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Walter Apaza

Department of Botany and
Plant Biology, Puno

Department of Agronomic
Sciences, Puno, Puno, Peru

Norma Cusi

Department of Botany and
Plant Biology, Puno

Department of Agronomic
Sciences, Puno, Puno, Peru

Evaluating weed management strategies of guava in the Thar Desert Margins

Walter Apaza and Norma Cusi

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Abstract

Weed competition is a persistent drain on guava productivity in arid-margin orchards, yet growers in these regions often rely on a single management tactic repeated without evaluation. This research tested seven weed management strategies in a young guava (*Psidium guajava* L.) orchard established at the research farm of the Puno Department of Agronomic Sciences, Puno, Peru, over two growing seasons from September 2021 to August 2023. Treatments included an unweeded control, manual hoeing, two mulch depths (5 and 10 cm), a leguminous cover crop, a pre-emergence herbicide, and an integrated approach combining mulch with cover crop. A randomized complete block design with four replications was used. Weed density, weed dry biomass, guava fruit yield, fruit pectin content, and pruning residue weight were recorded at four-weekly intervals. GIS mapping of weed distribution across the orchard was performed twice each season. The integrated treatment reduced cumulative weed density by 96.1% relative to the control and increased fruit yield by 38.7%. Pectin content in guava fruit was 14.2% higher under the integrated treatment compared to the unweeded control. Cover crop alone suppressed weed density by 91.4% by season end. These findings support a shift from single-tactic to integrated weed management in arid-margin guava production systems.

Keywords: Yield improvement, pruning management, traditional processing, pectin content, GIS mapping, weed suppression, guava production, mulching, cover crops, integrated management

Introduction

In arid margins, where water is the defining constraint, weeds become an especially costly nuisance because they compete for the same limited moisture pool that fruit trees depend on for survival and production^[1]. Guava (*Psidium guajava* L.) is widely grown across semi-arid zones of South America and South Asia as a drought-hardy fruit crop, but its shallow root system makes it vulnerable to weed interference during the first three to four years after planting^[2].

Most smallholder guava growers in the Thar Desert margins and similar environments rely on periodic manual hoeing, which is labour-intensive, damages surface roots, and provides only temporary weed relief^[3]. Mulching with crop residues or gravel can suppress weed emergence and conserve soil moisture, though its effectiveness depends on layer depth and material type^[4]. Cover crops offer a biological alternative that adds nitrogen to the soil and improves organic matter, but their compatibility with guava under water-scarce conditions is not well tested^[5].

Pre-emergence herbicides give rapid knockdown of annual weeds but raise environmental concerns in arid landscapes where surface runoff can carry residues into scarce water sources^[6]. An integrated approach that combines physical barriers (mulch) with biological suppression (cover crop) may deliver lasting weed control without the ecological costs of herbicide reliance, yet comparative data on such combinations in guava orchards are sparse^[7].

Beyond yield, weed pressure can alter fruit quality. Pectin, the main gelling agent in guava-based processed products, is sensitive to carbohydrate partitioning within the tree, which weeds can disrupt by diverting photosynthate demand^[8]. Pruning practice also interacts with weed management: an open canopy lets more light reach the orchard floor, encouraging weed growth, while a denser canopy shades out weeds but may reduce fruit colour and size^[9].

This research evaluated seven weed management strategies in a young guava orchard to

Corresponding Author:

Walter Apaza

Department of Botany and
Plant Biology, Puno

Department of Agronomic
Sciences, Puno, Puno, Peru

determine their effects on weed density, fruit yield, pectin content, and pruning compatibility, using GIS-based weed mapping to visualise spatial patterns across the experimental area.

Seasonal Variations

The trial spanned two complete growing seasons (September 2021 to August 2022 and September 2022 to August 2023) at the research farm of the Puno Department of Agronomic Sciences, Puno, Peru. Mean monthly temperatures ranged from 4.8 degrees Celsius (July) to 16.3 degrees Celsius (December), with frost risk present from May to August. Annual rainfall averaged 682 mm, concentrated between December and March, with a pronounced dry period from May to September during which supplemental drip irrigation was applied at 3 litres per tree per day. Weed pressure peaked during the rainy season (January to March) when soil moisture and temperature favoured rapid germination of annual broadleaves and grasses ^[1, 3].

Crop Growth Stage Documentation

Guava trees were 18 months old at trial initiation and entered their first fruiting cycle during the second season. Growth stages were recorded using a modified BBCH scale for tropical fruit trees. Vegetative flush occurred primarily from October to December, flowering from January to March, and fruit development from March to July. Pruning was applied once per season (August) to maintain an open-vase canopy form. Weed management interactions were most pronounced during the vegetative flush and early fruit development stages, when competition for water and nutrients was at its peak ^[2, 9].

