77-91%) at 15, 30 and 45 DAA in comparison to unweeded control. It also shown superior performance in both the years among the herbicidal treatments in terms of plant height (33-34 cm), no. of branches per plant (6.9-7.6), no. of pods per plant (8.8-9.3) and seed yield (1950-1986 kg ha$^{-1}$) which are on par with weed-free control (35.6-36.3 cm, 7.3-8.0 no plant$^{-1}$, 9.3-9.7 no. plant$^{-1}$, 2153-2028 kg ha$^{-1}$). The treatment $T_5$has recorded a similar trend in terms of plant height (33-33.8 cm) and grain yield (1942-1978 kg ha$^{-1}$), indicating that the higher herbicide dose effectively controlled weeds and reduced crop-weed competition. The economic analysis revealed that the treatment Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 1000 ml/ha ($T_5$) has recorded higher net returns and B: C ratio, which is followed by $T_6$. The studies concluded that the Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 1000-1250 ml ha$^{-1}$ is highly effective, non-phytotoxic, and economically viable for post-emergence application in groundnut: providing a practical solution to the challenge of weed management.*

***Keywords:*** *Groundnut, Green Gram, Composite weed, Post-emergence herbicides, Yield, Weed control efficiency, Phytotoxicity.*

## INTRODUCTION

Groundnut is the major contributor to edible oil production among the oil seed crops in India, accounting for 67%, while the demand for edible oil grows by 6% each year. Therefore, to increase the oilseed production, many attempts are being made [1]. Groundnut is one of the most important oilseed crops because it contains around 50 per cent oil and 26 per cent protein. Groundnut production is declining due to improper agronomic practices and weed control methods employed during the crop production [2]. Groundnut (*Arachis hypogaea* L.) is highly vulnerable to weed infestation because its initial growth is slow, which limits its ability to compete with weeds for natural resources. Weed infestation is a significant factor that restricts the potential productivity of groundnut, particularly in bunch-type varieties that have a poor competitive ability.

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*DOI: https://doi.org/10.21276/AATCCReview.2025.13.04.125*



In India, yield losses due to heavy weed infestation in groundnut have been reported to range from 13% to 80% [3] and 70 % [4]. Weeds are one of the major challenges in sustainable crop production, causing significant losses, which can range from 15% to 80% in groundnut crops during the monsoon season [5]. They diminish yield by competing with groundnut plants for essential resources such as nutrients, moisture, space, and sunlight [6]. Unlike other crops, weeds interfere with the pegging, pod development, and harvesting of groundnuts at various stages of growth while also competing for these vital growth resources. Initial weed management is crucial for optimizing the use of essential resources in crops. Effective weed control enhances sunlight capture through a well-spread crop canopy, as well as nutrient and water absorption through better root development in a weed-free environment.

Research indicates that the critical period for crop and weed competition in groundnut is between 40 to 60 days after sowing (DAS). To achieve a higher yield of pods per hectare, timely and effective weed management during this competition period is essential. While hand weeding is an effective method, it is often tedious, time-consuming, and costly in India [7].

Delays in weeding can lead to reduced economic yield and quality of the produce, as well as an increased incidence of diseases and pests. In such cases, applying recommended herbicides may be a suitable option for comprehensive weed control. The use of pre- and post-emergence herbicides provides an effective and timely option for controlling weeds in groundnut cultivation. However, each herbicide targets a specific range of weeds. Pre-emergence (PE) herbicides are applied to manage weeds during the germination stage, but they may allow some weeds to emerge later on. These herbicides have proven to be very effective for about 20 to 25 DAS. However, late-emerging weeds can interfere with crucial stages such as pegging, pod development, and harvesting [8]. Therefore, the timing of herbicide application is critical for maximizing weed control efficiency. In this context, it is necessary to evaluate suitable premix formulations of post-emergence herbicides to control all categories of weeds, including perennial sedges, in groundnut crops. Therefore, the current investigation aims to evaluate the impact of post-emergence herbicides on the bio-efficacy, phytotoxicity, and profitability of groundnut cultivation. The goal is to develop a practical and economically feasible weed management strategy for groundnut production.

## MATERIALS AND METHODS

A consecutive two-year field experiment (2021 and 2022) was conducted to evaluate the impact of post-emergence herbicides on the bio-efficacy, phytotoxicity, and profitability of groundnut cultivation at the Instructional Farm of Uttar Banga Krishi Viswavidyalya, Pundibari, Cooch Behar, West Bengal, India. The groundnut variety 'Kanpur Local' was sown on 11$^{th}$ August 2021 and 9$^{th}$ July 2022 at 30 cm x 15 cm spacing. The experiment was laid out in a Randomized Block Design with 3 replications and 11 treatments, *i.e.*, $T_1$- Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME @ 800 ml/ha, $T_2$- Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME @ 1000 ml/ha, $T_3$- Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME @ 1250 ml/ha, $T_4$- Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 800 ml/ha, $T_5$- Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 1000 ml/ha, $T_6$- Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 1250 ml/ha, $T_7$- Imazethapyr 10% SL @ 750-1000 ml + MSO adjuvant @ 2 ml/l water, $T_8$- Imazethapyr 35% + Imazamox 35% WG @ 100 g MSO Adjuvant @ 2 ml/l water, $T_9$-Propaquizafop 2.5% + Imazethapyr 3.75% w/w ME @ 2000 ml/ha, $T_{10}$- Hand Weeding at 20 and 40 DAS, $T_{11}$- Weedy Check. The herbicide combination of Metamifop, Imazethapyr, and Imazamox under the trade name *Vostrix* is used in the present experiment. The chemical treatments were applied at 20 days after sowing (DAS) of groundnut. However, hand weeding twice was carried out at 20 and 40 DAS. Bioefficacy evaluation was done by recording the number of species-wise weed count and total biomass of major weed flora on a 1 sq. m quadrate from each plot at 15, 30, and 45 days after herbicide application (DAA). Dry weight of weeds was recorded and represented in g per sq. m. The data collected on weeds were transformed to a square root transformation ($\sqrt{X+0.5}$) for statistical analysis. The per cent weed control efficiency (WCE) was calculated at 15, 30, and 45 DAA based on the dry weight of individual weeds using the following formula:

$$WCE\ (\%) = \frac{WC - WT}{WC} \times 100$$

Where, WC = Weed dry weight in control plot; WT = Weed dry weight in treated plot

Experimental data on yield attributes was recorded from each plot (on 1 $m^2$ area basis) and yield of ground nut was recorded from each plot (on net plot basis). Phytotoxicity observations on stunting, yellowing, necrosis, wilting, chlorosis, epinasty, and hyponasty on groundnut and succeeding crop green gram were recorded at 1, 3, 7, 10, and 15 days after application (DAA). The plant injury was estimated based on the phytotoxicity rating scale (PRS) of 0 (no toxicity) to 10 (100% toxicity).

