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LEAF LITTERS IMPROVES THE PRODUCTION OF *Zea mays* L. -*Heinsia crinita* (Afzel.) G. Taylor BASED ECOSYSTEM IN ONNE-RIVERS STATE, NIGERIA

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ABSTRACT

Leaf litter has long been recognized for its importance in the nutrient dynamics of plant communities, growth and yield of arable crops are due to constant litter fall rates throughout the year. Leaf litters adds both macro and micro-nutrients to the soil, hence improves crop production. Study on leaf litters improves the production of Zea mays - Heinsia crinita based was carried out in Swamp Forest Research Station (SFRS), Onne, Rivers State, Nigeria with the aims to increase food production. A 2 x 3 experiment in complete randomised design (CRD), replicated three times was used in applying three treatments: leaf litter of Allanblackia floribunda (T_1), leaf litter of Garcinia kola (T_2) and Control (T_3) on each sub-plots size 4m x 4m within 16m x 16m per block. Data on the initial and final growth attributes of Heinsia crinita and growth performance of maize were collected and analyzed using analysis of variance (ANOVA). The results revealed that despite tremendous increased in growth morphological characters of Heinsia crinita height, collar diameter and crown diameter, there were not significant different, while number of branch and crown depth were significantly different after initial and final assessment. Growth performance of maize showed that leaf litter of Allanblackia floribunda (T_1), leaf litter of Garcinia kola (T_2) and Control (T_3) had no significant different on height, collar diameter and internode length of maize, while the leaf number exhibited significant different among the treatments.Findings revealed that application of Allanblackia floribunda leaf litter had exhibited superiority in term of growth attributes than other treatments. Zea mays and *Heinsia crinita are arable crop and leafly vegetable respectively, which are highly consumed by Rivers state indigenes and its environs. In conclusion, application of leaf litters on arable crops should be encouraged for sustainable food production and environmental-eco-friendly disposition, since it has been proved effective in this study.*

Keywords: *Heinsia crinita, Zea mays,* leaf litter, growth attributes, food-security

INTRODUCTION

Maize is one of the stable food crops in Nigeria and beyond. In Africa, West Africa, and Nigeria, in particular, maize is a major staple food crop (Maini *et al.,* 2009). Maize is the most important cereal worldwide (Ashraf *et al.,* 2016a, and Mahmood *et al.,* 2017). Maize is more widely adapted to a variety of environments than any other cereal (Uko, 2000, and Nsien *et al.,* 2019). It can grow from latitude 58ºC N and latitude 40ºC S. Similarly, it is grown from below sea level to altitudes of about 4000 metres (Udounang, 2006). Maize is a warm-weather crop grown where the mean temperatures vary between 21ºC and 27ºC. Maize plays a role in filling the hunger gap after the dry season and serves as a stable diet for 200 million people (FAO, 2003). Despite all these, factors like soil fertility, imbalanced nutrition, disturbed soil properties, land pollution/degradation, and land hunger due to escalating population limit it's growth and yield of maize in most regions of the world. Over the years, intensive application of mineral fertilizer (NPK 15:15:15) is known to cause land degradation, deterioration of soil health, and also leaching of nutrients into the underground water thereby posing environmental risks for both flora and fauna.

Hence, need for maize to be intercropped with plantation tree/shrub like *Heinsia crinita* in a friendly environment to enhance its performance through organic matters and leaf litters in the soil. *Heinsia crinita* commonly called bush apple is a perennial shrub or small tree species that belongs to the family Rubiaceae. It is native to tropical areas of Africa. The species is popularly known as 'Atama' in Nigeria, especially in South-South and South-East Geo-political zones. The plant is used as a vegetable in cooking varieties of soup and medicine in these zones. This plant habitat has been threatened for some decades now due to anthropogenic activities. This makes it relatively scarce in the wild; hence most farmers resort to domesticating this tree in their homegarden/farmstead. Being a shrub and slow-growing plant, it can easily be intercropped with arable crops (maize, Okro, yam, melon, and fluted pumpkin etc). *Heinsia crinita* is one of those plants that spread moderately with heavy foliage, which normally shreds greater parts of its leaves during the dry season, which later adds nutrients to the soil.

