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Incorporating beneficial nematodes-based biocontrol agents into an integrated pest management strategy of Rwanda: A policy brief

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ABSTRACT

Climate change-induced insect pest outbreaks pose a significant threat to food security in Rwanda, particularly affecting small-holder farmers. Insect damage to crops heavily affects food production. Consequently, farmers have resorted to overreliance on chemical pesticides as control measures, thereby endangering humans and the environment. The use of beneficial nematodes for the biological control of insect pests offers an alternative solution to excessive usage of pesticides. Nematodes are tiny naturally occurring worms that attack insects and can be mass produced for use as biocontrol agents. Entomopathogenic nematodes are safe for farmers, consumers, livestock, crops and the environment. Globally they have been used for many decades for management of insect pests across various crops and against numerous pest species. Current research studies in Rwanda demonstrate their effectiveness in controlling both below-ground insect pests, such as grubs, and above-ground pests like the fall armyworm. They can be mass produced also in Rwanda and elsewhere in East Africa. Although this biological control method has shown promise in controlling insect-pests in Rwanda, there is limited availability and use of these products due to limits in commercialization. It is being proposed in this policy brief that an easy and minimized registration process be put in place for indigenous beneficial nematodes to facilitate making such products available to Rwandan farmers. It is also proposed to enhance government-led extension services and outreach programs to educate farmers and stakeholders about the benefits and proper use of biological control methods. In addition, beneficial nematodes should become a component in the national integrated pest management strategy of Rwanda.

Keywords: Entomopathogenic nematodes, Insect-pests, Macrobial biological agents, National strategy, Pest Management, Regulation, Registration

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RÉSUMÉ
Les épidémies de ravageurs d'insectes induites par le changement climatique représentent une menace significative pour la sécurité alimentaire au Rwanda, affectant particulièrement les petits exploitants agricoles. Les dommages causés par les insectes aux cultures nuisent fortement à la production alimentaire. Par conséquent, les agriculteurs ont eu recours à une dépendance excessive aux pesticides chimiques comme mesures de lutte, mettant ainsi en danger la santé humaine et l'environnement. L'utilisation de nématodes bénéfiques pour la lutte biologique contre les insectes ravageurs constitue une solution de rechange à l'utilisation excessive des pesticides. Les nématodes sont de petits vers naturellement présents qui attaquent les insectes et peuvent être produits en masse pour servir d'agents de lutte biologique. Les nématodes entomopathogènes sont sans danger pour les agriculteurs, les consommateurs, le bétail, les cultures et l'environnement. À l'échelle mondiale, ils sont utilisés depuis de nombreuses décennies pour la gestion des insectes nuisibles sur diverses cultures et contre de nombreuses espèces de ravageurs. Des études récentes menées au Rwanda démontrent leur efficacité dans la lutte contre les insectes nuisibles souterrains, tels que les larves, ainsi que les ravageurs aériens comme la chenille légionnaire d'automne. Ils peuvent également être produits en masse au Rwanda et ailleurs en Afrique de l'Est. Bien que cette méthode de lutte biologique ait montré son efficacité au Rwanda, sa disponibilité et son utilisation restent limitées en raison des obstacles à la commercialisation. Ce document de politique recommande la mise en place d'un processus d'enregistrement simplifié pour les nématodes bénéfiques indigènes afin de faciliter leur mise à disposition pour les agriculteurs rwandais. Il est également proposé de renforcer les services d'extension et les programmes de sensibilisation pilotés par le gouvernement pour éduquer les agriculteurs et les parties prenantes sur les avantages et l'utilisation appropriée des méthodes de lutte biologique. En outre, les nématodes bénéfiques devraient être intégrés à la stratégie nationale de lutte intégrée contre les ravageurs au Rwanda.

