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Research Article

Efficacy of Naturally Occurring Sulphur and Kaolin Insect Pesticides in Management of Tomato Pests: An Alternative to Chemical Synthetics in Uganda

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ABSTRACT

Tomatoes (*Solanum lycopersicum*) are a very important horticultural crop in Uganda but their production is constrained by the economic damage caused by several insect pests. To counter the pests, farmers dominantly use chemical pesticides; yet this method is associated with residual problems. This study adopted an experimental design and assessed the efficacy of naturally occurring sulfur and kaolin in the management of tomato insect pests. Substituting synthetic chemical pesticides and preventing their residual effects informed the initiation of the study. A complete randomized block design both inside and outside the green house of tomato variety MT56 formed the experiment lay out. Data on insect pests (Aphids, Thrips, whiteflies, leaf miners and tomato bollworm) incidence and tomato field performance was collected from treated and untreated tomatoes.

Results indicated that sulfur had a significant effect on reduction of pest incidence insect while kaolin treatment had the highest reduction effect on the incidence of all insect pests except whiteflies *Bemisia tabaci*. Sulfur- and kaolin-treated tomato fruits performed significantly better in leaf canopy area, plant height and blossom yield than the untreated ones. We recommend the adoption of kaolin in order to effectively control tomato insect pests and promote field their field performance.

Keywords: Photo-assimilate; Translocated; Antithrombotic; Anti-atherogenic

INTRODUCTION

Tomato (*Solanum lycopersicum* L) is the World's most cultivated horticultural crop with a global production of 180.6 M mt, valued at USD 88 billion [1]. It is also the fourth most economically valuable food crop produced in low-and middle-income countries such as Uganda because they offer employment, income, and contributes to food security for large numbers of rural and peri-urban areas. Tomatoes are the most widely produced and consumed vegetables within the world, both for fresh fruit market and processed food industry [2].

Belonging to the Solanaceae family [3] tomatoes are known as; tomate (Spain, France), tomat (Indonesia), faan kele (China), tomati (West Africa), Jitomate (Mexico), pomodoro (Italy), nyanya (Swahili) [4]. They are the main sources of minerals and vitamins[5]; containing various phytochemicals such as β-carotene, lycopene, flavonoids, vitamins A and C, and several other essential nutrients[3,6]. Lycopene, the main carotenoid in tomatoes responsible for their red color plays several pharmacological roles. It is an anticancer agent important in prevention of colon, lung, liver, prostate and breast cancers. Also anti-inflammatory, anti-diabetic, anti-allergic, anti-atherogenic, antithrombotic, antimicrobial, antioxidant, vasodilator, and cardio-protective effects [7].

In Uganda, tomatoes remain the highest locally demanded among all the vegetables produced. Their production is even expanding to peri-urban area. According to, Uganda produced 40,124 tons of tomato from 6,671 hectares with an average of 3,625 kg/ha. The commonly grown tomato varieties include; Marglobe, Pakmor, Tropic, VF 6203, Peto-C-8100159, Heinz 1370, Moneymaker, Roma and Tengeru-97 [8].

However, despite their importance, tomato production is seriously constrained by insect pests. The most important and damaging insect pests include Aphids (*Myzus persicae*), fruit worms (*Helicoverpa armigera*),

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mites (*Tetranychus evansi*), white flies (*Bemisia tabaci*) and Thrips (*Frankliiella occidentalis*) [9]. These pests reduce the photosynthetic rate, vector several viruses and mycoplasmas, and cause fruit damage in form of tissue destruction, scarring and aberrations in shape or color [10]. Some (whiteflies, Aphids and Thrips) suck phloem sap causing a reduction in the net photo-assimilate available for partitioning.

In controlling the pests, farmers often use chemical methods and increase the frequency of pesticides application; thereby affecting non-targeted insects too. In addition, chemical use causes resistance development in pathogens, environmental deterioration and several health hazards to humans and other living organisms. Reducing pesticides' impact requires eco-friendly alternatives such as the use of naturally occurring compounds like Sulfur. However, the use and efficacy of kaolin and sulfur is not deeply investigated in Uganda especially for new tomato varieties such as the MT56.

In bridging the gap, the current study investigated the efficacy of; and generated knowledge on naturally occurring sulfur and kaolin in managing tomato insect pests and their effect on field performance of tomato crops. It sought to determine the effect of kaolin and sulfur on incidence, severity of insect pests and on field performance and yield of tomatoes.