## RESULTS AND DISCUSSION

### Weed density

Herbicidal treatments had a substantial effect on weed density of different weeds identified among grasses, sedges, and broad-leaved weeds (BLW). The treatment $T_6$ (Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 1250 ml $ha^{-1}$) significantly reduced the density of all weed species by 79-95% in comparison to unweeded control (Table 1). Among different weed species, *Echinochloa colona*, *Commelina benghalensis*, *Euphorbia hirta*, and *Cyperus rotundus* densities were reduced significantly (1.4–2.5 $m^2$) in comparison to the weedy check (11.0–18.8 $m^2$). The results emphasize that treatments $T_4$ (Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 800 ml $ha^{-1}$) and $T_5$ (Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 1000 ml $ha^{-1}$) are in line with $T_6$in terms of weed suppression (75-94%). The treatments without surfactant, i.e., $T_1$-$T_3$ reflected the moderate performance and efficacy, 56-91% suppression, increasing with dose. Among the commercial formulations, the treatment $T_8$ (Imazethapyr 35% + Imazamox 35% WG + MSO adjuvant @ 100 gm $ha^{-1}$) was found to be least effective (< 50%) among the other herbicidal treatments, particularly against broad-leaved weeds and sedges.

A similar trend was reported at both 30 and 45 DAA, with $T_6$ being the most effective treatment in reducing the weed density by 78-86% and 80-90%, respectively (Table 2 and 3). The treatment performed very well in managing the crucial weeds like *Echinochloa colona*, *Commelina benghalensis,* and *Cyperus rotundus*. The treatments $T_4$ and $T_5$with lower doses, also reported comparable results with $T_6$ by suppressing the weeds by 66-82% and 66-86% at 30 and 45 DAA, respectively. The treatments, $T_1$–$T_3$ showed an increasing trend of weed control with dose by 61–76% and 66-86% suppression at 30 and 45 DAA, respectively. The commercial herbicides reported the suboptimal performance, with $T_7$ (Imazethapyr 10% SL + MSO adjuvant @ 750-1000 ml $ha^{-1}$) showing 47-68%, $T_8$ (Imazethapyr 35% + Imazamox 35% WG + MSO adjuvant @ 100 gm $ha^{-1}$) 34-65% and $T_9$ (Propaquizafop 2.5% + Imazethapyr 3.75% w/w ME @ 2000 ml $ha^{-1}$) 38-63% of inadequate suppression, particularly against broad-leaved weeds and sedges. This highlights the ineffectiveness of herbicides with a single mode of action in controlling diverse weed flora.

### Weed dry weight

The weed dry weight has varied significantly at 15 DAA across all the treatments. The treatment $T_6$ reduced the weed dry weight by 79-89% in comparison to the untreated control (Table 4). The treatment $T_5$, an intermediate dose of Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 1000 ml $ha^{-1}$, also recorded on par results (75-85%) to the higher dose $T_6$. Meanwhile, the standalone treatments $T_1$-$T_3$ exhibited moderate efficacy in reducing the weed dry weight (56-78%) in comparison to the unweeded control.

In contrast, commercial herbicide treatments such as $T_8$ (Imazethapyr 35% + Imazamox 35% WG + MSO adjuvant) were notably less effective, particularly against broad-leaved weeds and sedges, with only 45–65% suppression, with improvement reported at higher doses.

A considerable trend was reported at 30 and 45 DAA, where $T_6$ has shown a higher amount of weed suppression, reducing the weed dry weight (87-93% and 77-93%, respectively) in comparison to the unweeded control (Table 5 and 6). The lower dosage treatments $T_4$ and $T_5$ also reflected equivalent performance with $T_6$ by reducing the weed dry weight by 75-90% and 70-88% at 30 and 45 DAA, respectively. The standalone treatments ($T_1$-$T_3$) showed an increasing trend of weed control with dose by 65–82% and 70-88% suppression at 30 and 45 DAA, respectively. The commercial herbicides ($T_7$-$T_9$) continued to underperform, with weed suppression of 50–70% and 40-65%, revealing their limited effectiveness against mixed weed flora. This highlights the importance of diverse modes of action of herbicides for the suppression of mixed weed flora. The hand weeding ($T_{10}$) has shown superior weed control, but it is labour-intensive and costly.

**Weed control efficiency**

Weed control efficiency (WCE) differed considerably between treatments at 15, 30, and 45 DAA, demonstrating herbicide efficacy in controlling different weed species (Table 7). At 15 DAA, the treatment $T_6$ (Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 1250 ml $ha^{-1}$) has recorded higher weed control efficiency (79-93%) across all the weed species. This treatment has reported higher efficacy against *Cyperus rotundus* (88-90%) and *Celosia argentia* (89-93%), reflecting its broad-spectrum efficiency during both years. The treatment $T_4$-$T_6$ (Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 800-1250 ml $ha^{-1}$) has shown superior performance in terms of weed control efficiency (71-93%) compared to standalone herbicidal treatments ($T_1$-$T_3$: 64-84%), with improvement noticed at higher doses. The commercial herbicides reflected the marginal effectiveness, with $T_7$ (Imazethapyr 10% SL + MSO adjuvant @ 750-1000 ml $ha^{-1}$) showing 41-68%, $T_8$ (Imazethapyr 35% + Imazamox 35% WG + MSO adjuvant @ 100 gm $ha^{-1}$) 48-61% and $T_9$ (Propaquizafop 2.5% + Imazethapyr 3.75% w/w ME @ 2000 ml $ha^{-1}$) 58-73%, particularly against broad-leaved weeds and sedges.

A comparable trend was reported at 30 and 45 DAA, with $T_6$ showing the highest weed control efficiency of 85-93% and 85-91%, respectively. This treatment has shown outstanding performance, especially against *Commelina benghalensis* (90-91% and 82-88%) and *Euphorbia hirta* (86-93% and 87-91%), and *Cyperus rotandus* (78-81% and 84-88%) at 30 and 45 DAA, respectively. The ammonium sulphate combinations, i.e., $T_4$-$T_6$ have shown superior performance in terms of weed control efficiency (73-93% and 70-91%) compared to standalone herbicidal treatments ($T_1$-$T_3$: 63-86% and 63-83%) at 30 and 45 DAA, with improvement noticed at higher doses. The commercial herbicides reflected the marginal effectiveness, with $T_7$ (Imazethapyr 10% SL + MSO adjuvant @ 750-1000 ml $ha^{-1}$) showing 41-68%, $T_8$ (Imazethapyr 35% + Imazamox 35% WG + MSO adjuvant @ 100 gm $ha^{-1}$) 48-61% and $T_9$ (Propaquizafop 2.5% + Imazethapyr 3.75% w/w ME @ 2000 ml $ha^{-1}$) 58-73%, particularly against broad-leaved weeds and sedges.

The commercial herbicides showed substandard performance at these stages, with $T_7$-$T_9$ remaining inconsistent (52-76% and 23-78%) at 30 and 45 DAS, respectively. The progressive decline in performance of commercial herbicides compared to Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME combinations illustrate the latter's superior residual activity and resistance management potential.