Availability of organic matter also contributes to crop growth and yield directly by supplying nutrients and indirectly by modifying soil physical properties such as stability of aggregates and porosity that can improve the root growth, rhizosphere and stimulate plant growth (Idem *et al.,* 2012). Organic fertilizer apart from releasing nutrient elements to the soil also improves other soil chemical and physical properties which enhance crop growth and development (Ogbonna, 2008, and Dauda *et al*., 2008). *Zea mays* and *Heinsia crinita* are arable crops and leafy vegetables respectively, which are highly consumed by Rivers state indigenes and its environs. Their effective production via leaf litter application will guarantee sustainable food production and also ameliorate carbon iv oxide (CO_2) that aids in climate change and encourages an eco-friendly environment. This therefore necessitated the study on leaf litter on *Zea mays* - *Heinsia crinita* based to aid in food security in Onne, Rivers state, Nigeria.

MATERIALS AND METHODS

Description of the study site

A study on the integration of leaf litter performance on *Zea mays* - *Heinsia crinita* based was carried out in Swamp Forest Research Station (SFRS), Onne in Eleme Local Government Area of Rivers State, Nigeria. Onne is a village located about 7km off Port Harcourt, Rivers State capital. It lies on latitude 4°42'5.86" - 4°42'2.59"N and Longitude 7º10'36.57" - 7°10'42.65"E with an elevation of 40 meters above sea level (Anegbeh,1997). It has an annual rainfall of 2500mm with a mean value of 75% relative humidity in February and 80% in July (Okonkwo *et al*., 2014). The mean minimum temperature is 25^0C (ICRAF/IITA, 1994). The general feature of the landform is one of long connecting, slopes with gentle gradients (Koyejo, 2002). The soil is an Ultisols derived from coastal sediments.

METHODS

A 2 x 3 experiment in a complete randomised design (CRD) with three replicates was used to study leaf litters performance on maize (*Zea mays*) - *Heinsia crinita* based home garden in a 2 year old plantation in 2020. The treatments were: leaf litter of *Allanblackia floribunda* (T_1), leaf litter of *Garcinia kola* (T_2), and Control (T_3)

without any leaf litter. These leaf biomasses were chopped by hand and mixed uniformly with soil during final land preparation and then left to decompose for seven days (one week). Each of the treatments was randomly applied in each of the 4m x 4m plots, except control plots within a block (16m x 16m) with a ride of ways of 1m. A spacing of 40cm was adopted between the tree and maize crop, while a 60cm spacing was used in between maize crops. The study also evaluated the physicochemical properties of the soil within *Heinsia crinita* plantation and some nutrient contents of *Allanblackia floribunda* and *Garcinia kola* leaf litter.

Data collection

Data on *Heinsia crinita* plant morphological characteristics (plant height (cm), plant diameter (mm), leaf number, crown diameter (mm), and crown depth (cm) were collected at the onset and the end of the experiment (April – June, 2020), while assessment of *Zea mays* growth parameters was equally carried-out biweekly. Plant heights (m) - plant heights were obtained by measuring the total plant height from the base (soil level) to the terminal (apical bud) part of the plant with the aid of measuring tape. Plant diameter (cm) - plant diameters were obtained with venier callipers per tree at the height of fifteen centimetres (15 cm) above ground level against the traditional Diameter Breast Height (DBH) due to the age of the plants in the plantation. Leaf number- the total number of leaf per plant was counted individually. Crown diameter (cm) - crown diameter per plant was obtained by measuring the total length of the crown diameter from the following points: North –South, and West–East. The lengths obtained from each point per plant were added and divided by two to obtain the mean crown diameter per plant. Crown depth (cm) - crown depth was obtained by measuring from the first branch to the terminal (apical bud) of the plant using a measuring tape. Internodes- lengths (cm) of leaf interval were obtained by measuring the interval between leaves in maize plants.

