

INTERNATIONAL JOURNAL OF AGRICULTURE, MANAGEMENT AND TECHNOLOGY



Vol 8(1) 2024

Published by
Federal College of Agriculture,
Ishiagu Ebonyi State

BIO-PESTICIDAL POTENTIALS OF (*Petiveria allicea* L.) EXTRACTS ON LEAF-MINERS INFESTED TOMATO PADMA 108 F1

¹Aja, J. F., ²Obijekwu Olivia and ¹OKeta, Azubuike H.

¹Department of Horticulture and landscape Technology, School of Agriculture, Federal College of Agriculture, Moor Plantation, Apata, Ibadan, Oyo State, Nigeria.

²3Department of Physical and Health Education, Federal College of Education (Technical), Umunze, School of Science, Anambra State.

Corresponding author: joshua4real79@gmail.com. +2348030611360

ABSTRACT

The pot experiment was conducted at the Horticultural research garden, Federal College of Agriculture Ibadan during dry season of 2023 - 2024. The experiment aim is to ascertain bio-pesticide potentials of *Petiveria allicea* extracts on leaf-miners infested tomato PADMA 108 F1.

The experiment used 5.67g, 12.56 g of roots powder, 100% fresh leaf extracts at 2 ml, spinosad 25% SC at 0.05ml and control in Completely Randomized Design with three replications. Five plants were selected randomly from each replication and data recorded include: incidence of infestation on plant height (cm), branches, number of harvested fruit, fruit length (cm), fruit width (cm) and weight of fruit (t/ha). The bio-pesticide potential of each treatment was compared using Duncan Multiple Range Test (DMRT) and the overall result showed that application of *P. allicea* showed significant bio-control for vegetative and yield components of tomato compared to spinosad and control. The highest bio-control of tomato leaf miners infestation incidence was recorded for *P. allicea* extracts (64.11%) followed by synthetic (47.91%) and control (11.78%). Bio-pesticide potentials were obtained on the number of harvested fruit, fruit length, fruit diameter and weight (32.55, 6.87cm, 3.87cm, 674.24 g/plant, 16.18 t/ha), (30.22, 6.57cm, 3.93cm, 623.23g, 14.96 t/ha) and (28.10, 7.35cm, 3.38cm, 599.12g, 14.38 t/ha) for application of 100% fresh leaf extract, 5.67g and 12.56g respectively, compared to spinosad and control (18.92, 4.87 cm, 2.50 cm, 346.32 g/plant, 12.90 t/ha and 18.92, 4.87 cm, 2.50cm, 346.32g 8.31 t/ha). Use of *P. alliaceae* mostly at 100% fresh leaf is recommended for tomato leaf-miners control because of low infestation, economical and safety.

Key words: Bio-pesticide, infested-tomato PADMA 108 F1, leaf-miners, plant-extracts, potentials.

INTRODUCTION

Tomatoes both hybrid and local varieties are staple food and cash crop for many low-income farmers whose livelihoods depend on its production particularly in the developing countries of the tropics (Isman, 2006, Solar *et al.*, 2014). However, tomato production is affected by insect pests and pathogens which adversely affect its quality, quantity and profitability (Engindeniz *et al.*, 2013; Islam *et al.*, 2013).

Generally, tomato farmers face number of challenges including pest and diseases infestation, unimproved cultivars, poor plant stand, lack of use of fertilizers and other unimproved agricultural inputs in the management of the crop, biotic and abiotic factors (Tumwine *et al.*, 2002; Waiganjo *et al.*, 2006). Farmers have relied on synthetic pesticides to control pests and diseases in tomato farms for years (Mizubuti *et al.*, 2007). Some of these pests include leaf miners (*Tuta absoluta* Meyrick) an invasive pest of tomato which cause production decline both open and protected

environment and late blight (*Phytophthora infestans* Mont.de Bary) which are managed by a combination of protective and curative synthetic fungicides yet the losses in the field are devastating (Goufo *et al.*, 2010, Chidege *et al.*, 2016). Consumers and policy makers are demanding reduced synthetic inputs in food production, and practices that support agro-ecological intensification and pesticidal plant products may be well suited to this vision (Sola *et al.*, 2014; Pavela, 2016, Iman, 2017).

