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RESPONSE OF TOMATO (*Lycopersicon lycopersicum* L.) TO CONCENTRATION AND FREQUENCY OF APPLICATION OF MORINGA LEAF EXTRACT AT MAIDUGURI, SUDAN SAVANNA ECOLOGICAL ZONE, NIGERIA

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ABSTRACT: Field trial was conducted during 2021/2022 dry seasons at the Research Farm of the Faculty of Agriculture, University of Maiduguri to determine the response of tomato (L*ycopersicon lycopersicum* L.) to concentration and frequency of application of Moringa leaf extract (MLE) in the Sudan Savanna ecological zone of Nigeria. The treatments consisted of five concentrations of Moringa leaf extract (0, 3, 4, 5 and 6 % concentration) and three frequency of applications (4 WAT, 4 and 6 WAT and 4, 6 and 8 WAT). The treatments were laid out in a Randomised Complete Block Design (RCBD) replicated three times. Data were collected on number of branches per plant, leaf area per plant, days to 50% flowering, average fruit weight per plant, marketable fruit yield per hectare and total fruit yield per hectare. The data collected were subjected to analysis of variance (ANOVA) to test for significant difference among the means using GENSTAT 17th Edition. The treatments means were compared using Student-Newman Keuls (SNK) Test at 5% level of significance. The result showed that application of MLE significantly affected all the parameters evaluated. It has shown that the application 5 or 6 % concentration of the MLE recorded higher growth (number of branches/plant and leaf area/plant) and yield (marketable and total yield/hectare) parameters. It further showed that the higher the frequency of application, the higher the growth and yield. The study, therefore, recommends the application of 5% MLE at 4, 6 and 8 WAT for farmers in the Sudan Savanna of Nigeria.

Keywords: Tomato, Moringa Leaf Extract; Concentration; Frequency of Application; Weeks after transplanting

INTRODUCTION

Tomato belongs to the family *Solanaceae* (also known as the night shade family) which are native of the Andean region that includes part of Chile, Colombia, Ecuador, Bolivia and Peru (Sims, 1980). Tomato (*Lycopersicon lycopersicum* L.) is among the most widely used vegetable because of its short life cycle and high productivity (Adil *et al*., 2003). FAO (2023) estimated the world production of tomato in 2023 at 190 million tonnes with China leading with 67.5 million tonnes followed by India (21.1 million tonnes), Turkey (13 m tonnes) and United States of America recording 10.4 million tonnes. Africa produced 21.4 million tonnes with Egypt leading producer with 6.2 million tonnes followed by Nigeria with an estimated output of 3.6 million tonnes and average yield of 5 - 6 t ha^{-1}. This was lower than average yield of 13.5 t ha^{-1} in Africa and world average of 22.0 t ha^{-1} (FAO, 2023).

One of the constraints to sustained production of tomatoes in this region is lack of hormonal application because MLE contains many phytohormones like zeatin, indole acetic acid (IAA) and Indole butyric acid (IBA) (Fuglie, 2000). Plant hormones can be used to increase yield per unit area because they influence every phase of plant growth and development (Culver *et al*., 2012; Yusuf *et al*., 2018). Moringa leaf extract is one of such alternative which could be possibly used as fertilizer (Yusuf *et al*., 2018) because of higher nitrogen and bio-stimulant (Phiri 2010), having higher cytokinin, antioxidants, macro and micro nutrients in its leaves (Abdalla and El-Khoshiban, 2012; Abdalla, 2013). Moringa has proved to be a potential source for research as scientists have moved their focus to this "Miracle tree" because of its high content of Zeatin (between 5 mg and 200 mg/g of leaves) which is one form of the most common forms of naturally occurring cytokinin which plays an essential role in cell division and cell elongation (Fuglie, 2000).

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Foliar application of Moringa leaf extract on onions, bell pepper, soya beans, sorghum, coffee, tea, chili, melon and maize increased the yields of these crops (Fuglie, 2000). Biswas *et al*., (2016) recorded significant increase in growth and yield for each increase in the frequency of application of MLE. In addition, Moringa has many medicinal importance in the treatments of several diseases (Vergara-Jimenez *et al*., 2017; Kou *et al.*, 2018). In view of the above, research was conducted to determine the influence of MLE concentration and its optimum frequency of application for higher production of tomato in the Sudan savanna of Nigeria.

