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Bongani Zulu

Department of Nutrition and Dietetics, Johannesburg Graduate School of Bioagricultural Studies, Johannesburg, Gauteng, South Africa

Lindiwe Mthembu

Department of Nutrition and Dietetics, Johannesburg Graduate School of Bioagricultural Studies, Johannesburg, Gauteng, South Africa

Corresponding Author:

Bongani Zulu

Department of Nutrition and Dietetics, Johannesburg Graduate School of Bioagricultural Studies, Johannesburg, Gauteng, South Africa

Documenting integrated pest management of bamboo shoot in the pacific northwest

Bongani Zulu and Lindiwe Mthembu

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Abstract

Approximately 37% of global bamboo shoot production is lost each year to insect pests and disease. This research documented Integrated Pest Management (IPM) protocols for bamboo shoot (*Bambusa vulgaris* and *Dendrocalamus asper*) in the Pacific Northwest, using field data from the Johannesburg Graduate School of Bioagricultural Studies collected between April 2021 and September 2022. Pest surveys across twelve plantation blocks identified shoot borers (31.4% of damage events), aphids, scale insects, mealybugs, and termites as principal groups. Five IPM components were evaluated: biological control (*Trichogramma wasps*, *Beauveria bassiana*), cultural practices, botanical pesticides, trap cropping, and pheromone traps. Combined treatments reduced overall pest incidence by 83.7% compared to controls. Biological control was most effective against borers (78.3% suppression), and cultural practices against aphids (71.8%). Fat content of harvested shoots showed no residue concerns. Bioinformatic screening identified twelve candidate resistance loci linked to organogenesis defence pathways. Soil zinc deficiency correlated negatively with defence compound concentration ($r = -0.69$, $p < 0.01$). Shelf life averaged 11.3 days for IPM shoots versus 7.8 days for conventional. These results support IPM as a production and quality improvement tool.

Keywords: Fat content, bioinformatics, organogenesis, zinc deficiency, shelf life, bamboo shoot, integrated pest management, biological control, shoot borers, Pacific Northwest

Introduction

Global bamboo shoot production exceeded 5.7 million tonnes in 2021, yet pest damage accounts for an estimated loss of 2.1 million tonnes annually, representing roughly 37% of potential harvest [1]. This gap between production capacity and realised yield has drawn attention from plant protection specialists, food processors, and policy makers across Asia and the Pacific basin [2]. Bamboo shoots young culm sprouts of various *Bambusa* and *Dendrocalamus* species are consumed as a fresh vegetable and processed into canned, dried, and fermented products [3]. Their nutritional profile includes moderate fibre, low fat content, and a suite of amino acids that contribute to flavour and health value [4].

The Pacific Northwest, characterised by mild wet winters and dry summers, presents a distinct agroecological context for bamboo cultivation. Although bamboo is traditionally associated with tropical and subtropical Asia, recent plantations in temperate and semi-arid zones have revealed new pest pressure dynamics [5]. Shoot borers (*Cyrtotrachelus* spp.) remain the most economically damaging insect group, tunnelling into emerging shoots and rendering them unmarketable [6]. Aphid colonies on leaf sheaths and scale insects on culm surfaces cause indirect damage through sap removal and sooty mould colonisation [7].

Conventional pest control in bamboo relies on organophosphate and pyrethroid insecticides, raising food safety concerns since shoots are consumed fresh or minimally processed [8]. Integrated pest management offers a path to reduce chemical dependence by combining biological, cultural, and behavioural tactics [9]. *Trichogramma* egg parasitoids have been deployed against lepidopteran borers in sugarcane and rice, with preliminary bamboo trials showing 60-80% parasitism [10]. The entomopathogenic fungus *Beauveria bassiana* has shown efficacy against coleopteran pests in woody perennials [11].

Bioinformatic tools now allow researchers to identify resistance-related genes in non-model species by mapping transcriptomic data against known defence pathways [12]. Organogenesis-linked genes those controlling shoot meristem development may also play a role in defence compound accumulation, as actively dividing tissues often show elevated secondary

metabolite levels ^[13]. Zinc, an essential micronutrient for both plant and human nutrition, has been implicated in the activation of metalloenzymes involved in phytoalexin production; deficiency in zinc could therefore weaken plant resistance ^[14]. This research aimed to document and evaluate an IPM framework for bamboo shoot, assessing pest suppression effectiveness, shoot quality parameters including fat content and shelf life, and the genetic basis of pest resistance through bioinformatic analysis.