Biology of the common tomato insect pests

White flies (*B. tabaci*) are among the most important tomato pests [11]. They belong to order *Hemiptera*, Family Aleyrodidae and genus Bemisia. Whiteflies have a characteristic lifecycle of six stages: The egg, four immature stages and the adult stage. Adults lay eggs on the underside of the leaves and after hatching into nymphs, the nymphs move to a suitable feeding location on the lower leaf surfaces and feed on the phloem sap. This results in death of tomato seedlings, irregular ripening of fruits and physiological disorders and alteration of the plant defense signaling [12].

Whiteflies also transmit Tomato Yellow Leaf Curl Virus (TYLCV) and cause severe stuntedness, leaf yellowing and curling. They secret honey dew which serves as a substrate for growth of sooty mold fungi on the leaves [13] causing photosynthetic inefficiency. The tomato fruit worm; *H. armigera* which belongs to order: Lepidoptera, Family: Noctuidae and Genus: Helicoverpa is another important tomato insect pest. It is polyphagous but has a special liking for tomatoes compared to the other crops it attacks [14]. *H. armigera* results in economic losses due to fruit boring.

Females deposit 1,000-1,500 eggs singly on the upper side of leaves, on flowers, flower buds, stems and shoots usually at night and the eggs go through a number of developmental stages that affect crops. The larvae feed on leaves, stems, buds, inflorescences and fruits causing damage in both the vegetative and reproductive stages of plant growth. Their damage also results into secondary pests.

Thrips, the small, polyphagous insects of Order: Thysanoptera, Family: Thripidae and Genus: Thrips are also important tomato insect pests. They damage by making an incision in plant tissue by using an ovipositor and deposit eggs under the epidermis of succulent leaf, flower, or stem. Thrips pierce cells and suck the contents; making the cells lose their normal color. Thrips deposit small dark specks of excrement on the surface of tissue where they feed. They mostly damage plants indirectly by vectoring viruses such as The Spotted Wilt Virus (TSWV) which substantially affect the marketable value and yield of tomatoes [15]. Aphids (Order: *Hemiptera*, Family: Aphididae, Genus: Aphids) also damage tomatoes through feeding on phloem tissue. They harbor several plant viruses [16] and themselves continuously take in a large amount of plant resources [17].

Aphids suck, chew and bore plant parts [18] resulting into chlorosis, necrosis, fruit abortion and stunted growth [19] additionally, they excrete honeydew a sugar-rich substrate on the leaf surfaces which favors growth of the sooty mold fungus. This results in blackening of the leaves and branches and hence hindering photosynthesis.

Common pesticides used in control of tomato insect pests

Mancozeb, a mixture of manganese and zinc salts [20] is a grey powder with a slight sulphur odor. It is commonly used in tomato insect pest control, especially fungi. Mancozeb is associated with no incidences of pest resistance and is registered for use in a wide range of crops globally [21]. It acts by inhibiting or interfering with critical biochemical processes such as respiration, production of ATP and lipid metabolism within the fungal cell cytoplasm and mitochondria [22]. Azoxystrobin is also used for control of fungal plant pathogens of solanaceous crops [23]. It has characteristics of broad-spectrum effects, high efficiency, and low toxicity [24].

Azoxystrobin inhibits mitochondrial respiration. It is adsorbed quickly by the roots and translocated through the xylem to the stems and leaves where it inhibits spore germination, mycelial growth and spore production by the fungi. Kaolin, a naturally occurring white clay is another important tomato insect pesticide. It is non-porous, non-swelling, low-abrasive, fine-grained, plate-shaped, clay Aluminosilicate Mineral ($Al_2Si_2O_5(OH)_4$) [25]. It is chemically inert over a wide pH range and has no human toxicity or damage to the environment [26].

When sprayed, kaolin liquid suspension evaporates and leaves a protective white powdery film of interlocking, microscopic particles on the surfaces of the leaves, stems and fruit [27] controlling a wide range of arthropod pests on agricultural crops through six mechanisms. These include; repellence, ovipositional deterrence, reduced feeding efficacy, impeded grasping of host, host camouflaging and direct mortality [26]. Application of kaolin effectively controls whiteflies by 91% and significantly increases water use efficiency of tomatoes without affecting the organoleptic properties of the fruit. Sulfur, the oldest pesticide used in tomatoes insect pests has a high efficiency against a wide range of fungal diseases such as powdery mildew and black pot and rust [28]. It protects plants against pathogens because of its ability to permeate fungal hyphae and production of toxic H_2S which halts the germination and growth of conidial spores [29].

