

Research Application Summary

Biopesticide-based IPM systems to reduce synthetic pesticide residues in vegetables for niche market access by small holder growers

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Abstract

In the last few decades, farmers have relied on synthetic pesticides to managed crop pests and diseases. This is because synthetic pesticides are easily available, have quick knock down effect, have varied modes of action and are reliable. However, some synthetic pesticides are not easily degraded, they leave residues in crop products, are expensive, are harmful to the user and are an environmental hazard. In addition, some pests and disease pathogens have developed resistance to synthetic pesticides forcing farmers to apply even more pesticides since the target markets demand aesthetically presentable produce. Presence of residues in fresh vegetables has led to increased interceptions and famers have been denied access to lucrative markets. This has led to increased monetary losses, loss of market reputation and loss of income. Requirements by European and local market on maximum residue levels (MRLs) of pesticides in vegetable produce have resulted in reduced export and sale volumes due to non-compliance by small holder growers. The main objective of this study will be to develop alternative pest and disease management options in intensive smallholder vegetable production by incorporating botanical and microbial biopesticides in IPM programmes for enhanced niche market access. The objective of the study is to develop alternative pest and disease management options in intensive smallholder French bean and tomato production by incorporating botanical and microbial biopesticides in IPM programmes for enhanced niche market access. Biopesticides are safe, are degradable and do not have negative effects on non-target organisms and the environment. The project evaluated the efficacy of plant extracts and microbial antagonists in managing pests and diseases in French bean and tomato. The comparative effectiveness of plant extracts and antagonistic fungi with the synthetic pesticides and the commercialized antagonists and botanicals is proof that the crude products have similar potential as the synthetic pesticides. Therefore, there is need for further exploration of local environment for bio-active plants and organisms be identified and screened for antimicrobial properties and formulated for inclusion in IPM programmes. This will help the average farmer meet the production costs, have higher income and at the same time have clean, safe and quality produce for high value markets.

Key words: Biopesticides, fresh vegetables, niche market, pesticide residues

Résumé

Au cours des dernières décennies, les agriculteurs dépendaient des pesticides synthétiques pour lutter contre les ravageurs et les maladies des cultures. Ceci est attribué au fait que les pesticides synthétiques sont facilement disponibles, ont un effet pesticide rapide, ont des modes d'action variés et sont fiables. Toutefois, certains pesticides synthétiques ne sont pas facilement dégradés, ils laissent des résidus dans les produits végétaux, sont chers, sont nuisibles à l'utilisateur et posent un danger pour l'environnement. En outre, certains ravageurs et agents pathogènes ont développé une résistance aux pesticides synthétiques obligeant les agriculteurs à appliquer davantage de pesticides puisque les marchés cibles exigent des produits esthétiquement présentables. La présence des résidus dans les légumes frais a entraîné une augmentation des interceptions et agriculteurs se sont vus refuser l'accès à des marchés lucratifs. Cela a conduit à une augmentation des pertes monétaires, la perte de réputation sur le marché et la perte de revenu. Les exigences de marché européen et local sur les teneurs maximales en résidus (TMR) de pesticides dans les produits végétaux ont donné lieu à l'exportation et à la vente des volumes réduits en raison de non-respect par les petits exploitants agricoles. L'objectif principal de cette étude était de développer des options alternatives de la de gestion des ravageurs et des maladies dans la production intensive des haricots verts et des tomates par de petits exploitants, en incorporant les biopesticides botaniques et microbiens dans les programmes de lutte intégrée contre les ravageurs afin d'améliorer accès aux marchés de niche. L'objectif de l'étude visait l'élaboration des options alternatives de gestion des ravageurs et des maladies dans la production intensive des haricots verts et des tomates par des petits exploitants en incorporant des biopesticides botaniques et microbiennes dans les programmes de lutte intégrée contre les pestes pour un meilleur accès au marché cible. Les biopesticides sont sûrs, dégradables et n'ont pas d'effets négatifs sur les organismes non ciblés et l'environnement. Le projet a évalué l'efficacité d'extraits de plantes et des antagonistes microbiens dans la gestion des ravageurs et des maladies des haricots verts et des tomates. L'efficacité comparative entre des extraits de plantes et de champignons antagonistes et les pesticides de synthétiques et les antagonistes commercialisés et des plantes est la preuve que les produits bruts ont le même potentiel que les pesticides synthétiques. Par conséquent, il est nécessaire de poursuivre l'exploration de l'environnement local pour identifier et sélectionner les plantes et les organismes bio-actifs ayant des propriétés antimicrobiennes et les formuler pour l'inclusion dans les programmes de lutte intégrée contre les pestes. Cela aidera l'agriculteur moyen à réduire le coût de production, augmenter le revenu, et en même temps ont accès à des produits propres, sûrs et de qualité pour les marchés à forte valeur ajoutée.