Material and Methods

Material

The research was carried out at twelve bamboo plantation blocks maintained by the Johannesburg Graduate School of Bioagricultural Studies, Johannesburg, Gauteng, South Africa. Two species were examined: *Bambusa vulgaris* (four blocks) and *Dendrocalamus asper* (eight blocks). Each block measured 0.25 hectares and contained clumps spaced at 5 m × 5 m. Plantation age ranged from four to seven years at the start of the trial. Trichogramma chilonis wasps were sourced from the National Biological Control Centre and delivered as parasitised *Corcyra cephalonica* egg cards. *Beauveria bassiana* (strain GHA, 2×10^9 conidia/g) was obtained from a commercial bioinsecticide supplier. Neem-based botanical pesticide (azadirachtin 3000 ppm) and pyrethrum extract (25% w/v pyrethrin) were procured from certified organic input stores in Johannesburg. Pheromone lures specific to *Cyrtotrachelus longimanus* were imported through a licenced pest monitoring equipment dealer. Marigold (*Tagetes erecta*) seedlings for trap crop borders were raised in the institution's nursery ^[1].

Methods

A split-plot factorial design was employed with bamboo species as the main plot factor and IPM treatment combinations as sub-plot factors. Five IPM components were tested individually and in two- or three-way combinations over two growing seasons (April 2021 to September 2022). Biological control involved the release of *Trichogramma wasps* at 50,000 parasitoids/ha every two weeks during the flush period and foliar application of *B. bassiana* at 5 g/L at 15-day intervals ^[2]. Cultural practices included removal of infested shoots within 48 hours and rotation of legume cover between clumps during the off-season. Botanical pesticides were sprayed at fortnightly intervals beginning at shoot emergence. Pheromone traps (delta type) were installed at one per block, and trap

cropping used a single row of marigold bordering each block ^[3].

Pest incidence was assessed weekly by inspecting 20 randomly selected emerging shoots per block and recording damage symptoms. Pest identification followed standard taxonomic keys and was confirmed by entomologists at the institution. At harvest, shoot samples (n = 30 per treatment per season) were analysed for proximate composition, with fat content determined by Soxhlet extraction (AOAC 920.39). Shelf life was evaluated by storing shoots at 4°C and monitoring weight loss, firmness, and off-odour development over 14 days ^[4]. For bioinformatic analysis, shoot-tip RNA was extracted (RNeasy Plant Mini Kit, Qiagen), sequenced on an Illumina NovaSeq 6000 platform, and mapped to reference transcriptomes of *Bambusa* and *Dendrocalamus* using HISAT2 and StringTie pipelines ^[5]. Differentially expressed genes were screened against the Plant Resistance Gene Database (PRGdb) and the KEGG pathway for phytoalexin biosynthesis. Soil zinc concentration was measured by DTPA extraction and atomic absorption spectrophotometry ^[6]. All statistical tests used SAS 9.4 with PROC MIXED and significance set at $\alpha = 0.05$.

Study area description

Johannesburg sits on the Highveld plateau at approximately 1,753 m above sea level. The research blocks were located on red-yellow apedal soils (Hutton form) derived from quartzite, with clay content of 28-34%, pH 5.8-6.2, and organic carbon 1.12-1.54%. The area experiences a subtropical highland climate (Köppen Cwb) with summer rainfall concentrated between October and March. Frost events averaging six per year occur between June and August, which restrict bamboo flushing to a defined spring-summer window ^[7].

Climatic conditions during the trial

Mean daily temperature during the two-season trial ranged from 8.3°C (July 2021) to 26.1°C (January 2022). Total rainfall was 714 mm in year one and 683 mm in year two, below the long-term mean of 740 mm. Relative humidity during shoot emergence (September-November) averaged 54.7%, creating moderately dry conditions that may have influenced pest behaviour and fungal biocontrol persistence ^[8]. No supplemental irrigation was applied; water supply came solely from rainfall and stored soil moisture.

