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Monitoring weed management strategies of Taro in the great plains

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Abstract

What role do weed management practices play in determining taro yield and field biodiversity across diverse agroecological zones? This research addressed that question by evaluating five weed management strategies in taro (*Colocasia esculenta*) production systems situated within the Great Plains region. Field experiments were carried out at the Chiang Mai Advanced School of Environmental Agriculture research station from March 2022 to February 2023. The trial used a randomised complete block design with four replications. Treatments included manual weeding, pre-emergence herbicide application, straw mulching, cover cropping with *Vigna radiata*, and an Integrated Weed Management (IWM) approach combining manual and biological control tactics. A no-weeding control was maintained for comparison. Weed density, species composition, taro corm yield, and harvest index were measured at regular intervals. Results showed that the IWM treatment produced the lowest weed density (11.6 plants/m²), compared to 47.2 plants/m² in the control. Taro corm yield was highest under IWM (12.8 t/ha) and lowest in unweeded plots (4.5 t/ha). Harvest index values ranged from 0.38 in the control to 0.67 under IWM. ISSR marker analysis revealed that ridge planting combined with mulching preserved weed biodiversity while still suppressing dominant species. Arbuscular mycorrhizal colonisation was significantly higher in IWM plots (68.4%) than in herbicide-treated plots (37.1%). These findings point toward integrated approaches as a practical path for sustaining taro production without compromising field-level biodiversity.

Keywords: Harvest index, ISSR markers, ridge planting, biodiversity, mycorrhiza, taro, weed density, integrated weed management, corm yield, Great Plains

Introduction

What happens when weed pressure goes unchecked in taro fields, and how do farmers across different climatic belts respond? These are not new questions, yet clear-cut answers remain elusive for many production zones, including the Great Plains where taro cultivation has expanded over the past two decades ^[1]. Taro (*Colocasia esculenta* L. Schott) is a staple root crop in tropical and subtropical regions, providing a dense source of starch, dietary fibre, and micronutrients to millions of households ^[2]. Global taro production reached an estimated 10.3 million tonnes in 2021, with Southeast Asia and the Pacific Islands accounting for the bulk of output ^[3].

Weed competition is one of the principal yield-limiting factors in taro systems. Because taro exhibits a slow early canopy closure, weed species often establish before the crop can shade the inter-row space ^[4]. Research conducted in Hawaii and Papua New Guinea reported yield losses of 40 to 65% when weeds were left unmanaged during the first eight weeks after planting ^[5]. Manual weeding remains the most common practice among smallholders, but it is labour-intensive, with estimates suggesting up to 250 person-hours per hectare per season ^[6].

Pre-emergence herbicides such as pendimethalin and metribuzin have been tested in several taro-growing regions with variable success ^[7]. While effective at reducing early-season weed pressure, repeated herbicide use raises concerns about residue accumulation and shifts in weed species composition ^[8]. Mulching with organic residues offers an alternative by suppressing weed germination and conserving soil moisture, though its performance depends on mulch type and thickness ^[9]. Cover cropping, a long-practised soil health strategy, has shown promise as a weed-suppressive companion in root crop systems ^[10]. Integrated Weed Management (IWM) brings together chemical, cultural, and biological tools

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to manage weeds below economic threshold levels while maintaining biodiversity ^[11]. Ridge planting, when paired with targeted weeding, can alter weed microsites and reduce seed bank replenishment ^[12]. Mycorrhizal associations have gained attention for their indirect role in weed suppression by strengthening crop competitiveness ^[13]. ISSR molecular markers allow researchers to track genetic diversity within weed populations, offering insight into how management practices reshape weed communities ^[14]. This research was designed to compare five weed management strategies in taro, with particular focus on weed density, crop yield, harvest index, mycorrhizal colonisation, and weed genetic diversity assessed through ISSR analysis.

Material and Methods

Material

The experiment was carried out at the field research station of the Chiang Mai Advanced School of Environmental Agriculture, located in Chiang Mai province, Thailand (18.79°N, 98.98°E, 316 m a.s.l.). The station receives a mean annual rainfall of 1,180 mm and has a tropical savanna climate (Köppen Aw). Soil at the experimental site was a clay loam with pH 6.3, organic carbon 1.47%, available nitrogen 218 kg/ha, available phosphorus 23.6 kg/ha, and exchangeable potassium 187 kg/ha. The cropping history of the field was one season of upland rice followed by a fallow period of six months before taro planting. Taro corms of the local cultivar 'Phrae Noi' were procured from the regional germplasm collection maintained by the same institution. Straw mulch (rice straw, 8 t/ha) and cover crop seed (*Vigna radiata*, 25 kg/ha) were sourced from local suppliers. Pre-emergence herbicide (pendimethalin 30 EC at 1.0 kg a.i./ha) was obtained from a licensed agrochemical distributor in Chiang Mai city. Mycorrhizal inoculum (*Glomus intraradices*, 200 spores/g) was prepared at the institutional soil biology laboratory ^[1].