MATERIALS AND METHODS

Study Area

Field trial was conducted during 2021/2022 dry seasons at the Research Farm of the Faculty of Agriculture, University of Maiduguri (latitude 11.83° N and longitude 13.15° E, at altitude 355m above sea level) to determine the effect of concentration and frequency of application of Moringa leaf extract (MLE) on tomato (*Lycopersicon lycopersicum*, Karst.) in the Semi-Arid Region of Nigeria. The areas are characterized by natural vegetation with sparse trees (5-9 m tall), dominated by widely spaced shrubs and grasses (Abubakar, 2007). Short and erratic rainfall, usually falling between the months of June and September (500 – 800 mm/annum). Minimum and maximum temperature range from 16.8 ºC – 41.3 ºC. The soils in the study area are reddish-brown with little profile differentiation, generally described texturally as sandy and sandy loam with low organic matter content (Kabura *et al*., 2009; Muktar, 2021).

Treatments and experimental design

The treatments consisted of five (5) concentration of MLE (0, 3, 4, 5 and 6 %) and three (3) frequency of application (4 WAT, 4 and 6 WAT, 4, 6 and 8 WAT). The treatments were laid out in a Randomized Complete Block Design (RCBD) replicated three (3) times. Each plot was 3 m x 3 m (9 m^2) with Alley and path ways of 0.5 m and 1 m between plots and replicates, respectively. Soil samples were randomly collected from the experimental plots at a depth of 30 cm which were dried and bulked for physical and chemical analysis in accordance with Blake and Hartge (1986).

Land preparation and crop management

The land was cleared manually and harrowed to fine filth which was properly leveled and the beds marked out. The edges of each bed were raised to prevent run--off during irrigation. Seedlings were transplanted (5 weeks after sowing in the nursery) when they attained transplanting stage. The plots were irrigated to field capacity before transplanting the seedlings (11th Nov., 2021) at inter and intra-row spacing spacing of 60 cm x 60 cm, respectively. Immediately, after transplanting all the plots were irrigated in the evening on daily basis. Subsequently, after plants establishment the plots were irrigated at three-day intervals until final harvest.

At land preparation a boaster dose of 165 kg/ha NPK (15:15:15) was applied to all plots irrespective of treatments before transplanting. The plots were weeded thrice using hoes at three and six WAT and at eight WAT a single hand pulling was conducted. Cypermethrin (Cymbush) was applied twice (4 and 6 WAT) at the rates of 2 litre (L) ha^{-1} to control insect pests (flea beetles) attack during the vegetative growth of the crop.

Moringa leaf extract preparation and application

Moringa leaves were harvested and measured using a weighing scale. For each 1 kg of leaves, 200 ml of water was poured and blended with a blending machine, stirred properly and the solution was filtered through muslin cloth in accordance to Bashir, *et al*. (2013). After obtaining a fine filtrate, the residue was discarded. From the solution obtained, the 5 concentrations were obtained as follows; 0 % = Control, 3 % = 0.4 L of extract / 15 L of water, 4 % = 0.6 L of extract /15 L of water, 5 % = 0.8 L of extract / 15 L of water and 6% = 1 L of extract /15 L of water. The liquid extract obtained was sprayed onto the leaves as per treatment (4 WAT, 4 and 6 WAT and at 4, 6 and 8 WAT), immediately after preparation using 1 L hand sprayer.

Data collection and analysis

Data were collected on;

Number of branches/plant: The number of branches was counted from three tagged plants/plot and average number of branches per plant was computed and recorded.

Leaf area/plant (cm^2): The leaf area per plant was measured using a portable leaf area meter (YMJ/A model 1) from the three tagged plants/plot and the average recorded.

Days to 50 % flowering: Days to 50 % flowering was recorded from the three tagged plants from the time of transplanting to the time when 50 % of the plants in each plot had flowered.

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Average fruit weight/plant (g): This was obtained through weighing the harvested fruits from three tagged plants and the average computed.
Marketable fruit yield (t/ha): This was computed after harvesting the tomato fruits and sorting out the fruits according to sizes and weight. Non damaged fruits above 50 g was considered marketable while the damaged fruits and below 50 g was categorized as non-marketable (Halima, 2016). The marketable fruits were weighed/plot which was later extrapolated to per hectare basis.
Total fruit yield (t/ha): This was the summation of the marketable and the non-marketable fruit yield. Thus; Total fruit yield = marketable fruit yield + non-marketable fruit yield

The data collected were subjected to Analysis of Variance (ANOVA) to test for significant differences among the means using GENSTAT 17th Edition. The treatments means were compared using Student-Newman Keuls (SNK) Test at 5% level of significance.

