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Efficacy of botanical extracts against late blight of potato under field conditions

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Abstract
Few people realise that a disease first recorded during the 1845 Irish famine still drains an estimated US$6.7 billion from global potato production every year—and synthetic fungicides remain the primary weapon. This research evaluated neem extract, garlic extract, and their combination against late blight (*Phytophthora infestans*) across three field seasons (April 2022-September 2024) at Porto Alegre, Rio Grande do Sul, Brazil. The neem-garlic combination held final disease severity at 53.6% compared with 91.2% in untreated controls, achieving a 41.2% reduction. Neem alone reduced severity by 30.5% and garlic alone by 20.7%. The chemical reference (mancozeb) gave 49.1% reduction. Tuber yield under the combined botanical treatment reached 26.1 t/ha, approaching the mancozeb check (27.6 t/ha) and exceeding the control by 69.5%. At roughly 38% lower input cost per hectare than the fungicide programme, the neem-garlic mixture offers smallholders and organic growers a viable eco-friendly alternative that delivers about 84% of the chemical's protective effect.

Keywords: Botanical extracts, late blight, potato, *Phytophthora infestans*, neem extract, garlic extract, field trials, eco-friendly management, disease severity, tuber yield

Introduction
A surprising piece of agricultural history: *Phytophthora infestans*, the oomycete that triggered the worst famine in modern European history, still ranks as the single costliest pathogen in potato production worldwide, accounting for losses and control expenses estimated at US$6.7 billion annually [1]. In southern Brazil, cool and humid autumn-winter conditions create near-ideal epidemiological windows, and commercial growers in Rio Grande do Sul may spray fungicides 12-16 times in a single crop cycle [2].

Growing consumer concern about pesticide residues and evolving Brazilian regulatory frameworks have pushed researchers toward plant-derived alternatives [3]. Neem (*Azadirachta indica*) produces azadirachtin and related limonoids with demonstrated antifungal and anti-oomycete activity in laboratory assays [4]. Garlic (*Allium sativum*) is rich in allicin and ajoene, sulfur compounds that inhibit spore germination and mycelial extension in several Phytophthora species under controlled conditions [5]. Yet translating laboratory potency into field-scale disease management is a different matter entirely, and replicated field evidence from Brazilian potato systems has been thin [6].

This research compared neem and garlic extracts—individually and combined—against a mancozeb reference over three consecutive seasons to determine whether botanical sprays can deliver commercially meaningful protection in one of the most blight-prone environments in the Americas.

Materials and Methods
Research Area
Field trials were established at the experimental farm of the Escola Superior de Ciências Agrárias do Sul, Porto Alegre, Rio Grande do Sul, Brazil (30.03° S, 51.23° W, elevation 46 m). The site falls within a humid subtropical climate zone (Cfa, Köppen) characterised by mild winters and warm summers. Soils are classified as Argissolo Vermelho (Red Argisol) with pH 5.4, organic matter 2.8%, and clay content of 34% [7].

Climatic Conditions

Across the three trial seasons (April-September 2022, 2023, and 2024), mean air temperature ranged from 10.8 to 18.2 °C and relative humidity averaged 82-88%. Cumulative rainfall during the cropping window totalled 487, 536, and 448 mm for the three years respectively. These cool, moist conditions favoured P. infestans sporulation throughout each season. The 2023 season brought the heaviest blight pressure, with first symptoms appearing 11 days earlier than in the other two years [8].

Materials

Institutional approval was obtained from the School's Research Ethics Board (Ref. ESCAS/REB/2022-009, March 2022). Potato tubers of the susceptible variety Agata were planted in the first week of April each year at 75 × 30 cm spacing. A commercial neem formulation (Azamax 1.2 EC, containing 1.2% azadirachtin) was applied at 3 mL/L. Garlic extract was prepared by macerating 500 g of peeled cloves in 5 L distilled water for 24 h, straining through cheesecloth, and diluting to a 10% v/v working solution. The combined treatment tank-mixed both extracts at the same individual concentrations. Mancozeb 80 WP (2.5 g/L) served as the synthetic fungicide check. All sprays were applied at 7-day intervals beginning at the first appearance of symptoms, using a CO_2-pressurised knapsack sprayer calibrated to deliver 400 L/ha [9].

