IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 13, Issue 8 Ser. I (August 2020), PP 50-55
www.iosrjournals.org

Effects of *Tithoniadiversifolia* Extract and *Trichodermaasperellum* on Growth and Yield of Strawberry Fruit (*Fragaria× ananassavarDuch)*

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Abstract
A study on the effect of Tithoniadiversifolia extracts and Trichodermaasperellum on growth, yield, and quality of strawberry fruit (Fragaria× ananassavarDuch) wasconducted in Horticulture, Research and Teaching field, Egerton University. The field experiment was laid out in a Randomized Complete Block design (RCBD), with 3 replications. The treatments consisted of 3 levels of Tithoniadiversifolia (0,250ml, 500ml, and 750 ml) andTrichodermaasperellum at three levels 0ml, 40ml and 80ml. Data were subjected to Analysis of Variance (ANOVA) and significant treatment means separated using Turkey's Honestly Significant Difference Test at P ≤ 0.05. Application of Tithoniadiversifolia and Trichodermaasperellumincreased plant height, number of leaves per plant, number of flowers per plant, number of fruits per plant, increased fruit length and diameter, and total yield per plant compared to the control.

Keywords: strawberry, yield, Tithoniadiversifolia,Trichodermaasperellum,. Brix,

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Date of Submission: 02-08-2020 Date of Acceptance: 17-08-2020

I. Introduction

Strawberry is one of the most significant soft fruit cropsthought the world. It belongs to Rosacea family and genus fragaria. It is a highbreed between *F. virginia* (meadow strawberry) and *F. chiloensis* (Chilean strawberry) (Bowler andDefez, 2000). Strawberries are unique because they are rich in nutrients and minerals such as potassium, fiber, flavor, and excellent source of vitamins and sugars which results in desirable tastes (Sharma *et al.,* 2006). Among berry fruits, strawberry contains the highest percentage of vitamins, phenolic, and Flavonoids (Hakkinen and Torronen, 2000).

In Kenya Strawberry is largely grown for the domestic market.There is a huge market for strawberry in Kenya due to demand by food processing industries.The potential for increased production of strawberry is huge due to the ready market in the food processing industry. (HCD, 2014.). There is also growing interested in the healthy properties of strawberries, which has contributed to the production of strawberry thought the year hence increasing sales (Morgan, 2006).The major constraints to increased production of strawberry are pest and diseases incidence, limited knowledge on appropriate agronomic practices among growers, and use of inorganic chemicals which are not ecofriendly (HCD, 2014)

Trichodermaasperellum has been used in different fields of production and protection in agriculture (Howell, 2003; Harman *et al.,* 2004; Jacomett*iet al*., 2010). Many commercial plant growing companies are using these fungi to produce biological plant protection products or plant growth promoters. *Trichodermaasperellum*can stimulate growth by enhancing root development; production of auxin, inducing drought resistance, producing toxic compounds that have inhibits pathogen growth, and increasing photosynthesis (Chowdappa*et al.,* 2013; Shukla *et al.,* 2012).Konappa*et al*., (2018) reported an increase in growth and yield of tomato treated with *Trichodermaasperellum.* SimilarlyAloisio *et al.,* (2019) reported that*Trichodermaasperellum*was able to increase yield in soybean

Tithoniadiversifolia, also known as Mexican sunflower, is a shrub belonging to the family Asteraceae. Its green biomass is rich in nutrients (Nitrogen, phosphorus, and Potassium)which contributes to crop growth (Jamal*et al.,* 2000). Olabode*et al*., (2007) reported that application of crushed and dried ground *Tithoniadiversifolia resulted* to increase in yield in*Abelmoschusesculentus.* According to Aguyo*et al*., (2010) incorporation of*Tithoniadiversifolia*resulted to increase in growth and yields in watermelon. Similar results were obtained by Jeptoo *et al.,* (2013*)* who observed higher yield in carrots after the application of tithonia. The present study was taken to evaluate the performance of Trichoderma*asperellum* and *Tithoniadiversifolia*extracts on growth and yield of strawberry.

