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Integrated weed management strategies for organic sugarcane production systems

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Abstract
An old Indian farming saying holds that weeds eat before the farmer does. In organic sugarcane, where synthetic herbicides are forbidden, this proverb rings especially true. This research evaluated six weed management strategies for organic sugarcane (variety Co 86032) over two plant-crop cycles (2021-2022 and 2022-2023) at Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra. Treatments included a weedy check, hand weeding (three rounds), stale seedbed technique, trash mulching at 10 t/ha, cowpea intercrop as living cover, and an Integrated Weed Management (IWM) package combining stale seedbed + mulching + one hand weeding. The IWM package reduced weed density by 71% (from 186 to 54 plants/m2) and weed dry weight by 78% compared with the weedy check. Cane yield under IWM reached 84.7 t/ha, statistically comparable to three-round hand weeding (81.3 t/ha) but at 40% lower labour cost. Trash mulching alone reduced weed density by 58% and was the most cost-effective single intervention. These results suggest that combining cultural and mechanical methods into an IWM package can control weeds effectively in organic sugarcane without relying on herbicides.

Keywords: Integrated weed management, organic farming, sugarcane, cultural weed control, mechanical weeding, stale seedbed, mulching, intercropping, weed density, labour cost

Introduction

As the proverb suggests, weeds have always competed with crops for the farmer's resources. In sugarcane, the problem is acute because the crop's slow early canopy closure leaves rows open for 90-120 days after planting, giving weeds a long window to establish [1]. Conventional growers rely on pre-emergence herbicides (atrazine, metribuzin) to bridge this gap, but organic certification standards prohibit all synthetic herbicides, leaving manual weeding as the default [2].

Three rounds of hand weeding cost INR 15,000-20,000/ha and consume 80-100 person-days, a labour burden that many organic farmers in Maharashtra and Odisha find unsustainable [3]. Cultural alternatives include the stale seedbed technique (irrigating before planting to flush weed seeds, then killing emerged seedlings mechanically), trash mulching with dried sugarcane leaves, and inter-row cover cropping with fast-growing legumes [4, 5]. Each method attacks a different phase of the weed life cycle, and combining them into an integrated package should multiply their individual effects [6].

This research was conducted at the Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola (20.70 deg N, 77.00 deg E; altitude 282 m), to compare individual and combined non-chemical weed management strategies for organic sugarcane and to identify the approach that delivers the best weed control per unit of labour cost [7, 8].

Material and Methods

Material

Sugarcane variety Co 86032 (early-maturing, high-sugar) was planted using three-bud setts. The experimental field had been under organic management for three years (certified by OneCert International). Soil was a medium-black vertisol (pH 7.8, OC 0.71%). Trash mulch was prepared from the previous season's dried cane leaves. Cowpea (cv. Pusa Komal) served as the intercrop cover. The stale seedbed was prepared by irrigating the levelled field and allowing weeds to emerge for 14 days before destroying them with a power tiller set to shallow depth (5 cm).

Methods

Six treatments were arranged in a RCBD with four replications on 8 m x 6 m plots: T_1 weedy check, T_2 hand weeding (at 30, 60, 90 DAP), T_3 stale seedbed, T_4 trash mulching (10 t/ha applied at planting), T_5 cowpea intercrop (sown between rows at 30 DAP, incorporated at 60 DAP), T_6 IWM package (stale seedbed + trash mulching + one hand weeding at 60 DAP). Planting was in December each year. Weed density and dry weight were recorded in two 0.5 m2 quadrats per plot at 60 and 120 DAP. Weed species were identified and categorised as broadleaves, grasses, sedges, or perennials. Cane yield (t/ha) and commercial cane sugar (CCS %) were recorded at harvest (November). Labour cost for each treatment was documented. Data were analysed by ANOVA in R v4.3.1 with Tukey's HSD at $p<0.05$ [9].