Mots clés : Nématodes entomopathogènes, Insectes nuisibles, Agents biologiques macrobiaux, Stratégie nationale, Lutte antiparasitaire, Réglementation, Enregistrement

INTRODUCTION

Due to intensification of agriculture, climate change and insect invasions, Rwanda has been experiencing an increase in outbreaks of pests such as fall armyworm (FAW) which have negative effects on crops, resulting in heavy yield losses (Uzayisenga *et al.*, 2018). The FAW is causing huge yield losses of 22% to 67% across Africa and elsewhere in the world (Day *et al.*, 2017; Kumela *et al.*, 2018). Outbreaks of pests like FAW and others have led to extensive usage of synthetic pesticides by farmers with consequences on both human and the environment (Rugigana, 2022). Growing public concern over health risks of chemical pesticides has led to the need for minimizing the use of synthetic pesticides in the management of insect-pests. Therefore, there is a need for alternative methods of crop protection such as the application of biological control agents. Of these, the use of beneficial nematodes offers a suitable solution to be incorporated in the Integrated Pest Management (IPM) strategies in Rwanda. Beneficial nematodes also called entomopathogenic nematodes (EPNs) are tiny soil dwelling roundworms which can infest and kill a large variety of insect-pests (Kaya and Gaugler, 1993; Hominick *et al.*, 1996). They belong to the macro-organism and are therefore considered macrobial biocontrol agents, and not microbial biopesticides. Unlike many pesticides, beneficial nematodes pose no risk to farmers, consumers, livestock, crops or the

environment. Globally they have been used for many decades for a wide range of pest control targets and crops and have never caused any harm. Current research in Rwanda also indicates good control of soil insect pests such as grubs, or above ground pests such as fall army worm using beneficial nematodes (Kajuga *et al*., 2018; Fallet *et al*., 2022).

While EPNs are effective and well-understood biological control agents, they face several limitations such as environmental sensitivity to ultraviolet (UV) radiation, dessication and temperature fluctuation, limited shelf life of 3-6 months, and the need for technical expertise (Askary and Abd-Elgawad, 2021). Despite this, their benefits ultimately make them a valuable biological control option, and are therefore the 3rd most used group of biocontrol agents globally. Advantages include their ability to seek for and kill insect pest even when hidden, ability to multiply in the insect pests and to persist in the environment often reducing the need for repeated applications, no problems with resistance development in the pest, no residues on the crop, and their compatibility with most other agriculture practices. Application against soil pests or proper timing, such as evening applications when used against above ground pests, can minimize UV exposure, as do modern formulation techniques (Cruz-Martínez, 2017). This balance of limitations and benefits suggest that EPNs, despite their challenges, represent a promising and environmentally friendly approach to pest control in East Africa, as it is in many other regions globally.

Despite adopting East African Community (EAC) guidelines for bio-pesticide and biocontrol agent registration, Rwanda faces limited availability and use of these products. To address this, the Government should streamline the process for registering indigenous macrobial biological control agents, including beneficial nematodes. It is important to develop simplified, clear and practical national guidelines for registration including reduced registration requirement and with reduced bureaucracy. This could accelerate the registration and availability of biocontrol agents and subsequently the uptake of these integrated pest management (IPM) products. This approach would increase the availability and use of safe, environmentally friendly pest control methods while adhering to EAC principles. We also propose to integrate beneficial nematodes into IPM strategies; thus, Rwanda can enhance sustainable pest management, supporting food security and protecting health and the environment. The government should take proactive steps to develop these local guidelines and promote widespread adoption of these technologies.

Overview of the research. This policy brief is based on available data on beneficial nematodes from Rwanda (Yan *et al.*, 2016; Fallet *et al*., 2022; Machado *et al.*, 2022). In 2013 a pilot mass production facility on beneficial nematodes was established in Rwanda Agriculture and Animal Resources Development Board (RAB) at Rubona station, Huye District. Several internationally well-studied, commercial beneficial nematodes species namely *S. longicaudum* (X7), *S. carpocapsae* (All), *Heterorhabditis indica* (LN2) and *H. beicherriana* (HO6), with consistent pest control efficacies are available in culture. In addition, five local beneficial nematodes including *Steinernema carpocapsae* (RW14-G-R3a-2), *S. africanum* (RW14-MC2b-1), *S. africanum* (RW14-MC2a-3), *Heterorhabditis ruandica* (RW18-Hr-1a), and *H. ruandica* (RW14-NC4a) have been isolated in Rwanda, taxonomically described, and are being mass-produced at Rubona station (Yan *et al.*, 2016; Fallet *et al*., 2020; Machado *et al.*, 2022). Many more nematode species or strains can potentially be isolated from Rwandan soil. However, biocontrol companies often have certain capacity to produce a limited number of