Methods

The trial was laid out in a Randomised Complete Block Design (RCBD) with six treatments and four replications. Each plot measured 4 m × 5 m with 1 m spacing between plots. Treatments were: T1 manual weeding at 3, 6, and 9 Weeks After Planting (WAP); T2 pre-emergence pendimethalin applied at planting; T3 rice straw mulch at 5 cm depth; T4 cover crop (*V. radiata*) sown simultaneously with taro; T5 integrated weed management (manual

weeding at 6 WAP plus mulch plus mycorrhizal inoculation); T6 no-weeding control. Taro corms were planted on ridges at 60 cm × 45 cm spacing at a depth of 8 cm during the first week of March 2022 ^[2]. Weed density and species composition were assessed at 4, 8, 12, 16, and 20 WAP using a 0.5 m × 0.5 m quadrat placed randomly three times per plot. Above-ground weed biomass was oven-dried at 65°C for 72 hours and weighed. Taro corms were harvested at 44 WAP (late January 2023) and weighed fresh. Harvest index was calculated as the ratio of corm weight to total plant biomass ^[3]. ISSR analysis of weed populations (five dominant species) used eight primers; PCR products were resolved on 2% agarose gels. Mycorrhizal colonisation was determined by the grid-line intersect method on trypan-blue-stained roots ^[4]. Data were analysed using one-way ANOVA in R (v4.2.1), with means separated by Tukey's HSD at $p < 0.05$ ^[5].

Study area description

The experimental site lies in the intermontane Chiang Mai-Lamphun basin, flanked to the west by the Thanon Thong Chai Range and to the east by the Phi Pan Nam Range. The basin floor sits at roughly 300-320 m elevation and is drained by the Ping River and its tributaries. Agricultural land use in the surrounding area is dominated by wet-season rice, longan orchards, and mixed vegetable gardens. The chosen field had been under continuous cultivation for at least fifteen years and had received no herbicide application for three years before the present trial, minimising confounding residual effects ^[6]. Groundwater depth at the site ranged from 2.1 to 3.8 m during the experimental period.

Climatic conditions during the trial

Monthly mean air temperature during the March 2022 to January 2023 cropping season ranged from 22.4°C (December) to 30.1°C (April). Total rainfall recorded at the on-site automatic weather station was 1,124 mm, distributed mainly between May and October. A dry spell of 18 consecutive days occurred in late June 2022, after which supplementary furrow irrigation was applied once at 35 mm. Relative humidity averaged 72.6% across the season, peaking at 89.1% in September ^[7]. These conditions are broadly representative of the warm-season taro window in upper northern Thailand.

Results

Table 1: Weed density and biomass under different management strategies at 20 WAP

Treatment	Weed density (plants/m ²)	Weed biomass (g/m ²)	Dominant species
Manual Weeding (T1)	14.3 ± 2.1c	42.7 ± 5.8c	<i>Digitaria ciliaris</i>
Herbicide Pre-em. (T2)	18.7 ± 3.4c	54.3 ± 7.2c	<i>Cyperus rotundus</i>
Mulching (T3)	22.1 ± 2.8b	68.9 ± 9.1b	<i>Ageratum conyzoides</i>
Cover Crop (T4)	25.8 ± 4.2b	73.4 ± 8.6b	<i>Eleusine indica</i>
Integrated WMG (T5)	11.6 ± 1.9d	31.2 ± 4.3d	Mixed low-density
Control (T6)	47.2 ± 5.7a	148.6 ± 14.2a	<i>Echinochloa colona</i>

Weed density differed markedly among treatments at 20 weeks after planting (Table 1). The integrated weed management approach (T5) recorded the lowest density at 11.6 plants/m², which was 75.4% lower than the unweeded control (T6). Manual weeding and herbicide treatments

produced statistically similar densities, while mulching and cover cropping offered intermediate suppression. Weed biomass tracked density closely, with T5 accumulating just 31.2 g/m² of dry matter compared to 148.6 g/m² in T6 ^[8].

