EFFECT OF BIOSLURRY-ENRICHED VERMICOMPOSTS ON TWOSPOTTED SPIDER MITE (*Tetranychus urticae* Koch), YIELD AND POSTHARVEST QUALITY OF STATICE (*Limoniun sinuatum* Mill).

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A Thesis Submitted to the Graduate School in Partial Fulfilment of the Requirements for the Master of Science Degree in Horticulture of Egerton University

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DECLARATION AND RECOMMENDATION

Declaration

This thesis is my original work and has not been presented in this University or any other for the award of a degree.

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Recommendation

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DEDICATION

Dedicated to my mother, who in my innocent childhood ambition in 1977, I promised that I will school to Class 100 as she took me to enroll in primary school after my kindergarten education.

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ABSTRACT

Statice (*Limonium sinuatum* Mill) is an outdoor flower providing potential for expansion and product diversification in floriculture. Its production is constrained by rising cost of inputs, declining soil fertility and pest damage. The twospotted spider mite is a major pest causing yield losses. Inorganic fertilizers and synthetic miticides are expensive and cause pollution. This study sought to determine effects of bioslurry and vermicomposts as fertilizers on yields and quality of statice, and on TSSM. The study was conducted at Egerton University in Njoro, Kenya, using a 2×4 factorial experiment laid out in a RCBD in the field and CRD in the laboratory. The three vermicompost treatments were Kitchen waste (V_1), mowed lawn grass (V_2) and Weed biomass (V_3), all applied at a rate of 40% by volume mixed with garden soil, and compared with the control (V_0). Bioslurry was applied at 7.8 tons/ha (B_1), and compared with the control (B_0). Results showed significant main and combined treatment effects on parameters at $P \leq 0.05$, when compared with the control. Statice inflorescences from plants treated to the organic fertilizers, singly or in combination, had significantly fewer TSSM (ranging from 5.2 to 10.4 mites) indicating greater mite repellence, when compared with the control (11.2 mites). The biofertilizers, also had significant main and combined effect on growth and yield parameters, when compared with the control. They resulted in significant increased number of days to flowering (ranging from 17.3 to 26.9 days), compared to the control (12.3 days), increased number of stems per plant (ranging from 26.2 to 32.5 stems) compared to the control (22.1 stems), increased stem length at 60 days after transplanting (ranging from 77.0 cm to 112.6 cm) compared to the control (40.1 cm), and increased fresh weight of flower stems (ranging from 20.0g to 31.6g) compared to the control (12.4 g). The organic fertilizers also resulted in significant main and combined effect on statice postharvest quality parameters. When compared to the control, they resulted in significantly enhanced water uptake during days in the vase (DIV), throughout the observation period. The observed water uptake was significantly higher at 3 DIV (ranging from 52.8 to 70.8 ml), and was still much higher at 15 DIV (ranging from 34.7 ml to 50.8 ml) compared to the control (48.1 ml and 3.3 ml respectively at 3 DIV and 15 DIV). Application of the manures significantly increase vase life of statice (ranging from 15.8 days to 22.5 days) compared to the control (11.7 days). It is therefore concluded that the treatments have significant favourable effect on TSSM repellence, growth, yield and postharvest quality in

statice, sufficient basis to reject the null hypotheses.

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LIST OF ACRONYMS AND ABBREVIATIONS

ANOVA	- Analysis of Variance
DAT	- Days after transplanting
DLI	-Daily light integral
Gy	-Gray: SI Unit for absorption of ionizing radiation (as used in kGy)
HCD	-Horticultural Crops Directorate
HCDA	-Horticultural Crops Development Authority
ICM	- Integrated crop management
KES	- Kenya Shilling
MOA	-Ministry of Agriculture
MSW	- Municipal solid waste
n.d.	-Not dated
PAH	- Polycyclic aromatic hydrocarbons
PGRs	- Plant growth regulators
PPF	-Photosynthetic photon flux
PSB	- Phosphate solubilizing bacteria
RCBD	- Randomized complete block design
RPM	- Reflective plastic mulch
TSP	-Triple super phosphate
TSSM	-Twospotted spider mite
YSDPL	- Yashoda Sustainable Development (P) Ltd

CHAPTER ONE

INTRODUCTION

1.1 Background Information

Floriculture is an important economic sub-sector in Kenya with among the fastest growth rates. The value of earnings from floriculture rose from KES 35.5 billion in 2010 (HCDA, 2017) to KES 113.16 billion in 2018 (Horticultural Crops Directorate (HCD), 2018). However, the value reduced in 2020 to KES 107.51 billion (HCD, 2020). The main export destinations are European countries that include Germany (18%), the United Kingdom (17%), and the United States of America (16%) (Hornberger *et al*., 2007). There is an urgent need for diversification of products and markets to sustain competitiveness of the Kenyan flower industry (Rikken, 2011). This calls for deliberate inclusion of Kenyan smallholders in Floriculture.

Statice (*Limonium sinuatum* Mill: Plumbaginaceae) is among the most important cut flowers grown in Kenya. It is also one of the summer flowers that can potentially be grown under outdoor production systems by a large number of small-holder farmers to spur sub-sector growth (HCDA, 2011). Statice is an important annual cut flower used as filler in flower arrangements or as a dried item. Well maintained statice flowers can have a vase life of more than 10 days and keep their color even after drying. Despite the importance, statice exports have been on a sustained decline in recent years. In 2006, the crop commanded 3% of Kenyan flower exports and was ranked joint 4th with carnation behind roses at 74%, mixed bouquets at 10% and Alstroemeria 5% (Embassy of the Republic of Kenya in Japan, 2012). By 2011, statice exports no longer featured as stand-alone in the cut flower export statistics but as part of the mixed flowers fraction (HCDA, 2011). The decline persisted during 2018 as reflected in the drastic decline in the contribution of statice to Kenya's floriculture export value from 3.6% in 2016 to 0.4% in 2018. The crop was thus relegated to position 11 behind roses, cuttings, mixed flowers, carnations, gypsophilla, alstroemeria, chrysanthemum, hypericum, pelargonium and hydrangea (HCD, 2019).

The performance, yield and quality of statice flowers is often affected by the abiotic and biotic environments such as soil fertility and insect pests among other factors (Kumar & Chaudhary, 2018). To improve yields and quality of statice flowers, suitable soil fertility management practices is required. Adequate supply of both the macronutrients and micronutrients is critical for cut flower production in plant nutrition (Fasulo & Denmark, 2000).

Nutrient deficiencies may also result in smaller plants with shorter flowering stems, reduced overall yield and low postharvest quality (Konwar & Borgohain, 2019).

Kenya's flower industry which is among the largest in world (Leipold & Morgante, 2013) is often faced with volatile costs of chemical fertilizers and pesticides among other inputs. There is an urgent need for innovations and adoption of good agricultural practices to support profitability and environmental sustainability as well as bring more small-scale farmers into growing of summer flowers spur growth in floriculture sub-sector. The documented potential of organic manures for soil fertility management (Arancon et al., 2004) as well as pest tolerance or repellence (Blumberg *et al*., 1997; Culliney *et al*., 1986; Eigenbrode *et al*., 1988; Kajimura *et al*., 1993; Marques-Francovig *et al*., 2014) offers a possible cultural component for inclusion in an integrated crop management strategy.

The twospotted spider mite (*Tetranychus urticae* Koch: Tetranychidae) is a polyphagous pest of more than 900 plant species. It attacks about 150 economically important crops, including cut flowers (Najafabadi *et al.,* 2011), and is a serious pest of statice (HCDA, 2011). TSSM cause both direct and indirect damage to plants. Feeding mites cause direct damage to plants including leaf burning, defoliation and plant death while indirect damage includes bronzing (yellow to white discoloration of the leaf), resulting in decreased photosynthesis, transpiration, loss of quality and yield, and even death of host plants (Badawy *et al*., 2010; Park & Lee, 2002).

Vermicomposts are finely-divided fully-stabilized humus-like organic materials resulting from the activities of earthworms and microorganisms that bio-oxidatively convert and stabilize organic substrate (Tognetti *et al*., 2005). The earthworms' faecal materials improve overall soil fertility through gut microbial inocula (Munnoli *et al*., 2010). The process increases the bioavailability of phosphorus in the soil benefitting plant growth while enhancing soil nitrogen mineralization (Ansari, 2008). Vermicomposting represents an economic opportunity for viability, affordability, ecological friendliness in organic waste management benefitting society without adverse effects to human health.

Biogas on the other hand is a renewable and environmentally friendly energy source (Glover, 2009) which is a cheaper alternative to wood and fossil fuels. Digestate resulting from biogas plants as effluent referred to as bioslurry is useful manure utilized in soil fertility and moisture content management. Bioslurry has also been reported to repels termites, reduces weed growth in in the fields while increasing crop yields (Yashoda Sustainable Development (P) Ltd

(YSDPL), 2006). Plant nutrient needs can be realized by application of bioslurry at appropriate rates can greatly reduce the cost of crop production (Demont *et al*., 1991).

The pest suppression effect of vermicomposts (Edwards *et al*., 2009) and that of bioslurry (YSDPL, 2006) as well as the fertility improvement value of both (Munnoli *et al*., 2010.) make these technologies suitable for inclusion in integrated crop management (ICM) strategies. They can also help to reduce the pesticide and fertilizer costs in small-holder floriculture and other crop enterprises while at the same time contributing to sustainable organic waste management.

1.2 Statement of Problem

Statice is an important flower crop that can easily be grown outdoors by smallholder farmers. Declining soil fertility and pest incidences are major constraints in the cultivation of statice. Furthermore, many regions in Kenya have soils with low fertility due to intensive and continuous land use without adequate and appropriate replenishment of nutrients. This has necessitated the use of inorganic fertilizers which are expensive, with limited capacity to sustainably improve soil physical, biological and chemical fertility. The twospotted spider mite (TSSM) on the other hand is a serious pest of statice causing up to 80% yield loss annually. It is also listed as a quarantine pest and hence among the leading causes of rejection of flowers destined for the export market. Effective management of TSSM heavily relies on frequent sprays and high dosages of miticides. This does not only increase the production costs but also raises concerns about threats to the environment and development of pesticide resistance. The strict guidelines on maximum residue limits (MRL) in cut flower market has seen many small-holder farmers drop out of statice production in Kenya. Bioslurry and vermicomposts offers alternatives for safer and affordable soil fertility and TSSM management in statice production.

1.3 Objectives

1.3.1 Broad Objective

The main objective of the study was to contribute to improved yield and quality of statice through the utilization of bioslurry and vermicomposts for plant nutrition and management of the twospotted spider mite.

1.3.2 Specific Objectives

i. To determine the repellence effect of different vermicompost and bioslurry against the two spotted spider mite in statice.

ii. To determine the effect of different vermicompost and bioslurry on growth, and yield of statice.

iii. To determine the effect of different vermicompost and bioslurry on postharvest quality of statice.

1.4 Null Hypotheses

i. Different vermicomposts and bioslurry applications have no significant repellence effect on the twospotted spider mite in statice.

ii. Different vermicomposts and bioslurry treatments have no effect on the growth and yield of statice.

iii. Different vermicomposts and bioslurry treatments have no effect on postharvest quality of statice.

1.5 Justification of the Study

Kenya's Vision 2030 is the development blue print geared towards attainment of middle-income status by the year 2030. Small-holder floriculture farmers, can contribute to this aspiration through creation of employment and enhancing household incomes through export earnings. Although the floriculture subsector contributes 20.3% of domestic horticultural value, it is dominated by large scale growers with smallholders who constitute at least 70% of farmers contributing a mere 2%.

Smallholder floriculture faces various challenges such as declining soil fertility resulting from continuous cropping with very little investment in soil fertility replenishment. This is confounded by the high cost of inorganic inputs, pests and stringent export market access standards There is need to encourage increased diversification and participation of smallholders in floriculture by developing and promoting sustainable soil fertility and crop pest management technologies in the cultivation of cut flowers such as statice.

Vermicomposts and bioslurry, as organic manures, have been studied in diverse works as plant nutrient sources with effects on crop protection against pests and diseases. Available literature suggests their effectiveness in plant nutrition and protection in a number of cultivated crop species. However, there is limited knowledge on the specific and additive effects of vermicomposts and bioslurry on the management of TSSM, growth, yield and postharvest quality of statice.

The present study tested the applicability of both the plant nutrition and pest suppression

properties of bioslurry and vermicomposts under open field cultivation of statice.

CHAPTER TWO

LITERATURE REVIEW

2.1 Taxonomy, Origin and Importance of Statice

Statice belongs to the genus *Limonium* in the Family Plumbaginaceae which has approximately 300 species of herbaceous annuals and perennials. The genus is well adapted to Mediterranean conditions but with wider adaptability to diverse environments (Lopez & Gonzalez, 2008). *Limonium sp.* has worldwide occurrence (Waisel, 1972) although it classified as native to diverse latitudes including European-Nordic, Mediterranean and Sino-Japanese groups (Chapman, 1977).

Plate 1: Statice plants and flower stems in vases (Source: Primary)

The annuals species of statice namely *Limonium sinuatum* Mill and *L. latifolia* are important ornamentals in floriculture and landscape gardening (Lopez & Gonzalez, 2008) while *L. vulgare are important* for tannins (Uphof, 1959) and *L. carolinianum* for dye (Ahmed *et al.,* 1999). In Kenya, one of the most important cut flower species is *Limonium sinuatum* Mill which is mostly used in its fresh form as a filler in flower arrangements, or as a dried item for indoor decoration. Several cultivars which are classified into annuals and perennials are available for commercial growing. The annuals include the White, Blue, Misty Blue, Heavenly Blue, Yellow, Bundeli, Lavender, Moonfloat, Sky Walker, Pastel Walker, Pastel Pink, Pastel Lilac and Lipstick cultivars. Perennials on the other hand include Baltaard, Emile, Perezi and Confetti (MOA, 2003). Most of them are early maturing varieties which flower in 166 to 168 days after seeding.

However, the blue flowering varieties are late maturing while the white and lavender are intermediate. The variety 'Gold Coast' produces the most inflorescences but is the lightest in weight of all varieties while Midnight Blue produces the least flowers but with the highest individual inflorescences weight (Wilfret *et al*., 1973). The blue and purple cultivars are more adaptable to open field cultivation because of their relative resistance to fungal disease (RoyalVanZanten/Van Zanten Plants B.V., n.d.) and therefore have the greatest potential for smallholder cultivation.

There exists unexhausted potential for outdoor statice cultivation by smallholder farmers which can boost growth of the floriculture sub-sector. Statice cut flowers have a vase life of up to 10 days and keep their color even after drying up (Embassy of the Republic of Kenya in Japan, 2012). Due to decline in production and contribution to flower exports, by the year 2011, statice no longer featured as a stand-alone export crop, but as part of the mixed flowers (HCDA, 2011).

2.2 Factors affecting growth, yield and postharvest quality of statice

These factors can be grouped into edaphoclimatic and agronomic factors. Edaphoclimatic factors refer to the ecological conditions for plant growth and development. Agronomic factors include the cultural practices such as plant propagation, crop and pest management (Lopez & Gonzalez 2008).

2.2.1 Edaphoclimatic Factors

Statice (*Limonium sinuatum* Mill) does well in Upper Midland and Lower Midland Zones with the most suitable altitude ranging from 1,200 – 1,800 m above mean sea level. The soil should be well drained with pH range of between 6 and 7 (Zizzo *et al.,* 2000).and maintained moist at 75-95% humidity during early growth. Overhead sprinkler irrigation with fine water droplets ensures good soil and root contact without soil splash and damage to the young plants. However, overhead irrigation should be withdrawn at flower bud initiation to reduce incidence of grey mould. Weed competition for growth resources should be reduced by regular shallow weeding (Ministry of Agriculture (MOA), 2003).

The optimum temperature range for growing statice is from 15° C to 25° C (MOA, 2003) but with at least 3 to 6 weeks of 11 to 13 °C for floral initiation. A diurnal temperature variation of at least 10° C during development of the first leaves favours vernalization (Lopez & Gonzalez, 2008) although a facultative vernalization response for some cultivars has been reported by Semeniuk and Krizek (1973). Lower diurnal temperature variations for 2 – 3 weeks reverts

young plants to vegetative phase. Flowering, flower growth and development require cool temperatures while stem elongation, leaf initiation and growth require high temperatures (Healy & Espinosa, 1991).

Statice requires a photoperiod of 16 hours for growth. However, the species has also shown facultative, long-day plant tendencies with a photoperiod requirement of at least 13 hours (Semeniuk & Krizek, 1972; Shillo & Zamski, 1985) and 12 hours with photosynthetic photon flux density of 50 µmol m^{-2} s^{-1} for flowering (Lopez & Gonzalez, 2008). While Mattson & Erwin (2005) reported indifference to the day light integral (DLI), Shillo and Zamski (1985) reported a response to the product of photoperiod and photosynthetic photon flux (PPF) and day length under natural low light intensity. Statice crop production at exposure regime to DLI values ranging from 4 to 60 $mol \cdot m^{-2} \cdot d^{-1}$ have been reported in mainland America (Korczynski *et al., 20*02) and within New Zealand although the lower extreme of the range limited commercial production under greenhouse cultivation (Faust, 2003).

2.2.2 Agronomic Factors

Growth and yield of statice are affected by factors associated with ecology, cultural practices and biotic constraints. Soil physical and chemical fertility and the plant nutrition regime directly impacts on yields. Nursery beds for seed propagation should be prepared to a fine tilth followed by a base dressing with 5,000 kg/ha agricultural lime and 500Kg/ha triple super phosphate (TSP) or DAP. The beds should be top dressed after 10 – 15 days with 10g/m^2 NPK (20:10:10) fertilizer. Statice requires adequate supply of nitrogen and potassium but excessive nitrogen and inadequate potassium causes bushy growth and weak plants that easily fall over (MOA, 2003). The crop requires a basal application of 30 – 50g/m^2 sulfate of potash, magnesium sulfate or TSP at field planting. Liming reduces susceptibility to *Fusarium oxysporum*. In sandy soils, usually deficient of molybdenum, application of 300 – 350 kg/ha sodium molybdate starting when the crop is two months old and after every four months is recommended (Paparozzi & Hatterman, 1988).

