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Short title: Farmer survey in tree stands

Teak and melina farmers' perceptions about problematic weed species and management practices in the tropics of Costa Rica

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Abstract

A survey was conducted among teak and melina growers across Costa Rica to assess their perceptions of problematic weed species and to document current weed management practices in forest plantations. A total of 180 farmers were selected from six provinces, yielding an 87% response rate. Results revealed that 47% of respondents had established plantations on formerly forested land, while 43% did so on previously used pastureland. Most farmers employed an integrated weed management approach combining manual, mechanical, and chemical methods. The most frequently cited problematic species included coyol palm, jaraguagrass, orchid vine, raspa guacal, and arrocillo. Herbicide use was widespread, with glyphosate, metsulfuron-methyl, and paraquat being the most common active ingredients, typically applied singly, in mixtures, or sequentially. The findings underscore a heavy reliance on only three herbicides and highlight the need for targeted control of Poaceae species and climbing vines. This work contributes valuable insights into weed dynamics in tropical forest plantations and emphasizes the need for region-specific and sustainable management strategies to mitigate potential productivity constraints and reduce reliance on herbicides.

Nomenclature: Glyphosate; metsulfuron-methyl; paraquat; coyol palm, *Acrocomia aculeata* (Jacq.) Lodd. ex Mart.; jaraguagrass, *Hyparrhenia rufa* (Nees) Stapf; orchid vine, *Stigmaphyllon lindenianum* A. Juss; raspa guacal, *Davilla nitida* (Vahl) Kubitzki; arrocillo, *Paspalum paniculatum* L.; melina, *Gmelina arborea* Roxb. ex Sm.; teak, *Tectona grandis* L. f.

Keywords: cultural practices; forest plantations; forestry; herbicides; trees.

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Introduction

The importance of fast-growing (i.e production cycles of less than 10 years), intensively managed planted forests has increased globally during recent years due to the growing need for timber and derived goods (Fernández-Moya et al. 2017). Forest plantations play a crucial role in reforesting degraded tropical ecosystems, providing a reliable source of high-quality wood and multiple ecosystem services. Tropical timber plantations continue to be dominated by a few tree species grown in monocultures, including species of eucalyptus, acacia, pine, melina, and teak (Günter et al. 2011; Pancel and Kohl 2016).

Costa Rica has a long-standing tradition of cultivating teak and melina, which represent the largest areas of planted forest in the country, covering approximately 49,000 ha and 14,000 ha, respectively (INEC 2022). Both species are widely used in commercial reforestation projects (Boley et al. 2009), with end uses ranging from pallet production to construction timber for domestic use and export, primarily to Asian markets (Moya et al. 2014). Costa Rica ranks among the top 10 global exporters of teak roundwood and holds the third largest area of planted teak forests in the region, following Ecuador and Panama (Kollert et al. 2024).

Weed management during the establishment and early stages of growth of a plantation is crucial to improve final productivity. In the same way as in agricultural crops, weeds are among the major impediments to the successful establishment, survival, growth, and productivity of forest plantations (Adams et al. 2003; Garau et al. 2009; Ladrach 2010). The composition of weed communities determines the availability of resources such as water and soil nutrients that are essential to tree growth. This composition can be broad, depending on factors such as plantation age, topography, previous land use, initial land preparation, and silvicultural management practices (Zimdahl 2018). Generally, in the early stages of crop development, grasses and other herbaceous plants are the main competitors, whereas woody vegetation becomes the primary problem once the plantation canopy closes (Meza et al. 2019; Vargas et al. 2018).

In Costa Rica, research has been conducted on the composition of weed communities in crops such as coffee (Mora and Acosta 2001; Ricci et al. 2008; Rojas et al. 2003), banana (Agüero-Alvarado et al. 2018; Rodríguez and Agüero 2000), sugarcane (Leon et al. 2017), and pineapple

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(Brenes-Prendas and Agüero-Alvarado 2007). However, there is no information available on the composition of weed communities in teak and melina plantations. Furthermore, there is no data on the weed management practices used or the most problematic weeds that affect these plantations. To design successful weed management practices, it is necessary to identify the species associated with plantation species, the impact of the species on production, any beneficial attributes of the species, and effective management of the species. Weed control in plantation forests in Central America has been carried out in several ways, including machete or shovel weeding and, more recently, herbicides. The main reasons for herbicide use are their rapid control, high efficacy, and prolonged effect (Guevara 2011). Unfortunately, there is no information on how weed community composition influences herbicide selection by managers in forestry plantations.