II. Materials And Methods

Study site

The research was conducted at the Horticulture Research and Teaching Field, Egerton University, Njoro. The field lies at latitude of 0°23'South, longitudes 35° 35'East in the Lower Highland III Agro Ecological (LH3) at an altitude of approximately 2,238 meters above sea level. Average maximum and minimum temperature range from 19°C to 22°C and 5°C to 8°C respectively, with a mean annual rainfall of 1000 mm. The soils are predominately vitric mollicandosols (Jaetzold*et al.,* 2006).

Preparation of Materials of *Tithoniadiversifolia* Extract and *Trichodermaasperellum*

Tithoniadiversifolia biomass was obtained by cutting the foliage above the ground, which was then be cut into small pieces. Twenty kilograms of the cut foliage was mixed with 200 liters of distilled water to maintain the required ratio of leaf tea 1:10 (KATC and SCC, 2007; Altierri*et al.,* 1986). The mixture was stored in 200 liter plastic container which was covered using sisal sack to reduce volatilization. The container was held then under room temperature throughout the storage time.

The mixture was agitated once a day for three weeks to provide a sufficient aerobic environment. After incubation, the mixture was sieved using a white cloth and the filtrate was ready for application. Tithonia was applied at four concentrations; 0ml, 250ml, 500ml and 750ml per liter of water. *Trichodermaasperrelum* was obtained from Real IPM Company and the (Trade name: Real Trichoderma). *Trichodermaasperellum* was applied using a 20 liters backpack sprayer at three concentrations; 0ml, 40ml, and 80ml per 20 liters of chlorinated clean tap water.

Experimental Design and Treatment Application

A factorial experiment was carried out in a Randomized Complete Block Design (RCBD) with 3 replications. Tithonia extracts was applied at four concentration (0ml, 250ml, 500ml and 750ml per liter of water), *Tricodermaasperellum* was applied at three levels (0ml, 40ml and 80ml per 20 liters of water) the blocks were used to block against soil factors to reduce errors. The experiment covered an area of 33.3 m by 5.6 m with individual blocks measuring 33.3 m by 1.2 m separated by a 1m path. Individual experimental units within a block measured 1.2 m by 2.10 m with an inter-plot spacing of 0.5 m (Fig. 1). The treatments were applied two weeks after planting, during flowering and one week before harvest.

III. Data Collection And Analysis

The average height of six plants was measured in centimeters using a standard meter rule. The measurements were done from the crown level to the apex of the primary leaves. This was carried out after every two weeks starting at 21days after planting until the first harvest. Data on the number of leaves was recorded from six plants chosen at random from two rows in the center of each plot. The results were expressed as leaf number per plant.These results were collected out after every two weeks until the first harvest. Data on numbers of flowers per plant were recorded from six plants chosen at random from two rows in the center of each treatment. The results were then expressed as the average number of flowers per plant. The length of ten randomly selected fruits from each treatment was measured in centimeters from the calyx plug to the pointed end or apex of the fruit. The measurements were done using an ordinary 30-centimeter ruler.The diameter (latitude) of ten randomly selected fruits from each treatment was measured in centimeters using an ordinary 30-centimeter ruler. The diameter was taken at the full ripe stage.