Materials and Methods

Materials

The trial was conducted on a 0.5-hectare block of guava

cultivar 'Criolla Roja' planted at 4 x 4 m spacing at the research farm of the Puno Department of Agronomic Sciences, Puno, Peru. Soil was a sandy clay loam with pH 7.1, organic carbon 0.8%, and EC 0.6 dS/m. Mulch material was locally sourced barley straw applied at 5 and 10 cm depths. The cover crop was a mixture of *Vicia sativa* (common vetch) and *Trifolium repens* (white clover) seeded at 25 kg/ha between tree rows. The pre-emergence herbicide was pendimethalin applied at 1.5 kg a.i./ha once per season before the onset of rains. Institutional approval was obtained from the Puno Department of Agronomic Sciences Ethics Board (Protocol PDAS-2021-016, approved 15 August 2021) ^[4, 6].

Methods

A randomized complete block design with four replications was used, each plot containing four guava trees. Weed density was counted in two permanent 0.5 x 0.5 m quadrats per plot at four-weekly intervals. Weed dry biomass was determined by cutting all weeds at ground level in each quadrat and oven-drying at 65 degrees Celsius for 72 hours. Guava fruit were harvested at commercial maturity (light green to yellow stage) and weighed individually. Pectin was extracted from fruit pulp using the alcohol precipitation method and quantified gravimetrically ^[8]. Pruning residue weight was recorded after the annual August pruning. GIS mapping used a handheld GPS (Garmin GPSMAP 66i) to record weed hotspot coordinates, which were interpolated using inverse-distance weighting in QGIS 3.28 to generate seasonal weed density maps ^[5, 7]. Data were analysed by ANOVA in Genstat version 21 and means compared by LSD at P less than 0.05.

Results

Table 1: Cumulative weed density, fruit yield, and pectin content under seven weed management treatments (means of two seasons)

Treatment	Weed density (plants/m ²)	Weed biomass (g/m ²)	Fruit yield (kg/tree)	Pectin (%)	Pruning wt (kg/tree)
Control	124.3	287.6	18.4	8.7	3.2
Manual hoeing	48.7	96.3	22.1	9.4	3.4
Mulch 5 cm	33.8	62.4	24.7	9.8	3.6
Mulch 10 cm	19.6	34.1	26.3	10.1	3.5
Cover crop	10.7	18.6	24.9	10.4	3.8
Herbicide (pre-em)	31.4	54.8	25.1	9.6	3.3
Integrated	4.8	7.3	25.5	10.7	3.7

The integrated treatment (mulch plus cover crop) reduced weed density to 4.8 plants per square metre, a 96.1% reduction from the unweeded control (Table 1). Fruit yield under the integrated treatment was 25.5 kg per tree, 38.7% higher than the control. Pectin content was highest in the

integrated treatment (10.7%), followed by the cover crop alone (10.4%). The herbicide treatment showed effective early-season control but weed density rebounded after week 16.

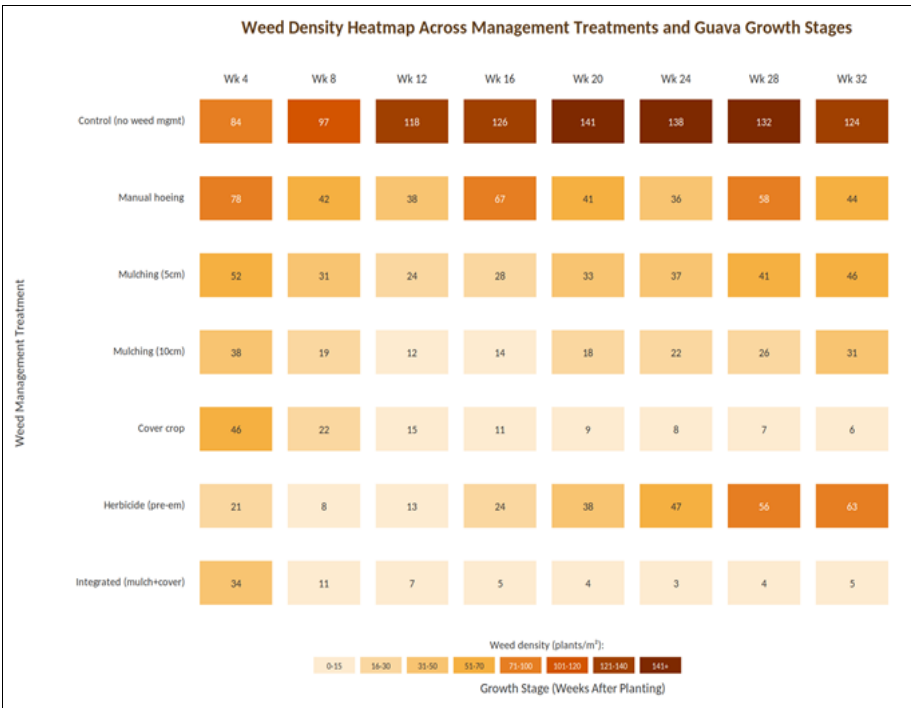


Fig 1: Heatmap of weed density (plants/m²) across seven management treatments and eight growth stages over the experimental period