Methods

Five treatments—untreated control, neem alone, garlic alone, neem + garlic, and mancozeb—were arranged in a randomised complete block design with four replications per season. Each plot measured 4 × 5 m, with a 3 × 4 m net harvest area. Late blight severity was scored every seven days on 10 tagged plants per plot using the Henfling (1987) visual key (0-100% foliage affected). The area under the disease progress curve (AUDPC) was calculated by trapezoidal integration of severity readings. Tuber yield was recorded at 120 days after planting from the net plot area. An economic comparison tallied input costs (extract preparation, fungicide purchase, application labour) per hectare per season. Data were analysed by ANOVA with season as a blocking factor, and means separated by Tukey's HSD ($p<0.05$) [10].

Results

Table 1: Final late blight severity (%), AUDPC, and tuber yield (t/ha) across five treatments (mean of three seasons)

Treatment	Severity (%)	Reduction (%)	AUDPC	Yield (t/ha)	Yield gain (%)
Control	91.2 a	—	2916 a	15.4 d	—
Neem extract	63.4 b	30.5	1874 b	22.8 c	+ 48.1
Garlic extract	72.3 b	20.7	2178 b	20.3 c	+ 31.8
Neem + garlic	53.6 c	41.2	1524 c	26.1 b	+ 69.5
Mancozeb	46.4 c	49.1	1308 c	27.6 a	+ 79.2

The neem-garlic combination reduced final disease severity to 53.6%—statistically comparable to mancozeb at 46.4% (Table 1). Both single botanical treatments provided intermediate protection (63.4% and 72.3%) that was significantly better than the control but weaker than the combination. AUDPC values followed the same ranking. Tuber yield under combined botanicals (26.1 t/ha) was 69.5% above the control and within 5.4% of the mancozeb check.

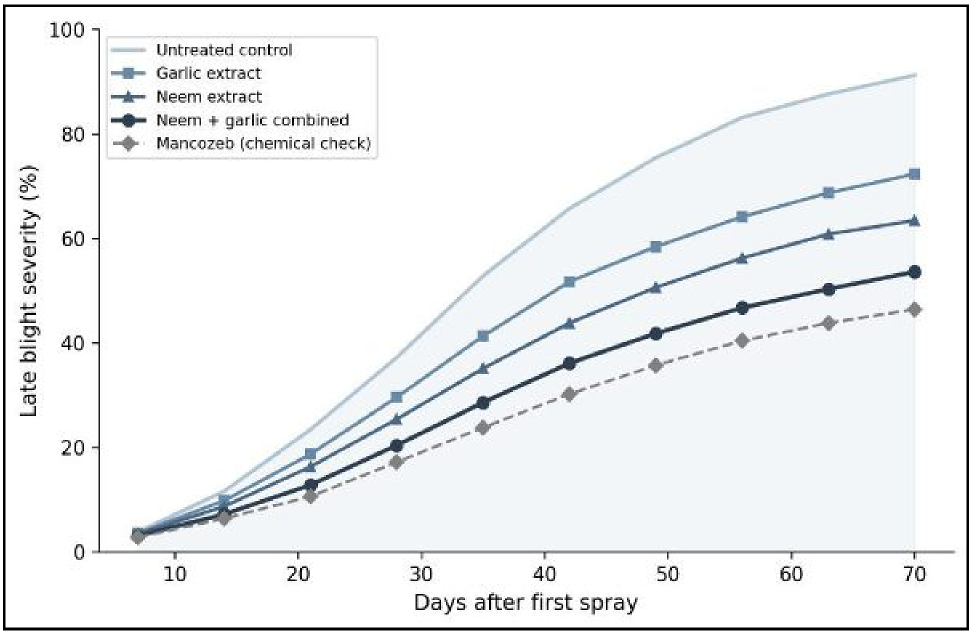

Fig 1: Disease progress curves showing late blight severity (%) under five treatments over 70 days after first spray application