The data for fruit weight, Number of fruits per plant and Total fruit yield per plant were collected to determine the yield variables. To determine the berry weight, ten berries from each treatment in tagged plants were randomly selected and the average weight of berry was measured using an electronic balance (model: Hangping JA 2003). The results were then expressed as mean fruit weight in grams.The number of fruits i.e., primary, and secondary, tertiary were counted from six plants at the time of fruit maturity and were expressed as the number of fruits per plant.The total fruit production in each treatment was recorded from six plants per plot and yield per plant were calculated and expressed in grams. The data obtained were subjected to Analysis of Variance (ANOVA) using the GenStart (15th Edition) at $P \leq 0.05$. Means for significant treatments, were separated using Turkey's honestly significant difference test at 5% level of significance

IV. Results And Discussion

In this study, combination of *Trichodermaasperrellum* and *Tithoniadiversifolia* significantly influenced plant height and number of leaves throughout the growing period compared to control.*Trichodermaasperellum* 80ml and *Tithoniadiversifolia* at 750ml produced the tallest plants (26.33cm) and higher number of leaves (58.23) compared to untreated plants (18cm) and (44.03) respectively. Taller plants and the high number of leaves recorded in this study as a result of application of *Trichodermaasperellum* could be attributed due to its ability to produce auxins, root colonization, and enhancing photosynthesis in plants (Contreras-Cornejo *et al.,*

2009). According to Morsy (2009) and Zaghloul*et al.,* (2007), *Trichoderma.asperrellum* produces toxic compounds which inhibit pathogen growth which leads to stronger and healthier plant leading to an increase in plant growth. These arguments support the findings of the current study. Hussain*et al*., (2011) findings reported that Trichoderma had significantly additional and promoting effects on vegetative and qualitative traits of cut flowers, bulbs, and tulip.

*Tihoniadiversifolia*resulted in strawberries with the highest plant height and increased number of leaves compared to control. The ability of *Tithoniadiversifolia* to supply essential plant nutrients such as N, P,K,(3.5% N, 0.37% P, and 4.1% K) resulted in a higher number of leaves and increased in plant height. Similar results were observed by Mustonen (2012) that showed significant responses by rice, maize, and vegetable crops to *Tithonia. diversifolia* application. According to Babajide*et al.,* (2012) *Tithoniadiversifolia* was able to increase the plant height in sesame.

Table 1. Effects of *Trichodermaasperellum* and *Tithoniadiversifolia* concentrations on plant height

***Trichodermaasperellum* Concentration (ml)**		***Tithoniadiversifolia* concentration (ml)**			
		0	250	500	750
28DAP	0	4.46b	5.63ab	6.00ab	6.83a
	40	6.26a	5.86ab	6.00ab	6.53a
	80	5.50ab	6.80a	6.80a	6.83a
42DAP	0	8.53e	8.83de	10.80c	11.20b
	40	9.13d	9.13d	10.80c	11.17bc
	80	8.90de	8.90de	11.23b	11.77a
56DAP	0	12.03h	12.67fg	13.50d	14.10b
	40	12.47g	12.87ef	13.63cd	14.23b
	80	12.63fg	13.03e	13.77c	14.77a
70DAP	0	15.03g	15.20fg	16.07de	17.03bc
	40	15.20fg	15.67efg	15.97def	16.53cd
	80	15.67efg	15.80defg	17.40b	18.67a
84DAP	0	18.00e	18.23e	19.83d	22.03c
	40	18.10e	18.43de	19.73d	24.50b
	80	18.47de	18.47de	21.83c	26.33a

Means followed bythe same letter within a trial are not significantly different according to Tukey's HSD test at p≤0.05. DAP refers to days after planting

Table 2. Effects of *Trichodermaasperellum* and *Tithoniadiversifolia* concentrations on number of leaves

Trichodermaasperellum concentration (ml)		*Tithoniadiversifoliar concentration (ml)*			
		0	250	500	750
28DAP	0	11.40e	11.47de	12.43abc	12.27bcde
	40	11.50de	11.80e	12.50abc	12.72ab
	80	12.13bcde	11.93bcde	12.33abcd	13.17a
42DAP	0	15.23e	15.40e	18.90bc	19.73a
	40	15.27e	15.80e	18.63c	19.77a
	80	17.27d	17.70d	19.53ab	19.77a
56DAP	0	21.03j	22.10h	26.77e	27.10c
	40	21.53i	22.23g	26.87de	27.53b
	80	23.03f	22.33gh	27.03cd	27.87a
70DAP	0	33.90d	34.60cd	36.77b	37.87ab
	40	34.70cd	34.77cd	36.83b	38.37a
	80	35.23c	34.83cd	37.20b	36.93b
84DAP	0	44.03e	44.10e	56.00a	57.17a
	40	44.23e	47.83cd	52.83b	57.80a
	80	45.63de	49.77c	55.77a	58.23a

