The 2nd International Online Conference on Mathematics and Applications

IOCMA 2026 Conference

10–12 June 2026 | Online

MDPI

Mathematical Analysis of the Impact of Vertical Transmission on Cassava Mosaic Disease Control and Harvest Quantity and Quality

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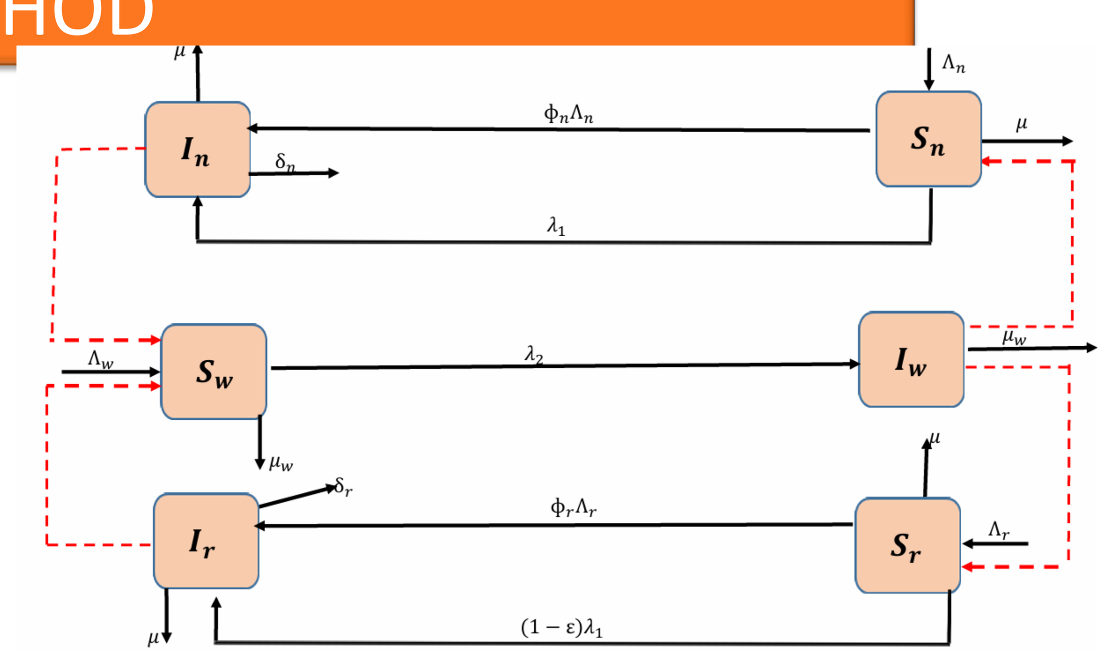
INTRODUCTION & AIM

- Cassava is a cheap staple which originated in South America and brought to Africa. Provide sustenance to millions of people globally. Cassava can be harvested six to eighteen months after planting, depending on the variety (6).
- Due to its vegetative propagation, cassava is susceptible to virus.Cassava Mosaic Virus (CMD) is spread by the whitefly insect. Significantly damages crops and destroy entire harvests (3).
- CMD started in Tanzania in 1894. Subsequently spreads and causes harm in Uganda, Nigeria, e.t.c.
- The virus disseminates mainly via cuttings and insect vectors, specifically the whitefly (*Bemisia tabaci*). It may also propagate through contaminated planting materials and, on occasion, by mechanical means (2).
- CMD symptoms include a mosaic pattern, discolored leaves, yellow, white, light, dark, alternating, thick leaves, small, wrinkled blades, shrinking, deformed, curved edges, possibly torn, premature leaf drop abnormal foliage growth, and, if infected early, dwarfed, stunted plants that either do not produce tubers or yield few tubers (2, 3, 4, 1).
- Although Once a plant is infected with CMD, there is no treatment, however there are a few cultural treatment methods to control the infection and lessen its effects: which includes planting resistant crop varieties, appropriate planting materials, adequate sanitation and roguing, and chemical treatment of whiteflies (3, 2)
- **AIM:** To assess the impact of vertical transmission on cassava mosaic transmission dynamics

