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Evaluation of Mulch Types on the Distribution and Diversity of Insect Pollinators and Pests in Tomato (*Solanum Lycopersicum*)

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ABSTRACT

Insect pollinators play an important role in most agricultural ecosystems, where many species of plants and animals would not survive if they were missing. Insect bees, butterflies, moths, flies, beetles, wasps and thrips maintain the ecosystem biodiversity through pollination of flowering plants. Tomato (*Solanum lycopersicum*) is a pollinator dependent plant with brightly coloured and scented flowers evolved to attract insect pollinators. Tomato production heavily involves the use of synthetic pesticides with detrimental impact on insect pollinators. This study employs mulching technologies to mitigate this problem. Four mulch treatments of white transparent polyethylene, maize stalks, grass clippings, guava leaves and no mulch as control, with three popularly cultivated tomato varieties, were arranged in a completely randomized block design (CRBD), replicated three times in the experimental plots at Masinde Muliro University of Science and Technology ($0^0 17^1$N, $34^0 45^1$E). The field experiment was conducted under rain fed conditions during the short rains and long rains season of 2016-2017. Distribution data obtained was analysed using SAS software, version 9.3 at $p<0.05$ confidence level. The means were separated by least significance difference (LSD). Mean incidence of insect pollinators was significantly highest in mulched (77.86%) and lowest in control plots

(22.14%) while pest mean incidence, was significantly highest in control (67.99%) than mulched plots (32.01%). Integrated use of mulches promotes distribution of insect pollinator diversity pollinating tomato crops. This technology selectively deters landing of some virus disease causing pests/vectors, hence significantly reduces synthetic pesticide and herbicide application, thereby conserving biodiversity.

Keywords: Insect Pollinators; Mulching; Pests; Solanum lycopersicum.

1.0 INTRODUCTION

Solanaceous crops such as tomato (*Solanum lycopersicum*), sweet pepper (*Capsicum annum*), chillies (*Capsicum frutescens*), tobacco (Nicotiana tabacum), eggplant (*Solanum melongena*), potato (S. *tuberosum*) and tamarillo (*Cyphomandra betacea*) originated in the Americas (Milfont *et al*., 2013). They mostly have pendulous flowers that produce no nectar for foraging bees. Bees visit the flowers to gather pollen, which has the highest protein and nitrogen content among pollen varieties. Flowers are self-fertile and may self-pollinate through the action of wind or shaking, but cross-pollination is favoured by stigmatic receptivity before anthers dehisce (Bispo *et al*., 2009). Parthenocarpic tomato fruit is sometimes produced. *Solanum quitoense* is pollinated by bumblebees of the *Apidae* family in the native Andes. This research brings in new skills of establishing the impact of different mulch types on the distribution and diversity of insect pollinators, to complement existing research on high-throughput genetic sequencing, Next Generation Sequencing (NGS) technologies, novel techniques in epidemiological intelligence, ecological modelling and expertise in the pollinator research community.

Tomato (*Solanum lycopersicum)* production in Kenya is faced with many constraints including damage by insect pests and diseases, poor crop husbandry, low quality seeds and post-harvest losses among other factors (Mabele & Ndong'a, 2019a; Sigei *et al*., 2014). Tomato yield losses in East Africa can be as high as 88% of which pests account for 56% (Kiatoko *et al*., 2014). The tomato plant is attacked by a wide range of pests such as leaf miners (*Lyriomyza* spp), African bollworms (*Helicoverpa armigera*), whiteflies (*Bemisia tabaci*) thrips (*Ceratothripoides brunneus*) and aphids (*Aphis gosypii*), Red spider mite (*Tetranychus evansi*) and the tomato russet mite (*Aculops lycopersici*). Mites have been reported to cause high tomato yield losses through crop damage by sucking cell sap from underside of leaves, stems and fruits. They also cause leaf defoliation, flower abortion, fruit russeting and cracking. The seriously affected leaves turn pale and chlorotic, curl upwards and downwards, wither and die. Consequently, only small bunches of the new growth remain at the apical meristems of the plant. When infestation is severe, mites cause stunted growth, drying and falling of leaves, hence resulting to total crop failure (Anderson *et al*., 2012; Mabele & Ndonga, 2019b).

Insect pollinators which at times double up as pests, utilize flowers for food in the form of nectar and pollen, and in some cases oils and resins, as well as for shelter and mating rendezvous sites (Sajjat *et al*., 2008). Some pollinators also use flowers as brood sites hence mutualisms between plants and their floral visitors sustain plant diversity. The great majority of flowering plants (87.5%)

are adapted for pollination by animals with the remainder of species being either wind-pollinated or completely reliant on autonomous seed production (Kiatoko *et al*., 2014). The degree of ecological dependence of plants on pollen-vectors for seed production depends on their breeding systems. This study looks at the threats to insect pollinators and develops appropriate mitigation technologies, through different mulch types to provide a solid evidence based research, to inform new policies and approaches to reverse the decline in pollinators. It is clear at present that there is no single factor causing the problem. Insect pollinator decline causes are complex and involves interaction between pollinators, the environment, the pest parasitoids and diseases affecting these insects. However, because of the vital role that pollinating insects play in pollinating a range of agricultural crops grown globally and by extension wild plants, it is absolutely crucial that we generate knowledge through mulching technologies that can be applied to strategies aimed at reversing the declining trend. Some factors may affect all pollinating insects while some affect only one or two species.