METHODOLOGY

The study was conducted at Makerere University Agricultural Research Institute Kabanyolo (MUARIK), located 14 km north east of Kampala because the average annual rainfall of 1300 mm and daily maximum temperatures of 27°C favors pest survival in most cultivated crops grown there; including tomatoes. An experimental research design was adopted in which tomato seeds of Makerere Tomato Accession 56 (MT56) were used. The variety is high yielding (4,958 kg/ha), grows faster than existing varieties and has been recommended for inclusion in integrated pest management programs in tomato production in Uganda.

Tomato seeds were sown in trays filled with sandy loam soil mixed with peat moss in a green house. The seedlings were transplanted a month later into plastic pots of 50 cm diameter and a height of 28 cm. Each pot was filled with 5 kgs of air-dried soil that had been treated by direct heating for two days and allowed to cool for three days. A greenhouse of 10 m by 5 m was used to place pots in three rows, each replicate consisting of five tomato plants. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. This design is appropriate since it controls variation in an experiment by accounting for spatial effects.

There were five treatments. These which included; first, Azoxystrobin SC (20 MmL/20 L of water), second; Sulfur WP (30 gm in 20 L of water), third; Kaolin WP (500 g in 20 L of water), fourth; Mancozeb WP (50 g in 20 L of water) and the untreated control. A treatment of chlorpyrifos+cypermethrin premix at the rate of 7 ml per 20 L of water was added for comparison purposes with respect to insect pest incidence. The pesticides were applied at ten days interval, two weeks after transplanting.

Data was collected on plant parameters including plant height, leaf area, date of flowering, number of branches, and fruit yield. Yield was evaluated as number of fruits, total fruit weight, average fruit weight and proportion of the marketable fruits. The incidence of Thrips, spider mites, leaf miner, aphids, whiteflies, and tomato bollworm was investigated. For tomato bollworm, leaf miner and spider mites, a scale of 1-5 was used to score infestation depending on visual observation of damage on plant leaves and fruits where; 1-no symptoms, 2-mild, 3-moderate, 4-severe, and 5-very severe symptoms. Data was subjected to Analysis of Variance (ANOVA) by using the GENSTAT software while the means were separated using Least Significance Differences (LSD) at 5% significance level.

EMPIRICAL FINDINGS

Effects of kaolin and sulphur treatments on insect infestation: Results indicated a significant effect of the different treatments ($p<0.001$) on the count of the different insect pests on tomato fruits. Overall, kaolin treatment had the highest reduction effect on all insect pests. This could be due to ability to act as a barrier, repelling defeating infestations by making the plant visually unrecognizable as a host [26]. Thrips were the most available across all treatments, a finding in agreement with [30] who highlighted resistance of Thrips to diverse insecticides even with varying modes of actions. Table 1 further indicates that Whiteflies were best controlled by chlopyrifos+cypermethrin premix. However, a mix of chlorpyrifos+cypermethrin premix and kaolin did not have significant different on white fly control. Leaf miner infestations was the least realized across all treatments, implying that these insects can be controlled by a variety of insecticides. As expected, the untreated plants in the control experiment, registered higher infestation than those treated for all insects. Only Aphids indicated a reverse, prompting more research.

Table 1: Mean insect count on treated tomato plant inside the green house.

Treatment	Insect pest			
	Aphids	Thrips	Whiteflies	Leaf miner
Chlorpyrifos+cypermethrin premix	5.64	6.81	0.43	0.12
Kaolin	0	0	0.57	0
Sulfur	6.57	6.77	1.77	0.1
Control	4.67	7.1	8.47	2.53
Grand mean	4.22	5.17	2.81	0.69
LSD	3.116	3.159	1.3	0.69
F pr	<001	<001	<001	<001

In Table 2, it show about insect counts on plants outside the green house yet with the same treatments as those in the green house. Results still indicate that kaolin had a reduction effect on insect pest incidence. Overall there was more insect infestation on tomato plants outside the green house than those housed in a green house. This implies that well protected crops are less prone to insect pest infestation as documented in several literature.

Table 2: Mean insect count on treated tomato plant outside the green house.

