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RESEARCH ARTICLE

Effect of post-emergence herbicides on weed control in Teak (*Tectona grandis* Linn. f.) nurseries

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Abstract

The current investigation aims to assess the influence and suitability of post-emergence herbicides on weed management, germination and seedling development in teak nurseries. The teak drupes underwent soaking and drying processes for six days, followed by field emergence in a 10.5 m^2 nursery bed after preconditioning on the seventh day. The experiment, replicated four times, involved the application of post-emergence herbicides two months post-sowing. A total of twenty-one treatments were implemented: T_0 (Control), T_1 to T_4 (Halosulfuron methyl 75 % Water-dispersible Granule (WG) at rates of 45 g, 67 g, 90 g and 110 g/ha), T_5 to T_8 (Imazethapyr 10 % SL at rates of 156 mL, 234 mL, 312 mL and 390 mL/ha), T_9 to T_{12} (Quizalofop 5 % Emulsifiable Concentrate (EC) at rates of 600 mL, 900 mL, 1200 mL and 1500 mL/ha), T_{13} to T_{16} (2,4-Dichlorophenoxy acetic acid 58 % Soluble Liquid (SL) at rates of 430 mL, 620 mL, 860 mL and 1070 mL/ha) and T_{17} to T_{20} (Oxyfluorfen 23.5 % EC at rates of 375 mL, 560 mL, 750 mL and 937 mL/ha). The experimental design utilized a randomized block layout. Weed species (including broad-leaved plants, grasses and sedges) present in the nursery were documented in random 1 m^2 plots for each treatment thirty days post-herbicide application. The outcomes indicate that the post-emergence herbicide, imazethapyr 10 % SL at a rate of 234 mL/ha, demonstrates compatibility, effectively controlling monocot and broad-leaved weeds while promoting teak seedling germination and growth with minimal phytotoxic effects.

Keywords: phytotoxicity; post-emergence herbicides; seed germination; teak; weed control efficiency

Introduction

Teak (*Tectona grandis* Linn. f.) is a globally valued multipurpose timber species, renowned for its strength, durability, dimensional stability and resistance to corrosion when in contact with metal (1). Its durability is attributed to polyphenolic compounds that repel water and termites, making it a preferred material for high-end furniture, decking and yachts (2). Teak is primarily propagated through seeds and effective weed management in nurseries is crucial for producing quality seedlings. Weeds compete with seedlings for resources such as water, nutrients, light and space thereby affecting seedling growth (3). Weed infestation in nurseries is often intensified by conventional practices such as leaving bare soil gaps and monoculture systems, which fail to fully utilize available resources. Weeds can also exert allelopathic effects on nursery seedlings by releasing phytotoxic compounds into the surrounding environment, which inhibit seedlings growth and development. Additionally, the presence of weeds in nurseries can negatively affect the morale of workers and the perception of customers, potentially leading to reduced productivity and economic losses. Nursery media, typically prepared by blending red earth, sand and farmyard manure in varying proportions, often inadvertently incorporate weed seeds and other propagules such as rhizomes, tubers, roots, bulbs and bulbils, further contributing to weed proliferation (4). Nursery practices, such as leaving bare ground gaps; exacerbate weed infestation, which can negatively impact both productivity and profitability of teak nursery. Herbicides are widely used to control weeds in forest nurseries, reducing the need for labour-intensive hand weeding (5). Herbicide application constitutes the primary strategy for weed management in conventional forest species production systems (6). However, herbicide application requires careful consideration to avoid crop damage, as non-selective herbicides can harm the target species (7). Understanding the selectivity of herbicides applied to crops is critical to minimize or prevent damage to target species, as non-selective herbicides can cause greater harm than the competitive effects of weeds (8). Factors such as crop development stage, genetic material and environmental conditions influence herbicide selectivity (9, 10). Till date, no work has been carried out to find out the suitable post-emergence herbicide for weed control and seedling growth of teak nurseries. Against the stalemate, this study was proposed to evaluate the efficacy and compatibility of five post-emergence herbicides on weed control, germination and seedling growth in teak nurseries.