Data Analysis

The data collected from the above-mentioned plant morphological characteristics were analyzed using one-way analysis of variance (ANOVA) statistics with IBM-SPSS version 20. All data collected on *Heinsia crinita* and *Zea mays* plant morphological characteristics were later subjected to statistical analysis using Fisher's Least

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Significant Different (F-LSD) at $p \leq 0.05$ according to the procedures of Steel and Torrie (1980) and Alika (2006).

RESULTS AND DISCUSSION

Appendix/Table 1 showed the physico-chemical properties of soil, *Garcinia kola, Allanblackia floribunda and Heinsia crinita* leaf litters in the study site within the period of study. The pH-values of soil (5.66), *Allanblckia floribunda* (6.10), *Garcinia kola* (6.98) indicated acidic contents, while pH-values of *Heinsia crinita* (8.50) which indicated base contents. The nitrogen content of the soil sample was very low as compared to the nitrogen contents of leaf litters of above-mentioned species, while phosphorus contents of the soil was very high (66.10 c mol kg^{-1}) when compared with those of *Allanblckia floribunda* (0.37 c mol kg^{-1}), *Garcinia kola* (0.36 c mol kg^{-1}) and *Heinsia crinita* (0.58 c mol kg^{-1}) which showed low contents. Table 1 indicated that sodium was the only element present in the soil sample, but completely absent in the three leaf litters under investigation. Soil sample (6.40 c mol kg^{-1}) and *Heinsia crinita* (4.62 c mol kg^{-1}) showed higher contents than *Allanblckia floribunda* (2.82 c mol kg^{-1}), *Garcinia kola* (2.11 c mol kg^{-1}) which are almost similar. Consequently, magnesium in soil and *Heinsia crinita* leaf litter samples was greater than those of *Allanblckia floribunda* and *Garcinia kola* leaf litters samples. Table 1 further showed that organic matter and organic carbon contents in the soil sample were very negligible as compared to their contents in *Garcina kola, Allanblackia floribunda and Heinsia crinita* leaf litters. Exchangeable acidity (0.88 c mol kg^{-1}), effective cation exchange capacity (11.35 c mol kg^{-1}) contents and base saturation percentage (92.26%) were present in soil sample, but the trace of these substances could not be found in the various leaf litters under studied in table 1.

Growth morphological characteristics of *Heinsia crinita* in *Zea mays*- based plantation

Figures below present initial and final growth morphological characteristics of height, collar diameter, number of branches, crown diameter, and crown depth of *Heinsia crinita* in *Zea mays*-based plantation. Chart/Figure 1a showed the initial and final height of *Heinsia crinita* intercropped with *Zea mays* before and after applications of *Allanblackia floribunda* (T_1), *Garcinia kola* (T_2) leaf litters and control (T_3). The figure revealed the height of

Heinsia crinita increased within the period of study, but there was no significant difference ($P \geq 0.05$) among the three treatments. Collar diameter showed slide increment, but statistically no significant different ($P \geq 0.05$) was observed among treatments applied (Figure 1b and Table 2). Figure 1c showed that number of branch of *Heinsia crinita* was significant different ($p \leq 0.05$) from each other. However, control (T_3) plots gave highest branches, while plots applied with *Garcinia kola* leaf litter (T_2) gave least branches (Figure 1c and Table 1). Crown diameter showed some disparity, and there was no significant difference ($p \leq 0.05$) among treatments applied (Figure 1d and Table 1). Figure 1e showed the crown depth of *Heinsia crinita* at the inception and end of the study indicating uniformity among various treatments. Moreover, there were significant difference ($P \geq 0.05$) existed between treatments 1, 2, and 3 (Table 1). *Garcinia kola* and *Allanblackia floribunda* leaf litter had the highest and least crown depth respectively.