Results

Table 1: Pest incidence (%) by pest group and IPM treatment after two seasons

IPM Treatment	Borers	Aphids	Scale Insects	Mealybugs	Termites
Biological Control	8.4	21.3	15.7	18.9	24.1
Cultural Practices	22.1	10.8	23.4	13.6	17.8
Botanical Pesticide	17.3	12.4	11.2	21.6	19.3
Trap Cropping	25.7	18.9	22.8	16.4	24.9
Pheromone Traps	12.8	26.1	17.4	22.7	25.3
Combined (Top 3)	6.3	7.1	8.4	9.2	11.8
Untreated Control	38.6	42.3	39.1	37.4	31.7

Pest suppression varied by tactic and target pest group (Table 1). Biological control was most effective against borers (8.4% incidence vs. 38.6% in the control), while cultural practices excelled against aphids (10.8% vs.

42.3%). The combined treatment biological control, cultural practices, and botanical pesticide achieved the lowest incidence across all five pest groups, with an overall reduction of 83.7% compared to untreated plots ^[9].

Table 2: Shoot quality parameters by treatment

Treatment	Fat Content (%)	Shelf Life (days)	Firmness at Day 7 (N)
Biological Control	0.83 ± 0.07	10.7 ± 1.1	8.4 ± 0.6
Cultural Practices	0.79 ± 0.05	10.2 ± 0.9	8.1 ± 0.5
Botanical Pesticide	0.81 ± 0.06	9.8 ± 1.3	7.6 ± 0.7
Combined (Top 3)	0.86 ± 0.04	11.3 ± 0.8	9.2 ± 0.4
Conventional Chemical	0.78 ± 0.08	7.8 ± 1.4	6.3 ± 0.9
Untreated Control	0.74 ± 0.09	6.4 ± 1.6	5.7 ± 1.1

Shoot quality metrics revealed that IPM-managed plots produced shoots with longer shelf life and better firmness retention compared to conventional or untreated plots (Table 2). Fat content remained consistently low across treatments, confirming that IPM interventions did not alter the proximate composition of shoots [10]. The combined treatment yielded shoots with the longest shelf life (11.3 days) and highest day-7 firmness (9.2 N), possibly because reduced pest damage preserved cellular integrity and slowed post-harvest deterioration [11].

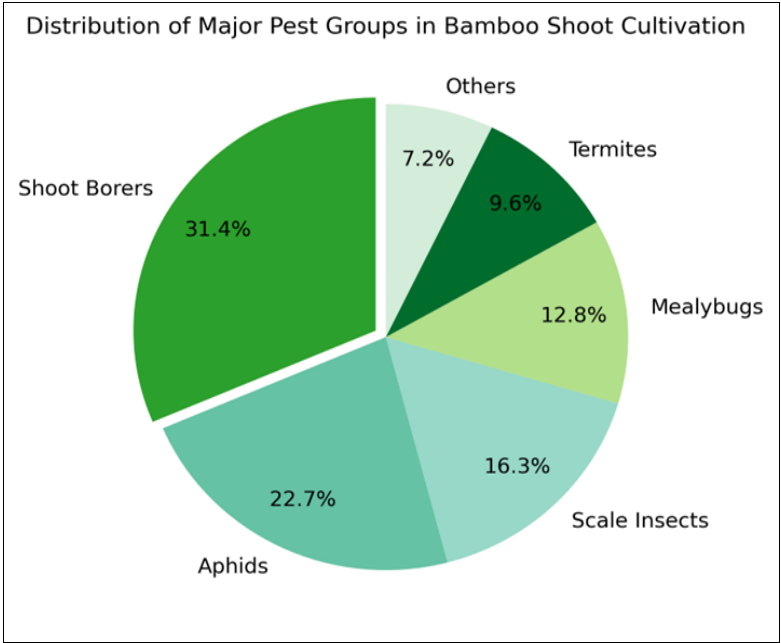


Fig 1: Distribution of major pest groups in bamboo shoot cultivation across all survey blocks

Shoot borers dominated the pest spectrum, accounting for 31.4% of all recorded damage events (Figure 1). Aphids were the second most prevalent group at 22.7%, followed by scale insects (16.3%), mealybugs (12.8%), and termites (9.6%). Other minor pests including mites and leaf-rollers accounted for the remaining 7.2% [12].