Mots clés: les biopesticides, les légumes frais, le marché cible, les résidus de pesticides

Background

Small scale vegetable farmers in Kenya mainly depend on synthetic pesticides to keep pest and disease damage below economic levels. This is to conform with the requirements of the European Union market, which accounts for up to 80% of Kenya's fruit and vegetable sales and 42% of flower exports (Business Daily, 2014). French bean (*Phaseolus vulgaris* L.) is a major export vegetable while tomato is a major vegetable for the local market. The frequent chemical sprays on vegetables have resulted in pest resurgence and resistance, environmental contamination and lethal effects on non-target organisms. Over use and misuse of pesticides lead to health risks to growers, environment, and threats of interception due to pesticide residue on the produce (Aktar *et al.*, 2009). The European Union has set the basal maximum residue limit (MRL) on all food products at 0.01mg/kg (European Commission, 2012). Previously, most vegetable farmers used the popular pesticide Dimethoate to control mites and insects in tomato, cabbage and kale but due to the ban on this product, more than a fifth of exports from Kenya have recently been rejected by the EU market due to presence of this chemical (Business Daily, 2014). As a result, several companies and farmers were delisted. In addition to the imposition of a 10% sampling per consignment on all beans and peas in pods from Kenya into the EU (European Commission, 2012). Recently the European Union conducted an audit of the Kenya horticultural industry following concerns over the safety of vegetable exports from the country (Business Daily, 2014). The audit was in reaction to concerns that vegetables from Kenya, especially peas and French beans contained harmful pesticide residues. The strict maximum residue level (MRLs) requirements could result into shortage of beans and loss of trade because small holder farmers may stop production due to fear of non-compliances, high costs, limited number of analytical laboratories and delays in clearing of consignments. The stringent pesticide regulations have adversely affected the vegetable export business resulting in a 25% reduction in bean sales in January 2013 compared to January 2012 sales. Therefore, if vegetable farmers are to access the niche EU and local supermarket markets, there is need to search for alternative pest and disease management approaches that are user friendly and that leave no chemical residues on the produce and in the environment.

Literature Summary

The negative effects of using synthetic pesticides in agricultural production has stimulated continued search for alternative pest control approaches (Nderitu *et al.*, 2009). The most commonly used biological pesticides include living organisms, bioinsecticides, botanicals and compost teas. Biological pesticides used to manage pests and diseases in vegetable production include microorganisms such *Metarhizium anisopliae*, *Bacillus thuringiensis*, *Beauveria bassiana*, *Pseudomonas syringae*, *Pantoea agglomerans*, *Streptomyces lydicus*, *Bacillus pumilus*, *Bacillus subtilis*, *Trichoderma harzianum*, *Trichoderma virens* and *Paecilomyces* sp.; and botanicals such as neem (*Azadirachtin*),

pyrethrum, garlic, eucalyptus, turmeric, tobacco, ginger; and essential oils such as nettle oil, thyme oil, eucalyptus oil, rue oil, lemon grass oil, tea tree oil; compost extracts and Aloe vera (Gurjar *et al.*, 2012).

Botanical pesticides such as pyrethroids and neem have also been shown to be as effective as the synthetic chemicals in reducing pest damage and recently some essential oils of higher plants have also been used as antimicrobials against storage pests because they are relatively safe and acceptable to consumers (Gurjar *et al.*, 2012). *Metarhizium anisopliae* has been shown to be effective as bio-control in the management of thrips (Nderitu *et al.*, 2009). A variety of foliar plant diseases such as powdery mildews, late blight and downy mildews have been suppressed by application of compost extracts or compost tea (Scheuerell and Mahaffee, 2002). *Bacillus subtilis* has been shown to be an effective biocontrol agent and a plant growth promoter with the ability to trigger induced systemic resistance in plants (Islam *et al.*, 2012) while combined application of *Trichoderma viride* and *Bacillus subtilis* gave better management of the soil borne pathogen *Fusarium solani* in tomato (Morsy *et al.*, 2009). Combinations of antagonistic microorganisms and compost extracts (compost tea) shown promising results in managing late blight (Ghorbani *et al.*, 2005). Plant growth promoting rhizobacteria and other microbial antagonists widely occur in the soil and rhizosphere (Kumar *et al.*, 2011). Methods of isolating and multiplying antagonistic microorganisms have been described (Valicente *et al.*, 2010). Biopesticides are less harmful to non-target organisms, are often effective in small quantities, decompose quickly, have no toxic residues, are harmless to beneficial organisms and pose minimal risk to the environment and humans (Gupta and Dikshit, 2010). Microorganisms in biopesticides can multiply on or in vicinity of the target pest thus giving self-perpetuating control (Chandler *et al.*, 2011).