Materials and methods

The study was conducted to determine the effects of various post-emergence herbicides on seedling growth and weed control efficacy in teak (*Tectona grandis*) nurseries at Agricultural Engineering College and Research Institute, Tamil Nadu Agricultural University, Kumulur, Tiruchirappalli, Tamil Nadu. Teak drupes were sourced from an established teak plantation at the same institute (latitude 74° N, longitude 34° E, elevation 750 m above sea level). The collected drupes were thoroughly dried and cleaned to eliminate shrivelled and insect -damaged, ensuring uniformity and quality for the experiment. Drupes measuring less than 9 mm in diameter were discarded, while those within the 9 - 12 mm size range were selected as experimental material. The selected drupes underwent a pre-treatment process involving soaking and drying over six days. On seventh day, the preconditioned drupes were sown in nursery beds measuring 10.5 m^2 (7 m × 1.5 m), with the experiment arranged in a randomized block design replicated four times. Sun hemp (*Crotalaria juncea*) green manure crop was raised in the field until the flowering stage and subsequently incorporated uniformly into the soil to improve soil fertility in the experimental field. Three days after sowing of teak seeds, a pre-emergence herbicide, Atrazine 50 % Wettable Powder (WP), was applied as a liquid spray at a concentration of 0.25 % across the nursery beds (11). Two months after sowing, post-emergence herbicides were applied in the nursery. The experiment comprised twenty-one treatments, including T_0- control, T_1 to T_4- Halosulfuron methyl 75 % Water-dispersible Granule (WG), 45 g, 67 g, 90g and 110 g/ha., T_5 to T_8- Imazethapyr 10 % Soluble Liquid (SL) 156 mL, 234 mL, 312 mL and 390 mL/ha, T_9 to T_{12} - Quizalofop 5 % Emulsifiable Concentrate (EC) 600 mL, 900 mL, 1200 mL and 1500 mL/ha, T_{13} to T_{16}- 2,4-Dichlorophenoxy acetic acid 58 % SL 430 mL, 620 mL, 860 mL and 1070 mL/ha and T_{17} to T_{20} - Oxyfluorfen 23.5 % EC, 375 mL, 560 mL, 750 mL and 937 mL/ha. These herbicides were sprayed at different concentrations using a knapsack sprayer. The experiment was conducted in Randomized Block Design (RBD). Weed flora, including broad-leaved weeds, grasses and sedges, were counted randomly by using quadrat (0.25 m^2) area for each treatment at 30 days after herbicide application (Table 1). Weed control efficiency (WCE) was calculated based on the dry weight of weeds (broad-leaved, grasses and sedges) recorded for each treatment at 45 days after herbicide application, following the standard methodology (12). Additionally, the number of teak seedlings per 10.5 m^2 nursery bed was recorded 60 Days After Herbicide Application (DAHA) to evaluate treatment effects on seedling establishment and growth.

$$\text{WCE} = \frac{\text{Weed dry weight in unweeded control plot - Weed dry weight in treated plot}}{\text{Weed dry weight in unweeded control}} \times 100 \quad \text{(Eqn. 1)}$$

To assess the efficacy and compatibility of post-emergence herbicides on teak seedling growth, phytotoxicity scoring was conducted (13). Phytotoxic effects were evaluated based on visual observations (Table 2) at 15-day intervals, starting from 15 DAHA and continuing up to 180 DAHA (i.e., 15, 30, 45, 60, 75, 90, 105, 120, 135, 150, 165 and 180 DAHA).

Six months after the application of post-emergence herbicides, several growth parameters were recorded to evaluate the treatment effects. These included the number of seedlings per 10.5 m^2, seedling root length (cm), shoot length (cm), number of leaves per seedling, stump girth (mm) and dry matter production (g/ $seedling^{-1}$). The collected data were subjected to analysis of variance (ANOVA) and significant differences among treatments were determined using the t-test at a significance level of p = 0.05, as per the standard methodology described in previous literature (14). Prior to statistical analysis, percentage values were transformed into arc sine values to ensure normality and homogeneity of variance.

Results and Discussions

Number of seedlings/m^2

The effect of the different post-emergence herbicides on number of seedlings/10.5 m^2 at 2 months after spray revealed that spraying imazethapyr 10 % SL 234 mL /ha (T_6) recorded significantly higher number of seedlings/10.5 m^2 (283). It was comparable with oxyfluorfen 23.5 % EC, 750 mL/ha (T_{19}) (280/10.5 m^2). Oxyfluorfen was comparable with halosulfuron methyl 75% WG, 45 g /ha (T_1) (276/10.5 m^2). T_1(Halosulfuron methyl 75 % WG, 45 g/ha) was comparable with T_{18}(Oxyfluorfen 23.5 % EC, 560 mL/ha). Next to that, T_5(Imazethapyr 10 % SL