The first few flower stems should be pinched back to discourage early flowering and to allow for uniform growth and development of basal rosette which feed the plant but care is needed to avoid excessive pinching which delays the crop. After harvesting of the first flush a top dress with 10 Kg/ha NPK fertilizer (20:10:10) should be applied and be repeated twice at intervals of 10 days. Weed competition and poor weeding practices affect crop performance and

yields. Regular shallow weeding or hand pulling is recommended to reduce weed competition for growth resources. Other biotic constraints in statice production include fungal diseases such as grey mould (*Botrytis cinerea*) and leaf spot (*Cercospora spp*), arthropod pests such as aphids and thrips (MOA, 2003) as well as the twospotted spider mite (Wilfret *et al*., 1973) all of which reduce crop yields and therefore require control.

2.2.3 Factors Affecting Postharvest Quality of Statice

Postharvest quality of statice is affected by pre-harvest factors including biotic and abiotic crop growing environment. Among the important pre-harvest factors that affect yield and quality in field production of statice are fertilizer application and planting density (Jain *et al*., 2018) as well as lighting duration and intensity (Lopez & Gonzalez, 2008). The total sunlight received determines the amount of accumulated carbohydrates in tissues (Halevy & Mayak, 1981).

Agronomic practices, incidences of pests and diseases as well as postharvest handling of the produce generally affect post-production quality in cut flowers (Nell *et al*., 1997). Weed competition for growth resources compromises plant nutrition and access to sunlight which results in poor yields and quality of flower crops. Weed management coupled with suitable planting density of 8 – 12 plants/m^2 enhances yields and quality of statice flower stems due to reduced shading among other beneficial effects (MOA, 2003).

The choice of statice variety affects postharvest quality of cut flowers as observed in Anthurium (*Anthurium andraeanum* Hort.) in which varieties with low abaxial stomata density generally had a sustained steady vase solution uptake for longer and hence had longer vase life (Elibox & Umaharan, 2010). The propagation method also affects quality of statice with Statice propagated asexually giving superior quality produce with uniform crop colour, height, head size and resistance to diseases when compared to sexual propagation. The watering regime during early growth stages and the method of irrigation also affects quality of statice. Adequate supply of water at the early stages ensures good statice flower quality but overhead irrigation after flowering should be avoided. These should be complemented with proper timing so that flowers are harvested with 85 – 95% of the flowers open as flower opening does not continue after harvest (Lopez & Gonzalez, 2008). Literature search did not find documented effects of vermicompost and bioslurry application as fertilizers and/or pest management inputs, on the postharvest quality of statice.

2.3 The Twospotted spider Mite (TSSM)

The TSSM (*Tetranychus urticae* Koch: Tetranychidae) is one of the most important mites that feeds on more than 900 plant species. It is described as a major pest of more than 150 important crops including field, forage and horticultural crops (Najafabadi *et al*., 2011). The TSSM is phytophagous in nature with all its active development destructive (James & Barbour, 2009). The mite has a high reproductive potential due to its short life cycle and rapidly gains resistance to many acaricides after a few applications (Edge & James, 1986; Stumpf & Nauen, 2001).

Plate 2: Image of TSSM (Swier, 2016).

2.3.1 Taxonomy and Morphology of the TSSM

The TSSM belongs to the phylum arthropoda, class arachnida and is a member of the family tetranychidae (Osborne & Petitt, 1985). The mite is oval in shape measuring about 0.5 mm long. It may be brown or orange-red, but a green, greenish-yellow or an almost translucent color is most common. Females measure about 0.4 mm long with elliptical body and bears 12 pairs of dorsal setae. Overwintering females hibernate in ground litter or under tree barks or shrubs. Hibernating females are orange to orange-red. The dark spots which are body contents visible through the body wall are accumulations of body wastes. Newly molted mites often lack the spots. The male is also elliptical with the caudal end tapering and smaller than the female. The axis of knob of aedeagus is parallel or forming a small angle with axis of shaft (Fasulo & Denmark, 2000).

2.3.2 Biology of the TSSM

The life cycle of the TSSM (Plate 3) consists of eggs attached to fine silk webbing which

hatch in approximately three days into larvae that undergo two nymphal stages (protonymph and deutonymph) before becoming adults. The duration from egg to adult varies with temperature but 12.4ºC is optimal at which the spider mites complete their life cycle in 5-20 days. Usually there are many overlapping generations in a year. The adult female lives two to four weeks and lays several hundred eggs during her life. The TSSM prefer hot, dry weather conditions although they may occur anytime during the year (Fasulo & Denmark, 2000). Hot and dry conditions favor mite proliferation and serious TSSM infestations. The mite exhibits rapid expansion in population with as much as 40 % increases per day (Najafabadi *et al*., 2011).

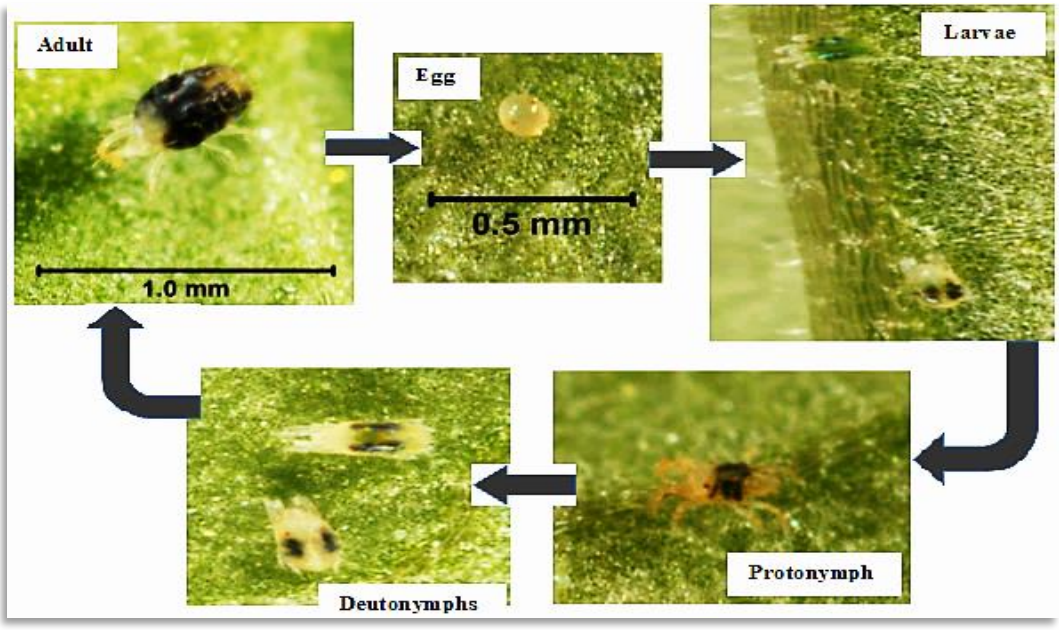

Plate 3: Life cycle of TSSM (Casuso & Smith, 2017)

2.3.3 Damage Caused by TSSM on Crops

The polyphagous mites cause damage by the feeding activity of larvae, nymphs, and the adults. TSSM usually infests underside of leaves and may cause profuse webbing but under severe infestation this occurs on leaf surfaces, stems and fruits. The mites puncture cell walls and suck cell contents, especially the chloroplasts. This leads to death of cells and tissues which appear as transparent, yellow, or tan patchwork of damage with patchy chlorotic appearances on leaves with portions or entire leaf surfaces bronzing. The damage generally reduces the plant vigor and may cause wilting. Mites also act as vectors of certain plant viruses (Johnson, 2008). Their rapid growth rate, short generation time and high net reproductive rate aids TSSM to

rapidly attain economic injury level. The blistering, deformation of leaf tissue and destruction of chloroplasts resulting from increased populations of feeding mites causes reduced photosynthesis, stomatal closure and decreased transpiration leading to reduced crop yields and quality (Najafabadi *et al*., 2011).

In statice, the most vulnerable crop stages are between flower bud initiation and flower harvesting, when the mite population increases rapidly often attaining economic injury level. The mites suck plant juices and cause yellowing, blistering and deformation of tissue mostly on leaves and flower buds, often causing premature drops. Signs of damage include bronzed, yellow or pinkish red to purple leaves (Wilfret *et al*., 1973).

2.3.4 Management Strategies for TSSM

Management of spider mites is normally done by use of granular systemic pesticides such as Aldicarb which may not be adequate for the late season pest buildup since the material may fail to be incorporated into the plant tissues. Chemical control of TSSM is expensive and poses risks to growers, non-target organisms and the environment besides development of resistance to acaricides (Motazedian *et al*., 2012). Sprays with Pentac, Dicofol, Tetradifon or Monocroptophos at large volumes per unit area lower mite populations and reduce flower losses (Wilfret *et al*., 1973).

Chemical control of mites is becoming a less preferred option due to rapid development of resistance and environmental concerns associated with pesticide use (Oliveira *et al*., 2007). Rapid development of acaricide resistance in TSSM even after only a few applications (Nauen *et al*., 2001) has been reported for compounds such as organophosphates (Sato *et al*., 1994), dicofol (Fergusson-Kolmes *et al*., 1991), organotins (Edge & James, 1986; Flexner *et al*., 1988) hexythiazox (Herron & Rophail, 1993), clofentezine (Herron *et al.,* 1993), fenpyroximate (Stumpf & Nauen, 2001; Sato *et al.,* 2004) and abamectin (Beers *et al.,* 1998). Biological control using predator mites *Phytoseiulus persimilis* and *Amblyseus californica* and the use of essential oils from plants such as *Rosmarinus officinalis, Corymbia citriodora, Mentha pulegium, Mentha piperita, Mentha longifolia, Salvia officinalis,* and *Myrtus communis* have shown promise as part of an IPM package (Motazedian *et al*., 2012).

The use of low dose gamma irradiation applying at least 0.15 kGy reportedly suppresses post-diapause hatching of wintering TSSM eggs and the survival of early nymphal stages. Also, mites surviving irradiation raise male dominated populations. Irradiation of both males and

females increases mortality with increase of dosage during embryonic development (International Atomic Energy Agency, 1999). However, this technique remains beyond many Kenyan farmers due to high cost and complexity of the technology. There is therefore need for alternative mite control technologies.

2.4 Vermicomposting and vermicomposts

In vermicomposting, coupled activities of the earthworms and microorganisms stabilize organic matter without a thermophilic phase (Tognetti *et al.,* 2005). Mesophilic bacteria and fungi which are predominate (Tomati & Galli, 1995) operate at 15° – 45°C to break down, bio-convert and stabilize the organic waste materials they feed on (Hartenstein & Bisesi, 1989). The earthworm species such as the red wriggler (*Eisenia foetida*) and the red worm (*Lumbricus rubellus*) are the most preferred in vermicomposting because their preferred environmental conditions are easily replicated. *E. foetida* is most suitable species for organic waste processing (Edwards & Bater, 1992).

These worms rapidly consume organic residues and fragment them by their gut to finer particles. They also elevate overall soil fertility by inoculating the soil with soil microorganisms through their feacal casts (Munnoli *et al*., 2010). The worms feed on microbial growths on the organic wastes and their excrement known as vermicast have even greater microbial activity than ingested organic material. This enhances microbial activity in the vermicompost. The microbes release and convert plant nutrients, particularly nitrogen, potassium, phosphorus and calcium, present in the material into more readily soluble and plant available forms than in the parent compounds (Edwards & Bohlen, 1996).

2.4.1 Properties and Agronomic Value of Vermicompost

Vermicomposts have much finer structure when compared to composts. They usually have higher plant nutrient content and in forms that are readily available for plant uptake (Edwards & Burrows, 1988). The various plant-available nutrient forms contained in vermicomposts include nitrates, phosphates, soluble potassium, and magnesium as well as exchangeable phosphorus and calcium (Edwards *et al*., 2004). The comparison of nitrogen (N), phosphorus (P) and potassium (K) content is reported by Agarwal (1999) as 0.4 – 1.0% N, 0.4 – 0.8% P and 0.8 – 1.2% K in cattle dung compost as opposed to 2.5 -3.0% N, 1.8 – 2.9 P and 1.4 – 2.0% K in cattle dung vermicompost. Singh (2009) reports 9.5 mg/g N, 0.137 mg/g P and 0.176 mg/g K content in food and garden waste vermicompost as compared to 6 mg/g N, 0.039 mg/g P and 0.152 mg/g K in aerobic compost of the same substrate. Anaerobic composts of the same substrate had 5.7 mg/g N, 0.05 mg/g P and 0.177 mg/g K. The superiority of the vermicompost was also observed with respect to comparative content of iron (Fe), Magnesium (Mg), Manganese (Mn) and Calcium (Ca) confirming a higher fertilizer status. The benefit of this

characteristic to yield and postharvest quality of Statice needs to be determined.

The large particulate surface area of vermicompost provides many sites for microbial activities and for strong adsorption of nutrients (Arancon *et al*., 2006). Vermicomposts are also rich in diverse microbial populations including fungi, bacterial and actinomycetes (Singh, 2009) with observed bacterial count of more than 10^{10} per gram. The count for the different microbial populations including *Actinomycetes spp.*, *Azotobacter spp.*, *Rhizobium spp.*, *Nitrobacter spp.* and phosphate solubilizing bacteria (PSB) ranged from 10^2-10^6 per gram of vermicompost (Suhane, 2007) and 32 million per gram in fresh vermicast as compared to 6 – 9 million per g in the surrounding soil (Parle, 1963). Cattle dung vermicompost had a bacterial count of 73×10^8 g, cellulolytic fungi count of 59×10^6 per g and N-fixing bacteria count of 18×10^3 per g as compared to 16×10^8 per g, 21×10^6 per g and 5×10^3 per g respectively in municipal solid waste (MSW) vermicompost (Pramanik *et al*., 2007). An increase in respiration rate by 90% in fresh vermicast was observed which corresponds to increase in the microbial population (Scheu, 1987). The PSB significantly enhance availability of the essential nutrient phosphorus for plant uptake to promote plant growth (Rodriguez & Fraga, 1999). Liming enhanced the population of all the mentioned microbes irrespective of the vermicomposting substrates used (Pramanik *et al*., 2007).

Plant growth and performance were directly enhanced by microbial activity including nitrogen fixation, nutrient solubilization, production of growth hormones such as 1-aminocyclopropane-1-carboxylate, deaminase and indirectly by antagonizing pathogenic fungi by production of siderophores, chitinase, ß-1,3-glucanase, antibiotics, fluorescent pigments and cyanide (Han *et al*., 2005). Vermicomposts produce plant growth regulators (PGRs) (Tomati and Galli, 1995) responsible for observed differences in growth performances when composts and vermicomposts are used as soil amendments or constituents of growth media (Atiyeh *et al*., 2000). Microbes in vermicomposts produce appreciable quantities of auxins, gibberellins, cytokinins, ethylene and ascorbic acids. Earthworms significantly boost microbial populations thereby availing large quantities of PGRs in vermicompost (Frankenberger & Arshad, 1995).

Vermicomposts stimulate plant growth even under optimal nutrition by improved seed germination, enhanced seedling growth and development. It increases plant performance regardless of the effects of increased bioavailability of mineral nutrients with maximum benefit being realized when vermicompost constitutes 10 – 40% of growing media (Arancon, 2004).

Ornamental plants treated with aqueous vermicompost extracts exhibit similar growth patterns as those observed with addition of auxins, gibberellins and cytogkinins through the soil (Tomati *et al*., 1988).

Vermicomposts produce plant growth responses similar to hormonal effects due to the high levels of humic acids and humates, and the high levels of available plant nutrients (Atiyeh *et al*., 2002) which when they were isolated from vermicompost enhanced root elongation and formation of lateral roots in maize (Canellas *et al*., 2000) while enhancing nutrient uptake by increased root cell membrane permeability, enhanced root growth and greater proliferation of root hairs (Pramanik *et al*., 2007).

Preparation by a combination of thermocomposting and vermicomposting over 21 days produces compost of good homogenous consistency, acceptable C:N ratio as a fertilizer and when such vermicomposts was stored for three months, it had greater pathogen reduction than composts produced by thermophilic composting only even after the three months (Nair *et al*., 2007). Earthworms are also effective in bioremediation as they bioaccumulate or biodegrade several organic and inorganic pollutants including heavy metals, organochlorine pesticides and polycyclic aromatic hydrocarbon residues in their habitat medium (Alam *et al*., 2009).

2.4.2 Use of Vermicompost in Crop Production

Vermicompost used as a partial substitute for peat, mixed with biochar in potting media, resulted in greater overall productivity in Petunia and Pelargonium, a significant improvement in the pot media quality (Alvarez *et al*., 2017). It has been reported that vermicompost at a rate of 6 t/ha produced greatest pH decrease from 9.51 to 8.41, highest reduction in electrical conductivity, increase in organic carbon, greatest increase in available nitrogen, greatest reduction in sodicity (Ansari, 2008).

Increased bioavailability of phosphorus in the soil was observed with benefits to plant growth in potato cropping resulting from organic matter applied as vermicompost, which also affected soil nitrogen mineralization (Ansari, 2008). The soil fertility improvement reported with the use of vermicompost fits well into an IPM strategy by guaranteeing crop-stand health and conferring increased pest load tolerance. However, this effect needs to be evaluated in pest management and also when applied in combination with one or more other approaches.

According to Carmen *et al*. (2006), vermicompost treatments in tomato resulted in significantly greater seedling height, and with significantly higher number of leaves at 85 days

after emergence when compared to those treated to application of urea and the control treatment. It also significantly increased all production variables studied. Physical-chemical evaluations showed that the vermicomposts had higher content of nitrates and calcium and magnesium, and it doubled the organic matter content over the control. These observations indicate possibility of conferring sufficient plant health to give pest tolerance to the host plants.