Surveys are useful tools to acquire information about weed management practices, problematic weeds, and have been used to assess farmer needs. Although farmer surveys do not provide a direct quantification of weed abundance and distribution, they are useful to describe the perceived importance of weeds in each production system and the decisions made by farmers regarding their preferred weed management tactics (Sarangi and Jhala 2018). Therefore, the main goal of the present study was to survey teak and melina farmers and characterize their current perceptions on weed problems and herbicide use. The survey hypothesis was that the problematic weed species of forest plantations will predominantly be grass species, vary across Costa Rican provinces, and require region-specific management strategies to effectively mitigate the weed interference challenges. The specific objectives of this survey were to determine (1) the most problematic weed species, (2) current weed management practices, and (3) the herbicides used in teak and melina plantations in Costa Rica.

Materials and Methods

Between January and May of 2021, a survey was conducted by email or phone call among farmers enrolled in the Payment for Environmental Services (PSA) program, reforestation modality (PSA-reforestation). This program is administered by the National Forestry Finance Fund (FONAFIFO by its acronym in Spanish). FONAFIFO's Environmental Services Department constructed a database of 525 active teak and melina farmers with plantations

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ranging from 1 to 10 years old. Based on this information, a random sample stratified by province of 180 farmers was selected. At the time of the survey, farmers with current contracts were only present in six of the country's seven provinces.

The survey consisted of 12 questions divided into three main themes (Table 1): (i) general information and plantation establishment information, (ii) weed management practices, and (iii) problematic weeds. In section one, respondents were asked about farm location (province and county), total planted area, and plantation establishment techniques. In the second section, respondents were asked about their current weed management practices. Finally, respondents were asked to identify (by local common name) and rank the five most problematic weeds based on their own experience and the reason(s) for their choice. The questionnaire was pretested on six people including farmers, weed scientists, foresters, and field technicians to assess its readability and its value for meeting the stated objectives. Later, their comments were reviewed and incorporated into the final version. The final questionnaire was sent by email or applied by phone call.

Insert table 1

Data analysis

To rank the most problematic weeds, we used the equation proposed by Sarangi and Jhala (2018; Equation 1) where F is the number of respondents choosing a particular rank (r) for a certain species, X is the problematic points associated with that rank, and n is the total number of responses for that rank including all weed species.

$$RP = \sum_{r=1}^{5} \frac{FX}{n} \qquad \text{Equation 1}$$

Results were tabulated, and a database was created. For each weed documented as problematic, its family, genus, and species were recorded. Additionally, each weed was grouped into one of the following functional groups: (i) grasses, (ii) vines, (iii) broadleaf plants, and (iv) sedges. Scientific names were assigned based on the common names provided by respondents. In cases

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of uncertainty, photographs were requested, or a field sample was obtained for identification. Common names are reported based on the PLANTS Database (USDA-NRCS 2025).

To analyze response patterns for categorical questions, response frequency was estimated as the number of times a category was mentioned divided by the total number of responses for a given question expressed as a percentage. This was done at the province level. Data on weed species were then compiled at the national level.

Results and Discussion

A total of 180 surveys were sent to growers across six of the seven provinces of Costa Rica, and 87% were completed in the provinces and returned for analysis. The largest number of surveys were done in the provinces of Guanacaste and Alajuela, representing 50% and 29% respectively of the surveys completed (Figure 1). The province of Cartago did not register any teak and melina farmers active in the PSA-reforestation program.

General information

The respondents were mainly plantation owners and, to a lesser extent, forestry engineers in charge of forest plantations from reforestation companies. Both the owners and the professionals oversaw removing weeds from the plantation. From all the surveyed participants, 75% identified themselves as teak farmers, while the remaining 25% had melina plantations. Among the respondents, 43% owned plantations larger than 50 ha, while 35% had plantations ranging from 1 to 20 ha. Furthermore, nearly 50% of respondents indicated that prior to establishing their current plantations, the land was used as forest plantation, while 43% noted pastures and grassland. The remaining 9% of previous land uses included fallow and agricultural crops such as cassava and corn (Table 2), were reported to a lesser extent. Even though 90% of the respondents had established plantations on pastures or immediately harvested a tree plantation before their current one, only 11% employed soil mechanization techniques such as push/pile debris, subsoiling, and harrowing. Thus, the majority of the plantations are established without using tillage (i.e. no-till) likely favoring perennial species (Scursoni et al. 2019).