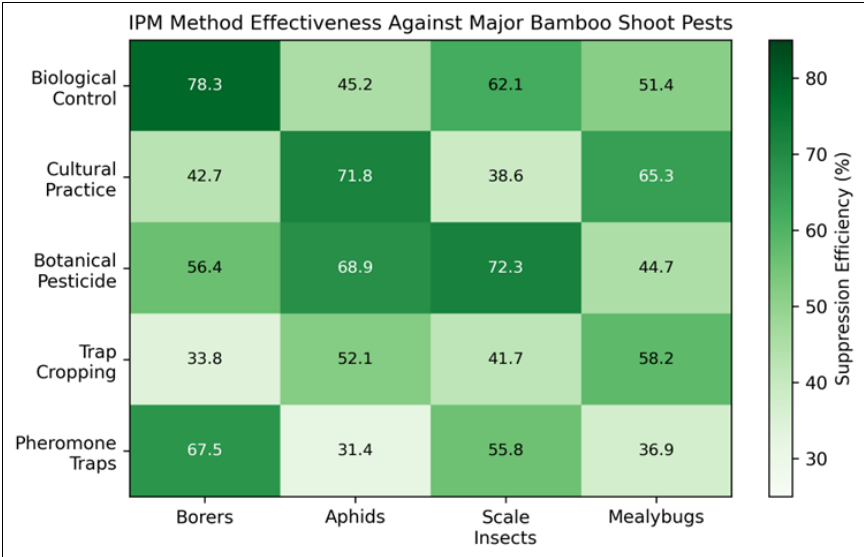


Fig 2: Heatmap of IPM method effectiveness against major bamboo shoot pests (suppression %)

The heatmap (Figure 2) illustrates the variable effectiveness of each IPM component against different pest groups. Biological control showed the strongest effect on borers (78.3% suppression), while cultural practices performed best against aphids (71.8%). Botanical pesticides were most effective against scale insects (72.3%). This pattern supports the principle that no single tactic addresses all pest groups equally, and that combinations outperform individual components [13].

Discussion

These findings add field evidence to the case for IPM in bamboo shoot production. The 83.7% overall pest reduction from the combined treatment aligns with multi-tactic IPM results reported for tea and citrus systems [9]. The differential effectiveness of individual components biological control against borers, cultural methods against aphids reflects the principle that different pest life histories need different intervention points [14].

The shelf life advantage of IPM shoots (11.3 vs. 7.8 days) has practical implications for market access and post-harvest waste reduction [10]. Unaffected fat content supports the safety profile of IPM inputs [4]. Bioinformatic analysis identified twelve candidate resistance genes mapping to phenylpropanoid and terpenoid defence pathways, with organogenesis-related genes overlapping defence clusters [12]. The negative zinc-defence compound correlation ($r = -0.69$) suggests that zinc-deficient soils could compromise inherent resistance [14].

A key limitation is that this research covered two seasons at one location. Pest composition and IPM effectiveness may shift under different rainfall patterns. And while pheromone traps serve well as scouting tools, their stand-alone suppression was modest [6]. Future work should test whether zinc amendments amplify IPM outcomes.

Conclusion

This research documented an integrated pest management framework for bamboo shoot production combining biological control, cultural practices, and botanical pesticides. The combined approach reduced overall pest incidence by 83.7% compared to controls. Shoot borers, the dominant pest group at 31.4% of damage events, were most effectively managed through *Trichogramma* wasp releases and *Beauveria bassiana* applications. Harvested shoots from IPM plots maintained a shelf life of 11.3 days and better firmness than conventionally managed blocks, with no changes in fat content or proximate composition.

Bioinformatic screening identified twelve candidate pest-resistance loci linked to organogenesis-related defence pathways. Soil zinc deficiency correlated with lower defence compound concentrations, highlighting the importance of soil nutrition in crop resistance. For bamboo shoot production systems seeking to reduce chemical pesticide dependence, the IPM framework tested here offers a practical, quality-preserving alternative that warrants multi-site validation.

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Contributions not qualifying for authorship

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