2.4.3 Vermicompost and Crop Pest Suppression

Organic soil amendments provide an option for the replacement of inorganic fertilizers, pesticides and fungicides. Successful and eco-friendly management of crop diseases and pests can be realized with minimal risk to human health and the environment, besides resulting in produce that is free of chemical residues, according to a review by Yatoo *et al*. (2021). Vermicomposts protect plants against various pests and diseases by suppression, repellence effects, induced biological resistance in plants or by pesticidal action (Al-Dahmani *et al.,* 2003). Induced biological resistance in plants is conferred by the presence of some antibiotics and actinomycetes which enhance resistance against pest and diseases and these significantly reduced pesticide sprays where earthworms and vermicompost were used (Suhane, 2007). Some hard-bodied pests are repelled (Anonymous, 2001) with 20% and 40% vermicompost in media producing significant decrease in aphids, bugs, mealy bug and spider mite populations, and reduction in plant damage as observed on tomato, pepper and cabbage trials (Edwards & Arancon, 2004a) due to effects of chitinase enzymes produced by earthworms which digest the insect cuticles (Munroe, 2007). Suppression of arthropod pests by vermicompost applications has also been reported for TSSM (Arancon *et al.,* 2007; Yardim *et al*., 2006) and hence the need to test it on statice and other crops in order to develop crop specific recommendations.

Edwards *et al*. (2009) reported that aqueous vermicompost extracts used as weekly root media drench suppressed spider mites dramatically, significantly and consistently reducing overall pest infestation and damage on tomato and cucumber. They further reported that when applied at a rate of 20%, the aqueous extract stopped virtually all pest infestations. The obtained results suggest that vermicompost extract treatments made both tomatoes and cucumber plants unattractive even at 5% extract hosts to the three pest species. They also observed decreased pest reproduction rates for the three species. Higher application rates caused the pests to either leave the plants or die with overall pest numbers on the crops decreasing significantly with time in at the higher rates. The mechanisms for these effects are not clear though there is presupposition

that soluble phenolics in vermicompost could be responsible. There is need to evaluate this effect on more crops and under different growing environments for suitability.

In combined treatments, Suryawana and Reyes (2006) reported that vermicomposts used in combination with reflective plastic mulch (RPM) significantly reduced population of pea leafminer (*Liriomyza huidobrensis* Blanchard) and mines. It has also been observed that soil amendment with vermicompost, alone or as part of an ICM program, apparently reduced the need for synthetic pesticide application to control the caterpillars *Helicoverpa zea* and *Pieris rapae* and the aphids *Myzus persicae* and *Brevicorryne brassici* on cabbage. The technology, being environmentally-friendly, can easily fit into pest management programs. Resistance mediated by vermicompost soil amendment apparently had no negative effect on the tri-trophic interaction when tested against the *Helicoverpa zea* parasitoid *Cotesia marginiventris* in cabbage plants. However, this should be evaluated with different host-parasitoid systems. The resistance observed in specialist *P. rapae* was attributed to antibiosis (Little *et al*., 2011).

When applied on impatiens or patience-plant (*Impatiens wallerana* J.D. Hook), obtained results suggest importance of vermicompost both as a growth promoter and to some extent as a suppressor of *Rhizoctonia solani* Kühn damping-off and root rot disease, especially when used in the initial phases of plant production (Asciutto *et al*., 2006). Similarly, small applications of commercial vermicompost on crops suppressed soil-borne fungal diseases such as *Pythium spp*. on cucumber, *Rhizoctonia spp*. on radishes, by *Verticillium spp*. on strawberries, as well as *Phomopsis spp*. and *Sphaerotheca fulginae* on grapes. It also suppressed plant parasitic nematodes in pepper, tomatoes, strawberries and grapes by the high levels of beneficial flora in vermicompost which would outcompete plant pathogens for available food resources and also block their access to plant roots by occupying all available sites. Pathogen suppression disappears with vermicompost sterilization suggesting involvement of microbial antagonism in disease suppression (Edwards & Arancon, 2004b). Aqueous vermicompost also produced 50% decrease the incidence of *Phytopthora infestans* in tomatoes relative to the control treatment (Zaller, 2006). Suppression of plant parasitic nematodes was reported with vermicompost application in fields at low rates, or as an alternative constituent in plant root media in greenhouses (Arancon *et al*., 2002). By this effect, vermicompost promises seedling health and enhanced plant capacity to tolerate arthropod pest incidence.

2.5 Bioslurry production

Bioslurry refers to the organic manure which is flowable effluent of anaerobic microbial bio-digestion of organic substrates. Unlike composting, this is an exclusively microbial process with no higher organism involved. However, anaerobic digestion is of widespread occurrence in nature in the guts of ruminants as other animals, as well as in moors, paddy fields and other natural anaerobic environments. Biogas and bioslurry result from anaerobic fermentation (Bonten *et al.,* 2014).

The bio-digestion process follows four major and distinct steps in sequence as follows. Hydrolysis of organic polymers to monomers such as sugars, fatty acids and amino acids, a rate limiting step of the process. This is followed by acidogenesis, the monomers are converted into volatile fatty acids, alcohols, hydrogen, ammonia and carbon dioxide. The third step is acetogenesis, the volatile fatty acids and alcohols are converted into acetate, hydrogen and carbon dioxide. The fourth step is methanogenesis, the conversion of acetate, hydrogen and carbon dioxide by methanogenic bacteria into methane and carbon dioxide (Angenent & Wrenn, 2008; Gijzen, 1987; Wilkie, 2008). During the bio-digestion 25% to 30% of the substrate organic matter converts into biogas while the rest becomes bioslurry rich in both macro and micro nutrients (Thu, 2007). The anaerobic bio-digestion has sterilizing effect on pathogenic bacteria such *Escherichia coli* and *Salmonella spp.,* while even when these bacteria and *Listeria spp.* are introduced with bioslurry or manure application, their populations in the soil tend to reduce to the preapplication levels within three months (Goberna *et al*., 2011).

2.5.1 Bioslurry Utilization as a Fertilizer in Crop Production

Bioslurry resulting from the anaerobic bio digestion of organic matter is good quality organic manure (Islam, 2006) which is safe because its bacterial parameters for hygiene quality are similar to or even better than for fresh organic manure (Bonetta *et al.*, 2011). In a review of literature, Bonten *et al*. (2014) conclude that bioslurry as a fertilizer is richer in readily available plant nutrients, especially nitrogen as $NH4^{+}$, when compared to other organic manures and results in immediate plant nutrition effect. According to Bustamante *et al.* (2012), volatilization and leaching related N losses during storage, handling and application tend to be greater for bioslurry than for the other organic manures. As much as 50% in N losses were observed in a single month for uncovered bioslurry while N losses of 15 – 27% were reported during composting of the solid fraction of biogas digestate.

Bioslurry supplies plant nutrients while improving soil physical and biological fertility by increased microbial population enhancing potential for quality crop (Wong *et al.,* 1999). It improves yields in crops including maize and cabbage (Karki, 2001), and in okra (Shahabz, 2011). Carrots treated with bioslurry at a rate of 7.8 t/ha increased shoot and root biomass at 18.7 – 21.2% and 18.2 – 19.7% respectively as well as increased root volume at 21 – 29.3%. Bioslurry also generally increased total fresh root yield with increase in application rates from 2.6 – 5.2 t/ha (Jeptoo *et al*., 2012)**.** When bioslurry was applied in combination with farm yard manure resulted in significantly enhanced tomato fruit size (Renuka & Ravishankar, 1998). Nour-Eldin & Sholla (2015) reported 120 – 150% increase in bean yields with the application of liquid manure treatments when compared with the control.

2.5.2 Bioslurry Utilization in Crop Pest Management

Recent decades have been characterized by increased pesticide usage frequency to control crop pests, which has led to the destruction of natural enemies, pest resurgence and pesticide residues on produce (Smitha & Giraddi, 2006). Other consequences include insecticide resistance, environmental pollution and upsetting of natural ecosystem (Singh & Kumar, 1998). All these necessitate adoption of alternative approaches including cultural practices for crop management including use of organic manures. In this regard, Nour-Eldin and Sholla (2015) reported significantly reduced TSSM infestation of green bean plants (93 – 95% reduction in mite population per leaf) with the application of bioslurry as fermented liquid animal manure in combination with neem when compared with the control treatment. The fermented liquid animal manure, when applied alone, resulted in 87% mite reduction. These observations compared favorably with the mite reduction under the acaricide Ortus (91 – 95%). The liquid manure treatments also resulted in increased bean yields of up to 120 – 150% when compared with the control. Shen (1997), asserts that beside enhanced plant growth, the use of bioslurry from organic waste improves stress-resistance, and suppresses some diseases, aphids and mites.

Several studies tend to affirm the suitability of bioslurry as fertilizer with plant protection properties. However, its specific suitability to statice needs to be investigated. When compared to the inorganic fertilizers, the organic manures contain plant nutrients in small quantities. However, they supply growth promoters such as enzymes and hormones, besides plant nutrients, hence are superior for improvement of soil fertility and productivity (Bhuma, 2001).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Site Description

The study was carried out in the laboratory and Horticulture Research and Teaching field at Egerton University's Njoro campus in Kenya. The site lies at a latitude of 0° 23′ South and longitude of 35° 35′ East in the Lower Highland III Agroecological Zone with an altitude of approximately 2,238 m above mean sea level. The temperature range of the area is 14.9-21.9°C with mean annual rainfall range of 850 to 1,100 mm (Jaetzold and Schmidt, 1983). The soils are predominantly vitric mollic andosols (Kinyanjui, 1979).

3.2 Soil Media Preparation

The garden soil used in potting media for this experiment was obtained from Egerton University's Horticulture Teaching and Research Farm, Field Three. Top soil was excavated from a designated site to a depth of 0-15 cm. The excavated soil was worked to fine tilth and mixed thoroughly by shoveling the heap to one side and back three times.

3.2.1 Vermicompost Preparation

The different vermicomposting substrates were collected within the campus at Egerton University. Food waste was collected from the various campus kitchens including the student mess and the Agriculture Resource Centre Hotel. Bones and egg shells were carefully removed from the kitchen waste. Mowed lawn grass was gathered from the various campus lawns while garden weed biomass was gathered from Horticulture Teaching and Research Farm.

The various materials were put into their respective vermicomposting bins and allowed to decompose for a month after which the red wriggler earthworms (*Eisenia fetida*) were introduced into the decomposed waste materials as described by Munroe (2007). Watering was done at three-day intervals to keep the substrate moderately moist and avoiding waterlogging. The worms fed on the substrates and their excreta known as worm casts was eventually harvested after vermicompost. Each of the different vermicompost was harvested from the respective bins after 90 days when all the substrate had been converted to worm casts.

3.2.2 Bioslurry Preparation

The bioslurry used in the experiment was obtained from Egerton University's Tatton Agricultural Park in Njoro, Kenya. It was taken in containers as a flowable effluent from the

biogas digester.

3.2.3 Soil, Vermicomposts and Bioslurry Analyses

Samples of the garden soil, the different vermicomposts and bioslurry used in growing media in the present study were analyzed at Kenya Agriculture and Livestock Research Organization's soil chemistry laboratories at Njoro, to establish their characteristics.

i. Determination of pH

The pH was measured using pH-meter (digital ion analyzer). Air dried samples weighing 50g for each of the different growing medium components were taken into separate 100-ml glass beakers. Into each beaker, 50 ml distilled water was added using a graduated cylinder and mixed thoroughly before being allowed to stand for 30 min. The resulting suspensions were stirred after every10 min. The pH of the different suspensions was determined according to the procedure described by Okalebo *et al.* (2002).

ii. Determination of bulk density and water holding capacity

The bulk density and water holding capacity of the garden soil and the different vermicomposts were determined according to the procedures described by Okalebo *et al.* (2002).

iii. Determination of total organic carbon

For each of the growing medium components, one gram of air-dried growing medium was placed into separate 500-ml beakers. Ten milliliters of 1 N potassium dichromate solution and 20 ml concentrated sulphuric acid was added in each beaker and swirled to mix the suspension. 20 ml of distilled water was added along with 10 ml concentrated orthophosphoric acid into each beaker after 30 minutes and the mixtures were then allowed to cool. Ten drops of diphenylamine indicator were added. Each of the solutions was then titrated with 0.50 M ferrous ammonium sulphate solution and the reading was recorded upon colour change from violet blue to green. Organic carbon was determined according to the method described by Walkley and Black (1934).

iv. Determination of nitrogen content (Kjeldahl method)

Nitrogen content was determined using Kjeldahl method (1883) as follows. A sample weighing 0.3g was digested in a digestion tube using a digestion mixture comprising of HCl, HNO_3, Se and $CuSO_4$. The heating block temperature was maintained at 360°C for 2 hours. The sample was then allowed to cool before transferring into a 50 ml volumetric flask and the volume adjusted to the mark. It was then allowed to settle and 5 ml of the aliquot was put into the

distillation bottle where 10ml of 40% NaOH was added. It was then steam distilled into 5ml 1% Boric acid containing 4 drops of mixed indicator for 2 min, from the time the indicator turned green. The distillate was titrated using HCl with the end point being reached when the indicator turned green through grey to definite pink. A blank experiment was then prepared as described by Kirk (1950).

v. Determination of nitrate -N

The nitrate content was determined by calorimetric method as described in Okalebo *et al*. (2002). A set of six clean well labeled 100 ml volumetric flasks was set up into which 0, 2.0, 4.0, 6.0, 8.0 and 10.0 ml of the standard solution (50 μg ml^{-1}) were separately transferred. These were the working standards and contained 0, 2, 4, 6, 8, and 10 μg NO_3 -N ml^{-1}. Each volumetric flask was filled to the 100 ml mark with 0.5 M potassium sulphate. 0.5 ml of the sample extract, blanks and the standard series K_2SO_4 soil were transferred each into suitably marked test tube. 1.0 ml of salicylic acid was added to each test tube and mixed well and left to stand for 30 min. 10 ml 4M sodium hydroxide was added to each test tube, mixed well and left for 1 hour to allow development of full yellow colour. The colour was stable for the day. The absorbency was measured at wavelength 419 nm. A calibration curve was plotted and the absorbency calculated for each particular standard in the series, read off the value of the samples and the blanks. The concentration of nitrate N was calculated using the following formula;

$$NO_3\text{-N (μg kg-1)} = \frac{(a-b) \times v \times MCF \times 1000}{w}$$

where a = concentration of NO_3^+-N in the solution, b = concentration of NO_3^+-N the blank, v = volume of the extract; w = weight of the fresh soil; MCF = moisture correction factor.

The aliquot taken for both the standards and the unknown are the same therefore no multiplication factor is required within the calculations.

vi. Determination of total phosphorous

Total phosphorus in the substrate samples was determined by the method described by Juma *et al.* (2018). A sample of 0.3g for each of the growing medium components was separately digested in digestion tubes using a digestion mixture comprising of HCl, HNO_3, Se and $CuSO_4$. Temperatures in the heating block were kept at 360°C for 2 hours and then left to cool before transferring into a separate 50 ml volumetric flask and volume adjusted to the mark. Five ml of

each of the aliquots was transferred into the sample bottles with 1 ml of developing colour solution (ammonium vanadate and ammonium molybdate in the ratio of 1:1). The samples were made to stand for 30 minutes after which they were transferred to cuvettes. Readings of atomic absorbance were taken using a spectrophotometer at λmax=430 nm. Calibration curve was done using laboratory certified standards containing 0, 0.2, 0.4, 0.6, 0.8 1.0 and 1.2 ppm P respectively.

vii. Determination of potassium

A sample weighing 0.3 g, for each of the growing medium components, was separately digested in digestion tubes using a mixture comprising HCl, HNO_3, HF and H_3BO_3. The temperature in the block was maintained at 360°C for 2 hours. Thereafter the samples were cooled, transferred to 50ml volumetric flasks and volume made to the mark. Calibration was done for potassium using certified standards. Samples were analyzed by atomic absorption spectrophotometer (AAS), Varian spectra AA10 AAS machine. The characteristics of the various growing medium components, used in the present study, are as presented below.

viii. Determination of calcium and magnesium

Determination of calcium and magnesium content was done following the procedures as described by Mehlich (1953) for the two elements respectively.

3.2.4 Characteristics of Soil, Different Vermicomposts and Bioslurry

i. Soil characteristics

The characteristics of the garden soil sample taken for analysis were established as presented in Table 1.

Table 1. Characteristics of garden soil

Parameter	
Final pH	5.84
Water holding capacity (%)	65.3
Total organic carbon (%)	1.72%
Total N (%)	0.25%
Available P (%)	0.18%
Exchangeable K (mg kg^{-1})	1.1

ii. Characteristics of the different vermicomposts

The characteristics of the different vermicomposts samples were established as given in

Table 2.

Table 2. Characteristics of the different vermicomposts

Parameter	Kitchen waste vermicompost (V_1)		Lawn grass vermicompost (V_2)		Weed biomass vermicompost (V_3)	
	Trial 1	Trial 2	Trial 1	Trial 2	Trial 1	Trial 2
Final pH	6.9	7.2	6.8	6.9	7.2	7.4
Water holding capacity %	79.2	78.8	78.1	77.8	78.6	78.2
Total organic carbon %	13.1	13.3	15.7	16.5	12.8	13.2
Nitrate (mg/kg)	28.24	27.98	21.62	20.14	25.44	23.8
Phosphate (mg/kg)	33.42	33.28	39.42	39.14	26.42	25.74
Total potassium (mg/kg)	19.6	20.1	20.2	19.2	22.6	22.8

iii. Bioslurry Characteristics

The characteristics of the bioslurry sample were established were as given in Table 3.