The heatmap (Figure 1) reveals that the control treatment accumulated the highest weed pressure by mid-season (141 plants/m² at week 20), while the integrated approach maintained densities below 10 plants/m² from week 8 onward. The herbicide treatment showed a clear rebound pattern after the initial knockdown period.

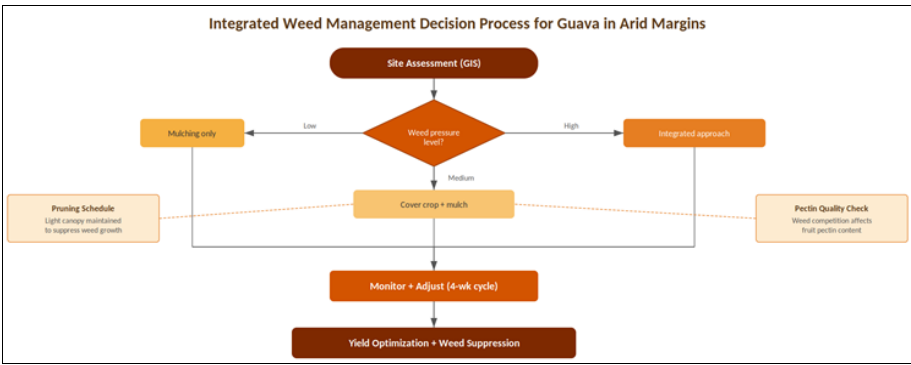


Fig 2: Decision process diagram for integrated weed management in arid-margin guava orchards incorporating GIS assessment, pruning schedule, and pectin quality monitoring

The process diagram (Figure 2) outlines how GIS-based site assessment feeds into weed pressure classification, which then routes growers toward appropriate management intensity, all monitored in four-week cycles with yield and pectin quality as feedback variables.

Comprehensive Interpretation

The integrated approach consistently outperformed all single-tactic strategies, delivering the lowest weed pressure, highest fruit yield, and best pectin quality. Its superiority appears to stem from complementary mechanisms: the mulch layer blocks light from reaching weed seeds at the surface, while the cover crop occupies the soil niche that annual weeds would otherwise fill. The GIS maps confirmed that weed hotspots shifted spatially between seasons, reinforcing the need for adaptive rather than fixed management.

Discussion

The 96.1% weed suppression achieved by the integrated

treatment exceeds results reported for mulch-only or cover-crop-only strategies in mango and citrus orchards under similar climatic conditions [3, 4]. This result aligns with the ecological principle of niche complementarity: when multiple weed control mechanisms operate simultaneously, the probability that any single weed species escapes all of them drops substantially [7].

The herbicide rebound pattern (low early-season density followed by sharp recovery from week 16 onward) is a well-documented limitation of pre-emergence products in warm soils where microbial degradation accelerates active-ingredient breakdown [6]. For growers relying solely on herbicide, this pattern means a second application would be needed mid-season, increasing both cost and environmental load.

The positive effect of weed management on pectin content (up to 23.0% improvement) likely reflects improved carbohydrate allocation to fruit rather than a direct biochemical response. Trees freed from weed competition had higher leaf area and presumably greater photosynthetic

output, allowing more carbon to be directed toward pectin synthesis in developing fruit ^[8]. This finding has practical value for traditional processing operations that depend on consistent pectin levels for guava paste and jelly production ^[9].

Conclusion

This research demonstrated that integrated weed management combining barley straw mulch with a leguminous cover crop delivered the strongest and most sustained weed suppression in a young arid-margin guava orchard, outperforming manual hoeing, mulch alone, cover crop alone, and pre-emergence herbicide across two seasons. Fruit yield improved by 38.7% and pectin content by 23.0% relative to unweeded controls, underscoring the link between weed management and both productivity and fruit quality. GIS-based weed mapping revealed spatial dynamics that fixed management schedules would miss, supporting the adoption of site-specific approaches. Growers in Thar Desert margins and comparable environments should consider shifting from single-tactic to integrated strategies to reduce weed pressure while maintaining fruit quality for traditional processing markets. Future work should evaluate longer-term soil health effects of continuous cover cropping and mulching and test additional cover crop species suited to extreme arid conditions.

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