Guinea hen weed or Anamu plant (*Petiveria alliceae*) is a decorative herbaceous perennial herb with medicinal properties as included in the global compendium of weed (Randall, 2012). It is known as agricultural weeds in coffee, maize and apple plantation in Mexico and listed as weeds in pasturelands and secondary forests (Randall, 2012; Mas and Lugo, 2013, Isman, 2013). The leaf, roots and powder of *P. allicea* have been tested in control of number of insects. For instance, Michael *et al.*, (2021) evaluated the efficacy of *Petiveria* leaf and

roots in the control of filariasis vector of culex mosquitos, yellow fever, and dengue fever and concluded that fumigants of the plant administered at different doses induced significantly the mortality rate of 18.3% - 60.0% for leaf powder and 23.3 – 71.6% of root bark powder within 2 hours of application. Similarly, Michael *et al.*, (2021) also noted that the *P. allicea* has the synergistic effect of leaf and root bark powder and would kill 50% of adult culex mosquitoes at 3.76g, 2.86g and 2.63g, while at 15.25 g and 12.94 g of the leaf, root bark powder would kill 90% (LD90) after 2 hours of exposure. The weed (*P. alliceae*) has been used in other insects like culex mosquitoes and pest like rats as an alternative to challenges of high cost and development of several synthetic insecticides, and to establish pest control potential of botanicals (Mkenda, 2015, Luz *et al.*, 2016, Isman, 2017, Mkindi, 2017). However, wide uses on the control of pest of the most important vegetables (tomatoes, pepper, okra, garden egg etc.) and food crops in the tropics are few or had not been reported. Hence, the present study is to ascertain bio-pesticide potentials of *P. alliceae* extracts on the control of tomato infested by leaf-miners. Specific objectives include:

- i. Ascertain the bio-pesticide potentials of *P. alliceae* extracts on control of leaf-miners infested tomato PADMA 108 F1
- ii. Determine the concentration and effectiveness of *P. alliceae* extracts for optimum yield of tomato PADMA 108 F1

MATERIALS AND METHODS

Study area: The study was carried out at horticultural garden of Federal College of Agriculture, Moor plantation, Ibadan during the dry season of 2023 - 2024.
Analysis soil of the location: Topsoil used was analyzed in the soil laboratory unit of the College.

The physical and chemical characteristics of the soil analysis showed that the soil had pH of 5.80, moderate organic matter (5.11 g/kg) and moderate total nitrogen (0.53mg/kg), high rate of organic carbon (3.53%) and high available phosphorus (30.24 g/kg). The particle size distribution or the physical constituent of the soil

indicated that the soil is sandy loam having 650g of sand, 230g silt and 120g of clay.

Materials used:(i) A uniform composted poultry droppings (equivalent of 15kg/ha) was collected from the College farm and mixed with top soil in the ratio 3:1.(ii) Collected fresh leaf, roots and root bark were air dried and grinded with commercial grinding machine. iii. Used cement bags. Iv. Hybrid tomato PADMA 108 F1

Treatments: *P. alliceae* leaf and root extracts and concentration: T₁ – Control, T₂ – 5.67 g of powder from roots and leaf extracts, T₃ – 12.56g of powder roots extracts only, T₄ – 100% fresh leaf extract (1 litre of undiluted extract and applied at equivalent of 2 ml per plant), T₅ – Synthetic pesticide Spinosad 25% SC (0.50 litre/g ha).

Preparation: The experiment was done with the use of polythene sacks and washed and sterilized cement bags of 60m long, 40cm in diameter and 60 cm deep, no perforation was made as the sacks have adequate drainage pores to drain easily as well as ensure aeration. Transplanting was done at the rate of two seedlings per polybags and transplanting done three weeks after sowing. Seedlings were isolated and infected in the nursery. These seedlings of infected leaf-miners were transplanted alongside with uninfected seedlings. The extracted liquid some were first diluted minimally with or without water at stated rates and temporally stored under a room temperature according Micheal *et al.*, (2021). The powdered applied on-spot immediately after irrigating the tomato crop i.e. dusting on the spot. Data generally was collected on: (i) Infected and treated.(ii) Partial-infected and treated. (iv) Infected and not treated. (iv) Non-infected leaf assessment on plant height (cm), stem girth (cm), number of leaf per plant, incidence of pest infestation on the leaves using a scale of 0-2, where 0 = no disease in the whole plot, 1 = disease present in spots within a plot, and 2 = disease distributed over the whole plot. Disease incidence was assessed as the number of plants showing infection out of the total number of plants per plot and converted to percent, where 0 = no disease and 100% = all plants showing infection as described by (Henfling, 1995)

$$\text{Incidence of pest infestation on leaf yield (\%/plot)} = \frac{\text{Total number of leaves affected / plot} \times 100}{\text{Total number of leaves produced by plant / plot}}$$

Number of branches, number of fruit harvested, fruit length, fruit diameter, fruit weight per pot and fruit weight per hectare. Data collected was subjected to analysis of variance (ANOVA) using SAS version 10.2 (2016) statistical computer packages and significant differences compared using the Duncan Multiple Range Test (DMRT) at 5% level of significance.