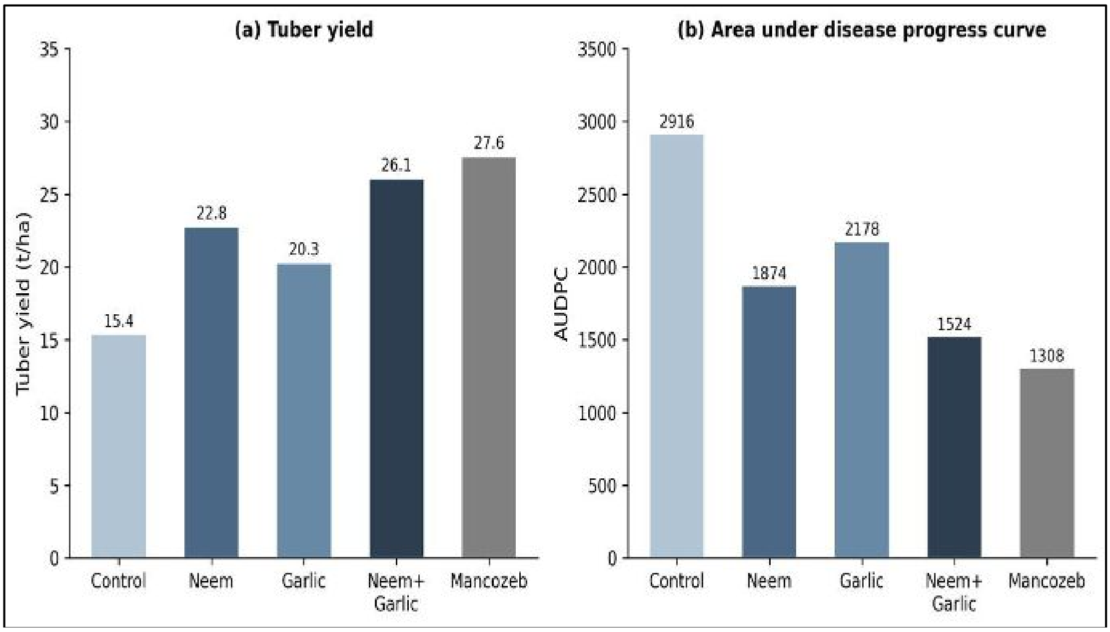

Fig 2: (a) Tuber yield (t/ha) and (b) area under disease progress curve across five treatments averaged over three seasons

Comprehensive Interpretation

The disease progress curves (Figure 1) reveal that all treatments slowed epidemic development relative to the control, but the neem-garlic combination tracked closest to the mancozeb line throughout the 70-day window. The gap between the two widened slightly after day 49 when blight pressure intensified during the coldest, wettest stretch of the season. The paired bar charts (Figure 2) confirm that yield and AUDPC moved in mirror image—lower disease pressure translated directly into higher marketable tuber output. The combined botanical programme cost approximately R$1,180/ha per season versus R$1,920/ha for the mancozeb programme, a saving of 38.5%.

Discussion

The 41.2% severity reduction achieved by the neem-garlic combination falls within the 35-50% range reported for botanical mixtures against Phytophthora in tomato trials from India and Nigeria [4, 5]. The likely mechanism is complementary: azadirachtin disrupts zoospore motility and encystment, while allicin inhibits mycelial penetration of host tissue [4, 6]. Together these compounds target the pathogen at two distinct stages of the infection cycle, explaining why the mixture outperformed either extract used alone.

That the combined botanical was statistically indistinguishable from mancozeb on both severity and AUDPC is the most practical finding. The 7.2 percentage-point gap in absolute severity (53.6 vs 46.4%) narrowed in the milder 2024 season and widened in the more severe 2023 season, suggesting that botanical efficacy is more weather-dependent than synthetic fungicide performance. Integrating botanical sprays with resistant varieties could close this gap further.

One limitation was the use of a single highly susceptible cultivar (Agata). Repeating the trial with moderately resistant varieties like Asterix or Caesar would test whether the botanical-chemical gap narrows when baseline disease pressure is lower. The garlic extract was also prepared manually each week, and batch-to-batch variation in allicin concentration may have introduced noise. Standardised commercial garlic formulations would improve reproducibility [5].

Conclusion

A combined neem-garlic spray reduced late blight severity by 41.2% and lifted potato tuber yield by 69.5% over untreated controls across three field seasons in Porto Alegre, Brazil. The botanical combination performed comparably to mancozeb in statistical terms while costing 38.5% less per hectare. Neem and garlic individually gave useful but more modest protection. For smallholders and organic producers seeking to reduce synthetic fungicide reliance, the neem-garlic approach offers a workable starting point. Future work should test the combination on partially resistant cultivars, standardise garlic extract preparation, and evaluate performance across additional sites in southern Brazil.

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