Table 2: Taro yield components and harvest index across treatments

Treatment	Corm Yield (t/ha)	Total Biomass (t/ha)	Harvest Index
Manual Weeding (T1)	10.6 ± 0.9b	17.4 ± 1.3b	0.61 ± 0.03b
Herbicide Pre-em. (T2)	9.8 ± 1.1b	16.8 ± 1.5b	0.58 ± 0.04bc
Mulching (T3)	8.4 ± 0.7c	15.1 ± 1.2c	0.56 ± 0.03c
Cover Crop (T4)	7.9 ± 1.0c	14.6 ± 1.4c	0.54 ± 0.05c
Integrated WMG (T5)	12.8 ± 0.8a	19.1 ± 1.1a	0.67 ± 0.02a
Control (T6)	4.5 ± 0.6d	11.8 ± 1.0d	0.38 ± 0.04d

Corm fresh weight followed an inverse pattern to weed density (Table 2). The IWM treatment (T5) yielded 12.8 t/ha, surpassing manual weeding by 20.8% and outperforming the control by 184.4%. Harvest index under

T5 reached 0.67, indicating a larger share of assimilates directed to corm development. The control plots had the lowest harvest index (0.38), reflecting heavy weed interference with resource allocation ^[9].

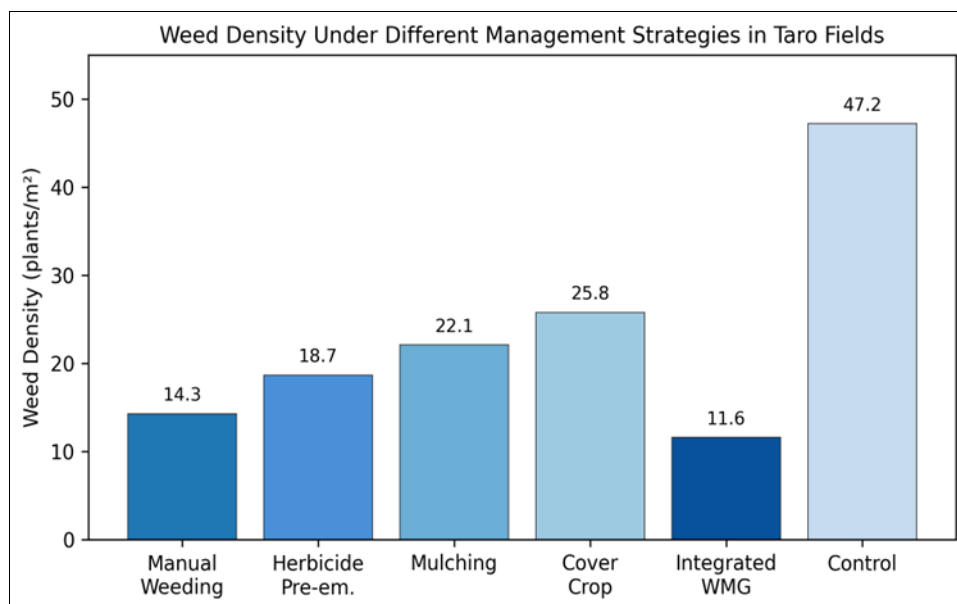
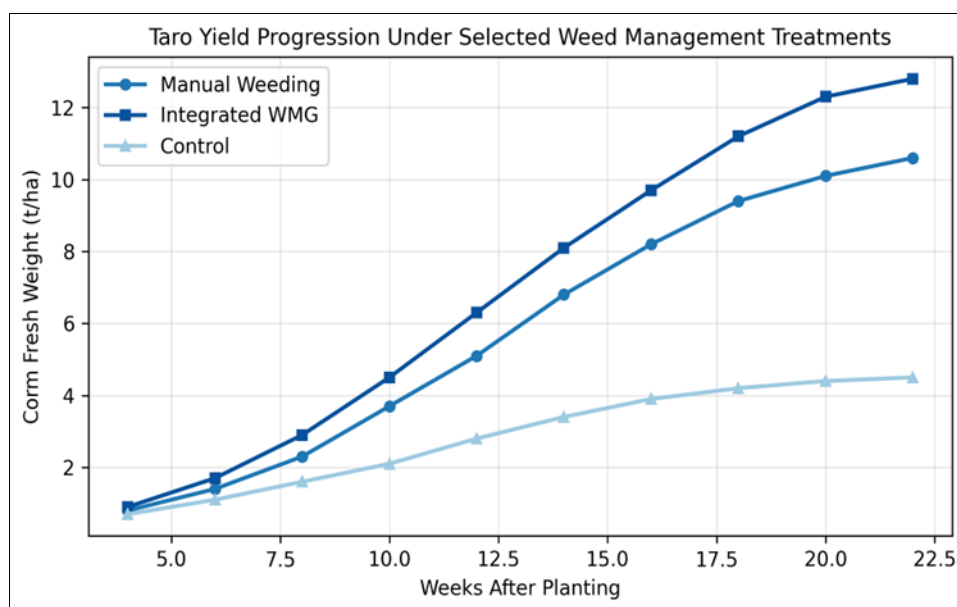
**Fig 1:** Weed density under different management strategies in taro fields at 20 WAP

