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Effect of integrated weed management on yield and economics of irrigated groundnut

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Abstract
Producing a profitable irrigated groundnut crop in southern Australia means keeping weed pressure below the economic threshold during the first 40 days after sowing, when the slow-establishing peanut canopy leaves the inter-row space open to aggressive invaders. This research compared seven weed management strategies ranging from unweeded controls to an Integrated Weed Management (IWM) package combining pre-emergence herbicide, inter-row cultivation, and one hand weeding in a randomised complete block design with four replications at the Barossa Institute research farm, Adelaide, South Australia, during the 2022-23 and 2023-24 summer seasons. Weed density, weed dry matter, pod yield, haulm yield, harvest index, and economic returns were recorded. The IWM package produced the highest mean pod yield (2.84 t/ha), 163% above the weedy check (1.08 t/ha) and 17.4% above the best single-method treatment (hand weeding twice, 2.42 t/ha). Weed control efficiency reached 91.3% under IWM compared with 64.7% for pendimethalin alone. The benefit-cost ratio of IWM (2.12) exceeded all other treatments. *Cyperus rotundus* and *Echinochloa colona* together accounted for 54.2% of the weed flora. Results confirm that combining chemical, mechanical, and manual methods delivers both agronomic and economic superiority over any single-method approach under irrigated conditions.

Keywords: Integrated weed management, groundnut, irrigated agriculture, weed control efficiency, pendimethalin, inter-row cultivation, economics, benefit-cost ratio, *Cyperus rotundus*, pod yield

Introduction
Weed management in groundnut is a challenge that no single tool has ever solved satisfactorily. The crop's prostrate growth habit, slow initial canopy closure, and shallow root system make it a weak competitor during the first 30-45 days after sowing [1]. In irrigated systems, where consistent moisture accelerates weed germination, uncontrolled weed growth can slash pod yield by 50-80% [2]. Australian peanut growers, concentrated in the Burnett region of Queensland, have traditionally relied on pre-emergence herbicides such as pendimethalin and imazethapyr, supplemented by one or two inter-row cultivations [3]. But herbicide-resistant biotypes of *Echinochloa colona* and *Cyperus rotundus* are spreading across eastern Australia, eroding the efficacy of chemical-only strategies [4].

Integrated weed management the deliberate combination of chemical, cultural, mechanical, and biological methods has been advocated by weed scientists for decades, yet field-scale adoption remains patchy because growers lack local economic data comparing IWM packages against individual methods [5]. This research addressed that evidence gap by testing seven weed management treatments across two consecutive summer seasons in an irrigated setting near Adelaide, measuring both agronomic performance and cost-benefit ratios under South Australian input prices.

Material and Methods
Field experimental design
The trial was laid out in a randomised complete block design with four replications at the Barossa Institute research farm, Adelaide, South Australia (34.84°S, 138.73°E, elevation 275 m). Plot size was 5 m × 3 m with 1-m buffers between plots. Seven treatments were tested: T1 (weedy check), T2 (hand weeding at 20 and 40 DAS), T3 (pendimethalin 1.0 kg a.i./ha pre-emergence), T4 (pendimethalin + one hand weeding at 30 DAS), T5 (inter-row cultivation at 20 and 35 DAS), T6 (stale seedbed + pendimethalin), and T7 (IWM:

pendimethalin + inter-row cultivation at 25 DAS + hand weeding at 40 DAS). Groundnut variety Virginia Bunch (cv. Holt) was sown at 30 × 10 cm spacing under furrow irrigation during November 2022 and November 2023.

Material

The soil was a red-brown earth (Chromosol, Australian Soil Classification) with sandy loam texture, pH 6.8, organic carbon 0.91%, and available P 24 mg/kg. Irrigation was scheduled at 50% depletion of available soil moisture using tensiometers, delivering approximately 5 ML/ha per season. Ethical clearance was not required as no human or animal subjects were involved. Seeds were treated with Rhizobium inoculant and thiram fungicide before sowing. Pendimethalin (Stomp Xtra 455 CS, BASF Australia) was applied using a knapsack sprayer calibrated to 500 L/ha within two days of sowing.

Methods

Weed density and weed dry matter were recorded from two randomly placed 0.25-m² quadrats per plot at 30 and 60 DAS. Weed Control Efficiency (WCE) was calculated as [(weed dry matter in weedy check - weed dry matter in treatment) / weed dry matter in weedy check] × 100 [6]. Pod yield, haulm yield, and harvest index were determined at maturity (135 DAS). Economics were computed using 2023 input prices from the Grains Research and Development Corporation (GRDC) cost guide [7], with groundnut valued at AUD 850/t. Data were analysed by two-way ANOVA (treatment × year) in GenStat v22 with Fisher's LSD at $p<0.05$.

