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Research Article

Impact of *Tithonia diversifolia* as Green Manure Amendment on Yield and Yield Attributes of Maize (*Zea mays*)

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Abstract

Manures improve soil fertility and crop yield; however, the optimum rate and method of application are important. This experiment was conducted to determine the impact of different rates and modes of application of *Tithonia diversifolia* on the yield and yield components of two maize varieties. The trial was conducted at the Teaching and Research Farm of the Federal University, Oye Ekiti, Nigeria, during the 2020 and 2021 cropping seasons. The experiment was laid out in a factorial arrangement fitted into a randomized complete block design, replicated 3 times. The trial comprised of two maize varieties (LNT-P-W and SAUWUAZ), two methods of application of *Tithonia diversifolia* amendments (chopped and unchopped). Grain yield and yield components were measured. The result showed that significant difference ($P < 0.01$) was observed among the maize varieties for number of seeds per cob, 100 seed weight and grain yield. Also the methods of amendments showed significant ($P < 0.01$) impact on cob length while the quantity of the amendment also had significant ($P < 0.01$) impact on the number of rows per cob, number of seeds per cob, 100 seed weight and grain yield in both years. Significant ($P < 0.01$) interaction was observed between the maize varieties and quantity of amendments used. Also the status of the amendment $\times$ quantity had significant ($P < 0.01$) impact on the number of rows per cob. However, varieties $\times$ status $\times$ quantity showed significant impact on the number of seeds per row and number of seeds per cob in 2021.

Keywords: *Tithonia diversifolia*, Green manure, Status, Maize varieties, Yield

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Introduction

The demand for maize in the developing world is predicted to double by 2050. However, low soil fertility is an important constraint to its production and productivity in sub-Saharan Africa (SSA). Continuous cropping without sufficient use of fertilizer on most arable land in the SSA has resulted in the depletion of essential soil nutrients and organic matter needed to support maize growth (Kolawole *et al.*, 2014). The quantity of fertilizer used by smallholder farmers in Africa is associated with the high price of fertilizer due to inadequate transportation and distribution network (Mosier *et al.*, 2006). Organic manures are alternatives to mineral

fertilizers and the addition of greenmanures and poultry manures to soil has been found to play an important role in maintaining soil organic matter content while securing adequate soil nutrient concentrations (Boateng *et al.*, 2006). Green manures are a key part of organic gardening, and they serve several purposes in improving soil structure, preventing soil erosion, inhibiting weed growth and most importantly, increasing soil fertility. Green manuring is an agronomic practice that entails incorporating green plants into the soil either in situ or ex-situ. (Maitra *et al.*, 2018). The plant then slowly releases its nutrients as it decays and increases the amount of organic

matter in the soil. A crop is considered suitable as manure if it is (i) non-woody, annual and vigorous (ii) grows well in poor soil without applying fertilizer (iii) easy to establish (iv) needs no pesticide (v) shade and drought-resistant (vi) High carbon-nitrogen ratio (Multifarious uses (fodder, green manure, N fixation, seed, shade, cover crop, erosion control) (Ramanjaneyulu et al., 2021;). Several crops have been identified as suitable green manure including legumes such as pigeon pea (*Cajanus cajan*), green gram (*Vigna radiata*), soybean (*Glycine max*), cowpea (*Vigna unguiculata*) or groundnut (*Arachis hypogea*), and Mexican sunflower (*Tithonia diversifolia*) (Ramanjaneyulu et al., 2021; Maitra et al., 2018). *Tithonia diversifolia* is a shrub and belongs to the family Asteraceae. It is abundant in the SSA and has been widely used in amending depleted soils in the region (Opala, 2020) and arable crops (Dayo-Olagbende et al., 2020). The C: N ratio, availability of nutrients for soil amendment and rate of decomposition of the plant is affected by the vegetative stage at which it was incorporated into the soil (Olabode et al., 2007). *Tithonia diversifolia* helps maintain soil moisture and the population of beneficial soil microbes for efficient crop production. Aderinoye-Abdulwahab (2017) reported the risk of using organic fertilizer by farmers because it has been observed to be slow in acting as it takes the soils a longer period to fully decomposed. Rapid decomposition of *Tithonia diversifolia* leaf biomass suggests a speedy release of N (Jama et al., 2000) which in turn increased yields of vegetables such as okra (*Abelmoschus esculentus*) and carrot (*Daucus carota*) (Agbede et al., 2017). Opala et al. (2015) reported *Tithonia diversifolia* is more effective or better than inorganic fertilizers due to its long-term effects on soil. Other uses of *Tithonia* are fodder (Mauricio et al., 2017), compost (Pelú et al., 2020), soil erosion control (Yulnafatmawita et al., 2017), control insect pests (Green et al., 2017), and weed control (Ajayi, 2017). Jama et al. (2000) reported that the concentration of nutrients in *Tithonia diversifolia* can conceivably be influenced by plant parts, age of *Tithonia*, and position of the leaf within the plant canopy. Information abounds in the literature on the benefits of *Tithonia* as a soil amendment for