Table 3. Characteristics of bioslurry

Parameter	Trial 1	Trial 2
pH	7.86	7.94
Nitrogen (%)	0.25	0.18
Phosphorus (mg kg-1)	4.57	5.96
Potassium (mg kg-1)	78.50	72.43
Calcium (mg kg-1)	3.97	3.78
Magnesium (mg kg-1)	19.84	19.79
Bulk density (g cm^{-3})	1.04	1.02

3.3 Plant materials

Seedlings of statice were obtained from Limuru Farm for use in the present study. They were lifted from the nursery late in the evening and transported to Egerton University in the night to minimize withering and the subsequent transplanting shock. The nursery bed was thoroughly wetted before lifting the seedlings. Nearly uniform sized seedlings were lifted with soil around their roots and placed in polythene bags containing moisture.

3.4 Mass rearing of TSSM

The TSSM used in the study were obtained from naturally infested common bean plants growing within the Egerton University Horticulture Teaching and Research Farm, that had not

been sprayed with any pesticide. Rearing was done on 3-week-old bean plants grown in plastic pots filled with peat moss and soil mixed at a ratio of 2:1 and cultured in the greenhouse. The rearing procedure was adapted from that described by Hoffman *et al*. (2008). Individual mites were then collected and transferred for bioassay studies using a fine hair brush. The mites were transferred onto fresh bean leaves using a fine soft brush. The fresh bean leaves were then placed in 5L clear plastic buckets with tight fitting lids to prevent the mites escaping. The buckets were quickly transported to the Horticulture Teaching and Research laboratory for use in the mite repellence bioassay.

3.5 Experimental design and treatment application

The various studies were conducted to determine how the different treatments of vermicomposts and bioslurry affected the twospotted spider mite (TSSM) population, growth, yield and postharvest quality of statice during two separate experimental trials.

The various treatments applied for the study of the main and combined effects were as presented in the following tables.

Table 4. Treatments factors applied in the study of main effects

Vermicompost (V)		**Bioslurry (B)**	
Vermicompost type	**Notation**	**Bioslurry type**	**Notation**
Untreated	V_0	Untreated	B_0
Kitchen waste vermicompost*	V_1	Bioslurry at 7.8 t/ha	B_1
Lawn grass vermicompost*	V_2		
Weed biomass vermicompost*	V_3		

Table 5. Treatment factor combinations applied in the study of combined effects

Combination	Treatment Description
V_0B_0	Untreated (Soil with neither bioslurry nor vermicompost).
V_1B_0	Soil + 40% by volume kitchen waste vermicompost
V_2B_0	Soil + 40% by volume lawn grass vermicompost
V_3B_0	Soil + 40% by volume weed biomass vermicompost
V_0B_1	Soil + bioslurry at a rate of 7.8 t/ha.
V_1B_1	Soil + 40% by volume kitchen waste vermicompost + 7.8 t/ha bioslurry.
V_2B_1	Soil + 40% by volume lawn grass vermicompost + 7.8 t/ha bioslurry.
V_3B_1	Soil + 40% by volume weed biomass vermicompost + 7.8 t/ha bioslurry.

Key: V_1=kitchen waste vermicompost; V_2=lawn grass vermicompost; V_3=weed biomass vermicompost; V_0=no vermicompost; B_1=bioslurry; B_0=no bioslurry.

The statice seedlings were established in the field experimental plots by transplanting them singly into potting bags measuring 30 cm diameter and 40 cm depth. The potting plastic bags were filled to three quarters depth with appropriate potting media as per the treatments and watered. The seedlings were then transplanted at sufficient depth to cover all the roots. The potting bags were placed to ensure spacing of at least 30 cm inter-row and 15 cm intra-row, giving a plant population of 8-12 plants per square meter with each bag holding one plant. A support system was constructed using wooden posts and laterals supported by two layers of wire running along the length of the plots to encourage straight flower stem growth.

The first few early flowering stems were pinched back to ensure uniform growth and development of basal rosette. Excessive pinching was avoided so as not to delay the crop. Four stems were randomly tagged in each plot to measure the subsequent postharvest quality parameters. Weeding was done by hand pulling when necessary to eliminate weed competition. Irrigation was done on need basis to supply the crop water requirement at all growth stages, avoiding overhead irrigation after flowering to avoid incidence of grey mold (*Botrytis cinerea*). Pest and disease scouting were done before decisions on their control.

3.5.1 The Effect of Different Vermicompost and Bioslurry on TSSM

The repellence effect of different vermicomposts and bioslurry on the TSSM was studied at the Egerton University Horticulture Teaching and Research laboratory using choice feeding arena. The bioassay procedure was adapted from that described by Roberson *et al*. (2007). A working space was prepared on a laboratory bench by sticking white manila paper onto the bench using masking tape so that it was as flat as possible on bench top. A circle of 30 cm radius was drawn by pencil on the manila paper. Clear odourless petroleum jelly was smeared along the inside of the arc of the circle to create a greasy sticky circular band of 20 cm radius. Three flower stems from each treatment in the field production experiment were harvested 30 cm long and when at least 50% of the inflorescence had opened and appropriately tagged according to the treatment.

Statice inflorescences were prepared by trimming the flower stems from each treatment to retain lengths of 10 cm from the apical end. These were then placed in a circular arrangement, equidistantly along the greasy band to create a bioassay of choice-feeding arena for the TSSM. The inflorescences were placed to have their apical ends on the arc of the greasy band proximal to the center of the arena. In order to give equal chance for positional placement in the laboratory set up, the placement of specimens from the different blocks and treatments in the field production experiment followed the procedure for a completely randomized design. A petri dish containing approximately 100 mites, with its cover in place was placed at the center of the arena. The mites were released at the center of the arena by removing the cover of the petri dish. The mites were allowed to wander within the arena for 30 minutes and move to the inflorescences.

The TSSM repellence study was repeated in two consecutive seasons using plant materials produced during the respective seasons. In each season, the bioassay experiment was run three times and the mite counts from each run was recorded and used to compute mean counts for the different treatments.

3.5.2 Effect of Different Vermicompost and Bioslurry on Growth and Yield of Statice

The first experiment was established in February 2013 and ended in June 2013 while the second was established in June 2013 and ended in November 2013. The study was conducted using a 2×4 factorial arrangement, laid out in a randomized complete block design (RCBD) with four blocks. Three different vermicomposts prepared from kitchen waste, mowed lawn grass and weed biomass were mixed at a rate of 40% by volume with garden soil and tested against the

untreated control.

The treatments included 4 levels of vermicomposts applied as 60% garden soil with 40% kitchen waste vermicompost (V_1), 60% garden soil with 40% mowed lawn grass vermicompost, 60% garden soil with 40% garden weed biomass vermicompost (V_3) and 100% garden soil (V_0) as the control. The 2 levels of Bioslurry (B_1) and untreated control (B_0). The bioslurry was applied at 7.8 t/ha (Jeptoo *et al*., 2012) as a drench in four equal splits. Each split was directly drenched into the potted growing media (either garden soil alone or in mixture with vermicompost) starting at 35 DAT and subsequently repeated at four intervals of 15 days.

3.5.3 The Effect of Different Vermicompost and Bioslurry on Postharvest Quality of Statice

The study of statice postharvest quality was conducted on a laboratory bench in the horticulture teaching and research laboratory of Egerton University. The studied parameters were water uptake during days in the vase (DIV) and vase life of statice. Flower stems for the postharvest experiment were obtained from the tagged plants (see 3.5.1 above). The stems were harvested when at least 30 cm long and when 85% of the inflorescence have opened and tagged according to the treatment applied during field production. Harvesting and handling were done as described by MOA (2003). Each stem was trimmed under water to retain a uniform length of 30 cm from the point of cut to the apex. These stems were quickly transferred and held in 500 ml plastic flower vases filled with tap water to approximately 80% and the level marked on the vases with indelible ink. The plastic flower vases were arranged according to experimental treatments. The flower vases were placed on the laboratory in 2×4 factorial arrangement in a completely randomized design, and positioning for each treatment was determined by the drawing of lots with replacement.

3.6 Data collection

3.6.1 The Effect of Different Vermicomposts and Bioslurry on TSSM

Data was collected by recording the mite count on each of the inflorescences 30 minutes after release as a measure of mite repellence or feeding preference. Each inflorescence was removed from its position in the choice-feeding arena and quickly placed in an empty clear commercially available 5L plastic bucket and the lid was tightly replaced. The bag was immediately closed tightly and placed away from the arena. At the same time, a colourless transparent plastic of size A5 was immediately placed at the position of the removed

inflorescence and gently pressed so that any mites present would stick onto the greasy surface below.

The mites found stuck at the position of a particular inflorescence in the arena were counted under a magnifying glass (of ×15 magnification). After 5 minutes, each inflorescence was removed from the clear plastic bucket and strongly tapped above a white A3 manilla paper on a laboratory bench. Mites falling onto the manilla paper were counted and added to the corresponding mite count recorded from the treatment's position on the feeding arena. Mites present in the clear bucket were also counted and added to the corresponding treatment's mite counts from the arena and the manilla paper. Mites in the arena that were not associated to any of the inflorescences were also counted and recorded. These were used to establish the total number of mites in the bioassay, for calculation of the percentages of observed mite responses.

3.6.2 Effect of Different Vermicompost and Bioslurry on Growth and Yield of Statice

The statice growth and yield parameters studied were seedling takeoff, number of stems produced per plant, the number of days to flowering after initial pinching, stem length at 60 days after transplanting (DAT), the number of harvested flower stems and the fresh weight of flower stems. The procedure used in the study of growth and yield parameters was adapted from Kassa and Ibrahim (2013). The treatment effects for these parameters were determined as follows.

i. Seedling takeoff

Seedling takeoff was determined by counting the number of seedlings in each experimental unit at 14 and 21 DAT and expressed as a percentage.

ii. Number of days to 50% flowering

The number of days from the date of transplanting to 50% flowering in each experimental unit was recorded and used to calculate the effect of the treatments on the average duration to flowering of statice.

iii. Number of flower stems produced per plant

The number of stems produced per plant in each experimental unit were counted and the number used to estimate the treatment effects on statice growth and yield potential.

iv. Stem length at 60 DAT

The effect of the treatments on the flower stem lengths of statice at 60 DAT was measured from the point of cut to the apex.

v. Fresh weight of flower stems

A total of 10 flower stems were obtained from each of experimental unit. The flower stems were trimmed to a uniform length of 30 cm from the point of cut to the apical end. The flower stems from each experimental unit were separately weighed to calculate the effect of treatment on the mean fresh weight of statice.

3.6.3 Effect of Different Vermicompost and Bioslurry on Postharvest Quality of Statice

i. Water uptake during DIV

The procedure for study of postharvest water uptake in statice was adapted from that described by Buys and Cours (1981). Water uptake was observed and recorded at 3-day intervals starting from 3 DIV to 15 DIV. Water uptake at each interval was determined as the amount of water added using a measuring cylinder to top up to the initial level.

ii. Vase life of statice.

The procedure for the study of statice vase life was adapted from that described by Buys and Cours (1981). The treatment effect on vase life in statice was measured by the number of days during which flower stems retained freshness while in the vase before senescence. The number of days to senescence for individual flower stems in a vase were recorded and used to determine the mean vase life. The senescence symptoms observed were bent neck, leaf yellowing and wilting.

3.7 Data Analysis

Analysis of the data obtained was done by analysis of variance (ANOVA) and significant means were separated by Tukey's test at 5% level of significance. Data analysis was done using JMP (Version 10).

3.7.1 Statistical Models

The 4×2 factorial field experiment for production of statice was laid out in a completely randomized block design (RCBD). The laboratory experiments for the study of postharvest qualities of statice, and the bioassay for the study of treatment repellency effect on the twospotted spider mite were laid out in a completely randomized design (CRD).

i. Statistical model for the RCBD experiment.

The statistical model for the RCBD used for the production experiment was as below; -

$Y_{ijkl} = \mu + \beta_i + \alpha_j + \gamma_k + T_l + \alpha\gamma_{jk} + \alpha T_{jl} + \gamma T_{kl} + \alpha\gamma T_{jkl} + \varepsilon_{ijkl}$; with i = 1 …4, j = 1 …4, k = 1… 2, l = 1….2

Where Y_{ijkl} = Statice response

μ = overall mean which is a constant with all expected observation,

β_i = the effect of the i^{th} block

α_j = the effect of the j^{th} vermicompost

γ_k = the effect of the k^{th} bioslurry

T_l = the effect of the l^{th} season

$\alpha\gamma_{jk}$ = interaction effect of the j^{th} vermicompost and the k^{th} bioslurry

αT_{jl} = interaction effect of j^{th} vermicompost and the l^{th} season

γT_{kl} = interaction effect of the k^{th} bioslurry and the l^{th} season

$\alpha\gamma T_{jkl}$ = interaction effect the j^{th} vermicompost, the k^{th} bioslurry and the l^{th} season

ε_{ijk} = the random error component distributed normally N (0, σ^2)

ii. Statistical model for the CRD experiment.

The statistical model for the CRD experiment used for the study of treatment effect on populations of the two spotted spider mites was as given below; -

$Y_{ijkl} = \mu + \beta_i + \alpha_j + \gamma_k + T_l + \alpha\gamma_{jk} + \alpha T_{jl} + \gamma T_{kl} + \alpha\gamma T_{jkl} + \varepsilon_{ijkl}$; with i = 1 …4, j = 1 …2, k = 1… 2, l = 1….4

Where Y_{ijkl} = Statice response effect on populations of the two spotted spider mites

μ = overall mean which is a constant with all expected observation,

β_i = the effect of the i^{th} vermicompost

α_j = the effect of the j^{th} bioslurry

γ_k = the effect of the k^{th} season

$\beta\alpha_{ij}$ = interaction effect of the i^{th} vermicompost and the j^{th} bioslurry

$\beta\gamma_{ik}$ = interaction effect of i^{th} vermicompost and the k^{th} season

$\alpha\gamma_{jk}$ = interaction effect of the j^{th} bioslurry and the k^{th} season

$\beta\alpha\gamma_{ijk}$= interaction effect the i^{th} vermicompost, the j^{th} bioslurry and the k^{th} season

ε_{ijkl} = the random error component distributed normally N (0, σ^2)

CHAPTER FOUR

RESULTS

4.1 The effect of different vermicomposts and bioslurry on the repellence of twospotted spider mite (TSSM)

The results from the present study show that growth, yield and postharvest quality parameters in statice were significantly affected by the application of different vermicompost and bioslurry treatments as well as their various combinations when compared to the untreated control at P≤0.05. The same treatments also showed significant repellence to the twospotted spider mite in a bioassay of statice inflorescences arranged in a choice feeding arena.

4.1.1 The effect of different vermicomposts on repellence of TSSM in statice.

Application of kitchen waste vermicompost (V_1), mowed lawn grass vermicompost (V_2) and weed biomass vermicompost (V_3) on statice at a rate of 40% by volume mixed with garden soil all significantly affected the feeding preference of TSSM in a feeding arena bioassay when compared to the untreated control at $P \leq 0.05$ (Table 6). In a feeding arena bioassay, statice inflorescences prom plots treated to V_1, V_2 and V_3 had significantly lower mean mite counts (6.1 to 8.9 mites) and lower mean percentages (5.1% to 7.4%) of TSSM on or at the particular statice inflorescence when compared to inflorescences obtained from the control (11.2 mites, and 9.3%). Among the vermicompost treatments, the lowest mean mite count (6.1 mites) and percentage (5.1%) was observed on inflorescences obtained from V_3, followed by V_1 and V_2 (8.9 and 8.5 mites respectively), and mite percentages (7.4% and 7.1% respectively).

Table 6: The effect of different vermicomposts on repellence of TSSM in statice

Vermicompost type	No. of TSSM	% of TSSM
V_0	11.2 a	9.3 a
V_1	8.9 b	7.4 b
V_2	8.5 b	7.1 b
V_3	6.1 c	5.1 c
MSD	1.2934	1.5604
CV	25.1	20.3

Means followed by the same letter within a parameter are not significantly different according to Tukey's test at $P \leq 0.05$. Key: V_0- Untreated control, V_1- Soil with 40% kitchen waste vermicompost, V_2- Soil with 40% mowed lawn grass vermicompost, and V_3- Soil with 40% weed biomass vermicompost. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

4.1.2 The effect of bioslurry on repellence of TSSM in statice.

Application of bioslurry at a rate of 7.8 t/ha (B_1) on statice significantly affected the feeding preference of TSSM in a feeding arena bioassay, when compared to the untreated control (B_0) at $P \leq 0.05$ (Table 7). A significantly lower mean mite count (6.7 mites) and mean percentage (5.6%), respectively were observed on statice inflorescences obtained from plots treated to bioslurry (B_1) when compared to mite count (11.2) and percentage (9.3%) observed on inflorescences obtained from the untreated control plots (B_0).

Table 7. The effect of bioslurry on repellence of TSSM in statice

Bioslurry type	No. of TSSM	% of TSSM
B_0	11.2 a	9.3 a
B_1	6.7 b	5.6 b
MSD	0.8336	0.691
CV	20.4	23.9

Means followed by the same letter within a parameter and a main effect are not significantly different according to Tukey's test at $P \leq 0.05$. Key: B_0- Untreated control, B_1- Soil with bioslurry at a rate of 7.8 t/ha. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

4.1.3 The combined effect of different vermicompost and bioslurry on repellence of the TSSM in statice

Combined treatments of different vermicomposts at a rate of 40% by volume mixed in garden soil with bioslurry at a rate of 7.8 t/ha had significant repellent effect on TSSM in statice when compared to the untreated control at $P \leq 0.05$ (Table 8). In a choice feeding arena bioassay, combined application of kitchen waste vermicompost with bioslurry ($V_1 \times B_1$) mowed lawn grass vermicompost with bioslurry ($V_2 \times B_1$) and weed biomass vermicompost with bioslurry ($V_3 \times B_1$) all significantly reduced the mean mite counts on statice inflorescences (5.2 to 10.4 mites) and mean mite percentages (4.5 to 8.6%) found at or on statice inflorescences, when compared with the untreated control ($V_0 \times B_0$) with a mean of 11.2 mites and 9.3%. Approximately 50% of mites introduced in bioassay feeding arena did not move into or close to any inflorescence.