Table 2. Herbicide phytotoxicity rating on crops

Score	Grade	Phytotoxicity
0	None	None
1 to 3	Slight	Slight discolouration; stunting in growth; few plants may dry and die; Injury more pronounced and the effect will be temporary.
4 to 6	Moderate	Moderate injury; recovery possible; recovery doubtful; non-recoverable injury
7 to 9	Severe	Severe injury; with only few plants spared
10	Complete	Complete destruction

Table 1. Weed flora found in the teak nursery at 30 DAHA

Name of the weed species		
Grasses	**Broad leaved weeds**	**Sedges**
Digitaria sanguinalis	*Phyllanthus niruri*	*Cyperus rotundus*
Eragrostis unioloides	*Tridax procumbens*	*Cyperus aggregatus*
	Euphorbia hirta	
	Commelina benghalensis	
	Oldenlandia corymbosa	
	Corchorus olitorius	

DAHA -Days After Herbicide Application.

156 mL/ha.), T_2 (Halosulfuron methyl 75 % WG, 67 g /ha) and T_0 (Control) recorded a higher number of seedlings / 10.5m^2. The lowest number of seedlings (1/10.5 m^2) was found in T_{14} (2,4-Dichlorophenoxy acetic acid 58 % SL.620 mL/ha.) as and it was on par with T_{16}, $T_{15}$and T_{13}, with 2, 5 and 7 seedlings/10.5 m^2 respectively. Auxin-based herbicides like 2, 4-Dichlorophenoxy acetic acid (2,4-D) have direct action because they induce ethylene biosynthesis through the synthesis of ACC (1-amino cyclopropane-1- carboxylic acid). Additionally, in the indirect pathway of action, ethylene stimulates the production of Abscisic Acid (ABA). ABA inhibits cell division and expansion and ethylene promotes leaf senescence. Inhibition of growth, tissue damage and cell and plant death are the consequences (15). The mode of action of 2, 4-D is characterized by an increase in the plasticity of the cell wall and an abnormal increase in the synthesis of proteins and ethylene, resulting in uncontrolled cell division and. damage to the vascular tissue of plants. Therefore, because of its chemical resemblance to auxins, 2, 4-D over-stimulates growth, culminating in the death of the target plant (16, 17).

After six months of herbicide spray, application of Imazethapyr 10 % SL 234 mL /ha ($T_{6)}$ and (xyfluorfen 23.5 % EC, 937 mL/ha (T_{20}) recorded a higher number of seedlings/ 10.5 m^2 as 273 and 270 respectively. It was followed by T_5 (Imazethapyr 10 % SL 156 mL/ha.,), T_{19} (Oxyfluorfen 23.5 % EC, 750 mL/ha), T_{10} (Quizalofop 5 % EC 900 mL/ha.,) and T_1 (Halosulfuron methyl 75 % WG, 45 g/ha) which registered a greater number of seedlings of 255, 250 and 247/10.5 m^{2}respectively. The effective control of both monocot and dicot weeds could be well done with the application of imazathypr (18). Similarly, application of imazethapyr controlled weeds effectively in chickpea as well as increased the seed yield (19, 20)

The lowest number (10 Nos.) of seedlings per 10.5 m^2 was recorded in treatment T_{13} (2, 4-D) 58 % SL at 430 mL/ha). In treatments T_{14} and T_{15}, no seedlings were observed (Fig. 1). According to the U.S. Environmental Protection Agency (EPA), 2, 4-D exerts its herbicidal effects through three primary mechanisms: altering cell wall plasticity, modulating protein synthesis and increasing ethylene production. When applied at effective doses to dicotyledonous plants, 2, 4-D is absorbed through roots, stems and leaves and translocated to the meristematic regions (21). This results in morphological abnormalities such as thickened and stunted roots, disintegration or blockage of phloem and xylem tissues in stems and cessation of leaf growth. These disruptions lead to uncontrolled and unsustainable growth, causing symptoms such as stem curling, leaf withering and eventual plant death.