The weed index was significantly lower in $T_6$ (2.07–9.4%) and $T_5$ (2.47–9.8%), indicating superior weed suppression and minimal yield reduction (Figure 1). The weed-free control (T10) maintained a weed index of zero, while the unweeded check (T11) recorded the maximum (100%) in both years. Higher weed indices in T1–T4 reflected suboptimal weed control efficacy. Overall, $T_5$ and $T_6$ were statistically comparable to the weed-free treatment, demonstrating their agronomic superiority. The lower weed population and dry matter weight observed at early and later growth stages of the crop with the application of post-emergence herbicides, attributed to higher efficacy against composite weeds, reducing crop-weed competition for groundnut [9 and 10].

**Growth and yield**

The study clearly reflects the effect of different herbicide treatments on the growth and yield of groundnut (Table 8). Among different treatments $T_6$(Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 1250 ml $ha^{-1}$) has recorded higher plant growth i.e., plant height (33-34 cm), no. of branches per plant (6.9-7.6), no. of pods per plant (8.8-9.3) and seed yield (1950-1986 kg $ha^{-1}$) (Figure 1) which are on par with weed-free control (35.6-36.3 cm, 7.3-8.0 no $plant^{-1}$, 9.3-9.7 no. $plant^{-1}$, 2153-2028 kg $ha^{-1}$). These results demonstrated that a higher dose with acombination of ammonium sulphate surfactant provided nearly complete weed control and facilitating the crop to utilize the resources efficiently. The treatment $T_5$(Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 1000 ml $ha^{-1}$) has followed the similar trend in terms of plant growth and yield, i.e., plant height (33-33.8 cm), no. of branches per plant (6.8-7.6), no. of pods per plant (8.7-9.1) and seed yield (1942-1978 kg $ha^{-1}$) in both the years. The treatment $T_4$with (Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME + Ammonium Sulphate @ 800 ml $ha^{-1}$) an intermediate dose has shown moderate performance, which is significantly lower compared to higher doses $T_5$ and $T_6$, highlighting that the intermediate dose shows only partial weed control.

Among the standalone treatments $T_1$ and $T_2$ with lower doses have recorded marginal performance over the unweeded control with moderate growth, i.e., plant height (31-32 cm), no. of branches $plant^{-1}$ (5.3-6.3), no. of pods $plant^{-1}$ (7.3-8.3), and seed yield (1340-1468 kg $ha^{-1}$). The standalone treatment $T_3$ with a higher dose has demonstrated better performance compared to $T_1$ and $T_2$. In contrast, the commercial formulations $T_7$ (Imazethapyr 10% SL + MSO adjuvant @ 750-1000 ml $ha^{-1}$) and $T_8$ (Imazethapyr 35% + Imazamox 35% WG + MSO adjuvant @ 100 gm $ha^{-1}$) has recorded the suboptimal performance with small height (28-29 cm), fewer branches per plant (5.33–5.67), reduced pod numbers per plant (6.33–7.67), and lower seed yields (1253–1342 kg $ha^{-1}$), but the treatment $T_9$(Propaquizafop 2.5% + Imazethapyer 3.75% w/w ME @ 2000 ml $ha^{-1}$) has shown marginally better performance compared to $T_7$ and $T_8$ treatments. Enhanced values of yield attributing characters and higher yield might be due to better efficacy of herbicides towards effective weed control [11 and 12].

### Bioefficacy of succeeding green gram

The investigation recorded the residual effect of Metamifop 8% + Imazethapyr 4% + Imazamox 3% ME on a succeeding green gram crop and observed no significant phytotoxic effects on germination, growth, or yield (Table 4). Germination remained high (78-83%) across all treatments and was statistically on par with hand-weeded and untreated plots. No significant differences were recorded for plant height (39-42.4 cm), branching (5.33-7.8 per plant), and pods per plant (31.7-35), seeds per pod (6.33-7.02), and seed yield (1075-1120 kg $ha^{-1}$) among all the treatments, proving that there is no residual effect. Treatments combining with ammonium sulphate ($T_4$-$T_6$) recorded marginal improved growth vigour, though differences were statistically non-significant. Other herbicide treatments ($T_7$-$T_9$) recorded marginally lower germination (79%) without affecting the crop yield. Overall, Metamifop 8% + Imazethapyr 4% + Imazamox 3% ME, even at higher doses, left no harmful residues, reinforcing its safety and suitability for sustainable groundnut and green gram rotations.

### Phytotoxicity

The phytotoxicity assessment of combined Metamifop 8% + Imazethapyr 4% + Imazamox 3% ME with surfactant on groundnut and green gram revealed that it is safe at all tested concentrations. There are no symptoms of stunting, yellowing, necrosis, chlorosis, wilting, epinasty, or hyponasty observed in either crop at 1, 3, 7, 10, or 15 DAA. The absence of phytotoxic effects across treatments assures the formulation's crop safety. These results provide strong evidence of safety regarding its use in groundnut–green gram cropping systems.

### Economics

The economic analysis showed that treatment $T_5$ achieved the highest net returns (63,920-66,080 Rs) with the B: C ratio (1.22-1.26). A higher dose, $T_6$, also ensured strong profitability (Net returns: Rs 65,910-63,750; 1.20-1.24 B: C), confirming economic viability with improved weed control. In contrast, manual weeding, despite generating higher gross returns, involved higher labour costs (60,000 Rs $ha^{-1}$), which reduced B: C ratios (1.03-1.15). Using a standalone herbicide without ammonium sulphate was less profitable (B : C 0.41-0.78), highlighting the additive's essential role. Unweeded control plots recorded the lowest net returns (4,720-8,620 Rs) with B: C ratios (0.09-0.17).

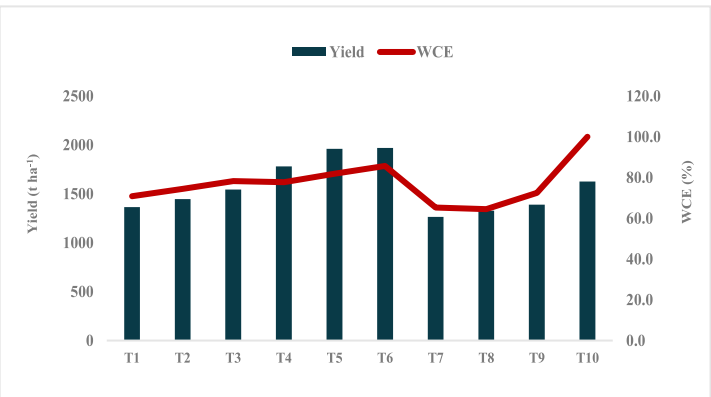


*Figure 1. Effect of Weed Management Treatments on Grain Yield and WCE (45 DAA) in Groundnut (2021 and 2022 Mean data)*

