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Response of Tomato (*Solanum lycopersicon* L.) to Antitranspirants and Moisture Stress in Kano, Sudan Savanna of Nigeria

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Abstract

The study was conducted to determine the effect of antitranspirants and moisture stress on productivity of tomato. The treatments consisted of two antitranspirants (Benzoic and Salicylic acids) at (0, 200, 400 and 600 ppm) concentration and three moisture stress stages (vegetative, flowering and fruit setting). These were arranged in a split-plot design and replicated three times. Antitranspirant and moisture stress constituted the main plots while concentrations were assigned to the sub-plots. Data were collected and analysed for plant height, leaf area index (LAI), plant fresh weight, fruits diameter, number of fruits and marketable fruit yield. Data generated were analysed using SAS. The results of the study revealed that although application of either of the antitranspirant significantly enhanced number of fruits, leaf area index, and marketable fruit yield per hectare, higher results were recorded at the fruit setting stage and similar results were observed from the plants treated with either Benzoic acid or Salicylic acid. However, fruiting growth stage was found to be the critical growth stage for moisture stress of tomato and applying 400 ppm of Salicylic acid recorded higher growth and yield characters of tomato.

Key words: Antitranspirants; Growth stages (Vegetative, Flowering and fruiting).

INTRODUCTION

Tomato (*Solanum lycopersicon* L.) belongs to the family *Solanaceae* .Although the ancestral forms of tomato grew in Peru and Ecuador area, the first extensive domestication of tomato seems to have occurred in Mexico which Spaniard introduced it into Europe in the early 16th Century (Harvey *et al.,* 2002) and subsequently to Africa through Gibraltar and Morocco. It was also thought by the early American colonials to be poisonous until the 1800's before it was eaten raw or in cooked dishes; today tomato is an almost daily part of the Nigerian diet. Cultivation of tomato is now widespread throughout the temperate and tropical climate (Harlan, 1984).

Tomatoes are known to possess antioxidants called lycopene, (Inmaculada *et al*., 2011) which has been shown to improve immune functions and reduce the risk of cancer and heart diseases. (Periago *et al.,* 2009). In addition, tomato also contains many vitamins and nutrients, including vitamins A, B and C with ascorbic acid and phenolic compounds (Balasundram *et al.,* 2006; Rakesh and Adarsh, 2010).

Tomato production in Nigeria is carried out in the northern part of the country during dry and raining seasons and the major production areas in identified in Kano, include Kura, Imawa Kadawa with the major market at Kwanar Gafa. However large-scale production is mainly under irrigation during the dry season because of the prevalence of pests and diseases associated with rain fed production as a result of high humidity. Major constraints in tomato production in these areas has to do with the fact that Kano is in the sudan savannah which is characterized with high temperatures that leads to high evapotranspiration. This means higher irrigation frequency and subsequently increased cost of production. This research aimed at reducing the frequency of irrigation through the use of antitranspirant which is a chemical that reduces the rate of transpiration of water into the atmosphere. The risk of moisture stress is however much higher in the Sudan Savannah zone of Northern Nigeria because rainfall in this area is unpredictable in quantity and distribution. Moisture deficit affects yield and yield components of crops. The yield decrease from the soil moisture deficit depends on the growth stage of the crop during which the moisture stress occurs, the severity and length of the stress (Leonardi *et al*., 1999). Previous studies indicated that foliar application of antitranspirant can increase leaf water potential, survival and subsequent yield of tomato transplanted into the field. In view of the above, experiment was conducted with the objectives of determining the effect of antitranspirants and moisture stress at different growth stages on the growth, yield and yield components of tomato.

MATERIALS AND METHODS

Experiment was conducted for the two successive dry seasons of 2011/2012 and 2012/2013 at the Teaching Research Farm of Faculty of Agriculture Bayero University, Kano (11° 97′ 98.6″ N, 8° 42′ 03.7″ E) 475 m above sea level in the Savannah zone of Northern Nigeria. The treatments consisted of two antitranspirants (Benzoic and Salicylic acids) at four concentrations each (0, 200, 400 and 600 ppm) and three moisture stress stages (vegetative, flowering and fruit setting). Antitranspirant and moisture stress were assigned to the main plots while concentrations of the two antitranspirants were assigned to the sub-plots. These were arranged in a split-plot design and replicated three times. The gross plot size was 3.6 m x 3.0 m (10.8 m^2) consisting of 6 rows of 3 m length, while the net plot size was 1.2 m x 1.8 m (2.16 m^2) consisting of 2 inner-most rows.