All treatment applications containing the organic manures, singly or in combination, resulted in significantly lowered mean mite counts (5.2 to 10.4) and mean mite percentages (4.4 to 9.3) when compared with observations on inflorescences obtained from the untreated control (11.2 mites, and 9.3%). On the other hand, the lowest significant mean mite counts and percentages were observed with the inflorescences obtained from plots treated to $V_1 \times B_1$ and $V_3 \times B_1$ treatments (5.2 and 5.5 mites representing 4.4 % and 4.5% respectively) when compared with other treatments containing organic manure with mean mites counts (ranging from 6.1 to 10.4 mites) and percentages (ranging from 5.1 to 8.6). The observed mean mite counts and mean mite percentages on inflorescences from the control treatment were higher by more than 100% over observations from both $V_1 \times B_1$ and $V_3 \times B_1$, suggesting some enhanced TSSM repellence effect from the two treatment combinations.

Table 8. Two-way interaction effect of vermicompost and bioslurry on twospotted spider mites on statice

Treatment	Number	Percentage
$V_0 \times B_0$	11.2 a	9.3 a
$V_1 \times B_0$	8.9 c	7.4 c
$V_2 \times B_0$	8.5 c	7.1 c
$V_3 \times B_0$	6.1 d	5.1 d
$V_0 \times B_1$	6.7 d	5.6 d
$V_1 \times B_1$	5.2 e	4.4 e
$V_2 \times B_1$	10.4 b	8.6 b
$V_3 \times B_1$	5.5 de	4.5 e
MSD	0.634802	0.508929
CV	22.9	22.6

Means followed by the same letter within a parameter are not significantly different according to Tukey's test at $P \leq 0.05$. Key: V_0B_0- Untreated control, V_1B_0- Soil with 40% kitchen waste vermicompost, V_2B_0- Soil with 40% mowed lawn grass vermicompost, V_3B_0- Soil with 40% weed biomass vermicompost, V_0B_1- Soil with bioslurry at a rate of 7.8 t/ha, V_1B_1- Soil with 40% kitchen waste vermicompost and 7.8 t/ha bioslurry, V_2B_1- Soil with 40% mowed lawn grass vermicompost and 7.8 t/ha bioslurry, V_3B_1- Soil with 40% weed biomass vermicompost and 7.8 t/ha bioslurry. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

4.1.4 The Interaction Effect of Vermicompost and Bioslurry on TSSM in Statice Production During Season One and Two

In the bioassay experiment, observed mite counts and percentages showed contrasting results with some significant while others were insignificant. There were generally lower mite counts and percentages in the second season when compared to the first season, when analyzed at $P \leq 0.05$ (Table 9). Across both seasons, significantly lower mean mite counts (ranging from 5.5 to 10.5 mites) and percentages (ranging from 4.2 to 9.1%) were observed with all treatments that had the organic manures, when compared with the mean mites count (11.0 to 11.4 mites) and percentage (8.6 to 10.0%) from untreated control.

Table 9. Three-way interaction effect of vermicompost and bioslurry on TSSM on statice production in season one and two

Bioslurry	Vermicompost	Number of mites		Percentage of mites	
		Season 1	Season 2	Season 1	Season 2
B_0	V_0	11.4 [a]	11.0 [ab]	10.0 [a]	8.6 [bc]
	V_1	9.8 [b]	8.0 [c]	9.1 [b]	5.7 [c]
	V_2	9.6 [b]	7.4 [cd]	7.3 [d]	6.9 [d]
	V_3	6.6 [d]	5.6 [e]	5.3 [ef]	4.9 [f]
B_1	V_0	6.9 [d]	6.4 [de]	5.7 [e]	5.5 [ef]
	V_1	5.7 [e]	4.7 [f]	4.7 [fg]	4.1 [g]
	V_2	10.3 [b]	10.5 [b]	9.0 [b]	8.2 [c]
	V_3	5.6 [d]	5.5 [ef]	4.8 [fg]	4.2 [g]
MSD		0.8336		0.6910	
CV		19.1		19.1	

Means followed by the same letter within a parameter are not significantly different according to Tukey's test at $P \leq 0.05$. Key: B_0- Untreated control, B_1- Soil with bioslurry at a rate of 7.8 t/ha, V_0- Soil without vermicompost, V_1- Soil with 40% kitchen waste vermicompost, V_2- Soil with 40% mowed lawn grass vermicompost, and V_3- Soil with 40% weed biomass vermicompost. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

4.2 The effect of different vermicompost and bioslurry treatments on the growth and yield of statice.

The growth and yield parameters studied were seedling takeoff, days to flowering, number of stems produced per plant, flower stem length at 60 days after transplanting (DAT) and fresh weight of flower stems. The results obtained show that except for seedling takeoff, the application of different vermicomposts had a significant effect on all the studied growth and yield parameters at $P \leq 0.05$.

4.2.1 Effect of Different Vermicompost on Growth and Yield of Statice

i. Effect on seedling takeoff

The application of the different vermicomposts had no significant effect on seedling

takeoff in statice at $P \leq 0.05$ (Table 10).

Table 10. Main effect of vermicompost on seedling take off, number of stems, days to first flowering, flower stem length and fresh weight of statice

Vermicompost type	Seedling take-off (no./plot)	Days to first flowering	Stem number (no./plant)	Flower stem length at 60 DAT (cm)	Fresh weight (g/plant)
V_0	0.97 a	12.3 c	22.1 c	40.1 d	12.4 c
V_1	1.02 a	24.4 a	26.2 b	88.3 a	24.9 a
V_2	1.03 a	17.3 b	26.8 b	85.6 b	20.5 b
V_3	1.04 a	17.8 b	29.4 a	77.0 c	20.0 b
MSD	0.0804	1.9004	1.1215	2.5049	1.7186
CV	5.1	11.8	12.7	20.7	25.1

Means followed by the same letter within a parameter are not significantly different according to Tukey's test at $P \leq 0.05$. Key: V_0- Untreated control, V_1- Soil with 40% kitchen waste vermicompost, V_2- Soil with 40% mowed lawn grass vermicompost, and V_3- Soil with 40% weed biomass vermicompost. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

ii. Effect on the number of days to flowering

Application of the different vermicomposts at a rate of 40% by volume mixed with garden soil significantly affected the days to flowering in statice when compared with the control treatment (V_0) at $P \leq 0.05$ (Table 10). Vermicompost regardless of type significantly increased the days to flowering (ranging from 17.8 to 24.4 days) across the treatments when compared to the untreated control (12.3 days). Plots treated to V_1 resulted in the highest significant number of days to flowering (24.4 days), significantly higher than both V_2 and V_3 (17.3 and 17.8 days respectively). Results from the latter two treatments had no significant difference between them.

iii. Effect on the number of stems per plant

Application of vermicompost regardless of the type, at a rate of 40% by volume mixed with garden soil significantly increased the number of stems per plant in statice, when compared

with the control treatment (V_0) at $P \leq 0.05$ (Table 9). Plots treated to V_3 resulted in the highest number of stems per plant (29.4 stems), significantly higher than both V_1 and V_2 (26.2 and 26.8 stems respectively) as well as the untreated (22.1 stems).

iv. Effect on stem length at 60 DAT

Application of vermicompost, regardless of type, significantly affected statice flower stem length at 60 days after transplanting (DAT) when compared with the untreated control (V_0) at $P \leq 0.05$ (Table 10). All the vermicompost treatments significantly increased statice flower stem lengths at 60 DAT (ranging from 77.0 to 88.3) cm when compared to 40.1 cm from the control treatment (V_0). The longest flower stems at 60 DAT (88.3 cm) resulted from plots treated to V_1, significantly higher than V_2 (85.9 cm), which was in turn significantly higher than V_3 (77.0 cm).

v. Effect on fresh weight of flower stems

The fresh weight of statice flower stems was significantly affected by the application of garden soil mixed with 40% kitchen waste vermicompost (V_1), mowed lawn grass vermicompost (V_2) and weed biomass vermicompost (V_3) when compared with the untreated control (V_0) at $P \leq 0.05$. different vermicompost treatments (Table 10). Regardless of type, vermicompost treatments resulted in significantly enhanced fresh weight of flower stems (20.0g to 24.9g) when compared with the control (12.4g). Plots treated to V_1 resulted in the highest fresh weight (24.9g), significantly higher than both V_2 and V_3 (20.5g and 20.0g respectively), which had no significant difference between them.

4.2.2 Main Effect of Bioslurry on Number of Stems, Days to Flowering, Flower Stem Length and Fresh Weight of Statice

i. Effect of bioslurry on the number of days to flowering

The application of bioslurry at a rate of 7.8 t/ha (B_1) increased the number of days to first flowering in statice when compared to the untreated control treatment (B_0) at $P \leq 0.05$ (Table 11). Treatment with B_1 significantly increased the mean number of days to first flowering (19.3 days) when compared to the control (12.3 days). Flowering in statice was delayed by 7 days in plots treated to bioslurry, when compared with the untreated control.

Table 11. Main effect of bioslurry on number of stems, days to flowering, flower stem length and fresh weight of statice

Bioslurry type	Days to flowering (no.)	Stem number (no./plant)	Flower stem length at 60 DAT (cm)	Fresh weight (g/plant)
B_0	12.3 b	22.1 b	40.1 b	12.4 b
B_1	19.3 a	27.4 a	86.4 a	23.8 a
MSD	0.2401	0.5987	1.3373	0.9175
CV	26.3	16.1	28.5	25.4

Means followed by the same letter within a parameter and a main effect are not significantly different according to Tukey's test at $P \leq 0.05$. Key: B_0- Untreated control, B_1- Soil with bioslurry at a rate of 7.8 t/ha. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

ii. Effect of bioslurry on the number of stems per plant

Application of bioslurry at a rate of 7.8 t/ha (B_1) on statice significantly affected the number of flower stems produced per plant when compared to observations from the untreated control (B_0) at $p \leq 0.05$ (Table 11). During trial one and two, statice plants treated to B_1 produced significantly higher numbers of flower stems (18.7 and 19.8 stems per plant respectively) when compared with observations from the control treatment (15.2 and 18.1 stems per plant respectively).

iii. Effect of bioslurry on stem length at 60 DAT

Application of B_1 significantly enhanced flower stem length in statice at 60 DAT when compared to results from the control treatment (B_0) at $P \leq 0.05$ (Table 11). On average, longer flower stems were produced under treatment with B_1 (86.4 cm) when compared with the observed mean stem lengths from the untreated control plots (40.1cm).

iv. Effect of bioslurry on fresh weight of flower stems

The application of bioslurry at a rate of 7.8 t/ha (B_1) significantly affected the fresh weight of flower stems in statice when compared to the untreated control (B_0) at $P \leq 0.05$ (Table 11). Flower stems from plots treated to B_1 had significantly enhanced mean fresh weight (23.8g) when compared to the untreated control (12.4g).

4.2.3 The Combined Treatment Effect of Bioslurry and Different Vermicompost on Growth and Yield of Statice

i. Combined treatment effect on number of days to flowering

The application of the different vermicomposts (40% by volume with 60% garden soil) in combination with bioslurry at a rate of 7.8 t/ha significantly affected the number of days to 50% flowering of statice plants at $P \leq 0.05$ (Table 12). The application of vermicompost, regardless of type, singly or in combination with bioslurry, significantly increased the number of days to flowering in statice (ranging from 15.6 days to 26.9 days) when compared with the control treatment (12.3 days). The highest significant number of days to flowering (26.9 days) resulted from plots treated to $V_1 \times B_1$ while the lowest number of days resulted from the control plots ($V_0 \times B_0$) and application of bioslurry alone ($V_0 \times B_1$) which had 12.3 days and12.4 days respectively. However, results from $V_0 \times B_0$ and $V_0 \times B_1$ had no significant difference between them. Days to flowering observed in plots treated to bioslurry in combination with the different vermicomposts (18.9 to 26.9 days) were significantly higher when compared with $V_0 \times B_0$ and $V_0 \times B_1$ (12.3 and12.4 days respectively).

Table 12: Two-way interaction effect of vermicompost and bioslurry on number of stems, days to first flowering, flower stem length and fresh weight of statice

Treatment combination	Days to first flowering	Stem number (no./plant)	Flower stem length at 60 DAT (cm)	Fresh weight (g/plant)
$V_0 \times B_0$	12.3 e	22.1 b	40.1 d	12.4 e
$V_1 \times B_0$	22.0 b	24.5 b	64.1 c	18.3 c
$V_2 \times B_0$	15.6 d	26.0 b	65.1 bc	15.1 d
$V_3 \times B_0$	16.6 d	26.3 b	70.8 b	14.5 d
$V_0 \times B_1$	12.4 e	21.9 b	43.9 d	12.5 e
$V_1 \times B_1$	26.9 a	27.9 b	112.6 a	31.6 a
$V_2 \times B_1$	18.9 c	27.5 b	88.8 ab	25.8 b
$V_3 \times B_1$	18.9 c	32.5 a	100.4 a	25.4 b
MSD	0.53283	1.06292	2.42529	0.84340
CV	8.7	11.5	9.9	10.8

Means followed by the same letter within a parameter are not significantly different according to Tukey's test at $P \leq 0.05$. Key: V_0B_0- Untreated control, V_1B_0- Soil with 40% kitchen waste vermicompost, V_2B_0- Soil with 40% mowed lawn grass vermicompost, V_3B_0- Soil with 40% weed biomass vermicompost, V_0B_1- Soil with bioslurry at a rate of 7.8 t/ha, V_1B_1- Soil with 40% kitchen waste vermicompost and 7.8 t/ha bioslurry, V_2B_1- Soil with 40% mowed lawn grass vermicompost and 7.8 t/ha bioslurry, V_3B_1- Soil with 40% weed biomass vermicompost and 7.8 t/ha bioslurry. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

ii. Combined effect on the number of stems per plant

The application of vermicompost, regardless of type in combination with bioslurry significantly enhanced the number of stems produced per plant in statice when compared with the untreated control ($V_0 \times B_0$) at $P \leq 0.05$ (Table 12). Weed biomass vermicompost with bioslurry ($V_3 \times B_1$) resulted in the highest mean number of stems (32.5 stems per plant), significantly higher than the other both $V_1 \times B_1$ and $V_2 \times B_1$ (27.5 and 27.9 stems per plant) and the control (22.1 stems per plant). While the main effect of vermicomposts, regardless of type, significantly mean number of stems per plant in statice (16.6 to 22.2 stems per plant), adding bioslurry treatment to the vermicomposts resulted in a significant further increase in the number of stems

per plant (27.5 to 32.5 stems per plant).

iii. Combined effect on stem length at 60 DAT

The application of vermicompost regardless of the type in combination with bioslurry significantly enhanced flower stem length in statice at 60 DAT when compared with the control treatment ($V_0 \times B_0$) at P≤0.05 (Table 12). The longest significant flower stems in statice at 60 cm DAT resulted from plots treated to $V_1 \times B_1$ (112.6 cm), 2followed by $V_3 \times B_1$ (100.4 cm) which in turn, was significantly longer than stems from $V_2 \times B_1$ (88.8 cm). However, all treatments that contained vermicompost regardless of type and bioslurry resulted in significantly increased stem lengths at 60 DAT (ranging from 43.9 cm to 112.6 cm) when compared with the untreated control plots (40.1 cm).

iv. Combined effect on fresh weight of statice flower stems

The application of treatments combining bioslurry with the different vermicomposts significantly increased the fresh weight of flower stems when compared with the untreated control at P≤0.05 (Table 12). Kitchen waste vermicompost with bioslurry ($V_1 \times B_1$), mowed lawn grass vermicompost with bioslurry ($V_2 \times B_1$) and weed biomass vermicompost with bioslurry ($V_3 \times B_1$) all produced significantly enhanced the fresh weight of flower stems (ranging from 25.4 to 31.6 g) when compared to the main effects of the different vermicomposts (ranging from 12.5g to 18.3g) and the untreated control (12.4g). The highest significant flower stem fresh weight resulted from $V_1 \times B_1$ (31.6 g) followed by both $V_2 \times B_1$ and $V_3 \times B_1$ (25.8g and 25.4 g respectively) which had no significant difference between them.

4.2.4 Effect of Combined Treatment and Growing Season on Days to First Flowering, Number of Stems per Plant and Flower Stem Length in Statice

i. Effect of combined treatment and growing season on days to first flowering statice

Results on days to flowering in statice from the combined treatments of different vermicomposts and bioslurry showed some significant variability across the production seasons at *P*≤0.05 (Table 13). $V_3 \times B_1$ during season two resulted in the highest significant number of days to flowering (33.8 days), significantly higher than its results during season one (31.3 days). Except for the results from V_1B_1 (28.3 and 27.5 days respectively in season one and two) which were statistically similar, all the other treatments had significantly different individual results across the production seasons.