Growth attributes of *Zea mays* in *Heinsia crinita* - based plantation

Figures below represent various growth attributes (height, collar diameter, leaf number, and internode length) of maize intercropped with *Heinsia crinita* plantation in Onne, Rivers State. Figure 2a showed that maize height systematically increased among treatments applied from 4 weeks of growth assessment throughout the duration of the experiment. Treatment T_1 (*Allanblankia floribunda* leaf litters) gave the highest growth rate, while treatment (T_3) control gave the least growth rate of maize height within the period of the 4^{th} , 6^{th} , 8^{th} and 12^{th} week except in 10 weeks which treatment T_2 (*Garcinia kola* leaf litters) was over shallow by treatment(T_3). From the ANOVA (Table 3), there was no significant difference among the various treatments applied on the height of the maize crop in *Heinsia crinita* plantation. Figure 2b indicated that Treatment T_1 (*Allanblankia floribunda* leaf litters) still had highest growth rate of collar diameter than treatments T_2 and T_3. The ANOVA (Table 3), showed that there was no significant difference among the different treatments. In terms of leaf number, figure 2c showed that treatment T_2 *(Garcinia kola)* leaf litters had continuously increased leaf number within the 4^{th}, 6^{th}, 8^{th}, 10^{th} and 12^{th} weeks of growth. From the ANOVA (Table 3), there was a significant difference among various treatments: Treatment T_1 *(Allanblankia floribunda)* leaf litters, treatment T_2 *(Garcinia kola)* leaf litters and treatment T_3 (control). However, treatment T_2 had highest leaf number, while treatment

(T_3) control had least leaf number of maize plants throughout the period of the 4th, 6th, 8th, 10th and 12th weeks of growth assessment. Figure 2d indicated that treatment T_3 (control) have positively affected internodes of maize at the 4th and 12th weeks, but in weeks 8th and 10th treatment T_2 (*Garcinia kola*) have higher internodes than the 4th, 6th and 12th weeks, while treatment T_1 (*Allanblankia floribunda)* leaf litters exhibited highest internodes in 6th weeks than treatments (T_2 and T_3). The ANOVA (Table 3) showed that there was a significant different among various treatments applied to maize internodes in *Heinsia crinita* plantation, which indicated means maize internodes responded positively to the treatments.

DISCUSSION

A study of growth morphological characters (height, collar diameter, number of branches, crown depth, and internode length) of *Heinsia crinita*/*Zea* mays production on leaf litter performance on maize showed both similarity and disparity among various treatments. Organic matter (leaf litters and other plant materials) has been the major way of enhancing soil nutrients (nutrient cycling) about four to five decades ago, when the bush fallow system was commonly practiced. Effective management of the bush fallow system created a conducive soil environment for plants to thrive well via the accumulation of leaf litter. Leaf litters of *Allanblackia floribunda* and *Garcinia kola* leaf litters on maize crop in *Heinsia crinita* home garden have shown overwhelmingly growth performance on various crop attributes than control (without application of leaf litters). This is in agreement with the findings of Murtadha *et al*., (2020) who noted that organic materials contribute positively to soil's physical, chemical, and biological properties and act as sources of nutrients for plant growth. Leaf litter decomposition is the major avenue of sustaining soil fertility in a tree-based ecosystem by providing organic and inorganic elements for nutrient cycling processes and controls nutrient returns to the ecosystem (Wang *et al.,* 2008), Isaac and Varghese (2020) also noted that leaf litter on decomposition offer ample scope for nutrient recycling and the slow release coincides with the requirements of the better crop production. Kumar (1998) and Arunkumar (2000) have reported similar increases in soil nutrient status on the application of compost in soil. Nsien *et al.,* (2016) also encouraged the incorporation of *Allanblackia floribunda* as agroforestry tree in the farming system, due to it high level of canopy formation, leaf litterfall and leaf litter decomposition potentials and nutrients cycling status.