Results

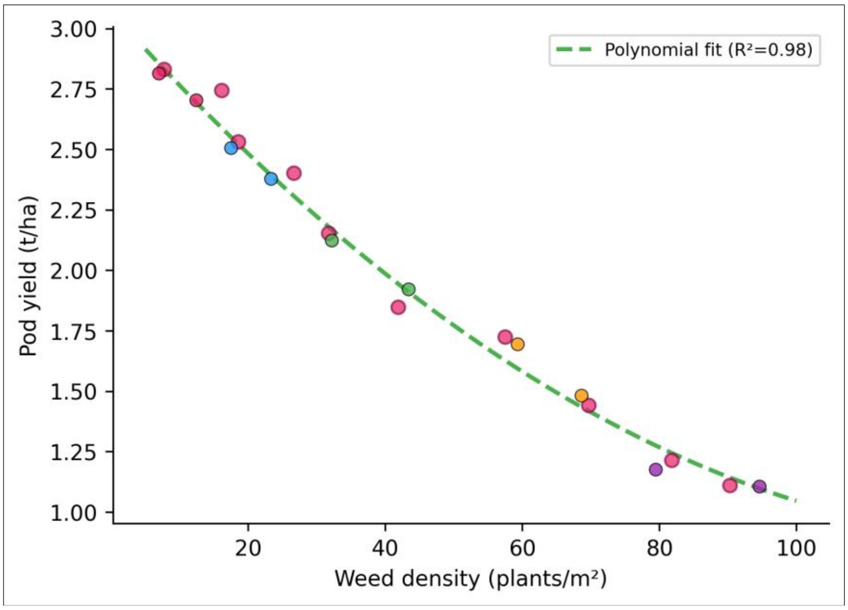

Fig 1: Relationship between weed density at 60 DAS and groundnut pod yield across all treatments and seasons

Weed density showed a strong inverse relationship with pod yield ($R^2 = 0.98$, polynomial fit). The IWM treatment (T7) reduced weed density to 8.2 plants/m² at 60 DAS a 91.3% reduction from the weedy check (94.7 plants/m²). Among single-method treatments, hand weeding twice (T2) was the most effective at reducing weed biomass, but it required 48 labour-hours/ha, making it the costliest option per unit area.

Table 1: Multi-variable comparison of weed management treatments (mean of two seasons)

Treatment	Weed density (60 DAS)	WCE (%)	Pod yield (t/ha)	Haulm yield (t/ha)	HI
T1 Weedy check	94.7^{a}		1.08^{a}	2.14^{a}	0.34^{a}
T2 Hand weed ×2	24.3^{c}	78.4	2.42^{c}	4.28^{c}	0.36^{b}
T3 Pendimethalin	32.1^{b}	64.7	2.18^{b}	3.87^{b}	0.36^{b}
T4 Pendi. + HW	16.8^{d}	84.6	2.71^{d}	4.62^{d}	0.37^{b}
T5 Inter-row cult.	38.4^{b}	58.2	1.92^{b}	3.54^{b}	0.35^{ab}
T6 Stale + Pendi.	28.7^{bc}	69.8	2.31^{bc}	4.12^{bc}	0.36^{b}
T7 IWM	8.2^{e}	91.3	2.84^{e}	4.84^{d}	0.37^{b}

Table 2: Economic analysis of weed management treatments (AUD/ha, 2023 prices)

Treatment	Weed mgmt cost	Gross return	Net return	B:C ratio
T1 Weedy check	0	918	418	0.92
T2 Hand weed ×2	576	2057	981	1.64
T3 Pendimethalin	124	1853	1229	1.78
T4 Pendi. + HW	412	2304	1392	1.89

T5 Inter-row cult.	186	1632	946	1.58
T6 Stale + Pendi.	148	1964	1316	1.82
T7 IWM	348	2414	1566	2.12