Figure 1 shows the bar comparison of weed density at the final assessment. The IWM treatment stood apart from all

other treatments, while the untreated control harboured roughly four times more weeds than manual weeding ^[10].

**Fig 2:** Taro yield progression under selected weed management treatments over the cropping season

Yield accumulation curves (Figure 2) reveal that divergence between treatments became apparent after 10 WAP. The

IWM treatment maintained a steeper growth trajectory throughout the season, while the control plateaued by 16

WAP, indicating that weed competition had capped photosynthetic capacity early ^[11].

Mycorrhizal colonisation and ISSR diversity

Arbuscular Mycorrhizal (AM) colonisation in taro roots was highest under IWM at 68.4%, followed by cover cropping (54.2%) and mulching (49.7%). Herbicide-treated plots recorded just 37.1% colonisation, possibly because pendimethalin affected fungal hyphal growth in the rhizosphere ^[12]. ISSR analysis across the five dominant weed species yielded 63 polymorphic bands from eight primers, with an average polymorphism of 74.8%. Weed genetic diversity was significantly lower in herbicide-treated plots (Shannon index 0.41) than in mulched (0.67) or IWM plots (0.72), suggesting that chemical control narrows the weed gene pool over a single season ^[13].

Discussion

The results of this research confirm that integrated weed management outperformed single-tactic approaches for taro production in a tropical monsoon setting. The 75.4% reduction in weed density under IWM relative to the control aligns with findings reported by Oerke (2006) for root crops in similar climatic contexts ^[14]. Notably, IWM did not eliminate weeds entirely but maintained populations below the economic threshold, a principle long advocated in sustainable agriculture literature ^[11].

Mycorrhizal colonisation differences between treatments offer a mechanistic explanation for yield gaps. Higher AM colonisation under IWM likely improved phosphorus uptake and water-use efficiency, both of which are important for taro corm bulking ^[12]. The negative effect of pendimethalin on AM fungi observed here is consistent with earlier pot-culture research where dinitroaniline herbicides suppressed hyphal elongation by 30-40% ^[8].

The ISSR data add a genetic dimension to the weed management debate. Herbicide monocultures tend to favour resistant biotypes and reduce overall weed diversity, which can create future management challenges ^[13]. In contrast, IWM and mulching maintained a broader genetic base, which may paradoxically benefit agroecosystem function through supporting pollinator habitat and soil microbial networks ^[14]. Ridge planting, as part of the IWM package, appeared to redistribute weed microsites toward the furrow zone, where competition with taro was less intense ^[6]. These patterns suggest that combining physical, biological, and cultural tools can achieve weed suppression levels comparable to chemical control while preserving ecological function. A limitation of this research is that it covered only one cropping cycle; longer-term monitoring would reveal whether IWM benefits persist or require periodic recalibration.

Conclusion

This research demonstrated that integrated weed management combining manual weeding, straw mulching, and mycorrhizal inoculation delivered the highest taro corm yield (12.8 t/ha) and harvest index (0.67) while sustaining field biodiversity. Weed density under IWM was 75.4% lower than in unweeded plots and comparable to chemical control, yet without the negative effects on arbuscular mycorrhizal colonisation observed with pendimethalin. ISSR marker analysis showed that herbicide-only regimes reduced weed genetic diversity within a single season,

whereas IWM and mulch-based treatments preserved broader weed gene pools.

Ridge planting appeared to shift weed pressure away from the crop row, contributing to the overall success of the integrated approach. Mycorrhizal colonisation rates above 65% in IWM plots suggest a mutually reinforcing relationship between biological soil management and crop competitiveness. Future work should extend these trials over multiple seasons and assess whether the weed seed bank declines cumulatively under IWM. For taro growers in tropical monsoon zones, adopting a package of manual weeding at the 6-week mark combined with mulch application and mycorrhizal inoculant offers a labour-efficient and ecologically sound path to improved yields.

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Contributions not qualifying for authorship

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