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Improvement in the soil properties had a bearing on the growth and yielding ability of the tuber crops as inclusion of litter in nutrient management recorded higher yields compare to 100% chemical fertilizer application (Isaac and Varghese, 2020). Khan *et al.,* (2010) noted that tree leaf litter is a very important organic source of soil fertility improvement and further said tree leaf biomass could successfully be used as an alternative to chemical fertilizers.

Findings revealed that the application of *Allanblackia floribunda* as leaf litter exhibited superiority in growth over other treatments; this could be due to the substrate and chemistry quality of the plant, which may be fast in releasing nutrients to the soil. The enhancement of maize production via treatments could be as a result of some primary nutrients (nitrogen, phosphorus and potassium) available in each leaf litters applied. Khan *et al.,* (2010) also reported that 300g of Neem leaf biomass and 300g of Mahogany leaf biomass were found the best for rice production and yield in Mymensing, Bangladesh. Equally, *Heinsia crinita* parameters (height, collar diameter, number of branches, crown diameter, and crown depth) were also significantly increased within the period of the study. This could be due to accumulation of nutrients in the plantation/field via leaf litter of *Heinsia crinita* that had decomposed since the establishment of the plantation.

CONCLUSION

Findings revealed that the application of *Allanblackia floribunda* leaf litter had exhibited superiority in both growth attributes over other treatments (Garcinia kola leaf litter and control). This could be due to leaf litter substrate and the chemistry quality of the plant and biota type, which may be fast in releasing nutrients to the soil for easy utilization by maize crops. The enhancement of maize (arable crop) and *Heinsia crinita* (leafly vegetable) production via treatments could be a result of some primary (nitrogen, phosphorus, and potassium) and secondary (sodium, calcium, and magnium etc) nutrients available in each leaf litters applied. *Heinsia crinita* parameters (height, collar diameter, number of branches, crown diameter, and crown depth) were significantly increased within the period of the study. This could also be due to accumulation of nutrients in the plantation/field via leaf litters of *Heinsia crinita* that had decomposed since the establishment of the plantation. The improvement of both maize (arable crop) and *Heinsia crinita* (leafly vegetable) through leaf litters have contributed tremendously for food supply, and also reduce excessive environmental pollution often culminated from mineral/inorganic fertilizers. *Heinsia crinita* being a leafly vegetable or a shrub has constant litter fall rates throughout the year, which aids in microbial-activities, aeration, moisture contents, porosity, and mineralization in the forest soil, that eventually improves fertility of the soil and increases maize production in the study area. It's further saved as a shelter for detrivores macrofauna and decomposers that enhance in nutrient cycling in the soil. The study therefore recommends further research work on *Allanblackia floribunda* and *Garcinia kola* leaf litter to be carried out in most arable crops, due to their environmentally friendly disposition.

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APPENDIX

Table 1: Physico-chemical properties of soil and analysis of *Garcina kola, Allanblackia floribunda,* and *Heinsia crinita* leaf litters in the study site

Soil Physical Properties	Soil (%)	*Allanblackia floribunda* (%)	*Garcina kola* (%)	*Heinsia crinita* (%)
Sand (%)	83.60	--	--	--
Silt (%)	6.80	--	--	--
Clay (%)	9.60	--	--	--
Texture	Sandy-loam	--	--	--
pH – H_2O	5.66	6.10	6.98	8.50
N (%)	0.25	1.89	1.75	2.52
P (c mol kg^{-1})	66.10	0.37	0.36	0.58
K (c mol kg^{-1})	0.25	0.65	0.76	0.65
Na (c mol kg^{-1})	0.22	--	--	--
Ca (c mol kg^{-1})	6.40	2.82	2.11	4.62
Mg (c mol kg^{-1})	3.60	0.91	0.73	1.71
OM (c mol kg^{-1})	5.15	44.58	43.13	46.93
OC (c mol kg^{-1})	2.99	25.86	25.05	27.22
EA (c mol kg^{-1})	0.88	--	--	--
ECEC(c mol kg^{-1})	11.35	--	--	--
BS (%)	92.26	--	--	--

N= nitrogen, K= potassium, P= phosphorus, Na= sodium, Ca=calcium, Mg= magnesium, OC= organic carbon, OM= organic matter, ECEC = effective cation exchange capacity**,** EA=exchangeable acidity, BS(%)= base saturation percentage.