beneficial nematodes depending on the market. Between 2014 and 2016, RAB and partners showed the efficacy of these nematodes in controlling a number of soil insect pests in Rwanda (Kajuga *et al*., 2018). Rwandan EPN isolate *S. africanum* RW14-M-C2b-1 was as effective as international strains in reducing white grubs in potato by 29 ± 33% and 80 ± 3% of grubs within 30 and 60 days, respectively. Between 2020 and 2022, field trials were conducted in the Southern Province of Rwanda to evaluate the potential of formulated beneficial nematodes in controlling fall armyworm in maize (Fallet *et al.*, 2022; 2024). From 2021 to 2023, further field studies were carried out in both the Eastern and Southern Provinces of Rwanda to evaluate the efficacy of formulated beneficial nematodes in controlling FAW compared to local pest management practices. Findings showed that formulated beneficial nematodes reduced the population of FAW by 23-50% and the damage on maize plants by 30-50% compared to untreated control (Figure 1, 2). Repeated application of beneficial nematodes is recommended to consistently reduce plant damage due to overlapping FAW generations during the vegetative maize growing season (Fallet *et al*, 2022; 2024). Compared with local pest management practices, the beneficial nematodes, were found equally effective in reducing FAW population and damage in maize as were the botanical pyrethrin, insecticide profenofos + cypermethrin, and more effective than manual placements of field soils into leaf whorls physical measures (Figure 3).

Our research and development on mass production, application techniques and use of beneficial nematodes is in line with the current National Agriculture Policy (MINAGRI, 2018), pillar No. 3 on productivity and sustainability through promotion of IPM technologies in controlling pests and diseases.

We propose the following policy recommendations:

1. The Government should incorporate beneficial nematodes-based biocontrol agents into an Integrated Pest Management Strategy of Rwanda.
2. The Government should develop clear, practical and effective national technical guidelines and simplified registration requirements for the commercialization of indigenous macrobial biocontrol agents including beneficial nematode products in line with the East African Community harmonized standards. These guidelines should streamline and economize the process for approving biological control agents.

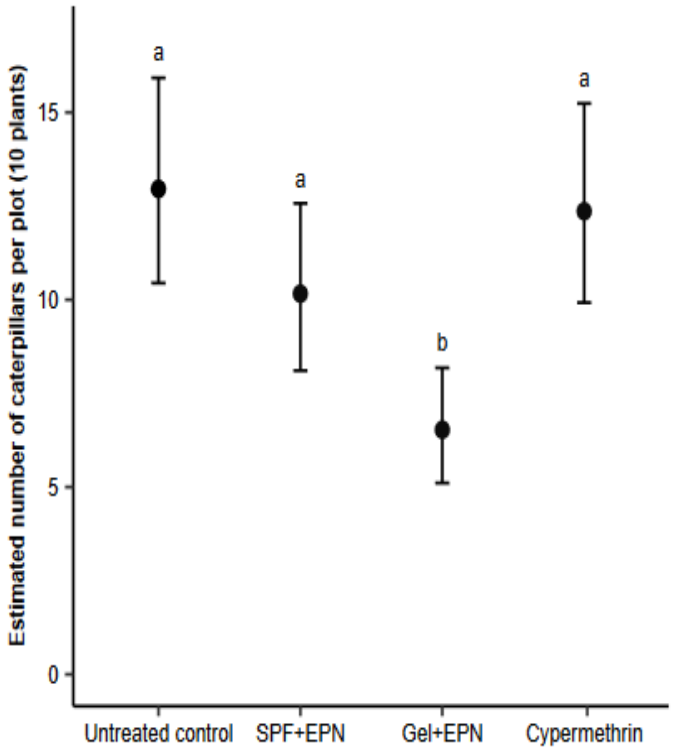

Figure 1. Number of caterpillars per plot. Number of caterpillars recovered per plot 5 days after the third application, averaged for the six fields with each five plots per treatment. Ten specific plants per plot (n=30 plots per treatment) were destroyed to inspect for caterpillars. Different letters indicate significant differences ($P<0.05$). EPN=Entomopathogenic nematodes; SPF+EPN=Application of EPN in a commercially available liquid Surfactant Polymer Formulation (e-nema GmbH, Schwentinental, Germany); Gel+EPN= application of EPN in a carboxymethyl cellulose (CMC) gel. Source: Fallet *et al*., 2024