Mulching inhibits the disease triangle pattern in tomato (S. *lycopersicum*) production by reducing pest infestation through promotion of clean field sanitation, improvement of water and nutrient absorption (Nunes-Silva *et al*., 2013; Mabele & Ndonga, 2019a, 2019b). The dangers associated with pesticides especially insecticides on pollinators, are well documented and understood (Chelelat *et al*., 2009). Recent trends in many parts of the world towards reducing the use of pesticides in agriculture and forestry, have lessened the overall incidence of pollinator poisoning. However, the problems are still severe in developing countries within sub-Saharan Africa where Kenya is included (Kiatoko *et al*., 2014, Mabele & Ndonga, 2019a). Although pesticides constitute an integral part of integrated pest management practices (IPM) for crop protection in modern agriculture, the dangers involved must still be kept in mind and a constant vigilance maintained.

The broader a spectrum of pest species a pesticide potentially controls, the more devastating its effect will be on the total fauna, both pests and beneficial insect pollinators alike. Its longevity in the environment and application timing and methods may further contribute to its destructiveness. Although many broad-spectrum pesticides have been banned from the markets of industrialized countries for health and environmental safety reasons, many if not most of them are still being used in tropical and subtropical countries (Depra *et al*., 2014). Low levels of farmer and consumer education, and strong political and economic interests, permit the continued use of these often cheaper but more dangerous toxins. Integrated pest management (IPM) methods that will reduce pesticide use, require very disciplined and well-educated farmers, with more technical assistance than is available in most rural areas, western Kenya included. Organic farming with the use of mulching types is an alternative solution that this study unravels to positively increase the abundance, distribution, diversity and health of insect pollinators within their ecological niche ecosystems emanating from the land-use change and climate change.

2.0 MATERIALS AND METHODS

2.1 Field experimental design

Completely randomized block design (CRBD) field experiment under rain fed conditions was done during the short rains season (August to December) of 2016 and long rains season (March to July) of 2017 at the Masinde Muliro University of Science and Technology (MMUST) (N00^{o} 17.104; E034^{0} 45.874^{1}). The tested soil nutrient composition was total Nitrogen (0.26%), Phosphorus (18.9 ppm), Organic Carbon (2.5%), Potassium (0.41 $cmolcKg^{-1}$), Sodium (0.1 $cmolcKg^{-1}$), Calcium (2.3 $cmolcKg^{-1}$), Magnesium (0.8 $cmolcKg^{-1}$), Zinc (1.9ppm) and Iron (0.37ppm), with acidic P^{H} of 4.2. The randomized experiment was replicated three times under the four mulch treatments of white polyethylene (0.18mm thick), maize stalks (18.0cm thick) grass clippings (18.0cm thick), guava leaves (18.0cm thick) and no mulch as control, with three determinate tomato varieties of Fortune Maker-F1, Cal-J and Monicah-F1. The four mulch treatments were arranged as factorial in replications of 15 experimental plots. Each experimental square plot size of 4m x 4m had a distance of 1m between the plots and 0.5m buffer zones along the edges of each plot. Each experimental plot had 32 plants (n) totaling to 480 plants (N). The tomato (*S. lycopersicum*) transplant spacing used was 0.5m both for intra row and inter row to avoid overcrowding and reduce the confounding influence of the intended pollinator objective. The tomato (S. *lycopersicum*) sub-treatments were also randomized in the plots to minimize non–experimental bias during sampling for insect pollinators and pests.

2.2 Tomato crop farm management

The determinate tomato seedlings were raised on the seedbed soil that had not been planted with *Solanaceae* family crops since 2010. Watering of the seedbeds was done regularly in the morning and evening during cool temperatures until the seedlings were hardy for transplanting. Transplanting was done late in the evening after the rains, on fallow soils not planted with a solanaceous crop since 2012. The mulches were set one day before transplanting, in a loosely well tilted soil devoid of weeds. Pruning of side shoots and extreme flowers was done to boost the leaf mosaic pattern. Harvesting of ripe tomato fruits was done early in the morning when the temperatures were cool and packed in clean wooden containers for transportation.

2.3 Data analysis

The data collected on incidence and diversity of insect pollinators and pests, was scored according to Reddy (1991) using a rating scale of low incidence = 1-20%; moderate incidence = 21-49% and high incidence = 50-100%. The data obtained was subjected to one-way analysis of variance (ANOVA) to determine the most effective mulch types on mitigating beneficial insect pollinators and associated pests in tomato using SAS software, version 9.3 (SAS Institute lnc., 2004) at P<0.05 confidence level. Mean separation was done at 95% confidence level using Fischer's protected least significant difference (LSD).