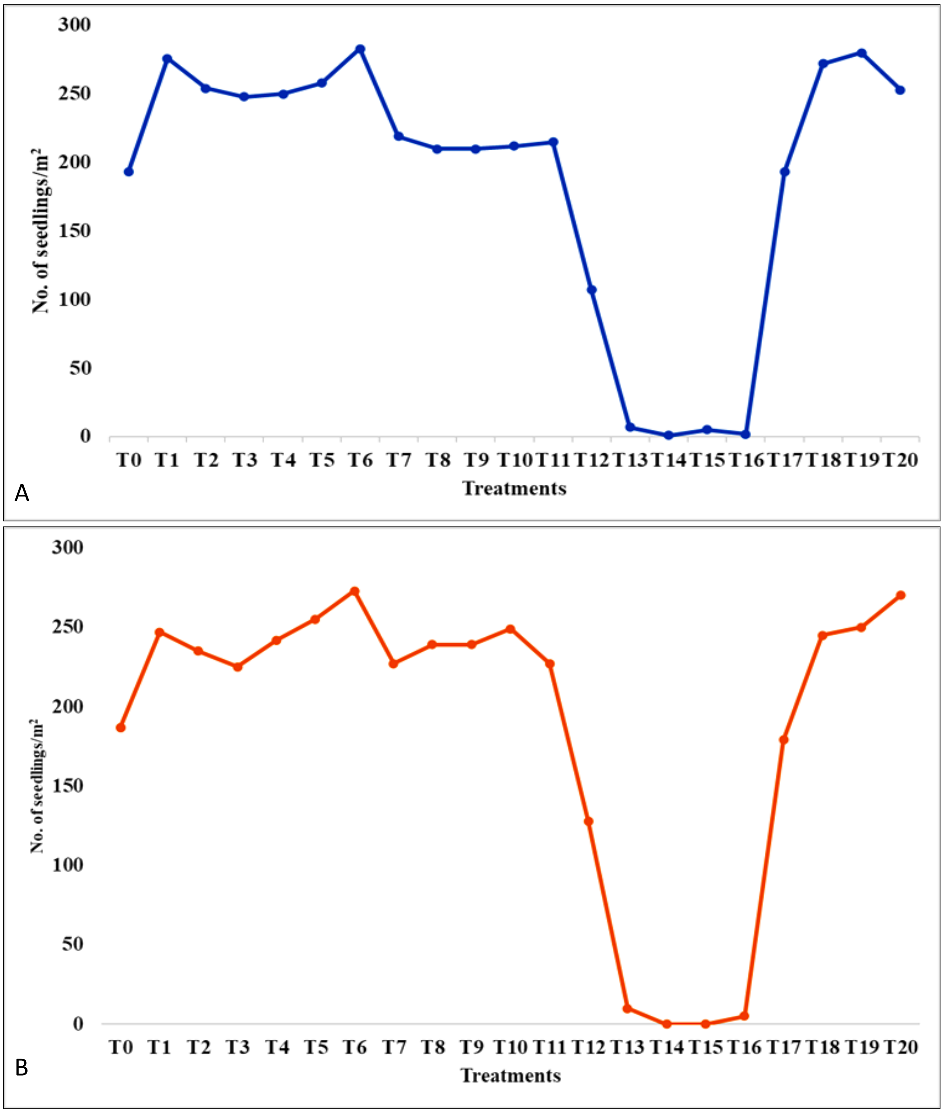

Fig. 1 Effect of post-emergence herbicides on number of seedlings/m^2 of teak nurseries. **A).** Two months after application of herbicides and **B)** Six months after application of herbicides.

Biometric observation

Biometric observations recorded six Months After Herbicide Application (MAHA) are presented in Table 3. The highest root length of 28.6 cm was observed in treatment T_4 (Halosulfuron methyl 75 % WG, 110 g/ha), followed by T_1 (26.2 cm), T_2 (26.0 cm) and the control (25.5 cm). Treatments T_1 and T_2 were statistically on par with each other. In contrast, the shortest root length (12.6 cm) was recorded in treatment T_{12}, with similarly reduced root lengths observed in treatments T_{16} (13.8 cm) and T_{17} (16.4 cm). Regarding shoot length, treatments T_7 (Imazethapyr 10 % SL at 312 mL/ha) and T_6 (Imazethapyr 10 % SL at 234 mL/ha) produced the highest values of 39.6 cm and 39.4 cm, respectively. These were followed by T_3 (38 cm), T_5 (36.8 cm), T_{13} (36.4 cm) and T_1 (36.2 cm), with treatment T_5 being statistically on par with T_{13} and T_1. Imazethapyr, a broad-spectrum herbicide, with both soil and foliar activity, provides flexibility in application timing and exhibiting low toxicity to mammals (22). When applied post-emergence at 50 to 75 g/ha, it provides season-long control of numerous weeds without adversely affecting soybean crops (23). Similarly, previous studies have reported that post-emergence application of imazethapyr at 25 g/ha did not adversely affect the growth parameters in rainfed black gram and resulted in grain yields statistically comparable to those obtained with two hand-weedings conducted at 20 and 40 days after sowing (24). Treatment T_{20} was statistically on par with T_4 (29.8 cm) and T_{19} (30.4 cm) in terms of shoot length.