maize production in Nigeria; however, information on the mode of application and the quantity per hectare is lacking. Therefore, the objectives of this study were to determine the ideal mode of applying, and the appropriate quantity of *Tithonia diversifolia* as a green manure that will improve the yield and yield attributes of maize and to assess the response of two maize varieties to the nutrient amendments.

Materials and Methods

Experimental Site, Location, and Duration

The field experiment was carried out at the Teaching and Research Farm, Ikole-Ekiti (Longitude 5°26'14"N, Latitude 4°50'15"E) during the 2020 and 2021 cropping seasons.

Source of seed and materials used

Two open-pollinated varieties of maize, LNTP-W and SAUWUAZ were used for this study. Seeds were collected from the Genetic Resource Unit of the International Institute of Tropical Agriculture (IITA). *Tithonia diversifolia* was sourced from the Ikole Campus of the Federal University of Oye-Ekiti. Leaves of 70 cm tall *Tithonia diversifolia* were collected at the height of 50 cm to the ground and used as soil amendments. Samples of *T. diversifolia* were collected at the height of 50cm to the ground. Three different applications of *Tithonia*, 3, 6 and 9 t ha⁻¹ and two modes of applications, chopped and unchopped, were used in the trial. *Tithonia* was chopped into tiny pieces and spread on the plots for chopped application which was then turned over with the soil while the unchopped was also laid on the plots for unchopped and was covered with soil to aid decomposition.

Land preparation

The site was manually cleared and after two weeks, the field was tilled with hoe to break up the soil in preparation for planting. Pre-planting herbicide (Glyphosate) was sprayed using a Knapsack sprayer. The *Tithonia diversifolia* treatments were incorporated into the soil as described by Fabunmi and Obisesan (2011) and left for two weeks after which planting was done.

Experimental design and treatments

The experiment was laid out as a factorial arrangement fitted into a randomised complete block design, replicated three times. The experiment had a factorial layout with two modes of application (Chopped and non-chopped) and three rates of application (3, 6 and 9 t ha⁻¹), the control plot had no soil amendment. Two maize varieties were planted on each of the experimental plots. Planting was done at the rate of three seeds per hole, which was thinned to two plants per stand after two weeks to ensure uniform field establishment. Spacing was 0.75 m x 0.5 m, which gave a plant population of 53,333 plants ha⁻¹. The plots were kept weed-free using hoe weeding all through the experiment. Insect pests were controlled by spraying cypermethrin when necessary.

Laboratory analyses

Before planting, the topsoil sample (0 - 15 cm deep) was collected randomly and bulked to form a composite sample. The sample was air-dried and passed through a 2mm sieve and analyzed for major physical (Table 1). The collected samples of *T. diversifolia* were air-dried and taken to the laboratory for nutrient analyses (Tables 1 and 2).

Data collection and measurement

Data collected from the maize yield after harvesting:

1. **Ear length (cm):** The average ear length from five randomly selected ears per plot, measured using a ruler.
2. **Ear girth (cm):** The circumference of five randomly selected maize ears in each plot was taken, and the average was recorded. This was done by using a rope and tape rule to measure the girth of the maize cob, after measuring then stretch on the meter rule to determine the girth of the maize cob.
3. **The number of seed per ear:** An average of the number of seeds from five randomly selected cobs in each plot.
4. **The number of rows per ear:** An average of number of rows from five randomly selected ears in each plot.
5. **Number of seeds per row:** Total number of seeds from five randomly selected ears in each plot divided by the number of rows from

the five ears.