*Table 1: Effect of herbicides on weed density ($m^{-2}$) on groundnut at 15 DAA*

| Treatments | *Echinochloa colonum* | | *Physalis minima* | | *Commelina bengalensis* | | *Amaranthus viridis* | | *Celosia argentea* | | *Cyperus rotundus* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 |
| $T_1$ | 4.3 (2.31) | 4.3 (2.29) | 2.7 (1.91) | 2.3 (1.81) | 3.3 (2.08) | 2.0 (1.72) | 4.3 (2.31) | 4.0 (2.23) | 2.3 (1.82) | 2.3 (1.82) | 3.7 (2.16) | 3.0 (1.99) |
| $T_2$ | 4.0 (2.23) | 4.0 (2.23) | 2.3 (1.79) | 2.3 (1.82) | 2.7 (1.91) | 2.3 (1.82) | 3.7 (2.16) | 3.3 (2.08) | 2.0 (1.72) | 2.0 (1.72) | 3.0 (2.00) | 3.7 (2.15) |
| $T_3$ | 3.7 (2.15) | 3.3 (2.08) | 1.3 (1.47) | 1.7 (1.63) | 1.0 (1.38) | 1.7 (1.63) | 3.3 (2.03) | 2.7 (1.91) | 1.3 (1.52) | 1.7 (1.63) | 2.7 (1.91) | 2.7 (1.91) |
| $T_4$ | 2.7 (1.79) | 3.4 (1.97) | 1.6 (1.45) | 1.9 (1.55) | 1.2 (1.30) | 1.8 (1.52) | 3.5 (2.0) | 2.8 (1.82) | 1.5 (1.41) | 1.8 (1.52) | 2.6 (1.76) | 2.9 (1.84) |
| $T_5$ | 2.2 (1.64) | 2.9 (1.84) | 1.1 (1.26) | 1.3 (1.34) | 0.6 (1.05) | 1.4 (1.38) | 2.8 (1.82) | 2.2 (1.64) | 1.0 (1.22) | 1.3 (1.34) | 2.2 (1.64) | 2.3 (1.67) |
| $T_6$ | 1.8 (1.52) | 2.4 (1.70) | 0.7 (1.10) | 0.8 (1.14) | 0.5 (1.00) | 1.1 (1.26) | 2.5 (1.73) | 2.0 (1.58) | 0.7 (1.10) | 0.9 (1.18) | 1.6 (1.45) | 1.8 (1.52) |
| $T_7$ | 6.3 (2.70) | 6.0 (2.64) | 4.3 (2.31) | 4.7 (2.38) | 5.3 (2.2) | 4.7 (2.38) | 5.3 (2.51) | 5.3 (2.52) | 3.7 (2.15) | 3.3 (2.08) | 4.7 (2.38) | 3.7 (2.16) |
| $T_8$ | 7.3 (2.89) | 7.0 (2.83) | 3.3 (2.06) | 4.3 (2.30) | 5.3 (2.48) | 5.0 (2.43) | 5.0 (2.44) | 5.3 (2.52) | 3.7 (2.16) | 4.3 (2.31) | 4.3 (2.31) | 4.7 (2.38) |
| $T_9$ | 4.7 (2.38) | 5.3 (2.51) | 3.3 (2.06) | 3.7 (2.15) | 3.3 (2.08) | 3.0 (1.99) | 4.7 (2.37) | 4.3 (2.29) | 2.7 (1.88) | 3.0 (1.99) | 3.7 (2.16) | 4.3 (2.30) |
| $T_{10}$ | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) |
| $T_{11}$ | 15.3 (4.04) | 14.7 (3.96) | 10.3 (3.35) | 12.7 (3.69) | 11.3 (3.51) | 10.3 (3.35) | 12.0 (3.59) | 11.7 (3.56) | 6.0 (2.64) | 5.3 (2.52) | 11.3 (3.51) | 12.3 (3.65) |
| **SEm±** | **0.11** | 0.11 | 0.20 | 0.13 | 0.16 | 0.16 | 0.18 | 0.11 | 0.14 | 0.10 | 0.07 | 0.12 |
| **LSD (p=0.05)** | **0.32** | **0.32** | **0.60** | **0.40** | **0.48** | **0.49** | **0.56** | **0.35** | **0.44** | **0.29** | **0.20** | **0.36** |

*Values in the parentheses are square root transformed ($\sqrt{X+0.5}$) values*

*Table 2: Effect of herbicides on weed density ($m^{-2}$) on groundnut at 30 DAA*

| Treatments | *Echinochloa colonum* | | *Physalis minima* | | *Commelina bengalensis* | | *Amaranthus viridis* | | *Celosia argentea* | | *Cyperus rotundus* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 |
| $T_1$ | 8.0 (3.00) | 7.3 (2.88) | 6.3 (2.70) | 7.0 (2.80) | 6.0 (2.63) | 6.7 (2.75) | 6.3 (2.70) | 5.7 (2.58) | 4.7 (2.38) | 4.3 (2.31) | 5.3 (2.51) | 6.3 (2.71) |
| $T_2$ | 6.3 (2.71) | 5.7 (2.58) | 5.7 (2.56) | 6.3 (2.70) | 5.3 (2.52) | 5.7 (2.58) | 6.3 (2.69) | 5.0 (2.44) | 4.3 (2.29) | 4.0 (2.23) | 4.0 (2.23) | 5.0 (2.45) |
| $T_3$ | 5.0 (2.44) | 5.3 (2.52) | 4.7 (2.37) | 5.0 (2.44) | 4.3 (2.28) | 5.3 (2.52) | 4.7 (2.38) | 3.7 (2.14) | 3.3 (2.08) | 3.7 (2.16) | 3.7 (2.16) | 4.3 (2.31) |
| $T_4$ | 5.4 (2.43) | 5.4 (2.43) | 4.8 (2.30) | 4.9 (2.32) | 3.6 (2.02) | 5.2 (2.39) | 4.8 (2.30) | 3.8 (2.07) | 3.3 (1.95) | 3.8 (2.07) | 3.8 (2.07) | 4.4 (2.21) |
| $T_5$ | 4.3 (2.19) | 4.6 (2.26) | 3.9 (2.10) | 4.1 (2.14) | 2.9 (1.84) | 4.5 (2.24) | 4.0 (2.12) | 3.2 (1.92) | 2.7 (1.79) | 3.1 (1.90) | 3.3 (1.95) | 3.4 (1.97) |
| $T_6$ | 3.7 (2.05) | 3.8 (2.07) | 3.2 (1.92) | 3.5 (2.00) | 2.3 (1.67) | 3.7 (2.05) | 3.1 (1.90) | 2.7 (1.79) | 2.1 (1.61) | 2.2 (1.64) | 2.7 (1.79) | 2.6 (1.76) |
| $T_7$ | 7.7 (2.94) | 7.3 (2.88) | 9.3 (3.21) | 7.7 (2.94) | 6.7 (2.77) | 7.7 (2.94) | 6.7 (2.76) | 5.3 (2.52) | 4.7 (2.38) | 4.3 (2.31) | 5.3 (2.51) | 6.0 (2.64) |
| $T_8$ | 11.3 (3.51) | 13.0 (3.74) | 11.3 (3.51) | 10.0 (3.31) | 8.3 (3.05) | 9.0 (3.16) | 7.7 (2.94) | 9.3 (3.21) | 6.7 (2.76) | 6.7 (2.76) | 5.7 (2.57) | 6.7 (2.76) |
| $T_9$ | 8.3 (3.05) | 8.7 (3.10) | 11.0 (3.46) | 8.3 (3.05) | 7.7 (2.94) | 8.3 (3.05) | 6.0 (2.64) | 7.3 (2.89) | 8.7 (3.10) | 8.3 (3.05) | 6.0 (2.63) | 7.3 (2.87) |
| $T_{10}$ | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) |
| $T_{11}$ | 21.3 (4.72) | 19.7 (4.54) | 17.7 (4.32) | 16.7 (4.20) | 16.7 (4.19) | 17.0 (4.23) | 14.3 (3.91) | 12.7 (3.70) | 14.0 (3.87) | 13.7 (3.83) | 16.3 (4.16) | 14.7 (3.96) |
| **SEm±** | **0.10** | 0.13 | 0.14 | 0.12 | 0.18 | 0.13 | 0.12 | 0.11 | 0.10 | 0.07 | 0.14 | 0.12 |
| **LSD (p=0.05)** | **0.31** | **0.40** | **0.47** | **0.37** | **0.56** | **0.39** | **0.35** | **0.3310** | **0.32** | **0.23** | **0.42** | **0.36** |