The number of leaves per seedling was significantly influenced by herbicide applications. The maximum number of leaves (8 per seedling) was recorded in T_4 (Halosulfuron methyl 75 % WG at 110 g/ha) and T_{20} (Oxyfluorfen 23.5 % EC at 937 mL/ha). This was followed by T_0 (Control), T_1 (Halosulfuron methyl 75 % WG at 45 g/ha), T_3 (Halosulfuron methyl 75 % WG at 90 g/ha), T_6 (Imazethapyr 10 % SL at 234 mL/ha), T_{10} (Quizalofop 5 % EC at 900 mL/ha), T_{11} (Quizalofop 5 % EC at 1200 mL/ha), T_{16} (2,4 -Dichlorophenoxy acetic acid 58 % SL at 1070 mL/ha) and T_{17} (Oxyfluorfen 23.5 % EC at 375 mL/ha), all of which recorded 7 leaves per seedling. The lowest number of leaves (6 per seedling) was observed in treatments T_5, T_7, T_8, T_{12} and T_{18}. Stump girth in teak seedlings was also significantly influenced by herbicide applications. Treatments T_6 (Imazethapyr 10 % SL at 234 mL/ha) and T_{13} (2,4-Dichlorophenoxy acetic acid 58 % SL at 430 mL/ha) recorded the highest stump girths of 27.3 mm and 26.8 mm, respectively. The stump girth in T_{13} (28.8 mm) was comparable to that of T_2 (Halosulfuron methyl 75 % WG at 67 g/ha) at 26.5 mm, which, in turn, was comparable to T_3 (Halosulfuron methyl 75 % WG at 90 g/ha) and T_{11} (Quizalofop 5 % EC at 1200 mL/ha), both recording 26.10 mm. The lowest stump girths were observed in T_4 (10.4 mm) and T_1 (13.2 mm). Dry Matter Production (DMP) of teak seedlings varied significantly across herbicide treatments. The highest DMP of 87 g was recorded in T_2 (Halosulfuron methyl 75 % WG at 67 g/ha), followed by T_1 (Halosulfuron methyl 75 % WG at 45 g/ha) with 64 g. The control (T_0) recorded 58 g of DMP, which was comparable to T_{20} (Oxyfluorfen 23.5 % EC at 937 mL/ha) (58 g). The lowest DMP of 22 g was observed in T_{18} (Oxyfluorfen 23.5 % EC at 560 mL/ha), followed by T_{10}, T_{17} and T_{16}, which recorded DMPs of 30 g, 32 g and 35 g, respectively.

Weed dry weight and weed control efficiency

Weed dry weight varied significantly across different herbicide treatments in the teak nursery. The control (T_0) recorded the highest weed dry weight of 2.434 kg/10.5 m^2, followed by T_{15} (2,4-D 58 % SL at 860 mL/ha) and T_2 (Halosulfuron methyl 75 % WG at 67 g/ha), which recorded weed dry weights of 1.93 kg/10.5 m^2 and 1.87 kg/10.5 m^2, respectively. Treatment T_2 was statistically on par with T_{18} (Oxyfluorfen 23.5 % EC at 560 mL/ha), which recorded a weed dry weight of 1.86 kg/10.5 m^2. The lowest weed dry matter production was observed in T_{11} (Quizalofop 5 % EC 1200 mL /ha) (0.7 kg/10.5 m^2), followed by T_{12} (Quizalofop 5 % EC at 1500 mL/ha), T_8 (Imazethapyr 10 % SL at 390 mL/ha) and T_{10} (Quizalofop 5 % EC at 900 mL/ha), with weed dry weights of 0.79 kg, 0.86 kg and 0.96 kg per 10.5 m^2, respectively. Weed control efficiency (WCE) was significantly influenced by herbicide treatments. The highest WCE of 71.24

Table 3. Effect of post-emergence herbicides on seedling growth of teak (6 MAHA)