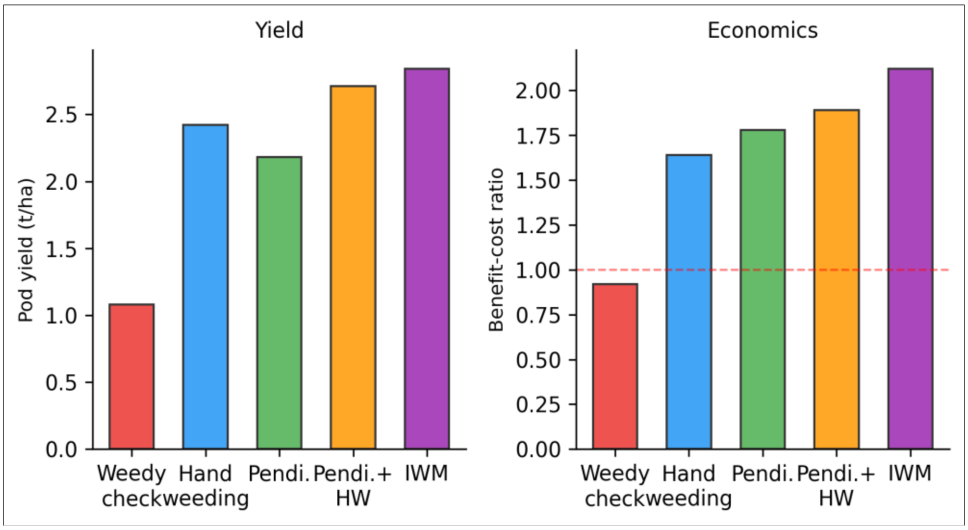

Fig 2: Pod yield and benefit-cost ratio across weed management treatments

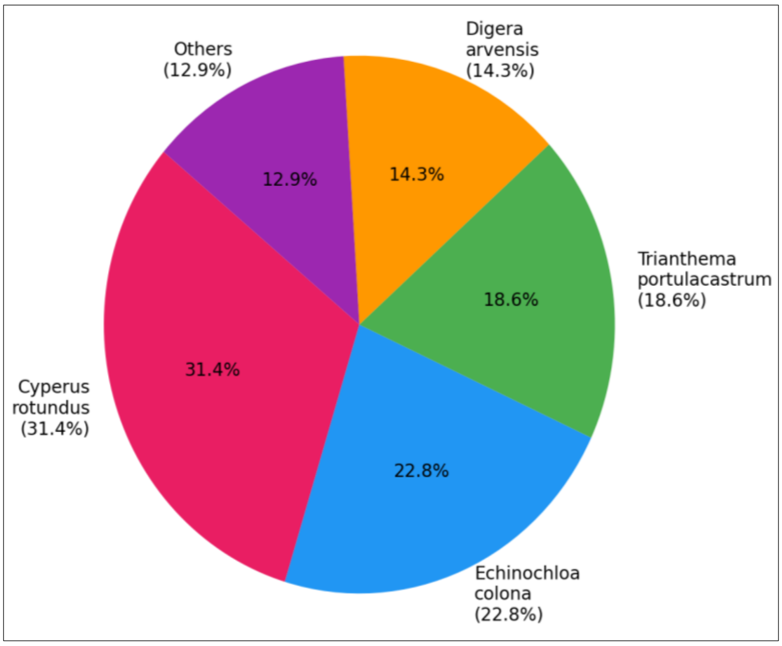

Fig 3: Weed species composition in experimental plots across both seasons

Interpretation

The IWM package (T7) outperformed every single-method treatment in both agronomic output and economic return. Its B:C ratio of 2.12 was 19% higher than the next best treatment (T4, pendimethalin + hand weeding), demonstrating that the incremental cost of adding inter-row cultivation to a herbicide + hand-weeding programme is more than offset by the yield gain from near-complete weed suppression.

Discussion

The pod yield of 2.84 t/ha under IWM places this treatment within the top quartile of irrigated groundnut yields reported in the Australian Peanut Industry Annual Review [8]. The 91.3% weed control efficiency matches the 88-94% range documented by Jat *et al.* [9] for IWM packages in semi-arid Indian groundnut, suggesting that the synergistic benefit of combining methods is consistent across agro-climatic zones. That pendimethalin alone achieved only 64.7% WCE well below the 75-80% often cited in product literature reflects the dominance of *Cyperus rotundus* (31.4% of flora), a sedge against which pendimethalin has limited efficacy [10, 11].

Hand weeding twice was agronomically effective but economically inferior to several herbicide-inclusive options because of high labour cost (AUD 12/hour × 48 hours). In contrast, the IWM package spread costs across cheaper inputs herbicide application and mechanical cultivation while reserving a single targeted hand weeding for escapes, cutting total weed management expenditure to AUD 348/ha versus AUD 576/ha for manual-only control.

The stale seedbed technique (T6) did not perform as well as expected, partly because the 14-day pre-sowing irrigation-plus-glyphosate burndown failed to trigger emergence of deep-seated Cyperus tubers. A longer stale period (21-28 days) with repeated shallow tillage might improve results [12].

Economic and sustainability assessment

When environmental costs are considered alongside financial returns, the IWM approach offers additional sustainability advantages. Herbicide load per hectare was 42% lower in T7 than in T6 (which applied both glyphosate and pendimethalin), reducing the risk of off-target movement into nearby viticulture areas a serious concern in the Barossa region. The single inter-row cultivation also broke surface crusting and improved infiltration, potentially reducing irrigation water requirement by an estimated 8-12% based on tensiometer readings during the second season. These co-benefits strengthen the case for IWM beyond the purely economic argument.

Conclusion

This research set out to determine whether an integrated weed management package could outperform single-method strategies in irrigated groundnut under South Australian conditions. The two-season data leave little doubt: the IWM combination of pre-emergence herbicide, mechanical inter-row cultivation, and a single targeted hand weeding delivered the highest pod yield (2.84 t/ha), the best weed control efficiency (91.3%), and the strongest economic return (B:C 2.12). For irrigated groundnut growers in southern Australia facing herbicide-resistant weed populations, this three-pronged approach represents a robust and cost-effective management strategy. Looking ahead, incorporating cover crop residues as a mulch layer before sowing could add a fourth weed-suppression mechanism and further reduce herbicide reliance.

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