6. **Ears per plant:** Number of ears harvested in each plot divided by the number of the maize stands at harvest.
7. **Cob weight (g):** The average weight of five randomly selected cobs in each plot.
8. **100 seed weight (g):** A hundred seeds collected from each of the five randomly selected ears in each plot were weighed and the average was recorded.
9. **Field weight:** harvested ears from the net plot of 2 m x 1 m were air-dried for five days and weighted.

Statistical analysis

Data on counts were transformed as [log (counts+1)] to reduce the heterogeneity of variances for the number of rows per ear, number of seeds per row and number of seeds per ear. Year and replication were treated as random effects, while modes and rates of amendment (treatment) and variety were treated as fixed effects. The analysis of variance was performed with PROC GLM using the RANDOM statement with the TEST option in SAS (SAS, 2012). Means of significant factors were compared using the least significant difference (DMRT).

Results and Discussion

Organic matter is known to be central in the sustainability of soil fertility for smallholder farmers in Africa, to this, the impact of *Tithonia diversifolia* as soil organic manure will play a great role in improving the yield of the smallholder farmers. Opala 2020 and Olubukola et al. 2010 have reported that *Tithonia diversifolia* increases organic carbon which in turn increases soil organic matter. *Tithonia diversifolia* has also been reported as a complete fertilizer (Reis et al 2018) because it contains a substantial amount of micro-nutrients.

The ANOVA of Table 3 showed that the main treatments had significant ($P < 0.05$) impact on the yield and yield attributes of maize in both years. Also varietal differences showed significant ($P < 0.05$) differences on number of seeds per cob, 100 seed weight and grain yield in 2020. Table 3 also showed that among the interactions only variety x status and maize variety x quantity of amendment had significant

($P < 0.05$) impact on the yield and yield component of maize, as this is in line with the finding of Kolawole *et al* 2014 that reported an increase in the tuber weight of cassava as a result of *Tithonia diversifolia* mulch. Nevertheless, maize variety x quantity of amendment had significant impact on cob length in 2021 and number of seeds per cob in 2020. This is also in line with the finding of Mahta 2015 and Roseline *et al* 2019 who reported the effect of *Tithonia diversifolia* on the growth and yield attribute of Amaranth.

The mean separation in Table 4 showed that among these variables measured, maize variety SAUWUAZ significantly ($P < 0.05$) had better number of seeds per cob, 100 seed weight and grain yield in 2020. As this could be because the maize variety were bred to be better than LNTP-W.

This is in line with the findings of Peter *et al*. 2015 that organic matter of tithonia and farm yard manure gave maize a better yield, also Olubode *et al* 2007, Ademiluyi and Omotosho, 2007 and Kolawole *et al*. 2014 reported the contribution of Tithonia mulch in the increase on the tuber of cassava. Also Aderibigbe *et al*. 2017 reported a positive correlation between maize yield and quantity of organic matter in the soil, as this findings further support the result of this study that maize performed better under the three quantities of amendment. The status of the amendment showed significant ($P < 0.05$) impact on the grain yield in both years. Organic manure has been reported to mineralize and release nutrients which has also been reported to be slow, however, *Tithonia diversifolia* has been reported to decompose very fast (James *et al* 2000) and releases N at the rate that the crop demands as it is known as good short-term soil fertility. In 2020 of table 4, the status of the plot (chopped and unchopped) had significant ($P < 0.05$) impact on cob length only as unchopped *Tithonia diversifolia* significantly ($P < 0.05$) increased the cob length (15.5cm).

Tithonia diversifolia at 3, 6 and 9 t ha⁻¹ was observed to have had significant ($P < 0.05$) impact on the number of rows per cob, number of seeds per cob and 100 seed weight. Table 4 showed that the application of *Tithonia diversifolia* at 3, 6 and 9 t ha⁻¹ increased the

number of rows and seed per cob of maize as against when no *Tithonia diversifolia* was applied. Several findings (Kolawole *et al* 2014; Peter *et al* 2015; Roseline *et al* 2019 and Dayo-Olagbende 2019) have also reported the improvement of soil amendment to yield attribute of crop. The quantity of 9 t ha⁻¹ of *Tithonia diversifolia* as amendment significantly ($P < 0.05$) improved the number of seeds per cob (733), 100 seed weight (71g) and grain yield (3.9) in the year 2020. The better performance of the impact of the amendment in 2020 could be attributed to the organic matter in the soil (3.18) (Table 1).