Treatments	Root length (cm)	Shoot length (cm)	No. of leaves per seedling	Stump girth (mm)	DMP (g/seedling?)
T_0-Control	25.5	30.5	7	24.0	58
T_1-Halosulfuron methyl, 75 % WG, 45 g/ha.,	26.2	36.2	7	13.2	64
T_2-Halosulfuron methyl, 75 % WG, 67 g/ha.,	26.0	34.6	8	26.5	87
T_3-Halosulfuron methyl, 75 % WG, 90 g/ha.,	22.8	38.0	7	26.1	55
T_4-Halosulfuron methyl, 75 % WG, 110 g/ha.,	28.6	29.8	9	10.4	50
T_5-Imazethapyr 10 %, SL 156 mL/ha.,	22.6	36.8	6	21.2	35
T_6-Imazethapyr 10 %, SL 234 mL /ha.,	24.2	39.4	7	27.3	55
T_7-Imazethapyr 10 %, SL 312 mL /ha.,	23.4	39.6	6	24.0	52
T_8-Imazethapyr 10 %, SL 390 mL/ha.,	19.2	33.6	6	23.0	50
T_9-Quizalofop 5 %, EC 600 mL /ha.,	22.6	30.6	8	25.9	50
T_{10}-Quizalofop 5 %, EC 900 mL/ha.,	21.0	34.4	7	25.4	30
T_{11}-Quizalofop 5 %, EC 1200 mL /ha.,	19.2	32.4	7	26.1	51
T_{12}- Quizalofop 5 %, EC 1500 mL/ha.,	12.6	27.0	6	23.2	50
T_{13}--2,4-Dichlorophenoxy acetic acid 58 % SL, 430 mL, /ha.	19.0	36.4	8	26.8	52
T_{14}--2,4-Dichlorophenoxy acetic acid 58 %, SL. 620 mL/ha.	0	0	0	0	0
T_{15}-2,4-Dichlorophenoxy acetic acid 58 % SL, 860 mL /ha.	0	0	0	0	0
T_{16}-2,4-Dichlorophenoxy acetic acid 58 % SL, 1070 mL/ha.	13.8	28.0	7	23.7	35
T_{17}-Oxyfluorfen 23.5 % EC, 375 mL/ha	16.4	30.4	7	23.9	32
T_{18}-Oxyfluorfen 23.5 % EC, 560 mL/ha	20.0	35.6	6	23.8	22
T_{19}-Oxyfluorfen 23.5 % EC, 750 mL/ha	18.0	30.4	8	24.1	48
T_{20}-Oxyfluorfen 23.5 % EC, 937 mL/ha	18.2	29.6	9	22.6	58
Mean	19.01	30.16	6.48	21.02	44.48
S.Ed	0.29	0.38	0.09	0.27	0.57
CD(P=0.05)	0.57	0.75	0.19	0.53	1.15

MAHA - Months After Herbicide Application.

% was achieved in T_{11}, followed by T_{12} (Quizalofop 5 % EC at 1500 mL/ha) with 67.63 % WCE. The lowest WCE values were recorded in T_{15} (2, 4-D 58 % SL at 860 mL/ha) at 20.7 %, T_2 (Halosulfuron methyl 75 % WG at 67 g/ha) at 23.2 % and T_{18} (Oxyfluorfen 23.5 % EC at 560 mL/ha) at 23.3 % (Table 4). It was also documented enhanced weed control efficiency (WCE) with imazethapyr application in soybean crops (25). These findings align with those of, who reported an 84.6 % reduction in weed biomass with imazethapyr treatment (20). The superior efficacy and prolonged residual activity of imazethapyr in reducing weed dry matter (up to 85 %) can be attributed to its broad-spectrum activity, particularly against established narrow and broad-leaved weeds. Further evidence supports the use of imazethapyr in legume crops, highlighting its role as an inhibitor of Acetohydroxy Acid Synthase (AHAS), which interferes with the synthesis of branched-chain amino acids in weeds (26). In chickpeas, significant reductions in total weed density and weed biomass were observed, with yield and yield attributes showing a strong negative correlation with weed infestation (27). Similarly, higher weed control efficiency and grain yield of black gram was obtained with application of imazethapyr at 75 g/ha as post emergence herbicide (28).