Table 13. Three-way interaction effect of vermicompost and bioslurry on number of stems, days to first flowering and length flower stem during statice production seasons

Bioslurry type	Vermicompost type	Days to first flowering		Stem number (no./plant)		Flower stem length at 60 DAT (cm)	
		Season 1	Season 2	Season 1	Season 2	Season 1	Season 2
B_0	V_0	23.5 ^{g}	21.0 ^{h}	21.8 ^{h}	22.4 ^{g}	32.6 ^{j}	39.9 ^{i}
	V_1	24.8 ^{f}	24.3 ^{fg}	23.5 ^{f}	25.5 ^{e}	57.7 ^{g}	70.5 ^{ef}
	V_2	25.3 ^{f}	26.8 ^{d}	27.3 ^{d}	24.7 ^{e}	59.2 ^{g}	71.0 ^{ef}
	V_3	27.8 ^{c}	24.8 ^{f}	25.3 ^{e}	27.3 ^{d}	64.3 ^{fg}	77.3^{de}
B_1	V_0	23.0 ^{g}	20.8 ^{e}	21.0 ^{h}	22.8 ^{g}	39.0 ^{ij}	48.7 ^{h}
	V_1	28.3 ^{c}	27.5 ^{c}	27.3 ^{d}	28.3 ^{c}	104.1 ^{b}	121.1 ^{a}
	V_2	28.5 ^{c}	26.5 ^{d}	26.8 ^{d}	28.2 ^{c}	83.4 ^{d}	94.3 ^{c}
	V_3	31.3 ^{b}	33.8 ^{a}	31.6 ^{b}	33.4 ^{a}	93.6 ^{c}	107.2 ^{b}
MSD		1.0146		0.5987		1.3373	
CV		7.7		6.6		3.6	

Means followed by the same letter within a parameter are not significantly different according to Tukey's test at $P \leq 0.05$. Key: B_0 and V_0- Untreated control, B_1- Soil with bioslurry at a rate of 7.8 t/ha, V_1- Soil with 40% kitchen waste vermicompost, V_2- Soil with 40% mowed lawn grass vermicompost, and V_3- Soil with 40% weed biomass vermicompost. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

ii. Effect of combined treatment and growing season on number of stems per plant in statice

The mean number of flower stems observed for each of the treatments, for both the main and combined effects showed variability across the growing seasons at $P \leq 0.05$ (Table 13). Generally, all the treatments produced significantly a higher number of stems in season two when compared to season one. The highest mean number of stems from the combined treatments resulted from the combined treatment $V_3 \times B_1$ in season two (33.4), significantly higher than in to season one (31.6). The lowest mean number of stems resulted from the untreated control plots (21.8) in season one, significantly lower than in season two (22.4).

iii. Effect of combined treatment and growing season on flower stem length in statice

Results on the treatment effects on flower stem lengths in statice at 60 DAT showed significant variability across the production seasons at $P \leq 0.05$ (Table 13). The longest stems resulted from plots treated to $V_1 \times B_1$ during both seasons with results from season two (121.1 cm) being significantly higher than from season one. The lowest mean stem lengths resulted from the untreated control plots with stem lengths in seasons two (22.4 cm) significantly longer than in season one (21.8 cm). Generally, each of the treatment combinations produced stem lengths in statice at 60 DAT that tended to be significantly higher than results from season one.

iv. Effect of combined treatment and growing season on fresh weight of flower stems in statice

The fresh weight of flower stems in statice resulting from the treatments that combined vermicompost and bioslurry showed significant variability across the growing seasons at $P \leq 0.005$ (Figure 1). The highest mean fresh weight of flower stems resulted from plots treated $V_1 \times B_1$ (35.2g) during season two, significantly higher than during season one (28g), and also significantly higher than results from the other two combination treatments, both $V_2 \times B_1$ (24.4g and 27.2g respectively in season in season one and two) and $V_3 \times B_1$ (22.8g and 28g respectively in season in season one and two).

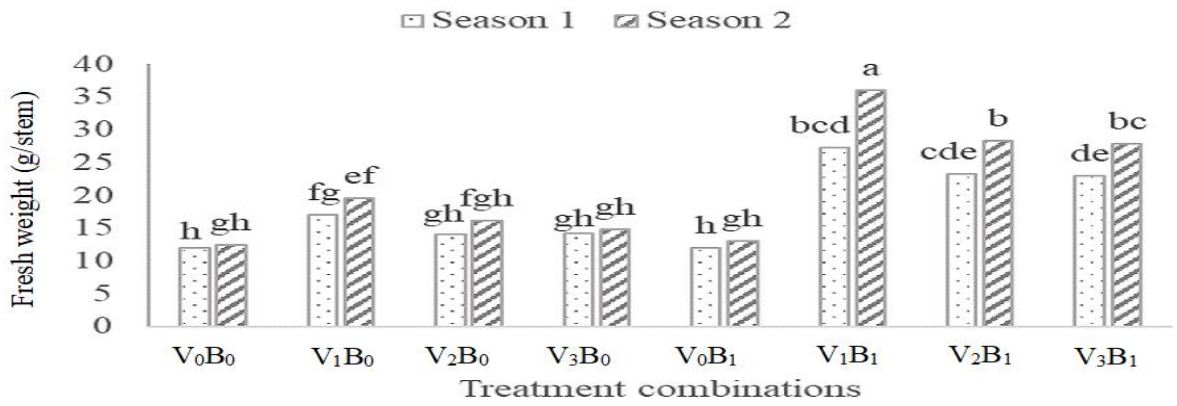

Figure 1: Three-way interaction effect of vermicompost and bioslurry on fresh weight of statice during production in season one and two. Means followed by the same letter within a parameter are not significantly different according to Tukey's test at $P \leq 0.05$. Key: V_0B_0- Untreated control, V_1B_0- Soil with 40% kitchen waste vermicompost, V_2B_0- Soil with 40% mowed lawn grass vermicompost, V_3B_0- Soil with 40% weed biomass vermicompost, V_0B_1- Soil with bioslurry at a rate of 7.8 t/ha, V_1B_1- Soil with 40% kitchen waste vermicompost and 7.8 t/ha bioslurry, V_2B_1- Soil with 40% mowed lawn grass vermicompost and 7.8 t/ha bioslurry, V_3B_1- Soil with 40% weed biomass vermicompost and 7.8 t/ha bioslurry. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

4.3 The effect of different vermicompost and bioslurry treatments on the postharvest quality of statice.

Treatment with different vermicomposts at a rate of 40% by volume mixed with garden soil and bioslurry at a rate of 7.8 t/ha, singly or in combinations significantly affected postharvest quality parameters under study when analyzed at P≤0.05. The treatments showed significant main and combined effects on the postharvest quality parameters of statice studied. Seasonal variability also significantly affected observed results from the different treatments.

4.3.1 Effect of Vermicomposts on Postharvest Quality of Statice

i. Effect of vermicompost on water uptake during days in the vase (DIV)

Applications of the different vermicomposts at a rate of 40% by volume mixed with garden soil as a planting media significantly enhanced water uptake of statice flower stems during the days in the vase when compared with the untreated control at P≤0.05 (Table 14). Statice flower stems obtained from plots treated to vermicompost, regardless of type,

consistently had significantly higher water uptake when compared to those from the untreated control throughout the observation period. The results showed significantly higher water uptake (ranging from 55.8 to 58.9 ml at three days in the vase and 54.2 to 59.1 ml at six DIV) when compared to the control (48.1 and 37.3 ml respectively at three and six DIV). Water uptake by statice flower stems from plots treated to the different vermicomposts had no significant difference by the sixth DIV.

At nine DIV, weed biomass vermicompost (V_3) had significantly higher water uptake (54.8 ml) when compared to V_1 and V_2 (47.0 ml and 49.7ml respectively). From the ninth DIV, weed biomass vermicompost consistently resulted in the highest significant water uptake (54.8 ml at nine DIV; 48.7 ml at 12 DIV; 41.0 ml at 15 DIV; and 32.2 ml at 18 DIV) when compared to both V_2 and V_3 (47.0 ml and 49.7 ml respectively at nine DIV; 41.2 ml and 42.7 ml respectively at 12 DIV; 34.7 ml and 36.9 ml at 15 DIV; 28.7 ml and 28.0 ml respectively at 18 DIV). Though significantly higher than results from the untreated control, there was no significant difference between results obtained from both V_1 and V_2.

Table 14. Main effect of vermicompost and bioslurry on statice water uptake and vase life

Vermicompost type	Water uptake during days in the vase (DIV)						Vase life
	Day 3	Day 6	Day 9	Day 12	Day 15	Day 18	
V_0	48.1 b	37.3 b	30.6 c	11.1 c	3.3 c	0.0 c	11.7 b
V_1	58.0 a	55.0 a	47.0 b	41.3 b	34.7 b	28.7 b	15.8 c
V_2	58.9 a	54.2 a	49.7 b	42.7 b	36.9 b	28.0 b	17.6 b
V_3	55.8 a	59.1 a	54.8 a	48.7 a	41.0 a	32.2 a	19.7 a
MSD	5.7872	5.1238	4.4013	3.2913	2.5192	1.8823	0.857
CV	24.4	15.4	17.9	19.6	21.9	20.5	12.8

Means followed by the same letter within a parameter are not significantly different according to Tukey's test at $P \leq 0.05$. Key: V_0- Untreated control, V_1- Soil with 40% kitchen waste vermicompost, V_2- Soil with 40% mowed lawn grass vermicompost, and V_3- Soil with 40% weed biomass vermicompost. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

ii. Effect of vermicompost on vase life of statice

Application of the different vermicomposts a rate of 40% by volume mixed with 60% garden soil as a planting media significantly extended vase life of statice when compared with the untreated control at $P \leq 0.05$ (Table 14). Treatment with vermicompost, regardless of type, resulted in significantly loner vase life in statice (ranging from 15.8 days to 19.7 days) when compared with the untreated control (11.7 days). The longest vase life was observed with flower stems obtained from plots treated to V_3 (19.7 days), significantly longer than both V_1 and V_2 (15.8 days and 17.6 days respectively).

4.3.2 Effect of Bioslurry on Postharvest Quality of Statice

i. Effect on water uptake during days in vase (DIV)

Application of bioslurry at a rate of 7.8 t/ha (B_1) significantly affected water uptake of statice during vase life when compared with the untreated control at $P \leq 0.05$ (Table 15). At three days in vase (DIV), water uptake by statice flower stems obtained from plots treated to B_1 had significantly higher water (52.8 ml) when compared with the untreated control (48.1 ml). The significantly higher water uptake was sustained by flower stems obtained plants treated to B_1 (58.1 ml at six DIV, 52.3 ml at nine DIV and 46.3 ml at 12 DIV) compared to the active water uptake by stems from the untreated control during active vase life (37.3 ml at six DIV, 30.6 ml at nine DIV and 11.1 ml at 12 DIV). Water uptake by flower stems obtained from plants in the control plots drastically decreased from 11.1 ml at 12 DIV to 0 ml at 18 DIV following senescence. On the other hand, flower stems from B_1 were still taking up water at 18 DIV (36.1 ml).

Table 15. Main effect of bioslurry water uptake and vase life in statice

Bioslurry type	Water uptake during days in vase (DIV)						Vase life
	Day 3	Day 6	Day 9	Day 12	Day 15	Day 18	
B_0	48.1 b	37.3 b	30.6 c	11.1 c	3.3 c	0.0 c	11.7 b
B_1	52.8 b	58.1 a	52.3 a	46.3 a	40.5 a	31.6 a	18.0 a
MSD	3.0766	2.7239	2.3398	1.7497	1.3393	1.0006	0.4556
CV	25.4	18.6	22.8	22.9	21.8	18.5	18.8

Means followed by the same letter within a parameter are not significantly different according to Tukey's test at $P \leq 0.05$. Key: B_0- Untreated control, B_1- Soil with bioslurry at a rate of 7.8 t/ha. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

ii. Effect of bioslurry on statice vase life

The application of bioslurry at a rate of 7.8 t/ha (B_1) significantly enhanced vase life in statice when compared to the untreated control (B_0) at $P \leq 0.05$ (Table 15). Flower stems from plants in plots treated to B1 had significantly longer vase life (18.8 days) when compared to the untreated control (11.7 days).

4.3.3 The Combined Treatment Effect of Different Vermicomposts and Bioslurry on the Postharvest Quality of Statice.

i. Combine treatment effect on water uptake during days in vase (DIV)

The applications of different vermicomposts at a rate of 40% by volume in combination with bioslurry at a rate of 7.8 t/ha significantly enhanced statice water uptake during the first three days of its vase life when compared with the control (Table 16). Flower stems obtained from plots treated to $V_3 \times B_1$ had higher water uptake (70.8 ml at three DIV, gradually decreasing to 38.0 ml at 18 DIV), significantly higher than both $V_1 \times B_1$ and $V_2 \times B_1$ (60.3 ml and 43.8 ml respectively at three DIV, decreasing to 33.7 ml and 32.8 ml respectively at 18 DIV). All treatments that contained any of the organic manures (vermicompost or bioslurry), singly or in combination resulted in significantly higher water uptake (ranging from 52.8 ml to 70.8 ml at three DIV, decreasing gradually to amounts ranging from 31.6 ml to 38.0 ml at 18 DIV) when compared to the untreated control (48.1 ml at three DIV reducing to 0.0 ml at 18 DIV, with a drastically decreased water uptake after 12 DIV). Two of the combination treatments ($V_1 \times B_1$ and $V_3 \times B_1$) generally resulted in significantly higher water uptake (60.3 ml and 70.8 ml respectively at three DIV, gradually decreasing to 33.7 ml and 38 ml respectively at 18 DIV) when compared to the other organic manure treatments (ranging from 43.8 ml to 58.9 ml at three DIV, decreasing gradually to amounts ranging from 28.0 ml to 32.8 ml at 18 DIV).

Table 16: Two-way interaction effect of vermicompost and bioslurry on statice water uptake and vase life

Treatment Combination	Water uptake during DIV (ml)						Vase life (days)
	Day 3	Day 6	Day 9	Day 12	Day 15	Day 18	
$V_0 \times B_0$	48.1 f	37.3 e	30.6 f	11.1 g	3.3 f	0.0 e	11.7 f
$V_1 \times B_0$	58.0 c	55.0 d	47.0 e	41.3 f	34.7 e	28.7 d	15.8 e
$V_2 \times B_0$	58.9 b	54.2 d	49.7 d	42.7 e	36.9 d	28.0 d	17.6 d
$V_3 \times B_0$	55.8 d	59.1 c	54.8 b	48.7 c	41.0 c	32.2 bc	19.7 b
$V_0 \times B_1$	52.8 e	58.1 c	52.3 c	46.3 d	40.5 c	31.6 c	18.8 c
$V_1 \times B_1$	60.3 b	63.5 b	55.7 b	50.0 b	43.7 b	33.7 b	17.9 d
$V_2 \times B_1$	43.8 g	57.5 c	53.5 c	50.5 b	44.7 b	32.8 b	19.8 b
$V_3 \times B_1$	70.8 a	71.5 a	66.7 a	60.0 a	50.8 a	38.0 a	22.5 a
MSD	2.0438	1.6208	1.7404	1.2977	1.1729	1.5243	0.3282
CV	8.9	7.5	9.6	8.2	8.5	12.3	5.2

Means followed by the same letter within a parameter are not significantly different according to Tukey's test at $P \leq 0.05$. Key: $V_0 \times B_0$- Untreated control, $V_1 \times B_0$- Soil with 40% kitchen waste vermicompost, $V_2 \times B_0$- Soil with 40% mowed lawn grass vermicompost, $V_3 \times B_0$- Soil with 40% weed biomass vermicompost, $V_0 \times B_1$- Soil with bioslurry at a rate of 7.8 t/ha, $V_1 \times B_1$- Soil with 40% kitchen waste vermicompost and 7.8 t/ha bioslurry, $V_2 \times B_1$- Soil with 40% mowed lawn grass vermicompost and 7.8 t/ha bioslurry, $V_3 \times B_1$- Soil with 40% weed biomass vermicompost and 7.8 t/ha bioslurry. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

ii. Combined treatment effect on statice vase life

Applications of the different vermicomposts at a rate of 40% by volume in combination with bioslurry at a rate of 7.8 t/ha significantly enhanced the vase life of statice, when compared with the untreated control at $P \leq 0.05$ (Table 16). All treatments containing organic manure had significantly longer mean vase life (ranging from 15.8 days to 22.5 days) when compared to the untreated control (11.7 days). Flower stems obtained from plots treated to $V_3 \times B_1$ had the longest vase life (22.5 days), significantly longer than those from both $V_1 \times B_1$ and $V_2 \times B_1$ (17.9 and 19.8 days respectively), the latter two combined treatments having statistically similar effect. trial

one and two respectively compared to $V_1 \times B_1$ (19.5 and 20.1) days which was not significantly different from $V_2 \times B_1$ (7.3 and 18.5) days. The shortest vase life was recorded in the control (11.2 and 20.1) days in trail one and two respectively.

iii. Effect of combined treatments and seasonal variability on vase life of statice

Vase life response in statice treated to the combined application of different vermicomposts at a rate of 40% by volume and bioslurry at a rate of 7.8 t/ha showed significant variability due to the effects of the production season at $P \leq 0.05$ (Table 17). Vase life from each of the treatments with organic manures showed significant increase in season two when compared to season one results. The longest vase life was observed in flower stems obtained from plots treated to $V_3 \times B_1$ during season two (22.8 days), which was significantly longer than the results during season one (22.3 days). The combined treatments ($V_1 \times B_1$, $V_2 \times B_1$ and $V_3 \times B_1$) all resulted in significantly longer vase life (ranging from 18.5 days to 22.8 days) in season two when compared to season one (ranging from 17.3 days to 22.3 days). A similar trend was also observed with the main treatment effects. However, seasonal variability had no significant effect on vase life observed in flower stems obtained from the untreated control plots (11.5 days and 11.9 days respectively in season one and two).

Table 17. Three-way interaction effect of vermicompost and bioslurry on vase life (days) one statice in season one and two

Bioslurry type	Vermicompost type	Vase life (days)	
		Season 1	Season 2
B_0	V_0	11.5 k	11.9 k
	V_1	15.4 j	16.2 i
	V_2	16.8 h	18.4 fg
	V_3	18.7 f	20.7 c
B_1	V_0	18.2 g	19.4 e
	V_1	17.3 h	18.5 f
	V_2	19.5 e	20.1 d
	V_3	22.3 b	22.8 a
MSD		0.4556	
CV		4.8	

Means followed by the same letter are not significantly different according to Tukey's test at $p \leq 0.05$. Key: B_0 and V_0- Untreated control, B_1- Soil with bioslurry at a rate of 7.8 t/ha, V_1- Soil with 40% kitchen waste vermicompost, V_2- Soil with 40% mowed lawn grass vermicompost, and V_3- Soil with 40% weed biomass vermicompost. MSD -minimum significant difference, and CV -coefficient of variation. N=64.