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Table 2: Analysis of variable (ANOVA) for growth morphological characteristics of *Heinsia crinita* in *Zea mays*- based plantation

SOV	SS	Df	MS	F	P-Value
Height (cm)					
Between Groups	253.083	2	126.542	2.451	.234 ns
Within Groups	154.865	3	51.622		
Total	75.048	5			
Collar diameter (mm)					
Between Groups	30.333	2	15.167	1.058	.449 ns
Within Groups	43.000	3	14.333		
Total	73.333	5			
Number of branches					
Between Groups	15.210	2	7.605	28.342	.011*
Within Groups	.805	3	.268		
Total	16.015	5			
Crown diameter (cm)					
Between Groups	58.943	2	29.472	5.490	.099 ns
Within Groups	16.105	3	5.368		
Total	75.048	5			
Crown depth (cm)					
Between Groups	622.440	2	311.220	550.832	.000*
Within Groups	1.695	3	.565		
Total	624.135	5			

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Table 3: Analysis of variable (ANOVA) for growth attributes of *Zea mays* in *Heinsia crinita*-based plantation

SOV	SS	Df	MS	F	Sig.
Height (cm)					
Between Groups	6798.986	2	3399.49	1.213	.308 ns
Within Groups	117754.436	42	2803.68		
Total	124553.422	44			
Collar diameter (mm)					
Between Groups	402.820	2	201.41	2.513	.093 ns
Within Groups	3365.708	42	80.14		
Total	3768.529	44			
Leaf number					
Between Groups	23.080	2	11.54	3.568	.037*
Within Groups	135.854	42	3.235		
Total	158.934	44			
Internodes length (cm)					
Between Groups	24.890	2	12.445	.848	.435 ns
Within Groups	616.377	42	14.676		
Total	641.267	44			

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CHARTS

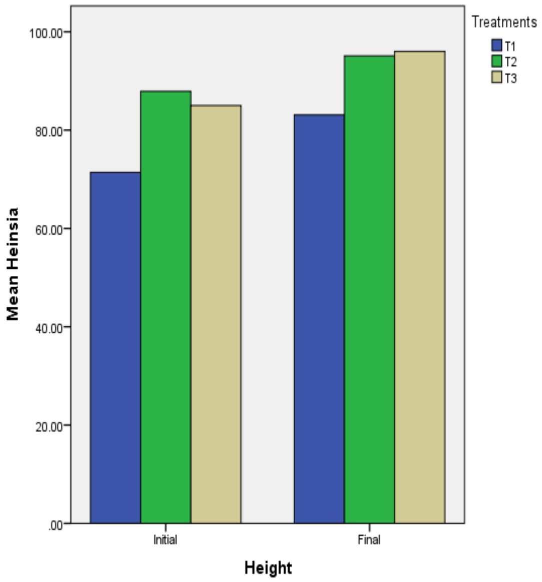

Figure 1a showed height (cm) of *Heinsia crinita*

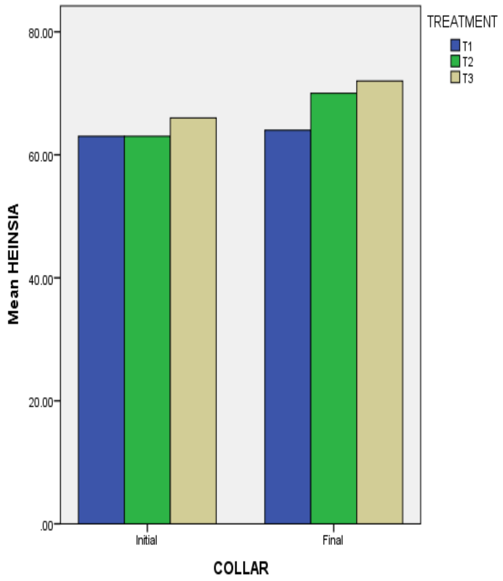

Figure 1b showed collar diameter (mm) of *Heinsia crinita*.