RESULTS AND DISCUSSION

The effect of MLE Concentration and its frequency of application on number of branches per plant, leaf area per plant and days to 50% flowering of tomato is being presented in table 1. The result showed that application of MLE was significant on number of branches of tomato because the treated plots recorded many branches than the control (0 %). Thus, the application of 5 and 6 % Concentrated Moringa recorded significantly many and similar number of branches compared to application of 3 and 4% Moringa which were also similar but recorded many branches than the control. The effect of frequency of application on the number of branches of tomato was significant. For each increase in application frequency resulted in significant increase in number of branches.

Table 1: Effect of Concentration and Frequency of Application of Moringa Leaf Extract (MLE) on Number of Branches per Plant, Leaf Area per Plant and Days to 50% flowering of Tomato (L*ycopersicon lycopersicum* L.) During 2021/2022 Dry Season at Maiduguri, Sudan Savanna of Nigeria.

Treatments	Number of branches/plant	Leaf area/plant (cm^2)	Days to 50% flowering
Concentration (C) of Moringa leaf extract (%)	8 WAT	8 WAT	
0	6.04^{c}	643.7^{d}	86.75
3	8.97^{b}	712.1^{c}	87.11
4	9.47^{b}	821.9^{b}	88.25
5	12.60^{a}	961.4^{a}	88.96
6	13.15^{a}	960.61^{a}	88.99
SE ±	0.317	31.07	1.101
Probability Level	0.001	0.001	0.001
Frequency of Application (F)			
4WAT	7.54^{c}	723.3^{c}	84.10^{c}
4 & 6WAT	9.32^{b}	901.4^{b}	86.88^{b}
4, 6 & 8WAT	11.85^{a}	997.5^{a}	89.01^{a}
SE±	0.324	30.45	0.910
Probability level	0.001	0.001	0.001
Interaction			
C × F	**	NS	NS

Means followed by the same letter(s) within a treatment column are not significantly different at 5% level of probability using Student-Newman Keuls (SNK) Test. NS = Not significant, and ** = Significant at 1%. WAT = weeks after transplanting.

Similarly, the effect of MLE on the leaf area per plant of tomato was significant. The result showed that each increase in MLE from the control to 5 % concentration resulted in significant increase in number of leaves of tomato. However,

further increase to 6 % has no significant effect on this parameter. The effect of application frequency of MLE on the leaf area per plant of tomato was also significant. For each increase in application frequency, it resulted in significant increase leaf area per plant. The concentration of MLE had no significant effect on days to 50 % flowering of tomato. However, Similar trend was also observed on the frequency of application of the MLE.

Table 2 shows interaction effect between concentration and frequency of application of Moringa leaf extract on the number of branches of tomato at Maiduguri during 2021/2022 dry season. The result showed that at constant concentration (5 and 6 %) as the frequency of application increases the number of branches per plant also increased. Thus, many branches were recorded at the highest frequency (trice application). However, at the control, increasing the frequency of application had no significant effect on the number of branches per plant but at 3 and 4 % increase in branches were only recorded at the highest frequency (trice). Similarly, at constant frequency varying the concentration had no effect on this parameter at single application, however, at twice application of 5 and 6 % recorded plants with many branches than the control but at trice application the treated (3, 4, 5 and 6 %) plants recorded many branches than the control.

Table 2: Interaction effects between concentration and frequency of application of Moringa leaf extract on number of branches of tomato (L*ycopersicon lycopersicum* L.) at Maiduguri during 2021/2022 dry season.

Application Frequency (F)	Moringa Leaf Extract (M) Concentration (%)				
	0 (control)	3	4	5	6
4 WAT	6.03^{c}	6.08^{c}	6.17^{c}	6.51^{c}	6.39^{c}
4 & 6 WAT	6.73^{c}	8.10^{bc}	8.62^{bc}	9.39^{b}	9.97^{b}
4, 6 & 8 WAT	6.71^{c}	13.87^{a}	13.33^{a}	14.25^{a}	14.33^{a}
SE±	0.488				

Values followed by the same letters are statistically the same at 5% level of probability using Fisher's protected least significant difference test. WAT= weeks after transplanting.