The interaction of maize variety x quantity of *Tithonia diversifolia* of Table 5 showed that SAUWUAZ with 9 t ha⁻¹ of *Tithonia diversifolia* amendment had significant ($P < 0.05$) impact on cob length (18.8 cm) in 2021 as against 6 t ha⁻¹ (13.7 cm) also SAUWUAZ with 9 t ha⁻¹ of *Tithonia diversifolia* amendment had significant impact on number of seeds per cob (872) in 2020 as against LNTP – W at no application had the least number of seeds per cob. The better performance of SAUWUAZ could be attributed to the superiority of the maize and the contribution of 9 t ha⁻¹ of *Tithonia diversifolia*. The effects of status (Chopped and unchopped) x quantities of *Tithonia diversifolia* on number of rows per cob in 2020 showed a linear progression from 0 to 9 t ha⁻¹ which implies that as the quantity is increased the number of rows increases as well (Fig 1), while unchopped *Tithonia diversifolia* and 3t ha⁻¹ had 17 rows per cob and decreases at 6 and 9 t ha⁻¹ (15 and 16 respectively).

The interaction of varieties x status x quantity showed significant ($P < 0.05$) impact on number of seeds per row in 2020 and seeds per cob in 2021. The significant ($P < 0.05$) interaction showed that LNTP-W with 3 t ha⁻¹ of chopped *Tithonia diversifolia* had significantly the highest number of seeds per row (35) in 2020 and number of seeds per cob (580) in 2021 while LNTP – W with 0 (Unchopped) and 9 (Chopped) t ha⁻¹ had the lowest number of seeds per row in 2020 (21) while in 2021 chopped *Tithonia diversifolia* at 9 t ha⁻¹ had the lowest number of seeds per cob (289) in 2021 (Table 6)

Declaration of competing interest.

The authors have no relevant financial or non – financial interest to disclose.

Author's Contributions.

- i. Okonji, C. J. Conceptualize the study and wrote the first draft of the manuscript.
 - ii. Adewale, D. Conducted the field trial, performed the statistical analysis and corrected the reviewed manuscript.
 - iii. Obisesan. O.I. Managed the literature searches and interpreted the results
 - iv. Osundare, O.T. Managed the analyses and contributed to development of manuscript
 - v. Ahaneku, C.G. Conducted the field trial and carried out data collection.
- This work was carried out in collaboration with the authors.

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Table 1: Soil samples before and after planting

Parameter	Before application	Two weeks after the application of <i>Tithonia diversifolia</i>		After harvesting	
		2020	2021	2020	2021
Organic matter (%)	1.77	3.18	3.01	2.04	2.1
pH 1:2 (water)	5.96	7.44	7.14	7.6	6.8
Exchange Acidity	0.75	0.40	0.41	0.40	0.31
Nitrogen (g/kg)	0.12	1.90	1.78	0.10	0.11
Available Phosphorus (mg/kg)	25.55	27.25	26.5	20.25	19.5
Calcium (Cmol/kg)	2.10	3.60	3.1	3.10	3.01
Magnesium (Cmol/kg)	1.10	1.70	1.5	1.40	1.44
Potassium (Cmol/kg)	0.56	4.65	4.25	1.48	1.48
Sodium (Cmol/kg)	0.12	0.14	0.13	0.10	0.10
Particle size analysis					
Sand %	79.4	81.6	83	81.6	83
Silt %	8.72	6.52	6.6	5.52	6.2
Clay %	11.88	11.88	10.4	12.88	10.8
Textural class	Sandy loam	Sandy loam	Sandy loam	Sandy loam	Sandy loam

Table 2: Analysis of *Tithonia diversifolia* sample used as manure

Parameter	Results
Nitrogen (%)	3.80
Total phosphorus (%)	0.36
Potassium (%)	4.20
Calcium (%)	0.80
Magnesium (%)	0.024