*Values in the parentheses are square root transformed ($\sqrt{X+0.5}$) values*

***Table 3: Effect of herbicides on weed density ($m^{-2}$) on groundnut at 45 DAA***

| Treatments | *Echinochloa colonum* | | *Physalis minima* | | *Commelina bengalensis* | | *Amaranthus viridis* | | *Celosia argentea* | | *Cyperus rotundus* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 |
| $T_1$ | 3.7 (2.16) | 4.3 (2.31) | 3.3 (2.06) | 3.7 (2.16) | 3.7 (2.15) | 4.0 (2.23) | 3.7 (2.15) | 3.3 (2.08) | 1.7 (1.63) | 2.7 (1.91) | 2.3 (1.82) | 2.3 (1.81) |
| $T_2$ | 3.3 (2.08) | 3.7 (2.15) | 3.0 (1.99) | 3.3 (2.08) | 2.3 (1.82) | 3.7 (2.16) | 3.7 (2.16) | 2.7 (1.91) | 1.7 (1.61) | 2.3 (1.82) | 2.3 (1.82) | 2.0 (1.73) |
| $T_3$ | 2.3 (1.82) | 2.7 (1.90) | 2.3 (1.82) | 2.3 (1.82) | 2.7 (1.91) | 3.3 (2.08) | 3.0 (2.00) | 2.3 (1.82) | 1.3 (1.52) | 1.7 (1.63) | 1.3 (1.52) | 1.3 (1.52) |
| $T_4$ | 2.5 (1.73) | 2.7 (1.79) | 2.4 (1.70) | 2.4 (1.70) | 2.8 (1.82) | 3.6 (2.02) | 2.9 (1.84) | 2.5 (1.73) | 1.2 (1.30) | 1.9 (1.55) | 1.4 (1.38) | 1.5 (1.41) |
| $T_5$ | 1.8 (1.52) | 2.3 (1.67) | 1.8 (1.52) | 1.8 (1.52) | 2.0 (1.58) | 2.2 (1.64) | 2.3 (1.67) | 1.8 (1.52) | 0.8 (1.14) | 1.3 (1.34) | 1.0 (1.22) | 0.8 (1.14) |
| $T_6$ | 1.4 (1.38) | 1.5 (1.41) | 1.1 (1.26) | 1.2 (1.30) | 1.8 (1.52) | 1.9 (1.55) | 1.6 (1.45) | 1.2 (1.30) | 0.6 (1.05) | 1.0 (1.22) | 0.7 (1.10) | 0.7 (1.10) |
| $T_7$ | 4.0 (2.23) | 6.7 (2.77) | 5.0 (2.44) | 4.7 (2.38) | 4.7 (2.38) | 4.7 (2.38) | 5.3 (2.51) | 5.0 (2.44) | 3.7 (2.15) | 3.3 (2.08) | 3.7 (2.16) | 3.3 (2.07) |
| $T_8$ | 4.3 (2.31) | 6.3 (2.70) | 4.7 (2.38) | 4.3 (2.29) | 4.3 (2.29) | 5.3 (2.51) | 5.0 (2.44) | 3.7 (2.16) | 3.3 (2.07) | 3.0 (1.99) | 3.0 (1.99) | 3.3 (2.06) |
| $T_9$ | 3.7 (2.16) | 4.0 (2.23) | 4.3 (2.30) | 3.7 (2.16) | 4.0 (2.23) | 3.7 (2.16) | 4.3 (2.31) | 2.7 (1.91) | 2.7 (1.91) | 2.3 (1.82) | 2.3 (1.82) | 2.7 (1.90) |
| $T_{10}$ | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) |
| $T_{11}$ | 12.3 (3.65) | 13.0 (3.74) | 11.3 (3.50) | 11.7 (3.56) | 9.3 (3.21) | 10.7 (3.41) | 10.3 (3.36) | 9.7 (3.26) | 5.7 (2.58) | 6.3 (2.71) | 5.7 (2.58) | 5.7 (2.58) |
| **SEm±** | 0.08 | 0.12 | 0.12 | 0.10 | 0.11 | 0.11 | 0.10 | 0.10 | 0.14 | 0.10 | 0.10 | 0.12 |
| **LSD (p=0.05)** | **0.23** | **0.35** | **0.36** | **0.30** | **0.34** | **0.32** | **0.31** | **0.29** | **0.42** | **0.30** | **0.30** | **0.37** |