CHAPTER FIVE

DISCUSSION

5.1 Effects of Different Vermicomposts and Bioslurry on Repellency of TSSM in Statice

Results of the present study demonstrate that the different vermicomposts and bioslurry conferred significant repellence to TSSM when compared to the control. It is probable that the characteristic difference between the pot media, especially the very high content of N, P and K, as well as the differences in pH cause the different mite responses. From the laboratory analyses of the different vermicomposts and bioslurry had low acidity with pH ranging from 6.8 to 7.94 when compared to 5.84 for garden soil. When compared to the native characteristics of the garden soil used in the control, the manures had high contents of N, P, K, and higher water holding capacities. This suggests a better synthesis and translocation of primary metabolites in the plants, possibly reducing residual sugars in tissues, perhaps affecting scent and taste. The delayed flowering in plants treated to the organic manures, and the diverse biochemicals present in vermicasts also points to a likelihood of succulence, strong scents and poor palatability responsible for the observed repellence effect.

Results of the present study are consistent with findings from several studies that point to reduced arthropod pest incidence and damage on crops when organic manures are applied. Hong *et al*. (2017) reports ovicidal activity against gnat (*Bradysia odoriphaga*) and repellence to adult oviposition and larval feeding in Chinese chive under treatments that utilized chicken manure bioslurry. Edwards *et al*. (2009) reported significant suppression of spotted spider mites (*Tetranychus spp*.) in tomato plants after application of vermiwash liquid, a body liquid obtained from vermicompost. Edwards and Arancon (2004) reported significant decrease in populations arthropods pest including spider mite and consequent plant damage in trials that applied 20% and 40% vermicompost on tomato, pepper and cabbage. Hussain *et al*. (2017) who reported suppression of fruit borer infestation in okra (*Abelmoschus esculentus*) in treatments with different rates of vermicompost prepared from weed salvinia (*Salvinia molesta* Mitchell). Arancon *et al*. (2002) reported upto 20% - 40% suppression of aphids (*Myzus persicae*), mealy bugs (*Pseudococcus spp*.) and cabbage white caterpillars (*Peiris brassicae*) with applications of vermicompost on pepper (*Capiscum annuum*), cabbage (*Brassica oleracea*) and tomato (*Lycopersicum esculentum*). Rao (2002) attributes the observed suppression of pest infestation in

groundnut with increased levels of phenols and tannins and reduced nitrogen observed in plants treated to application of organic manures including vermicomposts whereas straight fertilizers had opposite results. Chitinase produced by worms degrades arthropod exoskeletal chitin (Munroe, 2007) possibly impacting growth and survival.

In their mini-review, Mworia *et al*. (2017) reported that plant nutrition impacts host selection by TSSM. On the other hand, the review by Yatoo *et al*. (2021) concluded that the use of inorganic fertilizers and pesticides in agriculture, besides lowering soil fertility and altering agroecological biodiversity, it also lowers natural crops resistance to pests. They therefore consider vermicompost and vermicompost tea, both rich in plant nutrient content, growth promoters such as auxins, gibberellins, cytokinins, and beneficial microbes, as suitable alternatives for sustainably enhancement of crop growth and yield as well as suppression of diseases and pests. Further, the review by Hussain and Abbasi (2018) concludes that vermicomposts prepared from animal or plant based organic wastes repel plant pests and simultaneously present high plant nutrition potential.

5.2 Effects of different vermicomposts and bioslurry on growth and yield of statice

The present study sought to determine the effects of soil amendments using different vermicomposts, bioslurry as well as their treatment combinations on growth and yield of statice when compared to the native fertility as the control. The study established that different vermicomposts and bioslurry resulted in significant main and combined effects on the studied growth and yield parameters in statice except seedling takeoff at $P \leq 0.05$.

The results of the present study indicate promotive effects of vermicomposts on vegetative growth and yield of statice. This is likely due to the fertility and moisture holding capacity attributed to the organic manures. The manures were rich in carbon, macro and micro-nutrients, which favour growth and yield. The moisture retention capacity of the manures also ensures existence of soil solution in the root zones, enabling uptake of the nutrients to benefit the plant. This explains the superior vegetative growth and delayed flowering, favouring biomass accumulation, manifested in increased number of stems as well as longer and heavier flower stems. The findings of this study are discussed as follows.

5.2.1 Effect of the Different Vermicomposts on Growth and Yield of Statice

The findings of the present study are consistent with the findings of Mahmud *et al*. (2020) who reported insignificant difference in plant height and foliage parameters between

pineapple plants treated with vermicompost and chemical fertilizer. While working with strawberry cv. “Winter dawn”, Sahana *et al*. (2020) reported the best response in vegetative growth, and yield attributes from treatment combination that included vermicompost. Similarly, Pansuriya *et al*. (2018) reported significantly enhanced growth and yield parameters in gladiolus from treatment combinations containing bio fertilizers. Sharma *et al*. (2017) also reported increased plant height, number of branches, plant spread, flowering duration and flower yield in African marigold under vermicompost treatments. Abubaker *et al. (*2015) attributed superior plant performance under application of bioslurry to the inhibition of ammonia oxidation and denitrification which potentially benefits crop growth due to reduced losses of soil nitrogen.

Srivastava *et al*. (2014) reported enhanced vegetative growth and yield with use of vermicompost in tuberose var. Shringar. Geeta and Prabhat (2009) reported in gladiolus significant effect on both fresh and dry weight of spike, days taken to spike emergence, maximum diameter of first floret and number of florets opened from pre-harvest bio fertilizer treatments. Srivastava & Govil (2007) also reported improvement in the various characters of gladiolus resulting from the activity of rhizospheric bacteria attributable to bio fertilizer inoculation. Nikbakht *et al*. (2008) reported up to 52% increase in the number of harvested flowers per plant in Gerbera from humic acid treatments.

Atiyeh *et al*. (2000) observed faster growth on tomatoes when vermicompost was applied compared to the control probably due to supply of phosphorus and calcium, important nutrients for cell growth and development. While working with basil (*Ocimum basilicum* L.) and tomato (*Solanum lycopersicum* L. “Roma”), Huang *et al*. (2020) reported superior growth indexes from substrates mixes combining vermicompost and commercial peat-based substrate which they attributed to favourable substrate amendment including higher pH and better porosity.

Furthermore, literature reviews by Joshi *et al*. (2015), and Bhat *et al*. (2018) on effects of vermicomposts on growth, yield and quality of crops, assert that the enhanced observations on the studied parameters are due to positive effects of higher amounts of humic substances in the bio fertilizers on growth of plants. The meta-analysis by Blouin *et al*. (2019) also asserts that the presence of bio fertilizers promotes the increase in plant growth and yield due to effects of humic acids and growth promoting bacteria. Similarly, Kumar *et al*. (2018) in their review of the potential benefits of vermicomposts in crop production and soil fertility concluded that the bio fertilizer improves soil physical, chemical and biological properties sustainably supporting crop

production.

5.2.2 Effect of Bioslurry on Growth and Yield of Statice

In the present study, application of bioslurry at a rate of 7.8 t/ha significantly affected the statice growth and yield parameters. When compared with the untreated control, application of bioslurry on statice increased the number of days to flowering, number of stems produced per plant, stem length at 60 days after transplanting and fresh weight of flower stems.

Although no related literature in floriculture came up, findings of the present study on the enhanced growth and yield in statice subjected to bioslurry treatment are consistent with Basunia *et al*. (2020) who observed significant enhancement of stem diameter, vine length, leaf number, branches per plant, leaf area, dry matter, yield in potted Indian spinach (*Basella alba* L.). Similarly, Biramo *et al*. (2019) reported significant increase in plant height, branching and yield in tomatoes. Similarly, Haile *et al*. (2018) reported significant increase in plant height of kale crop under that bioslurry fertilization. While working with Chinese cabbage, Mwanga (2016) observed significant increase in plant height and fresh weight under application of organic manures including bioslurry. Islam *et al*. (2016) reported a significant increase in leaf area of spinach, variety Fordhook giant, with application of bioslurry. Shahabz *et al*. (2014) observed an increased growth okra when bioslurry was applied. Similarly, Jeptoo *et al*. (2012) reported increased plant growth in carrot plants treated with increased dosage of bioslurry while Shahabz (2011) reported increased plant height in okra with increased rate of bioslurry application. Mog (2007), and Apahidean *et al*. (2012) attributed observed leaf expansion in spinach under bioslurry application to significantly increased of cell division and elongation. On the other hand, Febrina *et al*. (2019) reported that bioslurry had no significant growth and yield responses in okra, especially on stem diameter, shoot dry weight and root crown ratio under application of bioslurry although it significantly increased fruit length.

According to Sangiga and Woomer (2009) organic manures contribute to improved edaphic condition for plant growth and yields due to considerable content of nitrogen, phosphorus and potassium as well as beneficial organic molecules readily available for uptake by plants (Islam, 2006). The significantly higher statice growth and yield responses to bioslurry application observed in the present study, when compared to the control treatment (plain garden soil) suggest a plant nutrition potential superior to the native soil fertility. The results of laboratory qualitative analyses of the sampled bioslurry and garden soil used in this study also pointed to

this possibility.

According to Coban *et al*. (2015), application of bioslurry resulting from biogas plants utilizing livestock manures primes mineralization processes on native soil organic matter, which is beneficial in the short run. In a review of a number of studies, Nkoa (2014) concludes that short-term effects of bioslurry application improves soil quality, specifically the microbial biomass, N and P contents. Further, Garg *et al*. (2005) reported a reduction in bulk density and increased soil moisture retention.

5.2.3 Combined Effect of Bioslurry and The Different Vermicomposts on Growth and Yield of Statice

Application of the different vermicomposts in combination with bioslurry resulted in significant enhanced growth and yield responses of statice due to the synergistic effect, when compared to the control treatment as well as the application of individual vermicomposts and bioslurry. The application of the different vermicomposts in combination with bioslurry increased the days to flowering, stems produced per plant, stem length at 60 days after transplanting and fresh weight of the flower stems. These findings suggest an additive effect of the manures used on statice growth and yield parameters.

While no literature specific to effects of vermicompost and bioslurry application in combination on crop growth and yields came up, findings of the present study are supported by Kartini (2021) who reported significant growth and yield enhancement in onion treated to a combination of 5000 kg/ha vermicompost and 3000L/ha bioslurry. El-Ghait *et al*. (2021) reported significant influence on stevia plant growth characteristics under application of bioslurry alongside different natural extracts while Laily *et al*. (2021) observed increased tomato yield with increased application of organic manure in combination with inorganic fertilizers. Sohel and Ghosh (2020) reported significantly enhanced growth and yield parameters in capsicum under combined application of inorganic fertilizer (at recommended NPK rate) and organic manure (compost+vermicompost+trichocompost). Also, Verma *et al*. (2020) reported enhanced plant height, numbers of leaves and branches produced per plant in stevia. Martinez *et al*. (2018) reported significant increase in production of leaves and buds in stevia under application of vermicompost. Rabie *et al*. (2020), and Kawtar *et al*. (2017) both reported that application of organic fertilizer with Azolla extracts led to significant increase of growth parameters including number of leaves, fresh and dry weight in chamomile. Bilkis *et al*. (2015) reported that

trichocompost and vermicomposts had significant increase in straw, yield and yield attributes in rice. All these tend to affirm Marculescu *et al*. (2002) on the beneficial properties of organic manures on plant growth and development.

5.3 Effect of different vermicomposts and bioslurry on postharvest quality of Statice

Application of the different vermicomposts and bioslurry significantly improved the postharvest quality of statice when compared with the control at $P \leq 0.05$. The results showed significant main and combine effects on postharvest water uptake as well as longer vase life in statice flower stems obtained from plants treated to bioslurry and vermicomposts.

When compared to the native fertility, the organic manures offered the plants more chemical elements which manifest in terms of the enhanced growth and yield parameters. Effects of the elements taken up include lower cellular water potential, explaining the enhanced water uptake by specimens obtained from manure treated plants. This then helps to sustain cell function which translates to sustained water uptake for longer during vase life, and an enhanced longevity of the flower stems in the vase.

5.3.1 Effect of Different Vermicomposts on Postharvest Quality of Statice

Application of the different vermicomposts and bioslurry significantly improved the postharvest quality of statice when compared with the control at $P \leq 0.05$. The different vermicomposts significantly enhanced water uptake during vase life in statice and also slowed the decline in water uptake throughout the observation period. The treatments also significantly extended vase life when compared to the plain garden soil. While no specific literature on statice came up, findings similar to the present study have been reported from various studies involving treatments with organic manures on other crops.

These findings are supported by Sharma *et al*. (2017) who when working with marigold (var. Pusa Narangi) reported maximum shelf life and flower vase life from treatments that included application of farm yard manure as organic manure alongside bio fertilizers and NPK in integrated plant nutrient management. Palagani and Alka (2017) observed significantly improved water uptake from treatments with bio-fertilizers inoculation alongside spermine foliar sprays. They also reported significantly improved flower quality parameters in Gerbera including improved postharvest physiology of flowers and higher retained flower fresh weight. Bohra and Kumar (2014) reported extended vase life in Chrysanthemum cv. Little Darling resulting from treatment that applied vermicompost at a rate of $300 g/m^2$.

Srivastava *et al*. (2007) reported maximum water uptake in tuberose under treatments incorporating vermicomposts. They also reported significantly longer vase life from treatments that had vermicompost while Ikram *et al*. (2012) reported enhanced shelf life and vase life from application of farm yard manure obtained from leaf compost. Geeta and Prabhat (2009) reported significantly extended vase life in gladiolus under treatments that combined vascular arbuscular mycorrhiza with vermicompost and vermiwash suggesting a positive contributive effect of vermicompost. Tejada *et al*. (2008) reported improved vase life in Gerbera from treatments that incorporated phosphorous solubilizing bacteria found among the diverse nutrient solubilizing microbes (Ayyadurai *et al*., 2007) present in vermicomposts and other organic manures (Sinha *et al*., 2010).

5.3.2 Effect of Bioslurry on Postharvest Quality of Statice

Application of bioslurry significantly improved the postharvest quality of statice when compared to the control values. The treatment resulted in higher water uptake during vase life of statice and a gradual decline in the same towards the end of the observation period. They also significantly extended vase life when compared to the plain garden soil used as control treatment.

No literature specific to effects of bioslurry on postharvest quality of statice came up. However, the findings of present study are supported by results of other studies involving use of organic manures on crops. Sharma *et al*. (2017) who when working with marigold (var. Pusa Narangi) reported maximum flower vase life from treatments that included application of farm yard manure as organic manure alongside bio fertilizers and NPK in integrated plant nutrient management. Palagani and Alka (2017) observed significantly improved water uptake from treatments with bio-fertilizers inoculation alongside spermine foliar sprays as well as significantly improved flower quality in Gerbera including improved postharvest physiology of flowers. Ikram *et al*. (2012) reported enhanced shelf life and vase life in tuberose (*Polianthes tuberosa* L.) from application of farm yard manure obtained from leaf compost. Tejada *et al*. (2008) reported improved vase life in Gerbera from treatments that incorporated phosphorous solubilizing bacteria found among the diverse nutrient solubilizing microbes (Ayyadurai *et al*., 2007) present in organic manures (Sinha *et al*., 2010).

According to Rocha *et al*. (2015), use of organic manures boosts the supply of plant nutrition needs due to increased N and K uptake. Plant nutrition influences in secondary plant

metabolism (Mditshwa *et al*., 2017). High N availability promotes synthesis of growth metabolites with plants prioritizing synthesis of secondary metabolites with declining N availability (Zahedipour *et al*., 2019). Results of laboratory analyses of sampled garden soil, bioslurry and the different vermicomposts used in the present study showed that the organic manures had a higher values of plant nutrients and suitable pH when compared to the native fertility of the garden soil used as a control.

5.3.3 The Combined Effect of the Different Vermicomposts and Bioslurry on Postharvest Quality of Statice

Applications that combined the different vermicomposts with bioslurry had significant combined effect on statice postharvest quality parameters when compared with control. However, these observations were not significantly different from observations under individual vermicomposts and bioslurry treatments. When compared to the control, the combined treatments significantly enhanced water uptake in statice which gradually declined during vase life and a significantly extended vase life.

Findings of the present study are supported by those of various studies that involved the use of combinations of organic manures on other crops. While working with marigold (var. Pusa Narangi), Sharma *et al*. (2017) reported maximum flower vase life from treatments that included application of farm yard manure as organic manure alongside bio fertilizers and NPK in integrated plant nutrient management. Palagani and Alka (2017) observed significantly improved water uptake during vase life and significantly improved flower quality parameters in Gerbera including improved postharvest physiology of flowers and higher retained flower fresh weight from treatments with bio-fertilizer soil amendments alongside spermine foliar sprays. Longchar and Keditsu (2013) reported significantly improved floral characteristics and flower vase life in Gerbera from treatments that included application of vermicompost as an organic nutrient source. Srivastava *et al*. (2007) observed enhanced water uptake and longer vase life in tuberose obtained from combination treatments that incorporated vermicomposts. Similarly, Ikram *et al*. (2012) reported enhanced vase life in tuberose with application of farm yard manure obtained from leaf compost.

In other supportive findings, Geeta and Prabhat (2009) reported significantly extended vase life in gladiolus under treatments that combined vascular arbuscular mycorrhiza with vermicompost and vermiwash suggesting a positive contributive effect of vermicompost.