Table 3: Mean squares of grain yield and yield attributes of maize as affected by *Tithonia diversifolia* in 2020 and 2021

Source	DF	Number of cob per stand		Cob girth (cm)		Cob length (cm)		Number of rows per cob		Number of seeds per row		Number of seeds per cob		100 seed weight		Grain yield (kg ha ⁻¹)	
Year		2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
Replication	2	0.43	0.27	10.32	1.98	1.40	1.35	23.98	1.39	40.39	38.08	81390.3	8717.58	177.45	10.08	0.64	2.16
Varieties	1	0.33	0.33	13.44	3.10	0.72	11.29	0.54	0.52	9.18	16.33	246118**	6510	1234.2**	56.24	2.55*	2.00
Status (Chopped and unchopped)	1	0.33	0.08	17.37	11.60	17.83**	5.01	13.54	0.02	20.02	21.33	7708.94	5187	47.20	70.90	0.82	0.90
Quantity of <i>Tithonia diversifolia</i>	3	0.02	0.13	13.70	4.62	7.15	7.97	69.15**	1.40	260.02**	124.72	334448**	20467	1396.4**	4.11	13.80**	14.44**
Varieties x Status	1	0.08	0.33	1.14	2.08	2.66	13.14	4.38	0.02	2.52	1.33	22.27	1938	10.26	13.23	0.004	0.007
Varieties x Quantity	3	0.05	0.38	4.49	2.10	1.69	44.21**	0.68	0.40	10.63	27.05	39737*	8802	28.97	25.16	0.95	0.69
Status x Quantity	3	0.05	0.02	8.20	6.60	6.96	27.99	12.42**	1.24	21.35	44.72	221.32	7749	12.75	66.79	0.34	0.59
Varieties x Status x Quantity	3	0.02	0.05	2.35	2.42	1.52	21.25	0.29	2.35	5.96	133.83**	315.05	53193**	11.03	17.57	0.11	0.15
Error		0.10	0.15	6.32	6.01	3.47	13.92	3.76	2.26	11.81	39.01	12577.2	10256.8	76.83	50.79	0.54	0.77
R-Square		0.4	0.39	0.42	0.27	0.42	0.44	0.73	0.22	0.73	0.48	0.80	0.49	0.72	0.24	0.75	0.70
C. V.		28.68	33.07	18.9	24.83	12.45	24.02	12.83	10.54	11.45	21.41	21.29	23.85	14.16	21.59	26.13	29.9

*, ** = Significant at 0.05 and 0.01 probability levels, respectively

Table 4: Means of maize varieties, status and quantities of *Tithonia diversifolia* on the yield and yield of maize in 2020 and 2021

Source	Number of cob per stand		Cob girth (cm)		Cob length (cm)		Number of row per cob		Number of seeds per row		Number of seeds per cob		100 seed weight (g)		Grain yield (t ha ⁻¹)	
Year	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
VARIETIES																
LNTP-W	1	1.1	12.7	10.1	15.0	15.0	15.2	14.1	29.5	29.7	455.1b	436.2	56.7b	34	2.5b	2.7
SAUWUAZ	1	1.2	13.7	9.6	14.8	16.0	15	14.3	30.4	28.5	598.3a	412.9	66.9a	31.9	3.0a	3.5
STATUS																
Chopped	14.3b	15.8	12.6	10.3	14.3b	15.8	15.6	14.2	29.3	29.8	539.4	435	62.8	34.2	2.9	3.0
Unchopped	15.5a	15.2	13.8	9.3	15.5a	15.2	14.5	14.2	30.6	28.5	514	414	60.8	31.7	2.6	2.7
QUANTITIES OF <i>TITHONIA DIVERSIFOLIA</i>																
0 t ha ⁻¹	1.1	1.3	11.6	9.5	13.8	16.1	11.6b	14.2	23.1b	25.5	351.7c	378	47.6c	32.9	1.5b	1.5
3 t ha ⁻¹	1	1.0	13.7	9.6	15.1	16.0	15.6a	14.3	33.3a	31.8	441.3c	474.6	59.3b	33	2.3b	2.5
6 t ha ⁻¹	1	1.1	14.0	9.5	15.7	14.3	15.9a	13.8	32.4a	31.9	580b	437.6	68.9ab	33.7	3.3a	3.5
9 t ha ⁻¹	1	1.2	13.4	10.8	15.0	15.5	17.1a	14.6	31.1a	27.4	733.8a	408	71.4a	32.3	3.9a	4.0