*Values in the parentheses are square root transformed ($\sqrt{X+0.5}$) values*

***Table 4: Effect of herbicides on weed dry matter accumulation (g $m^{-2}$) on groundnut at 15 DAA***

| Treatments | *Echinochloa colonum* | | *Physalis minima* | | *Commelina bengalensis* | | *Amaranthus viridis* | | *Celosia argentea* | | *Cyperus rotundus* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 |
| $T_1$ | 8.9 (3.13) | 8.3 (3.05) | 6.0 (2.65) | 6.3 (2.69) | 6.1 (2.67) | 5.8 (2.61) | 8.6 (3.09) | 7.3 (2.89) | 3.6 (2.14) | 3.7 (2.16) | 1.9 (1.71) | 1.8 (1.68) |
| $T_2$ | 7.1 (2.84) | 6.2 (2.68) | 5.9 (2.63) | 5.6 (2.57) | 5.4 (2.52) | 5.3 (2.50) | 6.4 (2.71) | 6.9 (2.80) | 2.8 (1.94) | 3.1 (2.03) | 1.2 (1.48) | 1.1 (1.44) |
| $T_3$ | 6.7 (2.76) | 5.4 (2.52) | 5.2 (2.50) | 5.2 (2.49) | 4.8 (2.41) | 4.3 (2.30) | 5.8 (2.61) | 6.3 (2.70) | 2.3 (1.82) | 2.5 (1.87) | 1.1 (1.44) | 0.8 (1.35) |
| $T_4$ | 6.8 (2.70) | 5.7 (2.49) | 5.3 (2.41) | 5.3 (2.41) | 4.9 (2.32) | 4.5 (2.24) | 4.9 (2.32) | 5.4 (2.43) | 2.0 (1.58) | 2.6 (1.76) | 1.2 (1.30) | 0.9 (1.18) |
| $T_5$ | 5.7 (2.49) | 5.1 (2.37) | 4.5 (2.24) | 4.6 (2.26) | 3.9 (2.10) | 3.6 (2.02) | 4.1 (2.14) | 4.3 (2.19) | 1.3 (1.34) | 2.0 (1.58) | 0.7 (1.10) | 0.5 (1.00) |
| $T_6$ | 5.1 (2.37) | 4.3 (2.19) | 3.9 (2.10) | 4.0 (2.12) | 3.1 (1.90) | 2.9 (1.84) | 3.2 (1.92) | 3.6 (2.02) | 1.0 (1.22) | 1.6 (1.45) | 0.5 (1.00) | 0.4 (0.95) |
| $T_7$ | 12.6 (3.68) | 12.8 (3.72) | 8.4 (3.07) | 8.4 (3.07) | 8.3 (3.05) | 7.8 (2.97) | 9.7 (3.27) | 10.9 (3.44) | 4.9 (2.43) | 4.6 (2.37) | 2.4 (1.83) | 2.1 (1.77) |
| $T_8$ | 9.9 (3.29) | 9.6 (3.25) | 7.9 (2.98) | 8.2 (3.03) | 8.2 (3.03) | 7.6 (2.93) | 9.5 (3.24) | 9.5 (3.29) | 4.0 (2.24) | 4.2 (2.27) | 2.1 (1.77) | 1.8 (1.68) |
| $T_9$ | 9.7 (3.25) | 9.3 (3.21) | 7.4 (2.90) | 7.4 (2.90) | 7.2 (2.87) | 6.9 (2.80) | 8.4 (3.06) | 9.0 (3.17) | 3.9 (2.22) | 3.9 (2.21) | 1.5 (1.58) | 1.4 (1.56) |
| $T_{10}$ | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) |
| $T_{11}$ | 24.9 (5.09) | 24.2 (5.02) | 22.3 (4.82) | 21.4 (4.73) | 18.8 (4.44) | 16.3 (4.16) | 27.0 (5.29) | 26.0 (5.19) | 14.1 (3.89) | 14.7 (3.96) | 4.1 (2.26) | 4.1 (2.25) |
| **SEm±** | **0.18** | **0.12** | **0.10** | **0.07** | **0.10** | **0.07** | **0.11** | **0.10** | **0.04** | **0.06** | **0.04** | **0.03** |
| **LSD (p=0.05)** | **0.55** | **0.35** | **0.32** | **0.22** | **0.31** | **0.22** | **0.34** | **0.32** | **0.12** | **0.17** | **0.11** | **0.10** |

*Values in the parentheses are square root transformed ($\sqrt{X+0.5}$) values*

***Table 5. Effect of herbicides on weed dry matter accumulation (g $m^{-2}$) on groundnut at 30 DAA***

| Treatments | *Echinochloa colonum* | | *Physalis minima* | | *Commelina bengalensis* | | *Amaranthus viridis* | | *Celosia argentea* | | *Cyperus rotundus* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 |
| $T_1$ | 4.8 (2.41) | 4.1 (2.26) | 3.9 (2.22) | 3.8 (2.20) | 4.0 (2.24) | 4.8 (2.41) | 4.2 (2.29) | 3.8 (2.18) | 3.8 (2.19) | 4.0 (2.24) | 3.7 (2.16) | 3.9 (2.21) |
| $T_2$ | 4.2 (2.27) | 3.7 (2.17) | 3.5 (2.13) | 3.4 (2.10) | 3.8 (2.20) | 4.4 (2.32) | 3.3 (2.08) | 3.3 (2.08) | 2.8 (1.96) | 3.3 (2.08) | 3.1 (2.03) | 3.5 (2.13) |
| $T_3$ | 3.5 (2.11) | 2.9 (1.98) | 2.9 (1.97) | 2.6 (1.89) | 2.7 (1.91) | 3.0 (2.01) | 2.2 (1.78) | 2.9 (1.96) | 2.6 (1.89) | 2.8 (1.95) | 2.9 (1.98) | 3.0 (1.99) |
| $T_4$ | 3.6 (2.02) | 3.1 (1.90) | 3.0 (1.87) | 2.8 (1.82) | 2.7 (1.79) | 28 (1.82) | 2.3 (1.67) | 3.0 (1.87) | 2.5 (1.73) | 2.9 (1.84) | 2.8 (1.82) | 3.3 (1.95) |
| $T_5$ | 2.5 (1.73) | 2.3 (1.67) | 2.1 (1.61) | 2.0 (1.58) | 2.0 (1.58) | 2.0 (1.58) | 1.6 (1.45) | 2.4 (1.70) | 2.0 (1.58) | 2.3 (1.67) | 2.5 (1.73) | 2.3 (1.67) |
| $T_6$ | 2.2 (1.64) | 1.9 (1.55) | 1.8 (1.52) | 1.2 (1.30) | 1.3 (1.34) | 1.3 (1.34) | 1.1 (1.26) | 2.1 (1.61) | 1.5 (1.41) | 1.9 (1.55) | 2.3 (1.67) | 2.0 (1.58) |
| $T_7$ | 6.8 (2.79) | 5.2 (2.48) | 4.9 (2.43) | 4.6 (2.37) | 5.0 (2.45) | 5.0 (2.46) | 4.6 (2.37) | 4.7 (2.38) | 4.6 (2.37) | 4.2 (2.29) | 4.9 (2.42) | 4.8 (2.41) |
| $T_8$ | 5.5 (2.56) | 5.7 (2.59) | 4.6 (2.37) | 4.5 (2.34) | 4.8 (2.42) | 4.7 (2.39) | 4.4 (2.32) | 4.3 (2.31) | 4.2 (2.27) | 4.1 (2.25) | 4.6 (2.37) | 4.4 (2.31) |
| $T_9$ | 4.7 (2.39) | 3.9 (2.21) | 4.2 (2.29) | 3.7 (2.17) | 4.1 (2.27) | 4.6 (2.36) | 4.1 (2.25) | 3.9 (2.21) | 3.7 (2.18) | 3.5 (2.13) | 4.0 (2.23) | 3.9 (2.21) |
| $T_{10}$ | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) |
| $T_{11}$ | 15.5 (4.03) | 16.5 (4.18) | 14.9 (3.99) | 13.8 (3.85) | 14.7 (3.96) | 14.1 (3.88) | 15.8 (4.09) | 15.4 (4.04) | 14.5 (3.94) | 13.6 (3.82) | 10.3 (3.36) | 10.4 (3.38) |
| **SEm±** | **0.13** | **0.08** | **0.04** | **0.06** | **0.05** | **0.04** | **0.06** | **0.06** | **0.05** | **0.06** | **0.05** | **0.06** |
| **LSD (p=0.05)** | **0.39** | **0.23** | **0.12** | **0.19** | **0.15** | **0.13** | **0.20** | **0.20** | **0.15** | **0.20** | **0.16** | **0.18** |