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Weed management practices

The diversity and availability of control tools and production practices can greatly influence the efficacy of weed management plans (Sarangi and Jhala 2018). Over 85% of respondents reported employing a combination of manual, mechanical (e.g. weed wacker and/or tractor-mounted mower), and herbicides to control weeds in their plantations. Only 2% mentioned that they control weeds exclusively with herbicides (Figure 2).

Another important parameter for weed management is properly identifying and characterizing the target area where weeds are more problematic (Garau et al. 2009). Plantation age is a determining factor in the selection of the area to be controlled. During plantation establishment, weed control at the base of the tree (≤ 50 cm radius) is the predominant method of vegetation management; however, as the plantation matures, the approach shifts toward strip or total vegetation control, with a corresponding increase in the reliance on herbicide applications (Murillo et al. 2024; Kogan and Alister 2010). The current survey confirms this observation since more than 50% of the respondents indicated that they control weeds in the entire plantation covering both tree lines and inter-row areas.

Herbicides are commonly used for weed control in intensively managed forest plantations due to their efficiency, cost-effectiveness, labor-saving benefits, and prolonged effect compared to other methods (Miller and Wigley 2004; Wang et al. 2001). Among the respondents, 90% reported using a total of nine herbicides with five different mechanisms of action. Among the herbicides mentioned, two specifically control grasses, and no pre-emergence herbicides were reported. The most frequently mentioned products were glyphosate, metsulfuron methyl, and paraquat (Figure 3 and Table 3). This trend was consistent across all six provinces.

There were cases in which farmers used a single herbicide in their plantations, and others in which they rotated two or three herbicides (Figure 4). Herbicide use varied among respondents, with most reporting the inclusion of two herbicides in their management plans (45%). Specifically, the most common pair was glyphosate and metsulfuron methyl. Among those who reported the use of a single herbicide, glyphosate was the dominant, far surpassing metsulfuron methyl and paraquat.

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Glyphosate is the most widely used herbicide for vegetation management in forest plantations in Costa Rica, primarily due to its broad-spectrum weed control, flexibility in application timing (e.g., plants of different sizes), and low cost. Its widespread use also reflects its effectiveness in perennial crop systems across the country (Ramírez-Muñoz et al. 2017; Kogan and Allister 2010). Glyphosate is sprayed several times during the first two to three years after plantation establishment to control weeds that grow understory, both in the alleys and at the base of the tree. In Costa Rica, glyphosate resistance has been documented in two grass species, goosegrass (Heap 2025) and arrocillo (Ramírez-Muñoz 2016), both of which are commonly found in forest plantations, raising concerns about the long-term effectiveness of glyphosate-based weed management strategies in these systems.

To a lesser extent, respondents reported the use of five herbicides in their weed management practices. These included glyphosate, paraquat, metsulfuron methyl, and the auxin herbicides (Group 4) 2, 4-D and triclopyr. These herbicides were valued for their efficacy against broadleaf species and the relatively low occurrence of resistance cases (Heap 2025). Specifically, triclopyr is often employed for stump removal in harvested plantations where site preparation for a new production cycle is underway.

Problematic weeds

In this survey, farmers identified a total of 40 weed species distributed across 21 plant families (Table 4). The frequency of these families varied among provinces according to farmer perceptions of their importance. Poaceae was consistently dominant across all provinces, ranking first in every region with frequencies ranging from 16% in Limón to 32% in Puntarenas. Other frequently mentioned families included Fabaceae, Cyperaceae, and Malvaceae, although their importance varied regionally (Table 5). For instance, Fabaceae was notably frequent in Guanacaste (13%) and Puntarenas (8%), while Cyperaceae was dominant in Heredia (12%) and Limón (8%). Furthermore, Melastomataceae and Dillenaceae were significant in Alajuela, with frequencies of 14% and 11%, respectively. This regional vegetation variation is strongly influenced by Costa Rica's physiography and climatic gradients. The country's two main mountain ranges run longitudinally through the central region, interacting with prevailing northeastern winds to create diverse ecological zones. As a result, provinces on the Atlantic side of the country are characterized by more humid conditions. For example, annual rainfall in

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Limón ranges from 2500 to over 4800 mm, and parts of Heredia and northern Alajuela present rainfall of 2700 to 3800 mm. Conversely, the Central Pacific (Puntarenas, San José) and Northwestern (Guanacaste) regions are drier with distinct wet and dry seasons and annual rainfall of 1800 to 2600 mm (Quintero and Villalobos 2001). During the dry season, from January to March, total rainfall is less than 6 mm, which favors the presence of drought and fire-tolerant weeds.