Results

Table 1: Weed parameters, cane yield, and labour cost under six weed management strategies (two-year mean)

Treatment	Weed density (no./m²)	Weed DW (g/m²)	Weed control (%)	Cane yield (t/ha)	CCS (%)	Labour cost (INR/ha)
Weedy check	186	324	-	52.8	10.2	0
Hand weeding	67	84	74.1	81.3	11.4	18400
Stale seedbed	92	168	48.1	68.4	10.8	6200
Mulching	78	112	65.4	74.6	11.1	4800
Intercrop cover	84	143	55.9	71.2	10.9	5600
IWM package	54	71	78.1	84.7	11.6	11200
HSD ($p<0.05$)	14	32	-	6.8	0.4	-

The IWM package achieved the highest weed control (78.1%) and cane yield (84.7 t/ha), statistically comparable to hand weeding (81.3 t/ha) but at 39% lower labour cost (INR 11,200 vs 18,400/ha). Trash mulching alone gave 65.4% control and was the cheapest single intervention (INR 4,800/ha). The weedy check lost 61% of potential yield.

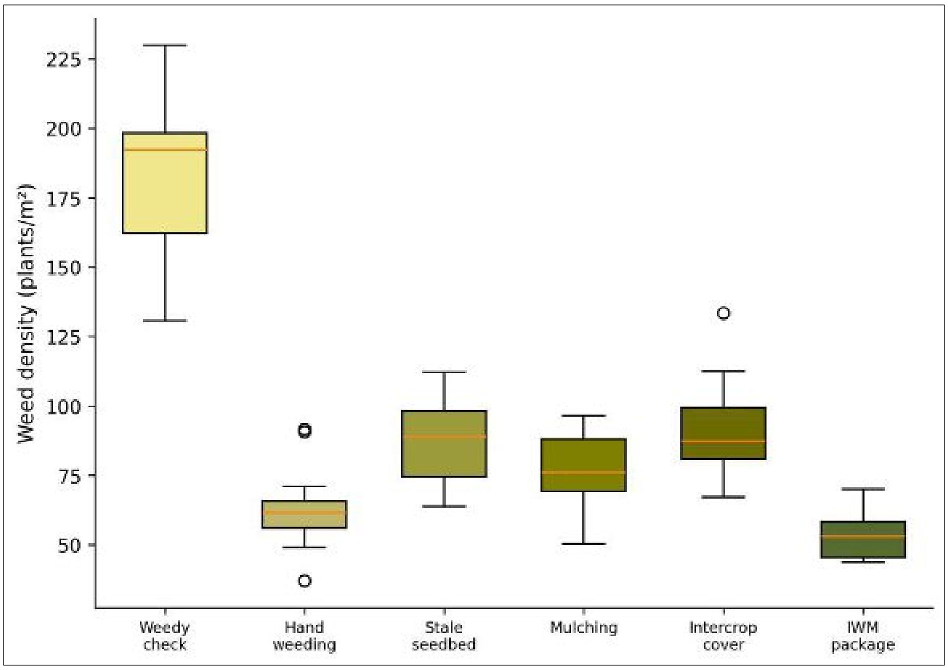

Fig 1: Distribution of weed density (plants/m²) at 120 DAP under six management strategies