Result

The effect of *P. allicea* extracts on the plant height of leaf-miners infested tomato PADMA 108 F1 is presented in (Table 1). There was no significant difference on the plant height at second weeks after transplanting. However, tomato PADMA 108 F1 responded differently on the plant height on various treatments ranging from the 4th weeks to 8th weeks after transplanting. Statistical similar plant heights starting from the 4th to 8th weeks after transplanting were

recorded for all the treatments except control (Table 1). The highest plant height was recorded for tomato by application of 100% fresh leaf extracts (28.30 cm, 50.60 cm and 125.70 cm). This was followed by 12.56 g of powder roots extracts only (27.00 cm, 49.20 cm and 122.35 cm), and 5.67 g of powder from roots and leaf extracts (27.50, 51.20 and 121.70 cm) which were statistically similar with plants treated with synthetic pesticide spinosad (27.90, 49.20 and 120.0 cm) respectively. Untreated tomato plants recorded the least plant heights (19.60 cm, 39.13 cm, and 79.60 cm) and significantly lower than other treatments from the 4th weeks to 8th weeks after transplanting.

Statistical similarities were obtained on stem girths were recorded for all the treatments. However, tomato PADMA 108 F1 responded differently on the total number of leaves, number of leaf affected, number of non-affected leaf, incidence of infestation rate on the

leaf on various treatments. Plants treated with pesticides spinosad produced the highest total number of leaf (112.70) but statistically similar to 12.56 g of powder root extracts only (111.70), 5.67 g of powder from roots and leaf extracts (110.30), and 100% fresh leaf extract (109.70) (Table 2). The number of infested leaves were significantly higher in control plants (65.70) compared to other treatments. The highest bio-pesticide potentials on the number of leaves affected and non-affected leaves (39.33 and 70.33a) were recorded for tomato treated with 100% fresh leaf extract while over 80% of the untreated plants were affected. Tomato PADMA 108 F1 plants treated with 100% fresh leaf extract of *P. allicea* controlled the rate of infestation of leaf-miners on the leaves up to 64.11 %, while treating the plants with synthetic pesticides spinosad can control the leaves up to 47.91% and non-application can reduce the leaves up to 11.78% (Table 2).

Table 1. Effect of *Petiveria allicea* extracts on plant height (cm) of leaf-miners infested tomato PADMA 108 F1

Treatment	2 WAT	4 WAT	6 WAT	8 WAT
T ₁	14.60a	19.60b	39.13b	79.60b
T ₂	16.90a	27.50a	51.20a	121.70a
T ₃	16.20a	27.00a	49.20a	122.35a
T ₄	17.20a	28.30a	50.60a	125.70a
T ₅	16.90a	27.90a	49.20a	120.00a

Values of the same letter on a column are statistically similar at 5% level of probability according to DMRT.

- i. T₁ – Control
- ii. T₂ – 5.67 g of powder from roots and leaf extracts
- iii. T₃ – 12.56g of powder roots extracts only
- iv. T₄ – 100% fresh leaf extract (1 litre of undiluted extract, applied 0.2 ml per plant).
- v. T₅ – Synthetic pesticide Spinosad (Tracer 14% SC - 15 ml/g plot)

WAT – weeks after transplanting

Table 2. Effect of *Petiveria allicea* extracts on the vegetative yield and Incidence of infestation rate on the leaf of tomato PADMA 108 F1

Treatment	Stem girth	Total No of L/plot	No of Leaf affected	Non-affected NL	IIRL %
T ₁	0.37a	70.70b	65.70a	8.33b	11.78c
T ₂	0.73a	110.30a	46.75bc	63.67a	57.72ab
T ₃	0.67a	111.70a	48.72bc	63.00a	56.40ab
T ₄	0.70a	109.70a	39.35c	70.33a	64.11a
T ₅	0.70a	112.70a	58.74ab	54.00a	47.91b

Values of the same letter on a column are statistically similar at 5% level of probability according to DMRT

No: number, NL – number of leaves, IIRL – Incidence of infestation rate on the leaf

The successful infection rate and white lesions, winding trails and whitish blotches on the leaves and branches of tomato PADMA 108 F1 were shown in (Fig. 3 and 4). Infestation rate on the plot on the number of branches decreased significantly from application of synthetic pesticides (4.33). This was followed by application of 5.67 g of powder root and leaf extracts (3.0) and 12.56g of powder roots extracts (3.0). Application of 100% fresh leaf extract and control revealed a statistical similarities (2.33), and this implies that there is increased in infestation rate when there is

no application of pesticides and botanicals and that some parts of the plants are more potential in control of leaf miners than others.