Research approach and conceptual framework

The research addresses the RUFORUM thematic agenda “innovation for sustainable systems within value chains that improve small holder incomes”. The project explores alternative pest and disease management options that will lead to reduction in the use of synthetic pesticides through incorporation of safe biopesticides in IPM programmes. The main objective is to develop alternative pest and disease management options in intensive smallholder vegetable production by incorporating botanical and microbial biopesticides in IPM programmes for enhanced niche market access. The research is implemented by a multi-disciplinary team comprising of senior and young academic staff to promote mentorship and high quality research. The project has trained two MSc students and offered internship to two undergraduate students. During the second year of research, one of the MSc students evaluated the effectiveness of local antagonistic microorganisms and crude plant extracts against major pests and diseases of snap bean as alternatives to synthetic pesticides. The second student evaluated the efficacy of plant extracts and antagonistic fungi in the management of pests and diseases of tomato. The two undergraduate students undertook their 4th year special projects under the guidance of postgraduate students with the aim of introducing them to participatory research to inculcate practical experience, creativity, team work and solving problems of rural

Benefits of biopesticides in vegetable IPM systems

The stringent conditions for fresh vegetable produce has seen some small scale farmers opt out of export markets forcing them to sell their produce in the local markets which do not fetch as much income. This has a negative effect on household incomes, livelihoods and employment creation in the horticultural industry. The high interception of export vegetables at port of entry due presence of high levels of pesticide residues and the resultant loss of markets have called for mitigation measures to close the gap between market access and safe food produce. The introduction of traceability systems ensures the farmers adhere to safe agricultural practices. Use of biopesticides, accreditation of laboratories to monitor pesticide levels, trainings and awareness creation on pesticide usage, and announcement of attractive prices for organically produced vegetables are some of the mitigation measures KEPHIS, 2016).

The stringent regulations by European Union (EU) especially on MRLs for fresh vegetables like snap beans can be addressed through the use of alternative approaches in pest management that do not result in accumulation of chemical residue in the produce. (Srinivasan, 2012). Botanical pesticides have antimicrobial properties which makes them useful as plant protection products. Goufo *et al.* (2008) reported a reduction of late blight of tomato by up to 75% by application of plant extracts from *Cupressus benthamii* and *Vetiveria zizanioides*. Fulano *et al.* (2016) reported that botanicals from neem, garlic, turmeric, lemon and ginger and antagonistic *Tichoderma* sp were effective in reducing the intensity of French bean diseases by up to 49%. Jahromi *et al.* (2012) evaluated the repellent activity of sirinol, garlic emulsion on several plant insect pests and reported reduction in the adults of red flour beetle (*Tribolium castaneu*) by up to 70%. Microbial-based pesticides registered by the Pesticide Control Products Board (PCPB) and available in the market in Kenya (PCPB, 2010) include BioCatch® (*Verticillium lecanii*), Biolep® (*Bacillus thuringiensis*), Bio-Nematon® (*Paecilomyces lilacinus*), Botanigard® (*Beauveria bassiana*), Trianum-P® (*Trichoderma harzianum*), and Trichotech® (*Trichoderma asperellum*). Botanical pesticides registered for commercial use in Kenya (PCPB, 2010) include Flower DS EC® (Pyrethrins), Neemark EC® (neem), Neemraj Super® (neem), Nimbecidine EC® (neem), Pyerin EC® (Pyrethrins), and Trilogy 70 EC® (neem oil).

Local environment is a rich source of microbial antagonists and botanicals that can be exploited as alternatives to synthetic pesticides. Use of natural plant products and microorganisms is safe to the environment, no residues are retained on the produce and if locally available (Srijita, 2015), it could be less expensive than the synthetic products (Goufo *et al.*, 2010). Biocontrol products have no harmful effects to the user as well as the beneficial organisms (Mizubuti *et al.*, 2007). In addition, biopesticides offer solutions to pest resistance, environmental and water body pollution, public concerns about food safety and improves agricultural productivity (Mishra *et al.*, 2015). The use of biopesticides will help overcome the negative effects of synthetic pesticides such as development of pest resistance, reduction of beneficial species, environmental and water

pollution and food poisoning due to presence of chemical residues (Mishra *et al.*, 2015; Srijita, 2015). This will improve the quality and safety of fresh vegetables and reduce the rate of interception and product rejection in the lucrative export markets leading to improved compliance with the MRL requirements, enhanced access to market, farmer incomes and employment for youth and women. This will boost agricultural productivity and rural economy in vegetable producing regions therefore improve compliance with the MRL requirements leading to enhanced access to market, farmer incomes and employment for youth and women.