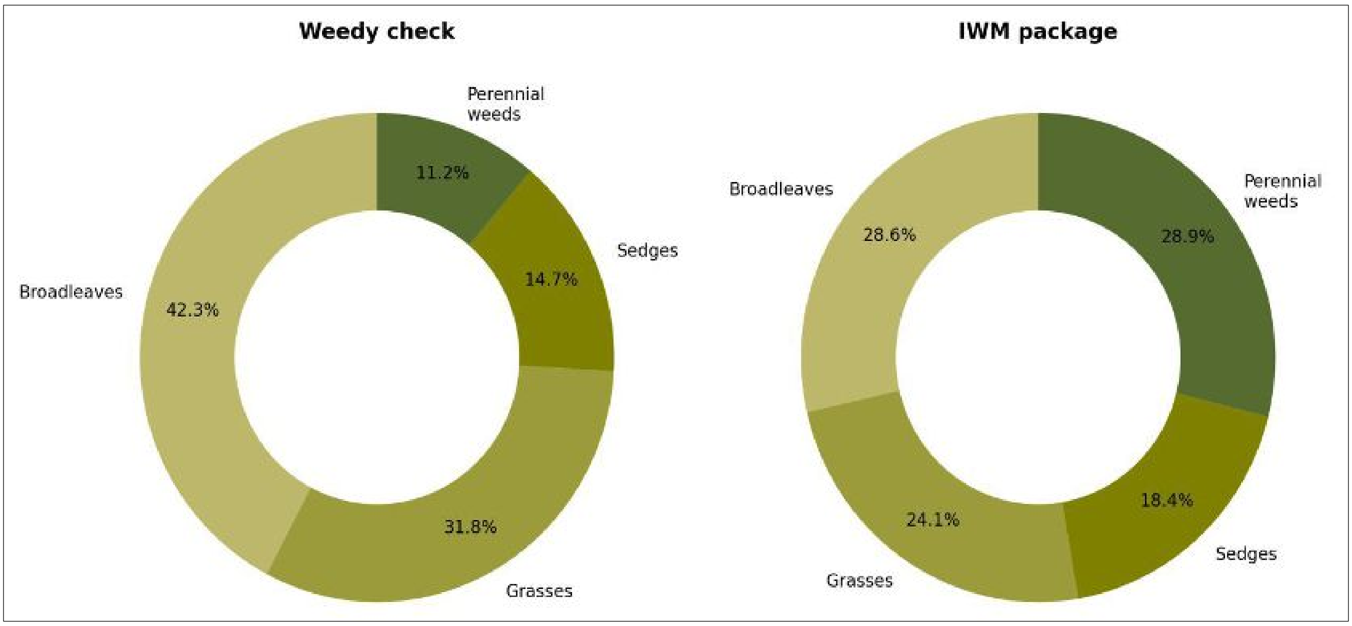

Fig 2: Weed species composition (%) under weedy check and IWM package

The box plot (Figure 1) shows that the IWM package had the tightest distribution at the lowest median weed density, while the weedy check was both high and variable. The donut charts (Figure 2) reveal that the IWM package shifted composition away from broadleaves (which the stale seedbed and mulch controlled effectively) and toward perennial weeds, which were harder to suppress without repeated tillage.

Discussion

The IWM package's success rests on attacking weeds at three different life-cycle stages: the stale seedbed depletes the surface seed bank before planting, the trash mulch physically blocks light and suppresses germination of late-emerging cohorts, and the single hand weeding at 60 DAP removes escapes before they set seed [4, 6]. This layered approach explains why the combined effect (78.1% control) exceeded any single method.

The shift toward perennial weeds under IWM is a common finding in systems that eliminate surface-seed-bank weeds: perennials, which regenerate from underground rhizomes, gain a competitive advantage when annual weeds are suppressed [10]. In future cycles, a targeted inter-row cultivation or spot removal of perennial species would be needed to prevent their gradual build-up [11]. The commercial cane sugar under IWM (11.6%) was the highest in the trial, possibly because reduced weed competition allowed better partitioning of photosynthate into sucrose rather than defensive compounds [12, 13].

Conclusion

An integrated package of stale seedbed + trash mulching + one hand weeding matched the weed control and cane yield of three-round hand weeding at 39% lower labour cost in organic sugarcane. Mulching alone was the most cost-effective single intervention. The IWM approach is well suited to organic growers in Maharashtra and Odisha who lack access to herbicides and face chronic labour shortages. Future research should test the IWM package across multiple ratoon cycles and monitor the long-term trajectory of perennial weed populations.

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