The experimental sites were harrowed and prepared into plots of slightly sunken beds of 3.6 m x 3.0 m (10.8m^2) sizes. Paired rows of beds were separated by 0.75m wide irrigation channels between the plots. Before removing the seedlings from the nursery, the beds were thoroughly irrigated, and seedlings were uprooted using a small hand hoe and then transplanted at a spacing of 60 cm x 60 cm.

Antitranspirant (Salicylic and Benzoic acids) were sprayed to the foliage using a hand sprayer at vegetative, flowering and fruit setting stages at the rate of 0, 200, 400 and 600 ppm equivalent to 0.2, 0.4 and 0.6 g L^{-1} of water. Each rate of the antitranspirants was dissolved separately in one litre of water and sprayed on the leaves of the tomato plants. All plots received full rates of P and K (20 and 37 Kg ha^{-1}, respectively) in form of SSP and MOP after land preparation. The first rate of N (45 Kg N ha^{-1}), in form of urea was applied 1 WAT. The remaining balance of 45 Kg N ha^{-1} was band applied in form of urea in two split applications at 3 and 6 WAT. Irrigation was by surface flooding allowing filling of the individual basins. The crops were irrigated initially at 5-day interval and thereafter following the stress treatments -- 3 weeks without irrigation and the application of the antitranspirants treatments.

Round up (Glyphosate) was applied at 1.0 kg a.i ha^{-1} two weeks before land preparation. Manual hoe weeding was also employed to control weeds at 4 and 8 WAT. Sherpa plus EC (Cypermethrin + Diamethoate) at 1.15 kg a.i ha^{-1} was used to control insect pests such as white fly (*Bemisia tabaci*), tomato leaf miner (*Tuta absoluta*) and white butterfly (*Pieris rapae*) Lepidoptera) (Borisade et al., 2017) biweekly commencing from 6 WAT. Data were collected on plant height, leaf area index (LAI), fresh plant weight, fruit diameter, number of fruits per plant and the marketable fruit yield.

RESULTS

Treatment effect on growth characters of tomato

Table 1 shows the effect of antitranspirants and moisture stress on tomato growth characters. There was no significant difference between the antitranspirant on plant height (cm) in both seasons and combined. The stress stages were significant on this parameter in both seasons and combined. Stressing the plant at fruit setting stage produced significantly taller plants (54.42cm, 52.58cm and 53.50cm) in both seasons and combined while stressing the plants at vegetative stage produced the shortest plants (45.58cm, 33.51cm and 39.66cm). The concentration of antitranspirant had significant effects on plant height in both seasons and combined.

Applying Antitranspirant at 600 ppm produced the tallest plants (53.85 cm), which was statistically similar to 400ppm (52.59 cm) but different from 200ppm (50.81cm) and 0 ppm (45.20 cm) in 2012 dry season. Applying antitranspirant at 400ppm had the tallest plants in 2013 (45.28 and 48.93 cm) and combined seasons while the control had the shortest (41.68 and 43.44cm). The interaction between antitranspirant and stress stages on plant height was significant in 2013 season when stressing the crop at fruit setting stage with the application of either Benzoic or Salicylic acids produced the tallest (54.22 and 50.95 cm) plants (Table 2). Opposite trend was observed when either Benzoic or Salicylic acids were applied at vegetative stage compared to other growth stages.

There was no significant difference between the antitranspirants and stress stages on leaf area index (LAI) of Tomato in both seasons and combined. Significant differences were however, observed on the concentration of antitranspirant where application of 200 ppm antitranspirant produced plants with higher LAI (1.81) while control had the lowest (1.60). There was no significant interaction of treatments recorded in both seasons and the combined.