Weed prevalence also reflected these climatic differences. In the humid provinces, vines such as raspa guacal and orchid vine were reported more frequently, while in the drier regions grasses such as jaraguagrass and arrocillo were considered more problematic. At the national scale, the ranking of the most problematic weeds based on farmer reports was: (1) raspa guacal, (2) arrocillo, (3) jaraguagrass, (4) coyol palm, and (5) orchid vine (Table 6). No single species was consistently reported across all provinces. Yet, it is noteworthy that two species belonging to the genus *Paspalum* were considered the most problematic in three provinces. In Costa Rica, arrocillo has been documented as resistant to glyphosate, specifically in the Caribbean region (Ramirez-Muñoz 2016). Given that glyphosate was reported as the most widely used herbicide among respondents, and that arrocillo was frequently identified as one of the most problematic weeds, these findings emphasize the urgent need for ongoing monitoring of this species in forest plantations to detect and manage emerging cases of resistance.

In the province of Alajuela, the top-ranked species were vines. Furthermore, volunteer teak and melina trees were mentioned as a concern because their strong regrowth and persistence capability, identifying a unique weed management challenge in this region. In established plantations where these species were previously grown, their rapid regrowth can compete with newly planted seedlings. If not managed promptly, this competition may hinder growth and, in some cases, lead to the death of newly planted individuals.

The considerable weed biodiversity present in teak and melina plantations in Costa Rica, which coincides with previous studies carried out by Agüero-Alvarado et al. (2018) in coffee and banana plantations and by Brenes-Prendas and Agüero-Alvarado (2007) in pineapple plantations. In particular, the predominance of grasses agrees with the studies by Takin et al. (2019) and

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Tuffi Santos et al. (2013) where the Poaceae family is the most representative in teak plantations in Nigeria and eucalyptus in Brazil.

This study identified the weed species that pose significant challenges to forestry plantation owners, with variations observed across provinces. Specific species of grasses and vines present major challenges in forest plantations Their impact varies across regions, but they are especially aggressive during the early stages of tree establishment, where competition for light, water, and nutrients can substantially inhibit tree growth, specifically reducing height increment and stem diameter development. In the case of grasses, combinations of herbicides and their application in bands can be more efficient than mechanical methods alone, leading to better vegetative growth (Domingos and Coelho 2018; Silva et al. 2012). Conversely, vines are frequently removed mechanically and treated with selective herbicides to effectively suppress regrowth and allow tree canopy closure (Paul and Yavitt 2011).

The results of the survey underscore the importance of tailoring weed management strategies to address regional differences in weed composition and abundance, thereby enhancing the efficacy of control efforts. Given the limited information on management of tropical weed species and silvicultural practices, more attention should be paid to the generation of information about the ecology of those weeds and development of cost-effective control tools.

Practical Implications

The findings of this survey provide a valuable characterization of the weed challenges faced by teak and melina plantation owners in the tropics, emphasizing the need for considering local-weed community composition to develop specific weed management strategies. The identification of Poaceae species and climbing vines as the most problematic weeds highlights the necessity for targeted control measures, particularly during the early establishment phase of plantations. Given the high reliance on glyphosate, metsulfuron methyl, and paraquat, there is a pressing need to diversify herbicide options to prevent resistance development and ensure long-term effectiveness.

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Competing Interests

The authors declare none.

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Table 1. Questionnaire about weed management practices and problematic weeds used for survey of teak and melina farmers in Costa Rica in 2021.

Section	Question	Answers
General information	1. Indicate the province where your plantation is located:	a. San José
		b. Alajuela
		c. Heredia
		d. Cartago
		e. Guanacaste
		f. Puntarenas
		g. Limón
	2. Indicate the county where your plantation is located:	oa[a]
	3. What was the land used for before the plantation was established?	a. Pasture
		b. Agricultural land
		c. Secondary forest
		c. Forest plantation
	4. What is the size of your plantation?	a. 1 to 20 ha
		b. More than 20 but less than 50 ha
		c. More than 50 ha
	5. What type of site preparation did you carry out?	a. Full mechanization of the land
		b. Weed control and residue removal
		c. None
	6. Indicate the species you have planted:[b]	a. Teak
		b. Melina

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	7. How old is your plantation?	a. Less than 2 years b. More than 2 years
Management practices	8. What weed control method do you use in your plantation?	a. Manual/mechanical (e.g., machete, brush cutter) (go to Q11) b. Chemical (go to Q9) c. Both (go to Q9) d. Other
	9. If you use herbicides, list the top 3 products:	oa
	10. Which weed control method do you use most? (Select just one option)	a. Around the tree weeding b. Strip weeding c. Full ground cover
Problematic weeds	11. List the 5 most problematic weeds (ranked). Indicate reasons for each.	oa
	12. Why is this weed problematic? (Check all that apply). This question was asked for the five weed species.	a. Difficult to control with herbicides b. Climbs on trees c. Very abundant d. Hard to remove manually or mechanically e. Harbors pests f. Other:

[a] oa: open answer. County data was not included in the analysis because sample sizes at this level was too small to allow meaningful comparisons.