3.0 RESULTS

3.1 Table of results for mean insect pollinator and pests' incidence and prevalence

Table 1: Mean insect pollinator incidence

Mulch type	Mean	LSD	P-value
PVC	113.2000^{cb}	30.21206	0.1470
Grass	116.4000^{ab}		
Maize	101.4000^{b}		
Guava	96.3000^{c}		
Control	19.8000^{d}		
Average mean	89.42*		

The mean incidence that have a common grouping letter are not significantly different. The frequency of insect pollinator visitation varied significantly during the day among the mulch types.

Table 2: Mean tomato pest prevalence

Mulch type	Mean	LSD	P-value
PVC	5.524^{a}	44.73157	0.0662
Grass	9.190^{b}		
Maize	8.952^{b}		
Guava	6.810^{b}		
Control	64.721^{c}		
Average mean	19.1852*		

Incidence of multiple insect pollinators and pests of whiteflies, thrips, aphids, caterpillars, moths, mites and leaf miners was highest in control with mixed flower colourations. The mean prevalence of pests for PVC was statistically lower and different from all the other mulch types. This is attributed to uniform bright yellow colouration of the tomato crop flowers and white PVC mulch.

4.0 DISCUSSION

Insect pollinators like bees increase productivity and the quality of tomato fruit. Although tomato produces fruit by self-pollination, pollinator visitation often increases the fruit number, size of fruit and number of seeds. The distribution (prevalence) and diversity (composition, richness and abundance) of insect pollinator species visiting tomato flowers, varied among the mulch types and hours of the day. Pollinator frequency varied significantly during the day when they arrived early in the morning. Their visitation started around 08:00 hours with a peak around 11:00 hours and a steep decline around noon upto 13:00 hours. The mean pollinator frequency was highest in grass mulch type followed by PVC, maize stalks, guava then control. Probably the grass mulch type ameliorated the soil humus supplement that significantly boosted the growth vigour of tomato flowers, becoming more brightly coloured with abundant pollen for attracting more pollinators. Tomato flowers have no nectar but their stamens have large yellow anthers with poricidal dehiscence, which need vibration for the pollen to leave them (Nunes-Silva *et al*., 2013). However, the pollinator efficiency was influenced by chemical ways through which bees among other pollinators, detected if a flower had very recently been visited by another bee before landing. This might mean that the pollen supply is temporarily low and some flowers changed colour when they had been fully pollinated (Bispo *et al*., 2009). The PVC mulch also due to their bright colour, attracted more insect pollinators which increased their incidence and prevalence. Studies of pollinator distribution in crop fields seem to indicate very limited foraging ranges of honey bees in situations with many more flowers than foragers.

The mean incidence of tomato pests was significantly highest in control and least in PVC mulch type. The sampled tomato pests included the leaf miners, tomato bugs, fruit worms, spider mites, white flies and thrips. The leaf miners damaged the leaves through feeding and egg-laying maggots which punctured while feeding/mining in readiness to pupate. The whiteflies (*Bemisia tabaci*) caused damage by sucking plant sap and transmitting virus diseases like the *Tomato yellow leaf curl virus* (TYLCV) while human contact and bumblebees (*Bombus terrestris*) transmit *Tomato brown lugose virus* (ToBLV). The tomato bugs caused damage by sucking plant sap causing brownish rings on stems, petioles, growing points and leaves making the leaves become brittle and crinkled. The fruitworms comprising the caterpillar of the African bollworm fed on both green and ripe fruits while the moths of the African bollworm damaged the green fruits. The spider mites of the red spider mite family on leaflets, severely damaged the plants and fruits through their extensive webbing pattern. The thrips caused severe damage on the leaves, flowers and fruits. They also acted as vectors of virus diseases like *Tomato spotted wilt virus* (TSWV). The risk to pollinators from pesticides arises through a combination of toxicity and the level of exposure, which varies geographically with the compounds used and the scale of land management and habitat in the landscape.

Insect Pollinators like honeybees, butterflies and moths are vital for the pollination of cultivated horticultural crops such as tomatoes (*Solanum lycopersicum*). Having a healthy population of pollinators is essential to maintain biodiversity in natural ecosystems. Pollinating insects are vulnerable to pests, diseases and environmental stressors that have threatened their decline, alternative mulching technology lowers pesticide use increasing the pollinator populations (Anderson *et al*., 2012).

5.0 Conclusion and Recommendations

In conclusion, this study used different mulch types to generate knowledge on extensive and multidimensional understanding of insect pollinators distribution, diversity and steps needed to protect pollinator populations with the values they produce in cultural (identity), financial (honey sales), health (pharmaceutical properties of bee products), human (employments in beekeeping), social (Beekeepers' Associations) and technology dimensions. Tomatoes have a herbaceous/shrubby habit and reach up to 2 m in height. Plants produce mature fruits 90 to 120 days after seed germination and 45 to 55 days after flowering. The availability of effective pollinators in tomato plant communities is an obvious requirement for successful seed production. The conservation of farmland biodiversity through reduction in pesticide application by encouraging mulch application technologies, sustains a higher frequency of insect pollinators on tomato flowers to boost productivity and reduce virus diseases.

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