There was significant difference between the antitranspirants in 2012 and the combined on tomato fresh weight. Application of Benzoic acid recorded the highest fresh weight in 2012 (724.80 g) and combined (669.78g) while application of Salicylic acid produced the lowest fresh weight (350.00 g) in 2012 and combined (494.4.70 g). Other treatment effects and interactions were not significant in both seasons and the combined for this parameter.

Treatment effect on yield characters of tomato

Table 3 showed treatment effects of antitranspirant and moisture stress on yield characters of tomato during 2012 and 2013 dry seasons at Kano. There was no significant difference between the antitranspirants on fruit diameter in both seasons and combined. Concentration of antitranspirants had significant effects on fruit diameter in both seasons and combined. Application of 200 ppm antitranspirant recorded the highest (307.54 mm) fruit diameter while the control recorded the lowest (230.47 mm) in 2012 season. Similar trends were observed in 2013 season and combined. Interaction between stress and concentration on fruit diameter was significant in 2012 season.

Table 4 shows the interaction between stress and concentration of antitranspirants on fruit diameter of tomato. Stressing the plant at vegetative stage had plants with significantly larger fruit diameter (364.89 mm) on application of 200 ppm than the other stages. When the concentrations were considered, 0 ppm at vegetative stage had plants with significantly smaller fruit diameter (190.48 mm) than all the other concentrations.

The effect of antitranspirants and moisture Stress on number of fruits plant^{-1} of tomato shows no significant differences between the two antitranspirants in both seasons and combined. Stress had significant effect on number of fruits plant^{-1} of tomato in both seasons and combined. In 2012 season, stressing the plants at fruit settings and vegetative stages produced plants with the highest (27.22) and lowest (16.75) number of fruits plant^{-1}, respectively. Similar trends were observed in 2013 season and combined except that stress imposed at flowering stage had plants with the lowest number of fruits plant^{-1}. Concentration also had significant effect on number of fruits plant^{-1} of tomato in 2012 season and combined such that application of 400 and 600 ppm of the antitranspirants recorded plants with the highest (25.68) and the lowest (18.36) number of fruits plant^{-1} . Similar trend was observed across the mean of the two seasons.

Although no significant differences were observed between the antitranspirants on marketable fruit yield, stress had significant effect on this parameter in both seasons and combined. Stress imposed at fruit setting stage produced plants with the highest marketable yield (20.75, 17.87 and 19.31 t ha^{-1}) while stress at vegetative stage in 2012 and at flowering stage in 2013 and combined seasons recorded plants with the lowest marketable yield (13.39, 10.59 and 12.37 t ha^{-1}). Concentration effect on marketable yield was significant in both seasons and combined. The application of antitranspirant at 400 ppm produced plants with the highest marketable yield in 2012 and 2013 (19.71 and 17.98 t ha^{-1}) seasons while the combined recorded lower marketable yield (13.66 and

15.92 t ha^{-1}) with the application of 0 ppm of the antitranspirants.

DISCUSSION

This study showed that there was no significant difference between the two antitranspirants in both seasons and combined in all the data evaluated except fresh weight per plant. The higher fresh weight of tomato observed on application of Benzoic acid than Salicylic acid could be attributed to the fact Benzoic acid being in powder form was able to dissolve faster and be retained on the leaves which reduce moisture loss of the plants grown under stress than Salicylic acid which is in granular form and dissolve slower than Benzoic acid. This supported the work of El-Zeeny *et al.* (2007) who obtained an increase in the fresh weight of sesame with the application of Kaolin while Parafin wax did not significantly increase this parameter. The decrease caused by high concentrations of Salicylic acid on the fresh weight of tomato could also be as a result of inhibition of chlorophyll biosynthesis or acceleration of chlorophyll destruction or both (Popova *et al.*, 2009). Similarly, the non-significant difference recorded on marketable yield of tomato on application of the two antitranspirants was in contrast with the findings of Del Amor and Rubio (2009) who reported that total marketable yield was not affected by antitranspirants.