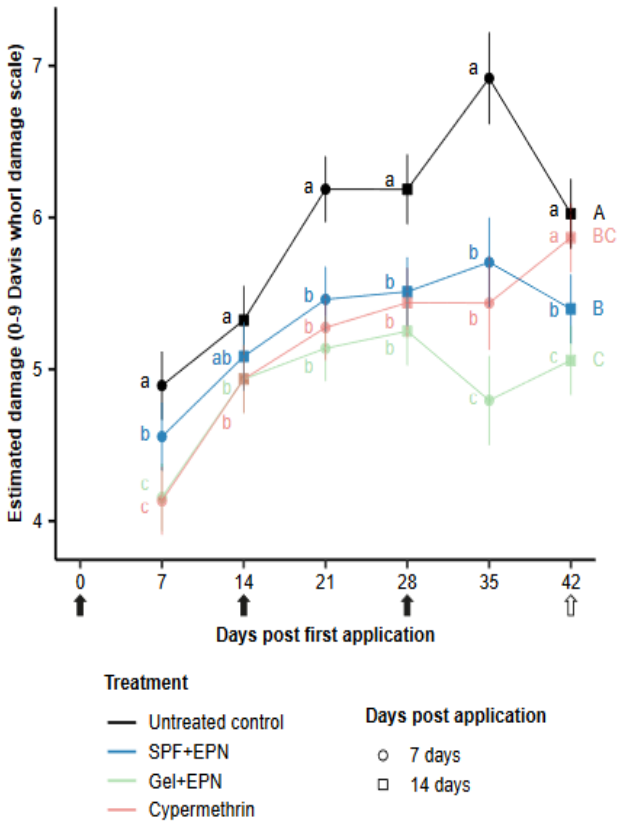

Figure 2. Whorl damage. Damage scores averaged for the six fields with each five plots per treatment. The arrows indicate the days of the treatment (black arrows: all fields treated; white arrow: only fields I, II, III and IV treated). Whorl damage was assessed 7 and 14 days after each application for 40 plants per plot (n=30 plots per treatment) using the Davis whorl damage scale, where a "0" represents intact whorl and a "9" represents an almost completely or completely destroyed whorl. Different letters indicate differences ($P<0.05$). Panel A: small letters: differences among treatments at a given assessment; capital letters: differences among treatments throughout the field trials. EPN = Entomopathogenic nematodes; SPF+EPN = Application of EPN in a commercially available liquid Surfactant Polymer Formulation (e-nema GmbH, Schwentinental, Germany); Gel+EPN = application of EPN in a carboxymethyl cellulose (CMC) gel. Source: Fallet *et al*., 2024

3. The Government should consider whether beneficial nematode species indigenous to East Africa and registered in any country of the East African Community could be automatically registered for Rwanda, or registered at minimum requirements, which would largely decrease registration burden.
4. The Government should further enhance extension services and outreach programs to raise awareness among farmers and other stakeholders on the benefits and application of biocontrol agents including beneficial nematodes.
5. Government, private sector and development partners should mobilize funding towards research, development and usage of beneficial nematodes-based pest management strategies.
6. The Government should promote Public-Private Partnerships (PPPs) to advance research and development in commercialization of beneficial nematode products.