Means followed by the same letter within a trial are not significantly different according to Tukey's HSD test at p≤0.05. DAP refers to days after planting

Yield Parameters

In the present study, the use of *Trichodermaasperellum* and *Tithoniadiversifolia* significantly affected the strawberry yield. The number of flowers per plant were significantly affected by the application of *Trichoderma. asperellum* and *Tithonia. diversifolia* rates. More flowers were observed in treated plants (23.03)

compared to control (8.30). Trichodermaspp were found to produce compounds such as phytohormones which stimulate root growth, thus increasing the absorptive surface of plant roots. These phytohormones include gibberellins cytokinins and indole-3-acetic acid which also promotes flowering (Tjamos*et al*., 2010) Similar results were observed by Kerroum*et al*., (2015) where the application of *Trichodermaasperellum* increased the number of flowers in tomato plants. Similar observations were reported by Tondje*et al.,* (2007) and Deberdt*et al.,* (2008) who observed a high number of flowers in the cocoa plants. According to Jayasundara*et al.,* (2011) tithonia produces nutrients which lead to vigorous growth in plants leading to the high number of flowers. This is in agreement with Ademiluyi (2012) who found tithonia to have a significant effect on the number of shoot yield in Okra which resulted to the higher number of flowers. A combination of all these factors contributed to a higher number of flowers in strawberry as a result of tithonia and trichoderma.

Fruits were longest in plots treated compared to untreated plots.Significant differences were observed in the combination with tithonia at 750 ml and trichoderma at 80 ml producing the longest fruits (6.36cm) compared to control (2.36cm), and largest diameter (4.13) compared to control (1.23). The results were similar to those of Setyowati, (2018) who observed an increase in cucumber length and diameter. This was as a result of high nutrient content in tithonia green biomass (Babajide, 2012). Jayasundara*et al.,* (2016) observed an increase in the length of okra after the application of *Tithoniadiversifolia*. The ability of *Trichodermasperellum* to stimulate plant growth and yield resulted in longer and large fruits in strawberry fruits(Stringlis*et al*., 2018).According to Jayaraman*et al.,* 2014 trichodermaspp can induce plant defense mechanism systems resulting in healthy and strong plants which can produce health large fruits.

Fruit number significantly increased in treated plants compared to control. A higher number of fruits were observed after application of *Trichodermaasperellum* 80 ml and *Tithoniadiversifolia* 750 ml (12.73) compared to control at (6.63). These results were similar to those of Zaghloul*et al*., (2007) who observed a higher number of fruits in tomato as a result of *Trichodermaasperellum*.This was in agreement with Vinale*et al.,* (2008) who reported that *Trichodermaasperellum* resulted to increase in the number of fruits in pepper and tomato. The enhancement of fruits number was due to ability of trichoderma to convert unavailable nutrients into available form leading to higher yields (Meunchang*et al.,* 2006)

In the present study, *Tithoniadiversifolia* significantly affected the number of fruits in both experiments. Consistent with the findings of the present study, Setyowati*et al*., (2018) reported a higher number of curds in cauliflower after treatment with tithonia. Similar to this finding, Babajide*et al.,* (2008) reported that tomato plant yield increased with increasing tithonia rate. Green leaf biomass of tithonia contains 3.5% N, 0.37% P and 4.1% K on a dry matter basis which contributes to increasing in the number of fruits and plant yields (Guong*et al.,* 2010). An increase in the number of fruits in this study also resulted due to the availability of phosphorous in tithonia which is a key element in fruiting (Muktamar*et al.,* 2017)