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References

- Aktar, M.W., Sengupta, D. and Chowdhury, A. 2009. Impact of pesticide use in Indian agriculture - Their benefits and hazards. *Interdisciplinary Toxicology* 2 (1): 1-12.
- Business Daily. 2014. EU agency to probe horticultural sector on safety concerns. 19th March 2014.
- Chandler, D., Bailey, A. S., Tatchell, G. M., Davidson, G., Greaves, J. and Grant, W. P. 2011. The development, regulation and use of biopesticides for integrated pest management. *Philosophical Transactions of the Royal Society B* 366: 1987–1998.
- European Commission. 2012. Amending Annex I to Regulation (EC) No 669/2009 implementing Regulation (EC) No 882/2004 of the European Parliament and of the Council as regards the increased level of official controls on imports of certain feed and food of non-animal origin. Official Journal of the European Union. L. 350/44. 20/12/2012.
- Fulano, A.M., Muthomi, J.W., Wagacha, J.M. and Mwang'ombe, A.W. 2016. Use of antagonistic microbes and plant extracts to manage diseases in snap beans. Nairobi Innovation Week Conference Proceedings, 1-5th August 2016, University of Nairobi.
- Goufo, P., Fontem, A. and Ngnokam, D. 2010. Evaluation of plant extracts for tomato late blight in Cameroon. *New Zealand Journal of Crop and Horticultural Science* 38 (3): 171-176.
- Gupta, S. and Dikshit, A. K. 2010. Biopesticides: An ecofriendly approach for pest control. *Journal of Biopesticides* 3 (1):186 – 188.
- Gurjar, M. S., Ali, S., Masood Akhtar, M. and Singh, K. S. 2012. Efficacy of plant extracts in plant disease management. *Agricultural Sciences* 3: 425-433.
- Kumar, A., Prakash, A. and Johri, B. N. 2011. Bacillus as PGPR in Crop Ecosystem: In: Maheshwari, D. K (Ed.). *Bacteria in Agrobiolgy: Crop Ecosystems*. Springer-Verlag Berlin Heidelberg 2011.

- Mishra, J., Tewari, S., Singh, S. and Arora, K. N. 2015. Biopesticides; where we stand. *Springer* 37-75.
- Mizubuti, G.S. E., Junior, V. L. and Forbes, G. A. 2007. Management of late blight with alternative products. *Pest Technology* 1 (2):106-116.
- Morsy, E. M., Abdel-Kawi, K. A. and Khalil, M.N.A. 2009. Efficiency of *Trichoderma viride* and *Bacillus subtilis* as biocontrol agents against *Fusarium solani* on tomato plants. *Egyptian Journal of Phytopathology* 37 (1): 47-57.
- Nderitu, J., Mwangi, F., Nyamasyo, G. and Kasina, M. 2009. Evaluation of cropping systems as a strategy for managing snap bean flower thrips in Kenya. *International Journal of Sustainable Crop Production* 4 (6): 22-25.
- Pest Control Products Board (PCPB), 2010. Pest control products registered for use in Kenya, 6th edition, Kenya. Available at www.pcpb.or.ke accessed 29th August 2016.
- Scheuerell, S. and Mahaffee, W. 2002. Compost tea: principles and prospects for plant disease control. *Compost Science and Utilization* 10 (4): 313-338.
- Srijita, D, 2015. Biopesticides: an eco-friendly approach for pest control. *World Journal of Pharmacy and Pharmaceutical Sciences* 4 (6): 250-265.
- Srinivasan, R. 2012. Integrating biopesticides in pest management strategies for tropical vegetable production. *Journal of Biopesticides* 5:36-45.
- Valicente, F. H., Tuelher, E. D., Leite, M. I. S., Freire, F. L. and Vieira, C. M. 2010. Production of *Bacillus Thuringiensis* biopesticide using commercial lab medium and agricultural by-products as nutrient sources. *Revista Brasileira De Milho E Sorgo* 9 (1): 1-11.