[b] If a farmer had fields with both species, separate surveys were completed for each species.

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Table 2. Characteristics of plantation ownership, previous land use, and site preparation methods reported by teak and melina farmers in Costa Rica in 2021.

Variable	Category	Frequency
		%
Plantation size	1 – 20 hectares	35
	20 – 50 hectares	22
	> 50 hectares	43
Previous land use	Forest plantation	48
	Pastureland	43
	Agricultural land	6
	Fallow land	3
Site preparation	General weed control and vegetation management	81
	Push/pile debris + soil mechanization (subsoiling and/or harrowing)	11
	No soil preparation (digging only)	8

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Table 3. Herbicides used in teak and melina plantations in Costa Rica: mechanism of action (code), formulation, concentration, dose, and growth stage for application based on the local recommendations.

Herbicide	WSSA/HRAC Code[a]	Label rate	Growth stage
		g ai ha^{-1}	
Glyphosate	9	360-1800	In post-emergence when weeds are actively growing
Metsulfuron methyl	2	15-30	Early post-emergence (weeds with 2 to 4 leaves). When mixed with glyphosate, weeds should be actively growing and between 15 and 30 cm tall
Paraquat	22	300-600	Post-emergence when weeds are less than 15 cm tall
2, 4-D	4	600-1800	Post-emergence when weeds are less than 15 cm tall.
2, 4-D + Aminopyralid	4	960-1280 + 120-160	Post-emergence when weeds are less than 15 cm tall Do not apply when weeds are flowering.
Triclopyr	4	240-480	Early post-emergence
Fluazifop-P-butyl	1	125-250	Post-emergence when grasses are fully developed and have two to five true leaves
Picloram + 2, 4-D	4	360-960 + 96-256	post-emergence. If you want to control shrubs, apply when they are fully developed, and the soil is moist.
Quizalofop-P	1	108-270	Annual grasses: when they have 2-5 true leaves. Perennial grasses: when they have 4-6 true leaves but before nodulation.

[a] WSSA-Herbide site of action (SOA) classification list. Available in https://wssa.net/wp-content/uploads/WSSA-Herbicide-SO_WSSA_20210505.xlsx"

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Table 4. Common weed species reported in teak and melina plantations based on perceptions of producers surveyed in Costa Rica in 2021.

Common name	Species	Family
Coyol palm	*Acrocomia aculeata* (Jacq.) Lodd. Ex Mart.	Arecaceae
Liana de cuello	*Amphilophium paniculatum* (L.) Kunth	Bignoniaceae
Chinese violet	*Asystasia gangetica* (L.) T. Anderson	Acanthaceae
Pata de vaca	*Bauhinia ungulata* L.	Fabaceae
Hairy beggarticks	*Bidens pilosa* L.	Asteraceae
Browne's blechum	*Blechum pyramidatum* (Lam.) Urb.	Acanthaceae
Field mustard	*Brassica rapa* L.	Brassicaceae
Woodland coffee	*Bunchosia nitida* (Jacq.) DC.	Malpighiaceae
Sopabush	*Clidemia hirta* (L.) D. Don	Melastomataceae
Varilla negra	*Cordia spinescens* L.	Boraginaceae
Bermudagrass	*Cynodon dactylon* (L.) Pers.	Poaceae
Raspa guacal	*Davilla nitida* (Vahl) Kubitzki	Dillenaceae
Creeping river grass	*Echinochloa polystachya* (Kunth) Hitch.	Poaceae
Goosegrass	*Eleusine indica* (L.) Gaertn.	Poaceae
Fire star orchid	*Epidendrum radicans* Pav. Ex Lindl.	Orchidaceae
Melina (volunteer)	*Gmelina arborea* Roxb. Ex Sm.	Lamiaceae
Expanded lobsterclaw	*Heliconia latispatha* Benth.	Heliconiaceae
Jaraguagrass	*Hyparrhenia rufa* (Nees) Stapf	Poaceae
Indian murainagrass	*Ischaemum indicum* (Houtt.) Merr.	Poaceae
Velvet bean	*Mucuna pruriens* (L.) DC.	Fabaceae
Guineagrass	*Panicum maximum* (Houtt.) Merr.	Poaceae
Mexican crowngrass	*Paspalum fasciculatum* Willd. ex Flugge	Poaceae
Arrocillo	*Paspalum paniculatum* L.	Poaceae
Elephant grass	*Pennisetum purpureum* Schumach.	Poaceae
Monkeypod	*Pithecellobium dulce* (Roxb.) Benth.	Fabaceae