In the current study treated plants yielded higher (194.9g) compared to untreated plants (54.8).The weight per fruit was also higher in treated plants (15.97g) compared to untreated plants (8.30g). *Trichodermaasperellum*at 80 ml and *Tithoniadiversifolia* at 750 ml produced the highest yields compared to other treatments. According to previous studies, Trichodermaspp were found to be plant symbionts that confer positive effects on crop yield, plant growth, and stimulation of plant defense through the production of secondary metabolites (Hermosa *et al.,* 2012). Mazhabi*et al*., (2011) revealed that, trichoderma had additional and promoting effects on vegetative and qualitative traits of tulip bulbs and cut flowers. Similar results were reported by Niknejad*et al*., (2000) and Zaghloul*et al*., (2007) who documented that application of trichoderma significantly influenced the weight of fruits, the number of fruits and the total yield of tomato fruits.*Trichodermaasperellum* increased yield in vegetable crops (Bal and Altintas, 2006). Tondje*et al.,* (2007)reported that*Trichodermaasperellum* was able to increase the number of the pod in the cacao plants.

The ability of *Tithoniadiversifolia* extracts to increase fruit yield in this study was due to its nitrogen, potassium, and phosphorous content (Hafifah*et al* .,2016).The results of the present study were similar to those of Fahrurrozi*et al.,* (2017) who observed an increase in carrot root yield with an increase in tithonia level. Tithonia can substitute for urea as N sources according to Opala *et al.* (2015*)* and as a complement of inorganic fertilizers in Kales (Mwangi and Mathenge, 2014)

Table 1. Effects of *Trichodermaasperellum* and *Tithoniadiversifolia* concentrations on strawberry yield

Trichodermaasperellum concentration(ml)	*Tithoniadiversifolia concentration (ml)*			
	0	250	500	750
Number of flowers per plant				
0	8.30e	9.17e	19.87b	22.30a
40	10.77d	10.40d	20.53b	22.43a
80	11.73c	11.20cd	22.77a	23.03a
Fruit diameter in cm				
0	1.23f	2.00de	3.67b	3.90ab
40	1.733e	2.13d	3.76b	3.80b
80	2.53c	2.80c	3.86ab	4.13a

		Fruit length in cm		
0	2.36b	3.13b	5.50a	6.20a
40	2.73b	3.83b	6.2a	6.00a
80	3.10b	3.43b	5.90a	6.36a
		Fruit weight in gram		
0	8.30e	8.47e	14.73c	15.20bc
40	9.83d	8.73e	14.73c	14.80c
80	9.70d	9.57d	15.67ab	15.97a
		Fruits per plant		
0	6.63g	8.20f	12.40a	12.17b
40	9.80d	9.13e	12.30ab	12.40ab
80	10.70c	9.17e	12.70a	12.73a
		Yields per plant in grams		
0	54.8f	80.0e	187.6b	185.1b
40	96.4cd	79.8e	181.3b	186.4a
80	103.9c	88.2de	193.1ab	194.9a

***Means followed by the same letter within a trial are not significantly different according to Tukey's HSD test at p≤0.05. DAP refers to days after planting**

V. Conclusions and Recommendations

Based on the findings, it can be concluded that; Use of *Tithoniadiversifolia* and *Trichodermaasperellum*influenced growth and yield of strawberry fruits.*Tithoniadiversifolia* and *Trichodermaasperellum*can therefore be recommended for use in strawberry production as an alternative source of nutrients.

Acknowledgement

The study was made possible by the support from Regional Universities Forum for Capacity building in Agriculture (RUFORUM) through TAGdev program at Egerton University.Thank you Egerton University and and Department of Crops Horticulture and Soils for support.

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