*Values in the parentheses are square root transformed ($\sqrt{X+0.5}$) values*

***Table 6: Effect of herbicides on weed dry matter accumulation (g $m^{-2}$) on groundnut at 45 DAA)***

| Treatments | *Echinochloa colonum* | | *Physalis minima* | | *Commelina bengalensis* | | *Amaranthus viridis* | | *Celosia argentea* | | *Cyperus rotundus* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 |
| $T_1$ | 4.0 (2.24) | 3.9 (2.21) | 4.2 (2.28) | 3.9 (2.21) | 4.0 (2.24) | 4.2 (2.27) | 4.2 (2.28) | 4.2 (2.29) | 5.1 (2.47) | 4.8 (2.40) | 4.3 (2.29) | 4.6 (2.36) |
| $T_2$ | 3.3 (2.08) | 3.6 (2.14) | 3.9 (2.21) | 3.4 (2.10) | 3.7 (2.17) | 3.6 (2.15) | 4.0 (2.24) | 3.6 (2.15) | 4.2 (2.28) | 4.3 (2.31) | 3.9 (2.21) | 3.6 (2.15) |
| $T_3$ | 2.3 (1.82) | 2.2 (1.79) | 3.2 (2.05) | 2.7 (1.92) | 3.7 (2.17) | 2.9 (1.97) | 3.1 (2.02) | 3.3 (2.06) | 3.7 (2.18) | 4.3 (2.29) | 3.7 (2.16) | 3.3 (2.07) |
| $T_4$ | 2.4 (1.70) | 2.5 (1.73) | 3.1 (1.90) | 2.8 (1.82) | 3.8 (2.07) | 3.2 (1.92) | 2.7 (1.79) | 3.5 (2.00) | 3.6 (2.02) | 4.5 (2.24) | 3.8 (2.07) | 3.4 (1.97) |
| $T_5$ | 1.8 (1.52) | 2.1 (1.61) | 2.4 (1.70) | 2.3 (1.67) | 3.1 (1.90) | 2.3 (1.67) | 2.1 (1.61) | 2.8 (1.82) | 3.2 (1.92) | 3.9 (2.10) | 3.2 (1.92) | 2.8 (1.82) |
| $T_6$ | 1.5 (1.41) | 1.6 (1.45) | 1.9 (1.55) | 1.7 (1.48) | 2.4 (1.70) | 1.5 (1.41) | 1.4 (1.38) | 2.0 (1.58) | 2.9 (1.84) | 3.5 (2.00) | 2.5 (1.73) | 2.3 (1.67) |
| $T_7$ | 5.2 (2.48) | 5.0 (2.44) | 5.0 (2.45) | 4.4 (2.33) | 5.0 (2.46) | 5.2 (2.49) | 5.9 (2.62) | 5.0 (2.46) | 5.7 (2.59) | 5.2 (2.50) | 4.8 (2.41) | 4.9 (2.44) |
| $T_8$ | 4.9 (2.42) | 4.6 (2.36) | 5.1 (2.48) | 9.7 (3.26) | 4.3 (2.29) | 4.2 (2.29) | 4.6 (2.37) | 4.7 (2.38) | 5.6 (2.57) | 5.2 (2.49) | 5.0 (2.45) | 4.7 (2.38) |
| $T_9$ | 3.8 (2.18) | 3.7 (2.17) | 4.0 (2.23) | 3.6 (2.13) | 3.9 (2.21) | 3.8 (2.18) | 4.2 (2.27) | 3.9 (2.21) | 5.0 (2.45) | 4.6 (2.37) | 4.0 (2.24) | 4.1 (2.25) |
| $T_{10}$ | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) | 0.0 (1.00) |
| $T_{11}$ | 11.0 (3.47) | 13.2 (3.76) | 13.0 (3.74) | 12.6 (3.69) | 13.5 (3.80) | 13.4 (3.79) | 15.7 (4.08) | 14.8 (3.98) | 19.8 (4.55) | 15.0 (4.00) | 15.5 (4.05) | 18.8 (4.45) |
| **SEm±** | **0.05** | **0.06** | **0.06** | **0.06** | **0.0.05** | **0.06** | **0.09** | **0.06** | **0.09** | **0.06** | **0.08** | **0.06** |
| **LSD (p=0.05)** | **0.15** | **0.18** | **0.19** | **0.20** | **0.16** | **0.18** | **0.26** | **0.20** | **0.28** | **0.19** | **0.24** | **0.18** |

*Values in the parentheses are square root transformed ($\sqrt{X+0.5}$) values*

*Table 7: Effect of herbicides on weed control efficiency (WCE) on ground nut (2021-2022 Mean data)*

| Treatment | *Echinochloa colonum* | | | *Physalis minima* | | | *Commelina bengalensis* | | | *Amaranthus viridis* | | | *Celosia argentea* | | | *Cyperus rotundus* | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 15 DAA | 30 DAA | 45 DAA | 15 DAA | 30 DAA | 45 DAA | 15 DAA | 30 DAA | 45 DAA | 15 DAA | 30 DAA | 45 DAA | 15 DAA | 30 DAA | 45 DAA | 15 DAA | 30 DAA | 45 DAA |
| $T_1$ | 64.9 | 70.4 | 66.8 | 71.6 | 72.8 | 68.2 | 65.2 | 69.1 | 69.5 | 69.7 | 74.2 | 71.9 | 74.8 | 72.0 | 71.0 | 53.8 | 63.4 | 73.6 |
| $T_2$ | 72.7 | 73.9 | 71.1 | 73.3 | 75.8 | 71.5 | 69.3 | 71.3 | 72.7 | 75.0 | 78.3 | 74.9 | 79.5 | 78.0 | 74.6 | 72.1 | 67.7 | 77.6 |
| $T_3$ | 75.1 | 79.1 | 80.9 | 75.8 | 80.9 | 77.2 | 73.8 | 80.1 | 75.2 | 76.8 | 83.6 | 79.0 | 83.3 | 80.8 | 76.1 | 76.9 | 71.5 | 79.2 |
| $T_4$ | 74.6 | 79.0 | 79.7 | 75.7 | 79.8 | 77.0 | 73.1 | 80.9 | 74.0 | 80.5 | 83.0 | 79.6 | 84.1 | 80.8 | 75.9 | 74.4 | 70.6 | 78.7 |
| $T_5$ | 78.0 | 78.0 | 78.0 | 79.2 | 85.7 | 81.6 | 78.6 | 86.1 | 79.9 | 84.1 | 87.2 | 87.4 | 88.5 | 84.7 | 78.9 | 85.4 | 76.8 | 82.3 |
| $T_6$ | 80.9 | 87.2 | 87.2 | 81.9 | 89.6 | 86.0 | 82.9 | 91.0 | 85.5 | 87.1 | 89.7 | 88.8 | 91.0 | 87.9 | 81.1 | 89.0 | 79.3 | 85.9 |
| $T_7$ | 47.9 | 60.9 | 68.7 | 61.3 | 66.7 | 70.5 | 53.7 | 65.0 | 71.5 | 61.0 | 69.8 | 73.6 | 66.9 | 68.4 | 71.9 | 45.0 | 53.0 | 75.9 |
| $T_8$ | 59.6 | 63.4 | 60.5 | 62.7 | 68.2 | 41.4 | 54.8 | 66.7 | 68.2 | 63.7 | 71.8 | 69.2 | 71.6 | 70.6 | 67.7 | 51.3 | 56.4 | 71.1 |
| $T_9$ | 60.3 | 71.9 | 68.7 | 65.9 | 72.2 | 70.5 | 59.1 | 69.7 | 71.5 | 66.6 | 74.2 | 73.6 | 72.9 | 74.1 | 71.9 | 64.1 | 61.7 | 75.9 |
| $T_{10}$ | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| $T_{11}$ | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |

*Table 8. Effect of herbicides on the growth and yield of groundnut and the residual effect on succeeding green gram*

| Treatment | Groundnut | | | | | | | | | | Green Gram | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Plant height (cm) | | Branches per plant | | Pod per plant | | Seed yield (kg ha$^{-1}$) | | B: C Ratio | | Germination (%) | | Plant height (cm) | | Branches per plant | | Pods per plant | | Seeds per pod | | Seed yield (kg ha$^{-1}$) | |
| | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2021 | 2022 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 | 2022 | 2023 |
| $T_1$ | 30.7 | 31.5 | 5.33 | 5.67 | 7.33 | 7.67 | 1340 | 1387 | 0.60 | 0.54 | 81.0 | 82.0 | 39.0 | 40.0 | 6.67 | 6.67 | 34.3 | 34.3 | 6.33 | 6.67 | 1092 | 1102 |
| $T_2$ | 31.5 | 31.7 | 5.67 | 6.33 | 7.67 | 8.33 | 1422 | 1468 | 0.68 | 0.62 | 81.7 | 82.3 | 40.0 | 40.3 | 6.67 | 6.67 | 33.0 | 35.0 | 6.67 | 7.00 | 1108 | 1113 |
| $T_3$ | 32.9 | 33.7 | 6.67 | 7.33 | 8.67 | 9.00 | 1512 | 1577 | 0.78 | 0.71 | 81.3 | 82.3 | 42.0 | 41.3 | 7.67 | 6.67 | 34.3 | 34.7 | 6.67 | 7.00 | 1103 | 1117 |
| $T_4$ | 31.9 | 33.2 | 6.43 | 7.53 | 8.45 | 8.87 | 1750 | 1813 | 1.09 | 1.02 | 81.1 | 81.9 | 41.8 | 41.4 | 7.73 | 6.64 | 34.1 | 33.3 | 6.39 | 6.78 | 1100 | 1120 |
| $T_5$ | 33.0 | 33.8 | 6.83 | 7.60 | 8.75 | 9.14 | 1978 | 1942 | 1.22 | 1.26 | 82.7 | 82.3 | 42.2 | 41.2 | 7.65 | 6.65 | 33.6 | 34.1 | 6.45 | 6.95 | 1109 | 1102 |
| $T_6$ | 33.2 | 34.0 | 6.90 | 7.64 | 8.80 | 9.28 | 1986 | 1950 | 1.20 | 1.24 | 83.0 | 82.5 | 42.4 | 41.7 | 7.80 | 6.62 | 32.6 | 34.1 | 6.33 | 7.02 | 1097 | 1111 |
| $T_7$ | 28.7 | 29.1 | 5.33 | 5.67 | 7.00 | 7.67 | 1253 | 1277 | 0.61 | 0.56 | 80.7 | 81.3 | 40.3 | 40.0 | 6.33 | 6.67 | 34.0 | 34.7 | 6.67 | 6.67 | 1093 | 1100 |
| $T_8$ | 28.5 | 28.9 | 5.33 | 5.67 | 6.33 | 7.00 | 1313 | 1342 | 0.53 | 0.50 | 79.7 | 79.0 | 39.7 | 40.7 | 6.33 | 6.33 | 33.3 | 34.3 | 6.33 | 6.33 | 1087 | 1098 |
| $T_9$ | 31.1 | 31.7 | 5.33 | 5.67 | 7.67 | 8.33 | 1368 | 1410 | 0.44 | 0.41 | 78.3 | 79.0 | 37.0 | 38.7 | 5.33 | 6.33 | 34.3 | 34.3 | 6.33 | 6.33 | 1097 | 1085 |
| $T_{10}$ | 35.6 | 36.3 | 7.33 | 8.00 | 9.33 | 9.67 | 1597 | 1653 | 1.15 | 1.03 | 82.0 | 83.0 | 42.0 | 41.7 | 6.67 | 7.67 | 31.7 | 34.0 | 6.67 | 7.00 | 1085 | 1105 |
| $T_{11}$ | 25.2 | 25.7 | 4.33 | 4.67 | 5.33 | 5.67 | 912 | 977 | 0.17 | 0.09 | 79.7 | 80.3 | 40.0 | 39.7 | 6.33 | 6.33 | 33.0 | 33.7 | 6.33 | 6.67 | 1075 | 1095 |
| **SEm±** | **0.52** | **0.45** | **0.32** | **0.30** | **0.5** | **0.34** | **16.19** | **18.27** | **-** | **-** | **1.08** | **1.00** | **0.67** | **0.97** | **0.40** | **0.32** | **0.12** | **0.83** | **0.56** | **0.56** | **14.84** | **15.39** |
| **LSD (p=0.05)** | **1.56** | **1.37** | **0.97** | **0.91** | **1.54** | **1.05** | **49.57** | **55.96** | **-** | **-** | **NS** | **NS** | **2.04** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** | **NS** |

## CONCLUSION

The research results revealed that the post-emergence application of Metamifop 8% + Imazethapyr 4% + Imazomox 3% ME in combination with Ammonium Sulphate at 1000–1250 mlha$^{-1}$ is a highly effective, safe, and economically viable option for weed management in groundnut. These treatments resulted in a substantial reduction in weed density, biomass, and an increase in crop growth, yield, and net returns comparable to the weed-free control. The outcomes highlight the potential of this combination for improving yield and economics in groundnut cultivation under similar agro-ecological conditions.

### Future Scope

While the present study establishes the efficacy and economic viability of the evaluated post-emergence herbicide combination in groundnut, future work should focus on multi-location trials to validate performance across environments. Long-term studies on soil residue behaviour, ecological interactions, and integration with non-chemical approaches will be essential to develop sustainable and resilient weed management strategies.

### Conflict of Interest

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

### Acknowledgement

The authors would like to thank the Parijat Industries Limited, India for providing the financial maintenance and Uttar Banga Krishi Viswavidyalaya for providing all kind of assistance to complete the work.

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