Table 3 shows effect of concentration and frequency of application of Moringa Leaf Extract (MLE) on average fruit weight, marketable fruit yield and total fruit yield of tomato during 2021/2022 Dry Season. The result showed that the effect of concentration and application frequency of MLE was significant on all the yield parameters evaluated (average fruit weight/plant, marketable fruit yield and total fruit yield) evaluated. The effect of concentration of MLE was significant on the average fruit weight per plant. The treated plots (4, 5 and 6 %) recorded significantly heavier fruits than the control, with the exception of 3 % which was comparable with respect to this parameter. Increase in concentration from 3 to 4 and 5 % resulted in significant increase in weight that were similar. Further increase from 5 % to 6 recorded heavier fruit. The effect of frequency of application on the average fruit weight was significant such that each increase in application frequency resulted in significant increase in weight of tomato.

The application of 5 and 6 % Concentrated Moringa recorded significantly higher and similar marketable fruit yield compared to application of 3 and 4% Moringa which recorded similar but higher yield than the control. Similar trend was observed on the frequency of application of MLE. The effect of concentration and frequency of application of MLE on the total fruit yield followed similar trend with the marketable fruit yield of tomato. The trend showed that the total fruit yield increased as the frequency of application increased from (once) 4 WAT to (twice) 4 and 6 WAT to (trice) 4, 6 and 8 WAT.

The result showed significant variation on all the parameters evaluated, except days to 50 % flowering which was not affected by the concentration of MLE. The application of MLE at 5 and 6 % concentrations recorded similar plants with many branches, larger leaf area, higher marketable and fruit yield per hectare. This corroborated Culver *et al*. (2012) who recorded significantly taller tomatoes and higher yield on application of MLE. This could also be due to the release of macro and micro nutrients in MLE (Yusuf *et al*., 2018). Similarly, it also supported Bashir *et al*. (2013) that recorded tomato with many leaves and taller plants on application of MLE.

Furthermore, for most of the parameters evaluated (number of branches/plants, leaf area/plant, days to 50 % flowering, marketing fruit yield/plant and total fruit yield t/ha) the result showed that each increase in number of application resulted in significant increase in the parameters. Triple application of the extract fortnightly with effect from 4 WAT

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recorded higher growth (number of branches, leaf area and days to 50 % flowering) and yield (average fruit weight, marketable and total fruit yield) characters. This corroborated Culver, *et al*. (2012); Biswas *et al*., (2016) who recorded significant increase in growth and yield for each increase in the frequency of application of MLE. The increase in growth and yield parameters observed in this trial might be due to the presence of zeatin, a cytokinin related hormone in the extract, which was responsible for the improved growth and yield as suggested by Abdalla, (2013); Biswas *et al*. (2016).

Table 3: Effect of Concentration and Frequency of Application of Moringa Leaf Extract (MLE) on Average Fruit Weight, Marketable Fruit Yield and Total Fruit Yield of Tomato (L*ycopersicon lycopersicum* L.) During 2021/2022 Dry Season at Maiduguri, Sudan Savanna of Nigeria.

Treatments	Average fruit weight/plant (g)	Marketable fruit yield (t/ha)	Total Fruit yield (t/ha)
Concentration (C) of Moringa leaf extract (%)			
0	265.05^{c}	7.22^{c}	10.27^{c}
3	269.11^{c}	8.31^{b}	13.12^{b}
4	308.99^{b}	8.62^{b}	13.43^{b}
5	315.17^{b}	9.54^{a}	16.27^{a}
6	360.83^{a}	9.82^{a}	17.61^{a}
SE±	14.111	0.314	1.132
Probability Level	0.001	0.001	0.001
Frequency of Application (F)			
4WAT	275.31^{b}	6.95^{c}	9.78^{c}
4 & 6WAT	290.56^{ab}	8.06^{a}	14.27^{b}
4, 6 & 8WAT	311.44^{a}	9.64^{a}	17.69^{a}
SE±	13.723	0.381	0.978
Probability level	0.001	0.001	0.001
Interaction			
C × F	NS	NS	NS

Means followed by the same letter(s) within a column are not significantly different at 5% level of probability using Student-Newman Keuls (SNK) Test. NS = Not significant, WAT = weeks after transplanting.

CONCLUSION

This research has shown that foliar application of MLE enhanced growth and yield parameters of tomato. It has also shown that the application 5 or 6 % concentration of the MLE recorded higher growth and yield parameters. It further showed that regular application of MLE enhanced growth and yield parameters. The study, therefore, recommends the application of 5% MLE at 4, 6 and 8 WAT.

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