Similarly, Tejada *et al*. (2008) reported extended vase life in Gerbera from treatments that incorporated phosphorous solubilizing bacteria found among the diverse nutrient solubilizing microbes (Ayyadurai *et al*., 2007) present in organic manures (Sinha *et al*., 2010).

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Based on the objectives of the present study, the results obtained lead to the following conclusions;

i. Different vermicomposts and bioslurry had significant main and combined effects on the repellence of the two spotted spider mite. The study established that significantly higher mite counts and percentages in a choice-feeding arena bioassay associated with inflorescence specimens were recorded from the untreated control. Therefore, it is concluded the different treatments had significant main and combined repellence against the two spotted spider mite. Since there is no evidence supporting the null hypothesis, it is hereby rejected.

ii. The different vermicomposts and bioslurry treatments, applied singly and in combination, significantly affected the studied growth and yield parameters except seedling takeoff. Significant main and combined treatment effects on growth and yield of statice were observed, implying insufficient evidence to support acceptance of the null hypothesis. The hypothesis is therefore rejected.

iii. Vermicompost and bioslurry treatments had significant main and combined effect on postharvest quality of statice. They resulted in significantly enhanced postharvest water uptake while extending the vase life of statice. There is sufficient evidence to concluded that the different treatments significantly affect the postharvest quality of statice. The null hypothesis is therefore rejected.

6.2 Recommendations

Informed by the findings of the present study, the following recommendations are made;

i. Bioslurry (B_1) at a rate of 7.8 t/ha, and the different vermicomposts (V_1, V_2 and V_3) at a rate of 40% by volume in mixture with garden soil, applied singly or in combination, are recommended for adoption as organic alternatives in the management of twospotted spider mite in statice.

ii. The use of bioslurry applied at a rate of 7.8 t/ha, and the different vermicomposts (V_1, V_2 and V_3), at a rate of 40% by volume in mixture with garden soil, singly or in combination, is hereby recommended as organic options for soil amendment to enhance growth and yield in statice.

iii. Application of bioslurry at a rate of 7.8 t/ha, and the different vermicomposts (V_1, V_2 and V_3) at a rate of 40% by volume in mixture with garden soil, singly or in combination, is hereby recommended for adoption as a strategy to improve the postharvest quality of statice.

6.3 Future research work

The present study generates new research questions that require to be addressed through further work.

i. There's need for a study to determine the cost-benefit analysis for applying vermicomposts and bioslurry *vis a vis* the alternative methods (inorganic fertilizers and the control) to guarantee economic value.

ii. There is need to test varied rates of vermicomposts and bioslurry to establish the optimal rates of application on statice.

iii. There is need for a study to identify and characterize the chemical compounds present in vermicomposts and bioslurry responsible for the observed mite repellence, with a view to extract, stabilize and commercialize.

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APPENDICES

APPENDIX A: ANOVA Tables

i. ANOVA on number of twospotted spider mites

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	63	893.750000			
Vermi	3	211.250000	70.416667	25.61	<.0001*
Bio	1	240.250000	240.25000	87.36	<.0001*
Season	1	64.0000000	64.000000	23.27	<.0001*
Vermi*Season	3	2.24000000	0.7500000	0.27	0.0470*
Bio*Season	1	1.96000000	1.9600000	0.71	0.0300*
Vermi*Bio	3	246.250000	82.083333	29.85	<.0001*
Vermi*Bio*Season	3	2.75000000	0.9200000	0.33	0.0450*
Error	48	132.000000	2.7500000		

*Significant at P≤0.05

ii. ANOVA % of twospotted spider mites

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	63	611.1415000			
Vermi	3	145.4674500	48.4891500	25.66	<.0001*
Bio	1	168.7401000	168.7401000	89.31	<.0001*
Season	1	32.7184000	32.7184000	17.32	0.0001*
Vermi*Season	3	1.1000000	0.0333333	0.19	0.0420*
Bio*Season	1	1.1500000	1.1500000	0.61	0.0520
Vermi*Bio	3	173.5214500	57.8404833	30.61	<.0001*
Vermi*Bio*Season	3	2.2500000	0.7500000	0.40	0.0460*
Error	48	90.6941000	1.8894604		

*Significant at P≤0.05

iii. ANOVA on takeoff

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	63	0.76230000			
Block	3	0.00000000			
Vermi	3	0.32670000	0.10890000	15.00	<.0001*
Bio	1	0.02722500	0.02722500	3.75	0.0591
Season	1	0.00000000	0.00000000	0.00	1.0000
Vermi*Season	3	0.00000000	0.00000000	0.00	1.0000
Bio*Season	1	0.00000000	0.00000000	0.00	1.0000
Vermi*Bio	3	0.08167500	0.02722500	3.75	0.0573
Vermi*Bio*Season	3	0.00000000	0.00000000	0.00	1.0000
Error	45	0.32670000	0.00726000		

*Significant at P≤0.05

iv. ANOVA on number of stems

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	63	1519.750000			
Block	3	7.375000	2.458333	1.74	0.1726
Vermi	3	1190.375000	396.791667	280.64	<.0001*
Bio	1	110.250000	110.250000	77.98	<.0001*
Season	1	64.000000	64.000000	45.27	<.0001*
Vermi*Season	3	7.125000	2.375000	1.68	0.1848
Bio*Season	1	12.250000	12.250000	8.66	0.0051*
Vermi*Bio	3	47.375000	15.791667	11.17	<.0001*
Vermi*Bio*Season	3	17.375000	5.791667	4.10	0.0118*
Error	45	63.625000	1.413889		

*Significant at P≤0.05

v. ANOVA on days to flowering

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	63	1229.437500			
Block	3	328.8125000			
Vermi	3	439.3125000	146.4375000	36.07	<.0001*
Bio	1	115.5625000	115.5625000	28.47	<.0001*
Season	1	12.2500000	12.2500000	3.02	0.0892
Vermi*Season	3	12.3750000	4.1250000	1.02	0.3945
Bio*Season	1	1.0000000	1.0000000	0.25	0.6221
Vermi*Bio	3	95.8125000	31.9375000	7.87	0.0003*
Vermi*Bio*Season	3	41.6250000	13.8750000	3.42	0.0251*
Error	45	182.687500	4.059722		

*Significant at $p \leq 0.05$

vi. ANOVA on length of stem

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	63	42092.13016			
Block	3	16.12792			
Vermi	3	23911.49900	7970.49967	1129.99	<.0001*
Bio	1	11997.09473	11997.09473	1700.84	<.0001*
Season	1	2317.33925	2317.33925	328.53	<.0001*
Vermi*Season	3	92.56789	30.85596	4.37	0.0087*
Bio*Season	1	10.40869	10.40869	1.48	0.2308
Vermi*Bio	3	3415.49109	1138.49703	161.41	<.0001*
Vermi*Bio*Season	3	14.18903	4.72968	0.67	0.0446*
Error	45	317.41256	7.05361		

*Significant at $P \leq 0.05$

vii. ANOVA on weight of stem

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	63	3446.414036			
Block	3	73.069967			
Vermi	3	1302.302167	434.100722	130.75	<.0001*
Bio	1	1233.677814	1233.677814	371.58	<.0001*
Season	1	162.275752	162.275752	48.88	<.0001*
Vermi*Season	3	51.469080	17.156360	5.17	0.0037*
Bio*Season	1	49.438477	49.438477	14.89	0.0004*
Vermi*Bio	3	406.455767	135.485256	40.81	<.0001*
Vermi*Bio*Season	3	18.319105	6.106368	1.84	0.0336*
Error	45	149.405908	3.320131		

*Significant at P≤0.05

viii. ANOVA tables for water uptake

ANOVA water uptake 3 DAS

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	47	9253.916667			
Vermi	3	872.416667	290.805556	10.62	<.0001*
Bio	1	280.333333	280.333333	10.24	0.0031*
Season	1	176.333333	176.333333	6.44	0.0162*
Vermi*Season	3	43.500000	14.500000	0.53	0.0451*
Bio*Season	1	10.083333	10.083333	0.37	0.0482*
Vermi*Bio	3	6919.166667	2306.388889	84.25	<.0001*
Vermi*Bio*Season	3	76.083333	25.361111	0.93	0.0392*
Error	32	876.000000	27.375000		

*Significant at $p \leq 0.05$

ix. ANOVA water uptake 6 DAS

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	47	7057.479167			
Vermi	3	3330.229167	1110.076389	51.73	<.0001*
Bio	1	2146.687500	2146.687500	100.04	<.0001*
Season	1	13.020833	13.020833	0.61	0.0417*
Vermi*Season	3	36.062500	12.020833	0.56	0.0452*
Bio*Season	1	20.020833	20.020833	0.93	0.0413*
Vermi*Bio	3	778.729167	259.576389	12.10	<.0001*
Vermi*Bio*Season	3	46.062500	15.354167	0.72	0.0500*
Error	32	686.666667	21.458333		

*Significant at P≤0.05

x. ANOVA water uptake 9 DAS

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	47	7604.000000			
Vermi	3	3932.166667	1310.722222	82.78	<.0001*
Bio	1	2187.000000	2187.000000	138.13	<.0001*
Season	1	80.083333	80.083333	5.06	0.0315*
Vermi*Season	3	38.416667	12.805556	0.81	0.0484*
Bio*Season	1	52.083333	52.083333	3.29	0.0291*
Vermi*Bio	3	674.833333	224.944444	14.21	<.0001*
Vermi*Bio*Season	3	132.750000	44.250000	2.79	0.0461*
Error	32	506.666667	15.833333		

*Significant at P≤0.05

xi. ANOVA water uptake 12 DAS

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	47	7299.666667			
Vermi	3	3659.166667	1219.722222	137.76	<.0001*
Bio	1	2241.333333	2241.333333	253.14	<.0001*
Season	1	24.083333	24.083333	2.72	0.0489*
Vermi*Season	3	35.416667	11.805556	1.33	0.0408*
Bio*Season	1	60.750000	60.750000	6.86	0.0134*
Vermi*Bio	3	959.166667	319.722222	36.11	<.0001*
Vermi*Bio*Season	3	36.416667	12.138889	1.37	0.0293*
Error	32	283.333333	8.854167		

*Significant at P≤0.05`

xii. ANOVA water uptake 15 DAS

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	47	5583.479167			
Vermi	3	2325.229167	775.076389	149.41	<.0001*
Bio	1	2173.520833	2173.520833	418.99	<.0001*
Season	1	42.187500	42.187500	8.13	0.0076*
Vermi*Season	3	63.229167	21.076389	4.06	0.0149*
Bio*Season	1	88.020833	88.020833	16.97	0.0003*
Vermi*Bio	3	680.895833	226.965278	43.75	<.0001*
Vermi*Bio*Season	3	44.395833	14.798611	2.85	0.0427*
Error	32	166.000000	5.187500		

*Significant at $P \leq 0.05$

xiii. ANOVA water uptake 18 DAS

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	47	2535.479167			
Vermi	3	700.2291667	233.4097222	80.60	<.0001*
Bio	1	776.0208333	776.0208333	267.98	<.0001*
Season	1	266.0208333	266.0208333	91.86	<.0001*
Vermi*Season	3	107.0625000	35.6875000	12.32	<.0001*
Bio*Season	1	266.0208333	266.0208333	91.86	<.0001*
Vermi*Bio	3	214.7291667	71.5763889	24.72	<.0001*
Vermi*Bio*Season	3	112.7291667	37.5763889	12.98	<.0001*
Error	32	92.666667	2.895833		

*Significant at P≤0.05

xiv. ANOVA Vase life

Source of Variation	DF	SS	MS	F Value	Pr > F
Total	47	647.4531250			
Vermi	3	416.6718750	138.8906250	231.38	<.0001*
Bio	1	159.5052083	159.5052083	265.73	<.0001*
Season	1	7.1302083	7.1302083	11.88	0.0016*
Vermi*Season	3	0.2760417	0.0920139	0.15	0.0468*
Bio*Season	1	0.2552083	0.2552083	0.43	0.0490*
Vermi*Bio	3	43.8802083	14.6267361	24.37	<.0001*
Vermi*Bio*Season	3	0.5260417	0.1753472	0.29	0.0308*
Error	32	19.2083333	0.6002604		

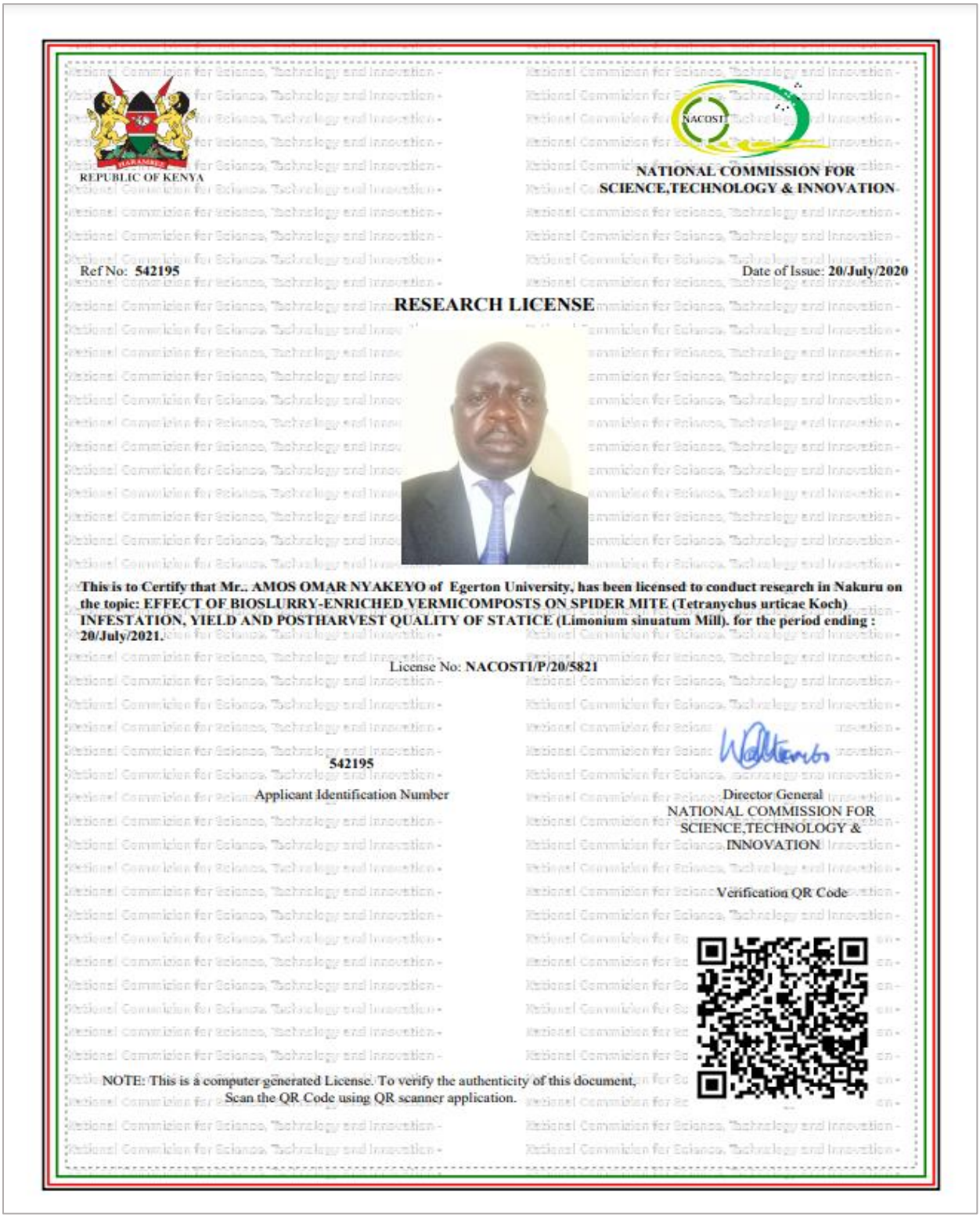
*Significant at P≤0.05

ANNEX B: Photographs from the Experiments

Treatment effect on flower stem length

Postharvest quality evaluation: water uptake and vase life

APPENDIX C: Research Permit



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APPENDIX D: Abstract of Published Journal Paper

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ACADEMIC JOURNALS

African Journal of Agricultural Research

Full Length Research Paper

Effect of different vermicomposts and bioslurry on growth, yield and postharvest quality of statice

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An experiment at Egerton University in Kenya studied effects of vermicomposts and bioslurry on growth, yield and postharvest quality in statice. Three vermicomposts prepared from Kitchen waste (V1), mowed lawn grass (V2) and Weed biomass (V3) were mixed at a rate of 40% by volume with garden soil and tested against the untreated control (V0). Bioslurry from a digester at Tatton Agricultural Park in the university was applied at 7.8 tons/ha (B1) alongside untreated control (B0). The results showed significant differences at P≤0.05 between treatments, where vermicomposts and bioslurry were separately applied compared to the controls. V1 and B1 had the most stems per plant (22.9, 26.0) and (18.7, 19.8) compared to the control (15.2, 18.1) in season 1 and 2 respectively. The number of stems per plant increased to 26.3 in season 1 and 27 in season 2 in the plots treated with both Kitchen waste vermicompost and bioslurry (V1 × B1). The flower stem lengths were higher under V1 treatment (80.9 and 95.8) cm but similar to V3 which recorded 78.9 and 92.2 cm in season 1 and 2 respectively. In season 1 and 2 respectively, bioslurry treatment (B1) recorded flower stem length of 80.0 and 92.8 cm, compared to the control (53.4 and 64.7 cm). Combined treatment V1 × B1 increased flower stem lengths to 104.1 and 121.1 cm in season 1 and 2 respectively. In season 1 and 2 respectively, V3 × B1 had the longest vase life (22.2 and 22.9 days) when compared to V1 × B1, V2 × B1, V1, V2, V3 and B1 (15.4 to 20.1 days) but all exceeded the untreated plots (11.2 and 12.2 days).

Key words: Statice, bioslurry, vermicompost, growth, postharvest.

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