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Blackbead	*Pithecellobium hymenaeifolium* (Humb. & Bonpl. Ex Willd.) Benth.	Fabaceae
Guava	*Psidium guajava* L.	Myrtaceae
Southern brackenfern	*Pteridium caudatum* (L.) Maxon	Dennstaedtiaceae
Itchgrass	*Rottboellia conchinchinensis* (Lour.) Clayton	Poaceae
Cortadora blanca	*Scleria pterota* var. melaleuca (Rchb. Ex Schltdl. & Cham.) Uittien	Cyperaceae
Common wireweed	*Sida acuta* Burm. f.	Malvaceae
Bay Biscayne creeping-oxeye	*Sphagneticola trilobata* (L.) Pruski	Asteraceae
Orchid vine	*Stigmaphyllon lindenianum* A. Juss.	Malpighiaceae
Matapalo	*Struthanthus orbicularis* (Kunth) Blume ex Eichler	Loranthaceae
Velvety syngonium	*Syngonium wendlandii* Schott	Araceae
Teak (volunteer)	*Tectona grandis* L. f.	Lamiaceae
Cresta de gallo blanco	*Teramnus uncinatus* (L.) Sw.	Fabaceae
Cat's claw	*Uncaria tomentosa* (Willd.) DC.	Rubiaceae
Palisade grass	*Urochloa brizantha* (Hochst. Ex A. Rich.) R.D. Webster	Poaceae
Tuete	*Vernonia patens* Kunth	Asteraceae

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Table 5. Ranking and frequency of the most commonly reported plant families by province based on farmers' perceptions of problematic weeds in teak and melina plantations in Costa Rica in 2021.

Province	Rank	Family	Frequency
			%
Guanacaste	1	Poaceae	26
	2	Fabaceae	13
	3	Malvaceae	7
	4	Arecaceae	7
	5	Asteraceae	3
Alajuela	1	Poaceae	17
	2	Melastomataceae	14
	3	Dillenaceae	11
	4	Lauraceae	8
	5	Malpighiaceae	8
Puntarenas	1	Poaceae	32
	2	Fabaceae	8
	3	Malvaceae	6
	4	Arecaceae	5
	5	Cyperaceae	3
Heredia	1	Poaceae	24
	2	Cyperaceae	12
	3	Dennstaedtiaceae	4
	4	Convolvulaceae	4
	5	Heliconiaceae	4
Limón	1	Poaceae	16
	2	Cyperaceae	8
	3	Dennstaedtiaceae	4
	4	Heliconiaceae	4
	5	Lamiaceae	4
San José	1	Poaceae	20
	2	Heliconiaceae	5
	3	Dennstaedtiaceae	5

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Table 6. Ranking of most problematic weed species and functional group at the country and province levels, based on farmers' perceptions of problematic weeds in teak and melina plantations in Costa Rica in 2021.

Area[a]	Rank	Species	Functional group
Country	1	Raspa guacal	Vines
	2	Arrocillo	Grasses
	3	Jaraguagrass	Grasses
	4	Coyol palm	Broadleaf
	5	Orchid vine	Vines
Guanacaste	1	Arrocillo	Grasses
	2	Jaraguagrass	Grasses
	3	Coyol palm	Broadleaf
	4	Palisade grass	Grasses
	5	Raspa guacal	Vines
Alajuela	1	Raspa guacal	Vines
	2	Orchid vine	Vines
	3	Indian murainagrass	Grasses
	4	Melina (volunteer)	Broadleaf
	5	Teak (volunteer)	Broadleaf
Puntarenas	1	Arrocillo	Grasses
	2	Cortadora blanca	Sedges
	3	Jaraguagrass	Grasses
	4	Velvet bean	Vines
	5	Coyol palm	Broadleaf
Heredia[b]	1	Mexican crowngrass	Grasses
	2	Cortadora blanca	Sedges
Limón	1	Cortadora blanca	Sedges
	2	Indian murainagrass	Grasses
	3	Elephant grass	Grasses
	4	Varilla negra	Vines
	5	Melina (volunteer)	Broadleaf

[a] San José respondents reported only functional groups and did not identify specific weed species.