METHOD

- The mode

$$\frac{dS_n}{dt} = (1-\phi_n I_n)\Lambda_n - \frac{\beta_r I_w S_n}{N_w} - \mu S_n,$$
$$\frac{dI_n}{dt} = \phi_n I_n \Lambda_n + \frac{\beta_r I_w S_n}{N_w} - (\mu+\delta_n) I_n,$$
$$\frac{dS_r}{dt} = (1-\phi_r I_r)\Lambda_r - (1-\epsilon)\frac{\beta_r I_w S_r}{N_w} - \mu S_r,$$
$$\frac{dI_r}{dt} = \phi_r I_r \Lambda_r + (1-\epsilon)\frac{\beta_r I_w S_r}{N_w} - (\mu+\delta_r) I_r,$$
$$\frac{dS_w}{dt} = \Lambda_w - \beta_w\left(\frac{I_n}{N_n} + \frac{\rho I_r}{N_r}\right) S_w - \mu_w S_w,$$
$$\frac{dI_w}{dt} = \beta_w\left(\frac{I_n}{N_n} + \frac{\rho I_r}{N_r}\right) S_w - \mu_w I_w,$$



- Qualitative analysis of the model
  - i. Reproduction number
  - ii. Disease free and Endemic equilibria
  - iii. Bifurcation analysis
  - iv. Stability analysis
  - v. Sensitivity analysis
- Simulation
- Scenario analysis

RESULTS & DISCUSSION

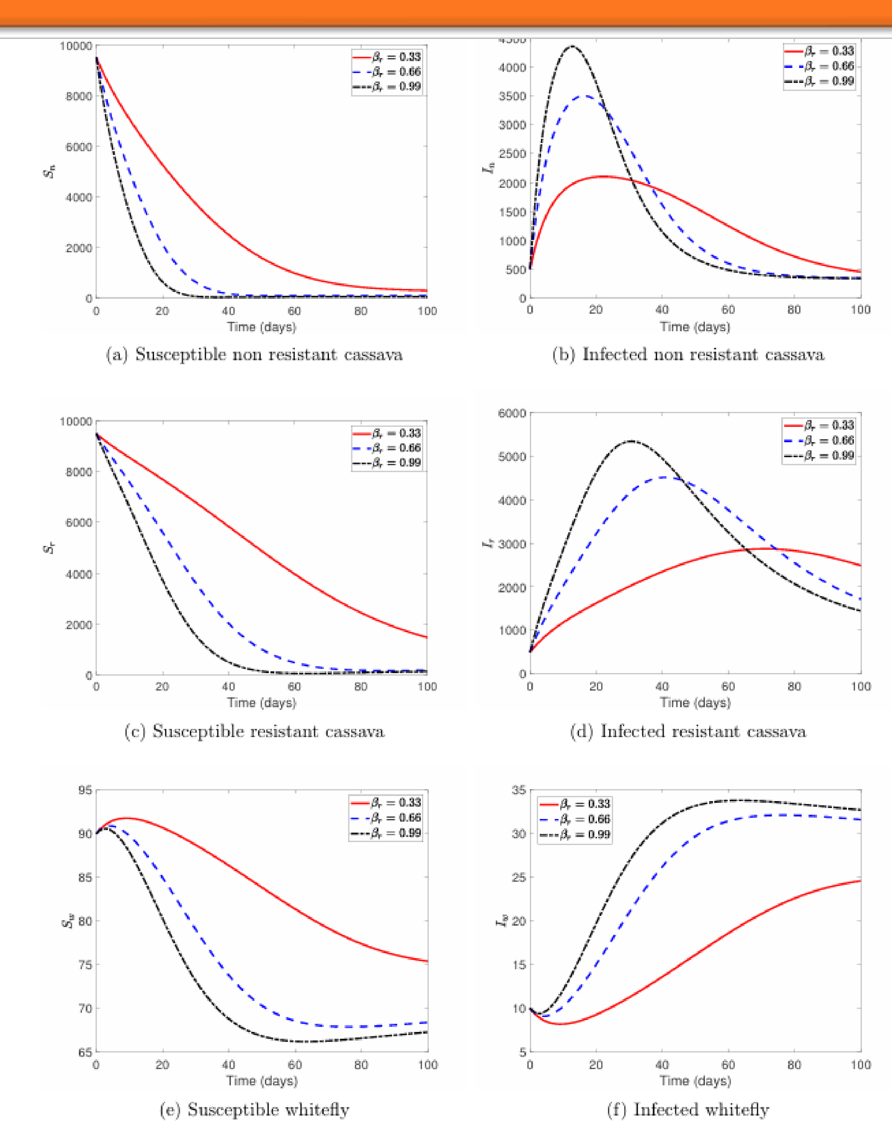
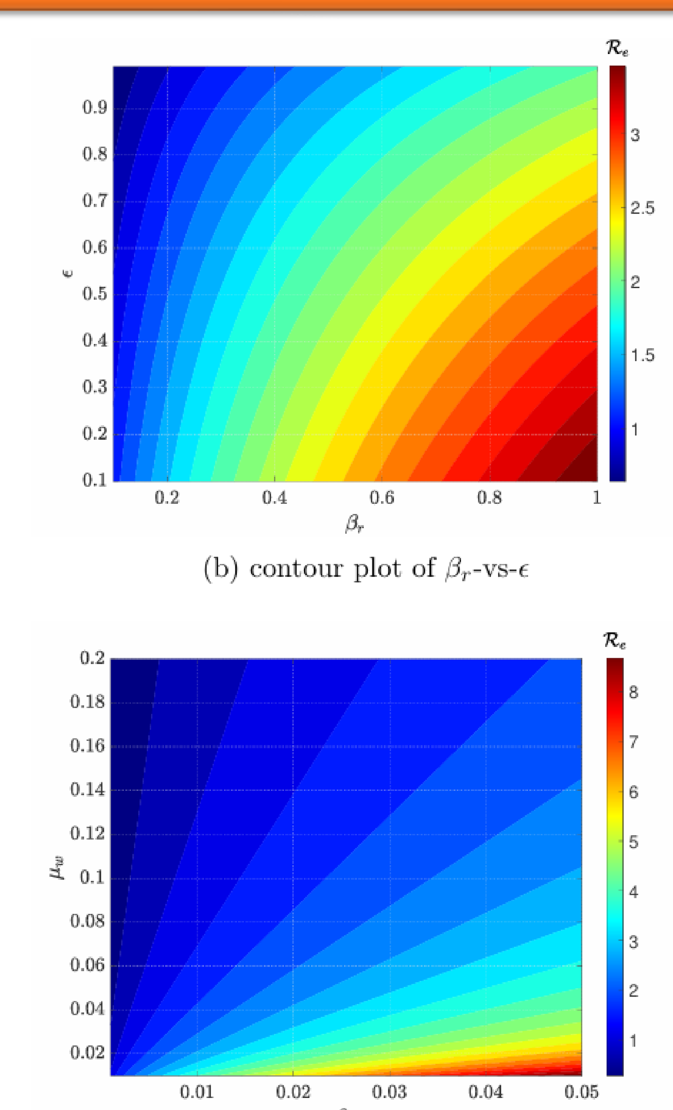