Plants that were stressed at fruiting stage significantly produced the taller plants, higher number of fruits and marketable fruit yield while those stressed at the vegetative stage had the shortest plants, lower number of fruits and marketable fruit yield. This could be due to moisture stress affects the water uptake of tomato plants and inhibit photosynthesis and its translocation to vegetative organs at vegetative growth stage. This supported the findings of Pervez *et al.* (2009) who observed that imposition of moisture stress at vegetative stage of tomato growth caused a significant reduction in plant height and fruit yield of treated plants compared to control plants. Similarly, higher number of fruits plant^{-1} and marketable yield recorded at fruiting stage than stressing the crop at the vegetative and flowering stages, which supported the findings of Nuruddin *et al.* (2003) who reported that plants stressed only during the flowering stage recorded fewer fruits.

The concentrations of antitranpirants applied for proper growth and yield of tomato differ for various parameters evaluated. Application of antitranspirant at either of the concentration treatment recorded taller plants than the untreated control. This means application of 200 – 600 ppm antitranspirant efficiently regulate transpiration without significant decrease on growth and development of the tomato. This could be attributed to the favourable effects of the rate of the antitranspirants on plant height at this stressed stage (El-Kobbia and Ibrahim, 1986).

The application of 400 ppm had resulted to higher leaf area index (LAI), higher fresh weight, higher number of fruits and higher marketable fruits yield. This means that the leaves being medium of photosynthesis utilised moderate rate (400 ppm) of the antitranspirants more efficiently than higher rate (600 ppm) due to toxicity commonly associated with the latter. The higher marketable yield could be attributed to the higher LAI observed, which means higher growth rate and also the fact that the crop might have recover from the stress imposed before the critical period of water requirement at reproductive stage (Najafian *et al.,* 2009). This could also be attributed to the effects of the concentration of the antitranspirants on fruit setting, plant height, and fresh weight which showed similar trends (Topcu *et al.,* 2007).

CONCLUSION

Based on the results obtained from this study, it could be concluded that the performance of the two antitranspirants were similar for the parameters evaluated such as plant height, leaf area index, fruit diameter, number of fruits plant^{-1} and marketable fruit yield except on fresh weight where Benzoic acid was better than Salicylic acid. Fruiting growth stage was found to be the critical growth stage for moisture stress of tomato with either of the antitranspirant. However, 400 ppm of Salicylic acid concentration was found to be optimum and recorded the highest total marketable fruit yield and is therefore recommended for use by farmers in the Savanna of Nigeria.

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Table 1: Effect of Antitranspirants and Moisture Stress on Growth Characters of Tomato during 2012, 2013 Dry Seasons and Combined at Kano, Nigeria.

Treatments	Plant height (cm)			Leaf area index (LAI)			Fresh weight plant^{-1} (g)		
	2012	2013	Combined	2012	2013	Combined	2012	2013	Combined
Antitranspirants (A)									
Benzoic acid	50.78	43.56	47.17	2.13	1.69	1.91	724.80a	614.7	669.78a
Salicylic acid	50.45	43.14	46.79	2.11	1.65	1.88	350.00b	638.8	494.40b
SE$\pm$	1.019	0.906	0.936	0.061	0.067	0.113	266	722	111.5
Level of significance	NS	NS	NS	NS	NS	NS	*	NS	*
Stress (S)									
Vegetative	45.58c	33.51c	39.66c	2.08	1.63	1.86	586	472	529
Flowering	51.63b	43.95b	47.79b	2.15	1.71	1.93	550.8	716.7	633.7
Fruit setting	54.42a	52.58a	53.50a	2.13	1.67	1.9	475.5	691.6	583.6
SE$\pm$	1.019	0.906	0.936	0.061	0.067	0.113	266	72.2	111.5
Level of significance	**	**	**	NS	NS	NS	NS	NS	NS
Concentrations ppm (C)									
0	45.20c	41.68b	43.44b	2.18	1.60b	1.92	469.1	527.7	498.4
200	50.81b	43.62ab	47.21a	2.12	1.81a	1.97	484.3	739.4	611.9
400	52.59ab	45.28a	48.93a	2.05	1.63ab	1.84	457.6	645.4	551.9
600	53.85a	42.82b	48.33a	2.13	1.65ab	1.89	738.7	594.4	666.6
SE$\pm$	1.176	0.74	0.612	0.071	0.055	0.052	307.1	58.9	85.1
Level of significance	**	*	**	NS	*	NS	NS	NS	NS
Interactions (I)									
A x S	NS	*	NS	NS	NS	NS	NS	NS	NS
A x C	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x C	NS	NS	NS	NS	NS	NS	NS	NS	NS
A x S x C	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using Student-Newman Keuls Test. * = significant at 5%; ** = significant at 1%; NS= not significant.