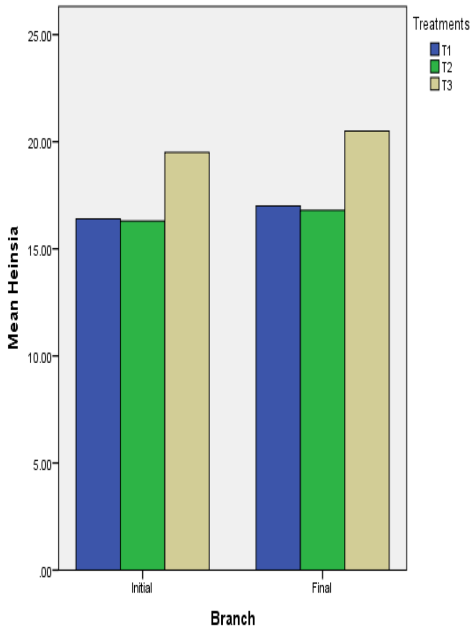

Figure 1c showed number of branch of *Heinsia crinita*.

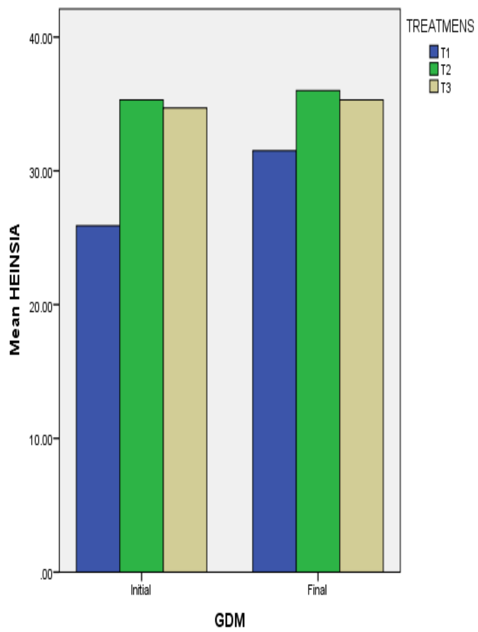

Figure 1d showed crown diameter (mm) of *Heinsia crinita*.

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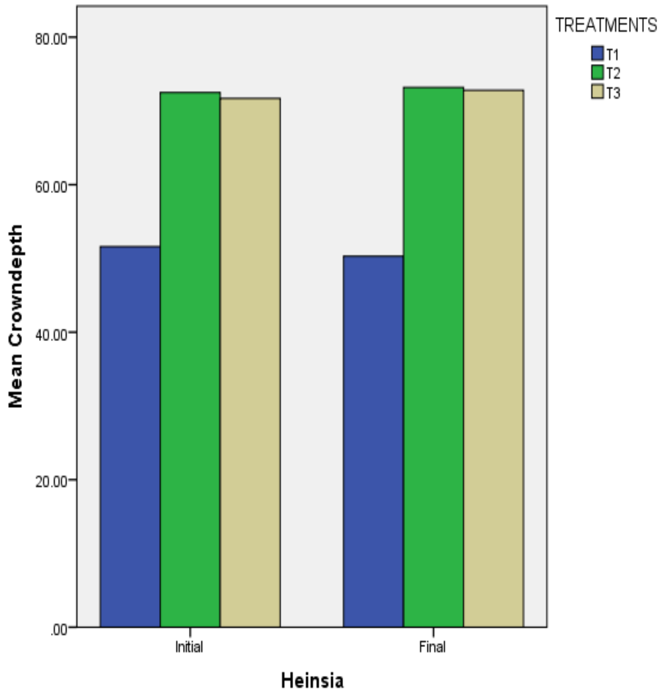