Phytotoxicity of teak seedling

The phytotoxicity scores of post-emergence herbicide applications revealed that treatments involving imazethapyr and quizalofop did not induce any phytotoxic effects on teak seedlings throughout the six-month observation period. In contrast, applications of 2, 4-D (ranging from 430 mL/ha to 1070 mL/ha) resulted in phytotoxicity scores between 7 and 10, persisting up to six MAHA. Severe seedling injury was observed 15 to 30 days after spraying, followed by destruction of the seedlings. Oxyfluorfen applications at varying concentrations (375 mL/ha to 937 mL/ha) exhibited slight to moderate phytotoxicity, with scores ranging from 3 to 7 up to 135 days after application. Beyond this period, lower concentrations showed a phytotoxicity score of 3, while higher concentrations-maintained scores of 5 - 6. Halosulfuron methyl at lower concentrations (45 g/ha to 67 g/ha) initially recorded phytotoxicity scores of 4 and 5, but seedlings recovered from these effects between 75 and 180 days after application. However, higher concentrations (90 g/ha and 110 g/ha) resulted in persistent phytotoxicity, with scores ranging from 5 to 7 up to 180 days after spraying. Among the herbicides tested, 2, 4-D caused the most persistent phytotoxicity, followed by oxyfluorfen and Halosulfuron methyl. In comparison, imazethapyr and quizalofop demonstrated minimal to no phytotoxic effects on teak seedlings.

Phytotoxic symptoms observed in the study included leaf chlorosis, leaf burn, stunted or distorted seedling growth, leaf curling, little leaf formation and necrotic spots (Table 5). These findings align with previous research. For instance, that excessive herbicide doses, improper application, or frequent treatments can lead to seedling stunting and phytotoxicity (29). Phytotoxic effects can manifest in various ways, including germination failure (30), needle chlorosis and burn (31, 32), stem swelling or lesions stunted or distorted growth of needles, shoots (33) and roots (32), as well as seedling mortality (34). Leaf chlorosis and necrotic spots are commonly observed phytotoxic symptoms on teak leaves (35). In some cases, herbicide-induced damage is severe and easily observable (e.g., high mortality or significant stunting), while in others, the effects are subtle and detectable only through meticulous observation. The phytotoxicity of these herbicides is likely attributed to their interference with critical plant metabolic processes, such as photosynthesis, respiration, protein synthesis and the metabolism of carbohydrates, lipids and nucleic acids. These disruptions impair plant growth and structural integrity, leading to visible injury or plant death, depending on the severity of the metabolic disruption (36).

Table 4. Effect of post emergence herbicides on weed dry weight and weed control efficiency (%)

Treatments	Weed dry weight (kg/10.5 m^2)	Weed control efficiency (%)
T_0-Control	2.4	-
T_1-Halosulfuron methyl, 75 % WG, 45 g/ha	1.0	60.0
T_2-Halosulfuron methyl, 75 % WG, 67 g/ha	1.9	23.2
T_3-Halosulfuron methyl, 75 % WG, 90g/ha	1.3	47.2
T_4-Halosulfuron methyl, 75 % WG, 110 g/ha	1.3	45.6
T_5-Imazethapyr 10 %, SL 156 mL/ha	1.3	48.3
T_6-Imazethapyr 10 %, SL 234 mL /ha	1.0	57.8
T_7-Imazethapyr 10 %, SL 312 mL /ha	1.0	59.4
T_8-Imazethapyr 10 %, SL 390 mL/ha	0.9	64.7
T_9-Quizalofop 5 %, EC 600 mL /ha	1.1	53.4
T_{10}-Quizalofop 5 %, EC 900 mL/ha	1.0	60.6
T_{11}-Quizalofop 5 %, EC 1200 mL /ha	0.7	71.2
T_{12}- Quizalofop 5 %, EC 1500 mL/ha	0.8	67.6
T_{13}.-2,4-Dichlorophenoxy acetic acid 58 %, SL 430 mL, /ha	1.2	51.0
T_{14}--2,4-Dichlorophenoxy acetic acid 58 %, SL. 620 mL/ha	1.2	49.4
T_{15}-2,4-Dichlorophenoxy acetic acid 58 %, SL 860 mL /ha	1.9	20.7
T_{16}-2,4-Dichlorophenoxy acetic acid 58 %, SL 1070 mL/ha	1.6	33.3
T_{17}-Oxyfluorfen 23.5 % EC, 375 mL/ha	1.1	55.1
T_{18}-Oxyfluorfen 23.5 % EC, 560 mL/ha	1.9	23.3
T_{19}-Oxyfluorfen 23.5 % EC, 750 mL/ha	1.0	57.3
T_{20}-Oxyfluorfen 23.5 % EC, 937 mL/ha	1.4	40.7
Mean	1.3	
S.Ed	0.0	
CD(P=0.05)	0.029	

Table 5. Effect of post-emergence herbicides spray on phytotoxicity of teak seedling.