[b] Only 2 species were reported for this province

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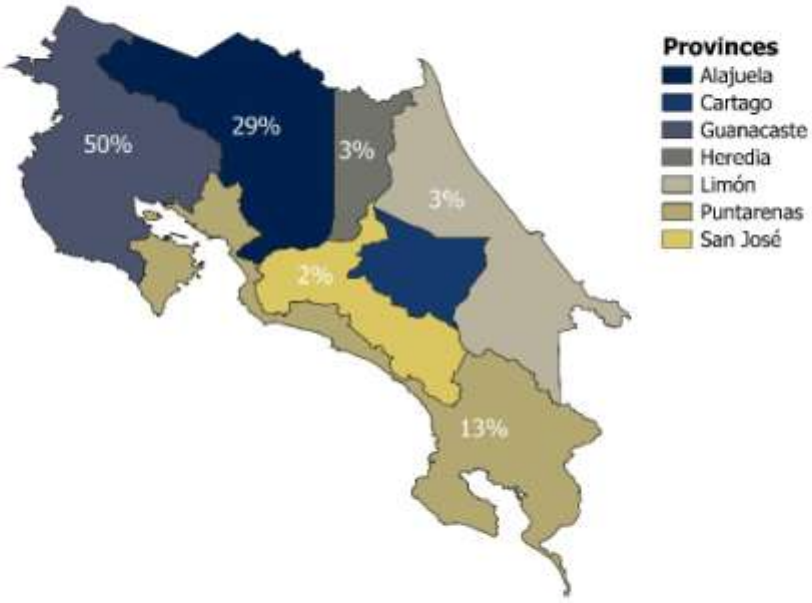

Figure 1. Distribution of respondents from each province participating in the survey on weed management in teak and melina plantations in Costa Rica in 2021.

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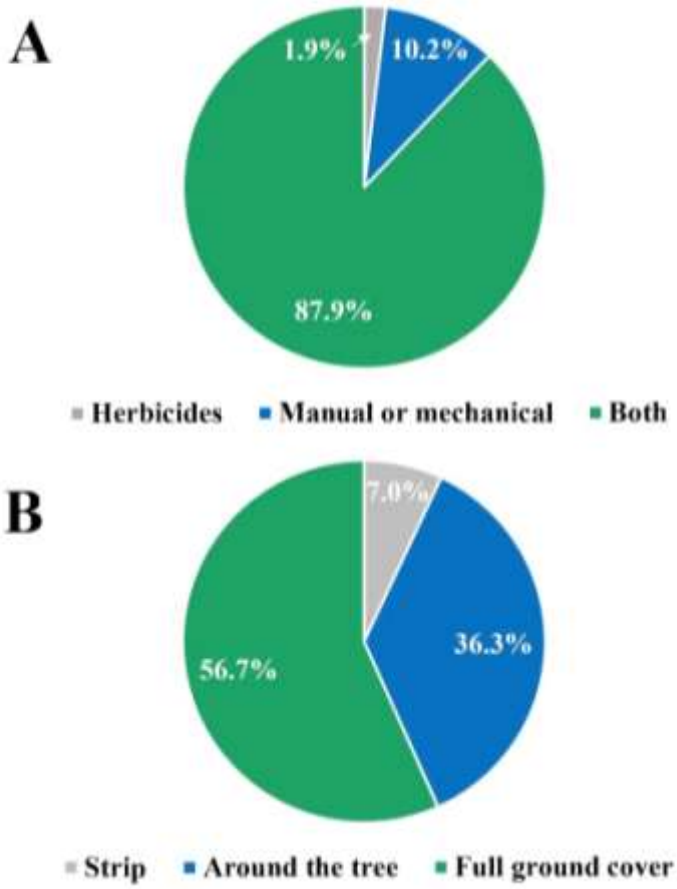

Figure 2. Response frequency for weed control tools used in forest plantations (A), and area targeted for control (B), according to teak and melina farmers' perceptions in Costa Rica in 2021.