Treatment of plants with *P. allicea* at different concentration positively reduced the number of day to 50% flowering. Synthetic pesticides application is also beneficiary for reduction in the number of days to 50% flowering. However, control plants had a prolong days to flowering.

Bio-pesticide potentials was recorded for all the treatments on the number of flowers. However

statistical similar number of flowers were recorded for plants treated with 100% fresh leaf extract recorded (12.63), synthetic pesticides (9.30) and 12.5g of powder extracts only (8.07), while the lowest number of flowers were recorded for untreated plants (2.63).

Application of 100% fresh leaf extract of *P. alliacea* for the control of leaf miners on the infested tomato on yields components were statistically comparable (30.22, 6.57cm, 3.93cm and 674.24 g/plant) to plants treated with 12.56g of powder roots extracts only (30.22, 6.57cm, 3.93cm, 623.23 g/plant) and 5.67 g of powder from roots and leaf extracts (28.10, 7.37cm, 3.38 cm and 599.12 g/plant). Application of 5.67 g of

powder from roots on the tomato increased significantly the number of fruits harvested compared to other treatments as presented in (Table 4). However, tomato fruits diameters (5.40 cm) increased significantly with application of synthetic pesticide. This was followed with tomato plants (3.93cm) with 12.56g of powder roots extract biocontrol. Application of 100% fresh leaf extract, 12.56g of powder roots extract and 5.67 g of powder from roots only significantly enhance the size and yield of fruits compared to use of one the most effective pesticides on tomato leafminers spinosad. Non-application result to heavy defoliation reduced flower, reduce yield and smaller fruit sizes.

Table 3. Effect of *P. alliacea* extracts on other vegetative component on leaf-miners infested tomato PADMA 108 F1

Treatment	NB affected	NB non-affected	Days to 50% flowering	No of flower/plant
T ₁	1.33a	2.33b	41.30a	2.63b
T ₂	1.33a	3.00ab	29.74c	7.63ab
T ₃	1.00a	3.00ab	35.76b	8.07a
T ₄	1.33a	2.33b	33.5bc	12.63a
T ₅	1.00a	4.33a	34.4bc	9.30a

Values of the same letter on a column are statistically similar at 5% level of probability according to DMRT

- i. T₁ – Control
- ii. T₂ – 5.67 g of powder from roots and leaf extracts
- iii. T₃ – 12.56g of powder roots extracts only
- iv. T₄ – 100% fresh leaf extract (1 litre of undiluted extract, applied 0.2 ml per plant).
- v. T₅ – Synthetic pesticide Spinosad (Tracer 14% SC - 15 ml/g plot)

WAT – weeks after transplanting, NB – number of branches

Table 4. Effect of *Petiveria alliacea* extracts on the yield component of leaf-miners infested tomato PADMA 108 F1

Treatment	Number of fruit	Fruit Length (cm)	Fruit diameter (cm)	Fruit weight g/plant	Fruit weight/ha	Fruit weight ton/ha
T ₁	18.92b	4.87b	2.50c	346.32b	8311.17b	8.31b
T ₂	28.10ab	7.37a	3.38bc	599.12a	14378.88a	14.38a
T ₃	30.22a	6.57ab	3.93b	623.23a	14957.52a	14.96a
T ₄	32.55a	6.87ab	3.87bc	674.24a	16181.76a	16.18a
T ₅	27.21ab	6.80ab	5.40a	537.19ab	12896.88ab	12.90ab

Values of the same letter on a column are statistically similar at 5% level of probability according to DMRT.