Treatments	Days after herbicide application											
	15	**30**	**45**	**60**	**75**	**90**	**105**	**120**	**135**	**150**	**165**	**180**
T_0-Control	0	0	0	0	0	0	0	0	0	0	0	0
T_1-Halosulfuron methyl 75 % WG, 45 g/ha	4	4	4	4	4	3	3	3	3	2	2	2
T_2-Halosulfuron methyl 75 % WG, 67g/ha	5	5	5	5	4	4	4	4	4	4	4	4
T_3-Halosulfuron methyl 75 % WG, 90 g/ha	5	5	5	5	5	5	6	6	6	6	6	6
T_4-Halosulfuron methyl 75 % WG, 110 g/ha	6	6	6	6	7	7	7	7	6	6	6	6
T_5-Imazethapyr 10 % SL 156 mL/ha	0	0	0	0	0	0	0	0	0	0	0	0
T_6-Imazethapyr 10 % SL 234 mL /ha	0	0	0	0	0	0	0	0	0	0	0	0
T_7-Imazethapyr 10 % SL 312 mL /ha	0	0	0	0	0	0	0	0	0	0	0	0
T_8-Imazethapyr 10 % SL 390 mL/ha	1	1	0	0	0	0	0	0	0	0	0	0
T_9-Quizalofop 5 %, EC 600 mL /ha	0	0	0	0	0	0	0	0	0	0	0	0
T_{10}-Quizalofop 5 %, EC 900 mL/ha	0	0	0	0	0	0	0	0	0	0	0	0
T_{11}-Quizalofop 5 %, EC 1200mL/ha	0	0	0	0	0	0	0	0	0	0	0	0
T_{12}- Quizalofop 5 %, EC 1500 mL/ha	1	0	0	0	0	0	0	0	0	0	0	0
T_{13}-2,4Dichlorophenoxyacetic acid 58 % , SL 430 mL, /ha	7	7	7	8	9	10	10	10	10	10	10	10
T_{14}--2,4Dichlorophenoxy acetic acid 58 %, SL. 620 mL/ha	7	7	7	8	9	10	10	10	10	10	10	10
T_{15}-2,4Dichlorophenoxy acetic acid 58 %, SL 860 mL/ha	7	7	8	8	9	10	10	10	10	10	10	10
T_{16}-2,4Dichlorophenoxy acetic acid 58 %, SL 1070 mL/ha	7	7	10	10	10	10	10	10	10	10	10	10
T_{17}-Oxyfluorfen 23.5 % EC,375 mL/ha	3	3	3	4	4	6	6	5	5	3	3	3
T_{18}-Oxyfluorfen 23.5 % EC,560 mL/ha	3	3	3	4	4	6	6	7	7	5	4	4
T_{19}-Oxyfluorfen 23.5 % EC,750 mL/ha	3	3	3	4	4	6	6	7	7	6	5	5
T_{20}-Oxyfluorfen 23.5 % EC,937 mL/ha	3	3	3	4	4	6	7	7	7	6	6	6

Pooled mean of four replications. Not statistically analysed.

Conclusion

The findings of this study demonstrate that post-emergence herbicides can effectively control monocot and broad-leaved weeds more efficiently than sedges in teak nurseries. Among the herbicides evaluated, Imazethapyr 10 % SL applied at a rate of 234 mL/ha emerged as the most compatible and effective option for controlling both monocots and broad-leaved weeds and also did not adversely affect seed germination or seedling growth, higher seedling survival rates and minimal phytotoxicity. Further, in-depth investigations, including economic analyses comparing manual and chemical weed control methods, are necessary to optimize weed management strategies in teak nurseries.

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Authors' contributions

PM designed the experiment and wrote the protocol. SV wrote the first draft of the manuscript. SDS collected the literature and reviewed. AV made the tables and figures and AA edited the manuscript. All authors read and approved the manuscript.

Compliance with ethical standards

Conflict of interest: There is no conflict of interest to declare.

Ethical issues: None

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