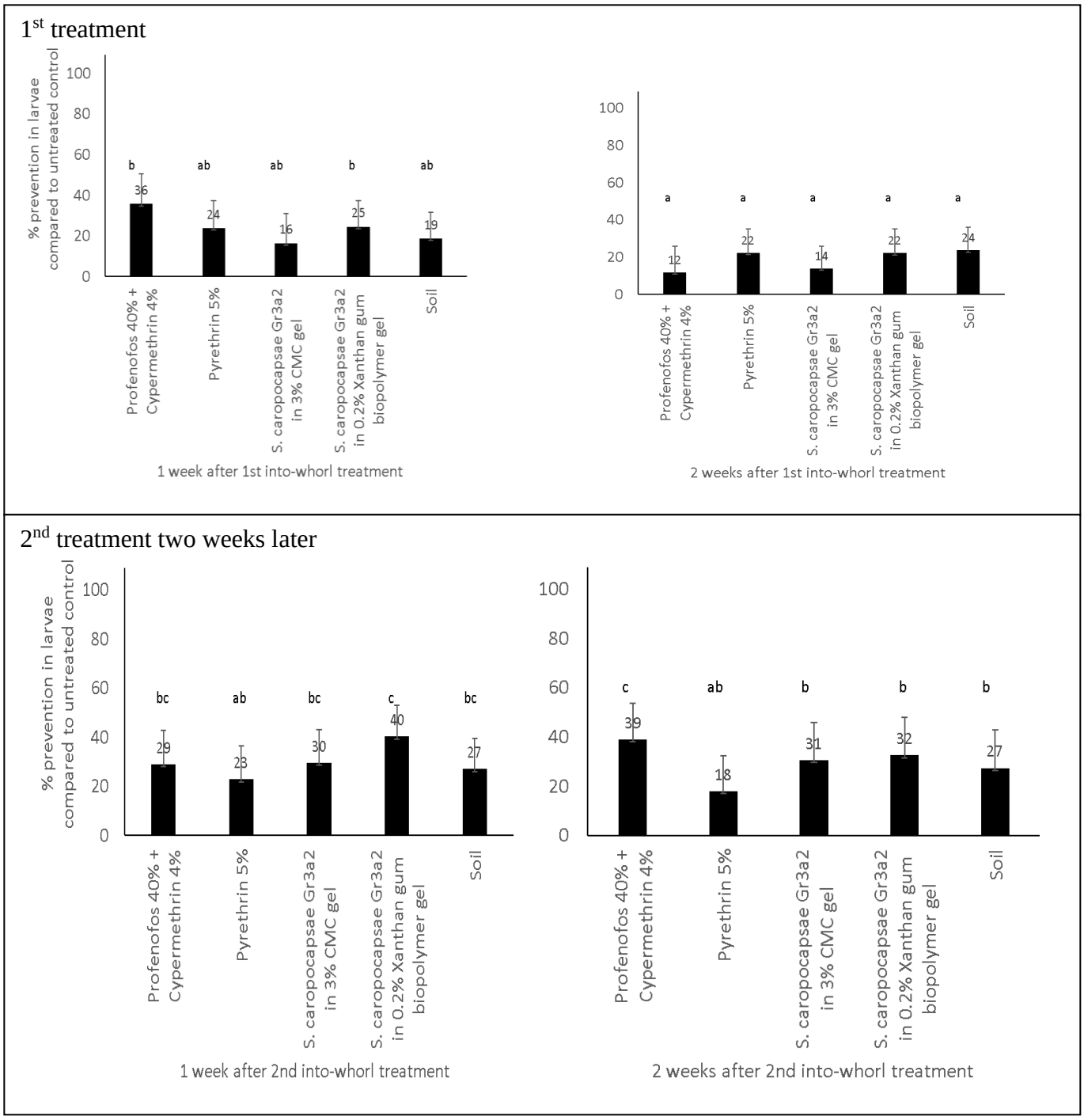

Figure 3. Efficacy of two applications of two formulations of the entomopathogenic nematode *Steinernema carpocapsae* strain RW14-G-R3a-2 (Rhabditida: Steinernematidae) compared to local pest management practices (standard pesticide, botanical pyrethrum, field soil placement) at reducing larvae of *Spodoptera frugiperda*. All treatments as spot applications into leaf whorls of maize, 2ml for liquid, 40 g for field soil. Five experiments in young vegetative maize fields in Rwanda in November to December 2022 and April to June 2023. Destructive sampling applied for larvae counts. 10 plants per each of 4 plots per treatment per each of five experiments assessed. CMC= Carboxymethyl cellulose (Own Data).

CONCLUSION

Beneficial nematodes are as effective for control of insect pests as other local pest management practices including insecticides, and pose no risks to farmers, consumers, livestock, crops and the environment. Therefore, their use in IPM should be promoted in Rwanda. In addition, both Government and private sector players should work together to facilitate registration requirements and to enhance research and development on nematode-based solutions for other insect pests.

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DECLARATION OF CONFLICT OF INTEREST

The authors declare that they have no competing interests.

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