Discussion

Preliminary trials demonstrated that tomato leaves, stems, flowers and fruits were more susceptible to infestation by *Tuta absolutath* stem girth and branches, such that there is clear distinction between application of petirivera extracts to spinosad and non-application. Untreated plants had significantly reduced morphological traits and yield components compare to other treatments. The number of infested leaves were significantly higher in control plants (65.70) than other treatments resulting to reduced number of fruit yields, size, length and weight of tomato fruits and also indicating the devastating effect of leaf miners on tomato leaf defoliation. The high infestation rate and significant yield decline in an untreated tomato confirms

the results obtained by Engindeniz *et al.*, (2013) and Islam *et al.*, (2013), tomato production is affected by insect pests and pathogens which adversely affect its quality, quantity and profitability. In other words, the significantly increased in the yield of tomatoes by application of 100% fresh leaf extract, 12.56g of powder root extracts only and 5.67 g of powder from roots and leaf extracts revealed the bio-pesticide potentials of *Peterveria aliaceae* plants control of leaf miners. This also implies that application could lead to the mortality of leaf miners eggs thereby reducing the infestation rate which could result to yield boost on the tomato plants applied. This observation corroborated with the findings of Michael *et al.*, (2021) who noted plant petiveria extracts administered at different doses

induced significantly the mortality rate of filariasis vector of culex mosquitos, yellow fever, and dengue fever 18.3% - 60.0% using leaf powder and 23.3 – 71.6% using leaf extracts.

Leaf defoliation by tomato leaf miners can cause reduced plant heights or stunted growth, blotches on the leaves, prolong days of flowering, reduced number of flowers and generally decline in the yield resulting to low quantity, quality and profitability. This observation is in agreement with findings of by Engindeniz *et al.*, (2013) and Islam *et al.*, (2013) who noted that tomato production is affected by insect pests and pathogens which adversely affect its quality, quantity and profitability.

Incidence of infestation rate on the leaves reduced the leaf number to as low to as 11.78% with windy trails and blotches symptoms on the leaf while plants with 100% fresh leaf extracts of *P. allicea* produced the highest number of leaves least affected (39.35) and highest number of non-affected number of leaves (70.33) with control incidence of infestation rate (64.11%) when compared to other treatments. This implies that application of 100% leaf extracts and other parts of the plant could resist or cause mortality rate of tomato leaf miners on tomato plants up to 64.11% compared to synthetic pesticides spinosad (47.91%). This observation corroborated with the assertion of Mkindi *et al.*, (2017) who reported that the application of 10% w/v as this was determined to be the most

effective concentration for reducing insect damage and maintaining high crop yield. This result also is in line with the findings of Michael *et al.*, (2021) who revealed that *Peteriveri aliaceae* leaf powder, roots and bark causes mortality rate of filariasis vector of culex mosquitos, yellow fever, and dengue fever 23.3 – 71.6%

Application of 100% fresh leaf extract, 12.56g of powder root extracts only and 5.67 g of powder from roots and leaf extracts revealed high bio-pesticide potentials of *Peterveria aliaceae* in controlling of leaf miners of tomato. This is true as the yields were statistically comparable (30.22, 6.57cm, 3.93cm and 674.24 g/plant, 16.81 t/ha), (30.22, 6.57cm, 3.93cm and 623.23 g/plant, 14.96 t/ha), and (28.10, 7.37cm, 3.38 cm and 599.12 g/plant, 14.38 t/ha) for number of fruit harvested, fruit length, fruit diameter and weight of fruits. Application of botanical extracts increased significantly the yield of tomato in this experiment while non-application result to high yield lost. This result agreed with of Lopez (1991) who reported that the larvae of tomato leaf miner (*Tuta absoluta*) attack on the leaves, stem and fruits of the tomato, and the devastating effect result to an injury to the crop which can lead to reduction in yield of tomato to about 80 – 100%.

Plates: Pictures of *Petiveria alliacea*, extraction process and leaf-miners symptomatic expression on infected plant parts



Fig1.. Fresh leaf of *Petiveria alliceae* plants Fig. Manual extraction of *petiveria alliaceae* leaf

Infected tomato PADAM 108 FI on polybags Symptomatic fruit cracking



Fig 3: symptomatic expression of leaf-miner on leaves



Fig. 4. Fruit cracking

Conclusion

From the results, it can be concluded that both vegetative and yield component of tomato PADMA 108 F1 were significantly improved by application *P. alliacea* extracts in controlling of leaf-miners infestation. Analysis of variance on the incidence rate of infestation on the plant leaves indicated significant reduction on the number of leaves of the affected plant up to 11.78%. Research works can now be based on the concentration, rates, parts of the plant most effective, like in this study, 100% fresh leaf extract is more effective than 12.57 g of roots powder and 5.56g of roots and leaf extracts in mixture. Meanwhile, treating tomato PADMA 108 F1 with *P. alliacea* extracts produced significant bio-control effect on leaf miners for vegetative and yield component compare to plants treated with synthetic pesticides spinosad and control. Tomato PADMA 108 F1 is improved positively with application of *P. alliacea* extracts in a well-managed soil compare to costly synthetic spinosad and non-application or control which incurred more yield loss. Consequently, effective control of leaf miners infestation require careful utilization of *P. alliacea* extracts for optimum yield of tomatoes. It is can be recommended for tomato farmers to adopt the usage as it is cheaper and safer than synthetic pesticides.