Table 5: Interaction effect of maize varieties x quantities of *Tithonia diversifolia* amendment

Varieties	Quantities (t ha ⁻¹)	Cob length (cm) 2021	Number of seeds per cob 2020
LNTP-W	0	16.5	330
LNTP-W	3	16.5	415
LNTP-W	6	15	479
LNTP-W	9	12.1	595
SAUWUAZ	0	15.7	372
SAUWUAZ	3	15.6	467
SAUWUAZ	6	13.7	680
SAUWUAZ	9	18.8	872
SE _±		3.6	105.3

Table 6: Interaction effect of maize varieties x Status x quantities of amendment

Varieties	Status	Quantities (t ha ⁻¹)	Number of	Number of seeds
			seeds per row	per cob
			2020	2021
LNTP-W	Chopped	0	33	488
LNTP-W	Chopped	3	35	580
LNTP-W	Chopped	6	34	454
LNTP-W	Chopped	9	21	289
LNTP-W	Unchopped	0	21	349
LNTP-W	Unchopped	3	31	398
LNTP-W	Unchopped	6	32	452
LNTP-W	Unchopped	9	31	477
SAUWUAZ	Chopped	0	24	346
SAUWUAZ	Chopped	3	27	382
SAUWUAZ	Chopped	6	33	455
SAUWUAZ	Chopped	9	32	483
SAUWUAZ	Unchopped	0	23	327
SAUWUAZ	Unchopped	3	35	537
SAUWUAZ	Unchopped	6	28	388
SAUWUAZ	Unchopped	9	26	382
SE _±			5.5	85.9

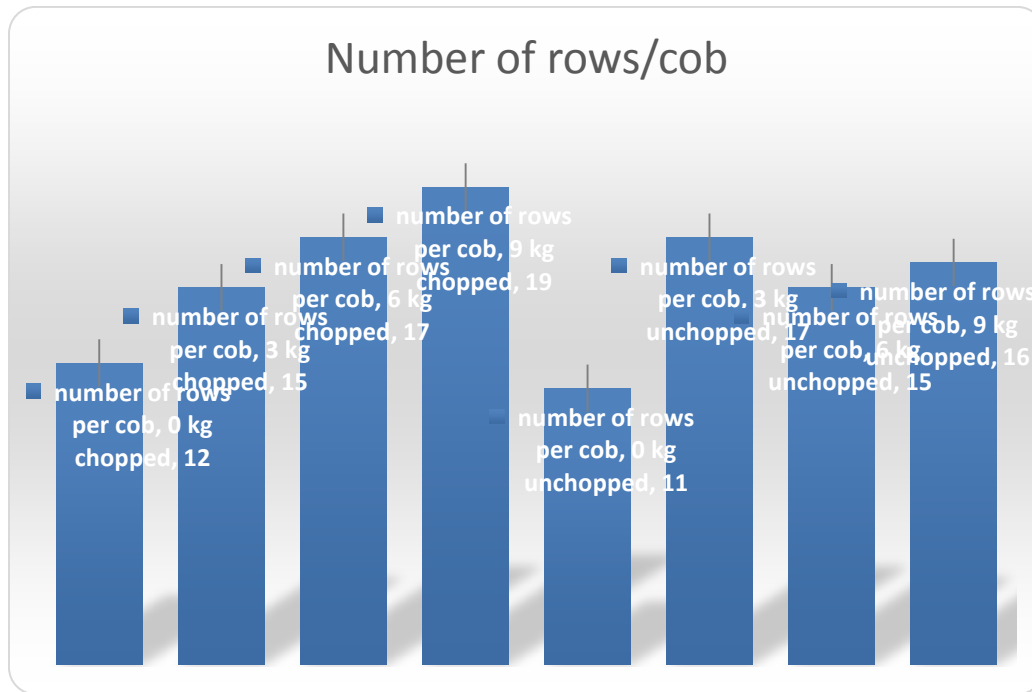


Fig 1: Effect of status x quantities of *Tithonia diversifolia* on number of row per cob in 2020