Table 2: Interaction between Antitranspirant and Stress stage on plant height of tomato at Kano in 2013 dry season

Antitranspirant	**Stress stage**		
	Vegetative	Flowering	fruit setting
Benzoic acid	32.10c	44.35b	54.22a
Salicylic acid	34.92c	43.54b	50.95a
SE+		6.196	

Means within and across column followed by the same letter (s) are not significantly different at 5% level of probability using Student-Newman-Keuls Test.

Table 3: Effect of Antitranspirants and Moisture Stress on Yield Characters of Tomato during 2012, 2013 Dry Seasons and Combined at Kano, Nigeria.

	Fruit diameter			**Number of fruits**			**Marketable fruit yield (**		
Treatments	2012	2013	Combined	2012	2013	Combined	2012	2013	Comb
Antitranspirants (A)									
Benzoic acid	261.7	155.53	208.61	20.98	21.96	21.47	15.97	15.1	15.53
Salicylic acid	267.6	165.52	216.56	21.31	22.12	21.71	16.21	17.18	16.69
SE+	17.9	7.57	8.49	0.957	1.133	1.252	0.775	1.384	1.305
Significance	NS	NS	NS	NS	NS	NS	NS	NS	NS
Stress (S)									
Vegetative	262.9	148.58	205.72	16.75c	23.95b	25.25b	13.39b	19.95a	16.67
Flowering	279.6	163.56	221.56	19.45b	14.00c	16.73c	14.14b	10.59b	12.37
Fruit setting	251.5	169.44	210.47	27.22a	28.16a	28.88a	20.75a	17.87a	19.31
SE+	17.90	7.57	8.49	0.957	1.133	1.252	0.775	1.384	1.305
Significance	NS	NS	NS	**	**	**	*	*	*
Concentrations (C) ppm									
0	230.47b	136.23c	183.35c	19.36b	21.34	20.35b	13.66b	15.92	14.79
200	307.54a	190.92a	249.23a	21.18b	22.72	21.95b	16.25b	17.15	16.70
400	256.55b	154.80b	205.65b	25.68a	22.74	24.21a	19.71a	16.25	17.98
600	264.04b	160.15b	212.10b	18.36b	21.35	19.86b	14.74b	15.22	14.98
SE+	20.60	6.18	8.46	1.104	0.925	0.588	0.895	1.13	0.699
Significance	*	**	**	**	NS	*	*	NS	*
Interactions (I)									
A x S	NS	NS	NS	NS	NS	NS	NS	NS	NS
A x C	NS	NS	NS	NS	NS	NS	NS	NS	NS
S x C	*	NS	NS	Ns	NS	NS	NS	NS	NS
A x S x C	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) in a column are not significantly different at 5% level of probability using Student-Newman Keuls Test. *=significant at 5%; **= significant at 1%; NS= not significant.

Table 4: Interaction between Stress and Concentrations on fruit diameter of tomato in 2012 dry season at Kano, Nigeria.

Stress stages	**Concentrations (ppm)**			
	0	200	400	600
Vegetative	190.48b	364.89a	238.75ab	257.35ab
Flowering	267.63ab	317.14ab	267.54ab	265.97ab
Fruit setting	233.29ab	240.57ab	263.35ab	268.78ab
SE±		23.090		

Means within and across column followed by the same letter (s) are not significantly different at 5% level of probability using Student-Newman-Keuls Test.