References

Chidege, M., Al-Zaid, S., Hassan, N., Juile, A., Kaaya, E. and Mirogoro, S. (2016). First record of tomato leaf miner (*Tuta absoluta* Meyrick) (Lepidoptera Gelechiidae) in Tanzania. *Journal of Agriculture and food security*, Pp 1 – 7.

Engindeniz, S. and Ozturk, G. C. (2013). An economic comparison of pesticide application for processing and table tomatoes, a case study for Turkey. *Journal of Plant Protection Research* 53(3): 230-237

Goufo, P., Fontem, D. A. and Ngnokam, D. (2010). Evaluation of plant extracts for tomato late blight control in Cameroon. *New Zealand Journal of Crop and Horticultural Science*, 38, 171–176.

Isman, M. B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. *Annual Review of Entomology* 51, 45–66.

Isman, M. B. and Grieneisen, M. L. (2013). Botanical insecticide research: many publications, limited useful data. *Trends Plant Sci.* 19, 140–145.

Isman M. B. (2017). Bridging the gap: moving botanical insecticides from the laboratory to the farm. *Industrial Crops Production*, 110, 10–14.

Lopez, E. (1991). Polilla del tomate: Problema cri'tico para la rentabilidad del cultivo de verano *Empressay Avance Agri'cola* 1: 6 – 7

Luz, Carlos, Luis, P., Rodrigues, Gabriela, Almeida, Rita, Cordovilf (2016). Development and validation of a model of motor competence in children and adolescents. *Journal of Science and Medicine in Sport* (19): 568 -572

Mas, E.G. and Lugo, M. L. T. (2013). Common weeds in Puerto Rico and U.S. Virgin Island, Puerto Rico. University of Puerto Rico Mayaguez Campus. Pp. 395

Michael, O. A. and Oluwatosin, B. I. (2021). Efficacy of petiveria allicea (Linnaeus) leaf and root bark powder in the control of filarisisis vector culex Quinquefasciatus. *The journal of Basic and Applied Zoology*, 7(5): 82 -86

- 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.
- Mkenda, P., Mwanauta, R., Stevenson, P. C., Ndakidemi, P., Mtei K. and Belmain S. R. (2015). Extracts from field margin weeds provide economically viable and environmentally benign pest control compared to synthetic pesticides. *PLoS ONE* 10:e0143530.
- Mkindi, A., Mpumi, N., Tembo Y., Stevenson, P. C., Ndakidemi, P. A. and Mtei K.. (2017). Invasive weeds with pesticidal properties as potential new crops. *Ind. Crops Prod.* 110, 113–122.
- Pavela, R. (2016). History, presence and perspective of using plant extracts as commercial botanical insecticides and farm products for protection against insects-a review. *Plant Prot. Sci.* 52, 229–241.
- Randall, R. P. (2012). A global compendium of weeds. Perth Australia, Department of Agriculture and food Western Australia, Pp. 1124
- Sola, P., Mvumi, B. M., Ogendo, J. O., Mponda, O., Kamanula, J. F. and Nyirenda, S. P. (2014). Botanical pesticide production, trade and regulatory mechanisms in sub-Saharan Africa: making a case for plant-based pesticidal products. *Food Secur.* 6, 369–384.
- Tumwine, J., Frinking, H. D. and Jeger, M. J. (2002). Integrating cultural control method for tomato late blight (*PytophthoraInfestian*) in Uganda, *Ann App.1 Biol.*, 225-236.
- USDA (2016). Organic 101: Allowed and Prohibited Substances. [Blogs.usda.gov](https://blogs.usda.gov). Retrieved 6 April 2016.
- Waiganjo, M. M., Wabule, N. M., Nyongesa, D., Kibak, J. M., Onyango, I., Webukhulu, S. B. and Muthoka, N. M. (2006). Tomato production in Kiriyanga District, Kenya. *A baseline survey report. KARIM/IPM-CRSP Collaborative project*