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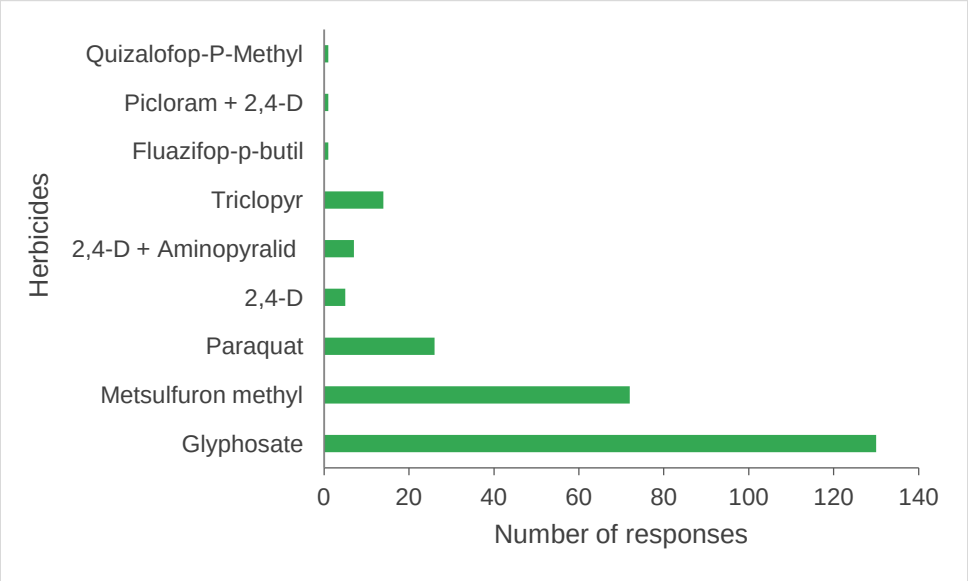

Figure 3. Number of responses indicating the use of specific herbicides in teak and melina plantations by farmers surveyed in Costa Rica in 2021.

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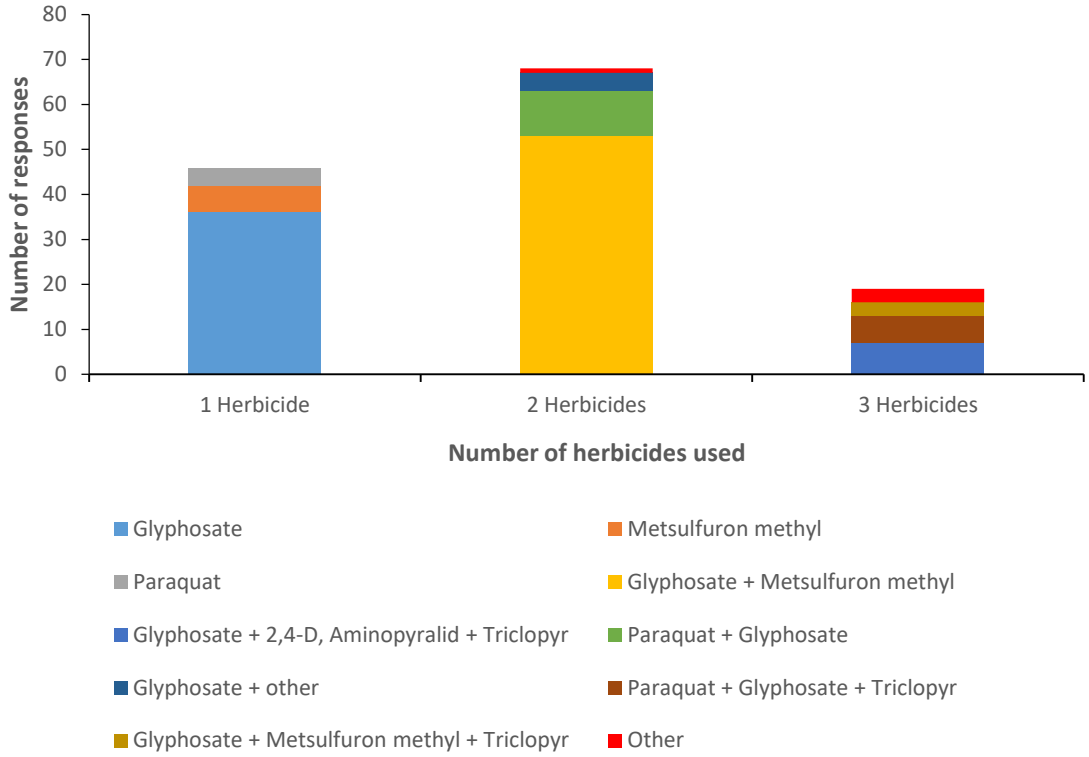

Figure 4. Number of farmers reporting the use of one, two, or three herbicides for weed management in teak and melina plantations in Costa Rica in 2021.

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