Fig 1e: showing Crown Depth (cm) of *Heinsia crinite*

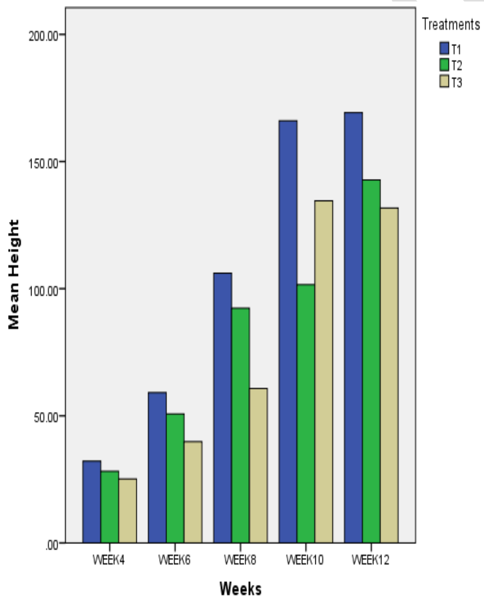

Figure 2a showed height (cm) per weeks of *Zea mays*.

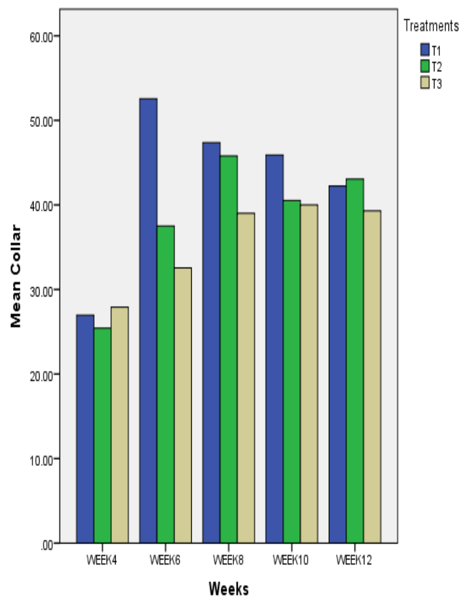

Figure 2b showed collar diameter (mm) per weeks of *Zea mays*.

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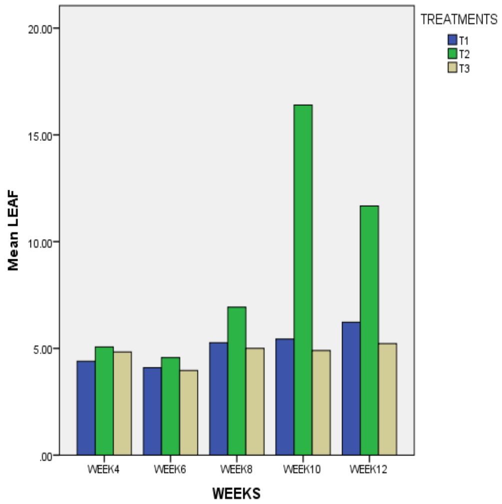

Figure 2c showed number of leaf per week of *Zea mays*.

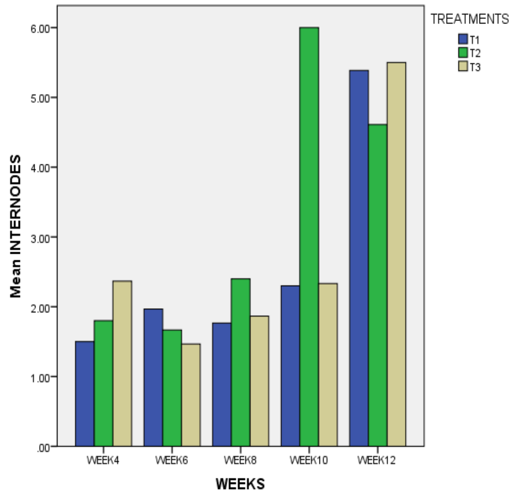

Figure 2d showed internodes per weeks of leaf of *Zea mays*.