Figure 6.1: Simulation showing the dynamics of the states variables of model (2.9) with effective transmission rate from vector to plant (β_r)



(b) contour plot of β_r-vs-ϵ

(c) contour plot of β_w-vs-μ_w

.1: Parameter sensitivity values (2.

Parameter	Values
δ_r	-0.1963220448
δ_n	-0.2759194514
β_r	0.5000000000
Λ_n	0.03013505592
ϕ_n	0.03013505592
Λ_r	0.06204139090
ϕ_r	0.06204139090

The figure illustrates the impact of varying the **vertical transmission rate** (ϕ_n) from the baseline values on the dynamics of CMD in both **non-resistant cassava** (S_n, I_n) and **resistant cassava** (S_r, I_r), as well as on the susceptible whitefly population (S_w) and infected whitefly population (I_w).

CONCLUSION

- This study developed and analyzed a mathematical model for the transmission dynamics of CMD incorporating both vertical transmission through infected stem cuttings and horizontal transmission through whitefly vectors.
- The model was biologically feasible through positivity and boundedness analyses,. The disease-free equilibrium was globally asymptotically stable when $R_e < 1$, while the endemic equilibrium exists and remains stable when $R_e > 1$ (R_0 > 1). The analytical and numerical results highlight the critical role of vertical transmission in maintaining CMD within cassava farms. Increased transmission through infected non-resistant and resistant cuttings was found to elevate the burden of infection, thereby reducing healthy cassava stands and potentially diminishing harvest quantity and quality. Conversely, increasing resistant efficacy (ε) substantially reduced the number of infected cassava plants, demonstrating the importance of deploying highly resistant cassava varieties. Similarly, enhanced roguing of infected plants and increased whitefly mortality contributed significantly to disease reduction by lowering the pool of infectious hosts and vectors.
- Epidemiologically and agriculturally, the findings suggest that sustainable CMD management should prioritize the cultivation of highly resistant cassava varieties, timely removal of infected plants, and effective whitefly control measures.

FUTURE WORK / REFERENCES

Future studies will extend the model by incorporating optimal control strategies, and cost-effectiveness analysis, to provide more comprehensive CMD management recommendations.

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