Treatment	Insect pest				
	Aphids	Thrips	Whiteflies	Spider mite	Leaf miner
Chlorpyrifos+cypermethrin premix	7.87	11.2	0.433	0.467	0.433
Kaolin	0	0	0.1	0	0
Sulfur	7.77	16.2	0.9	0.8	0.667
Control	1.9	17.5	2.133	0.767	0.433
Grand Mean	4.38	11.2	0.892	0.508	0.383
L S D	3.794	7.44	0.4765	0.1846	0.2867
F pr	<001	<001	<001	<001	<001

Effects of treatments on field performance and yield of MT56 tomatoes: 3 gives the analyzed data which was collected on treated plant parameters. These included plant height in centimeters, leaf area (cm^2), number of days taken in to flowering, number of branches, and fruit yield. Yield was evaluated as number of fruits, total fruit weight, average fruit weight and proportion of the marketable fruits.

RESULTS AND DISCUSSION

Indicate that untreated plants in the control experiment performed worst since they had the lowest plant height of 33.3 cm, indicating poor field performance. Kaolin treated tomatoes had the best field performance based in terms of plant heights and number of leaves. Our experiments further indicate significant difference in field performance of treated crops in terms of leaf canopy area, number of leaves and number of branches at significance, given the p-values in Table 3. Tomatoes treated with Sulphur performed best in terms of leaf canopy area.

Table 3: Field performance of treated tomatoes treated by different insect pesticides.

Field performance parameters				
Treatment	Plant height	Leaf canopy area	Number of leaves	Number of branches
Azoxystrobin	32.7	189.5	4.47	1.37
Mancozeb	29.6	146.2	10.6	0.57
Kaolin	52.7	187.5	14.03	0.93
Sulfur	35.3	268.9	13	1.93
Control	33.3	266.9	10.47	1
Grand Mean	36.7	211.8	12.49	1.16
LSD	9.5	39.06	3.29	0.72
F pr	0.001	0.001	0.057	0.01

According to Figure 1, significantly higher fruit yield was harvested in Azoxystrobin treated pots and it showed statistically similar to mancozeb and kaolin. The lowest yield was obtained in control pots. This implies that pest control is important in improving crop yield. Percentages of yield increased due to fungicidal application over control in order of descending were: Azoxystrobin (289 g), Mancozeb (248 g), kaolin (228 g), Sulfur (149 g), and Chlorpyrifos+cypermethrin premix (148 g) (Figure 1).

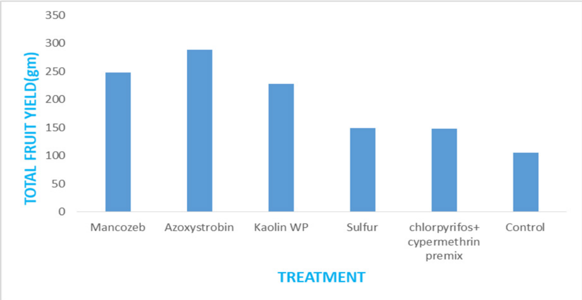

Figure 1: Graph showing total fruit weight against treatments.

CONCLUSION

In conclusion, adoption of naturally occurring chemical pesticides should be promoted since they have the possibility of managing insect pesticides in crops such as tomatoes. Kaolin and sulphur treatment on tomatoes, significantly influenced pest incidence and reduced their damage on crops. They boosted agronomic performance and yield of MT56 tomatoes and yet have limited or no chemical residual problems. However, a further study on biology of insects is required to further investigate their response to different pesticides.

RECOMMENDATIONS

Our study urges crop farmers to undertake crop protection measures in order to enhance yield and performance since pest incidence, tomato field performance and yield was lower in untreated tomato plants than the treated ones. It is recommended that adoption of kaolin as a suitable natural pesticide since it boosts tomato plant height, fruit yield, leaf canopy and photosynthetic efficiency better than the synthetic ones. The paper proposes a further experimental investigation on control of whiteflies by kaolin alone and its mixture with other pesticides such as chlopyrifos+cypermethrin since our results indicated that a mixture of chlorpyrifos+cypermethrin premix and kaolin did not have significant different on white fly control in the tomato plants studied.

Further studies should be undertaken on the efficacy and cost-returns of kaolin WP and sulfur to confirm their effectiveness in management of pests and diseases among different crops grown in the country. The biology and behavior of Aphids should further be investigated in different crops since it is only Aphids which registered higher infestation in treated plants than they were in the treated ones.

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