Journal of Agripreneurship and Sustainable Development (JASD)
Volume 4, Number 3, September, 2021
ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

EFFECTS OF SALICYLIC AND BENZOIC ACIDS ON THE MARKETABLE YIELD OF MOISTURE STRESSED TOMATO (*Solanum lycopersicum* L.) AT KADAWA IN NORTHERN NIGERIA

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ABSTRACT
Moisture stress is one of the abiotic factors affecting crop production in sub-Saharan Africa characterized by erratic rainfall. In order to address this problem, an experiment was conducted at the Agricultural Research Station Farm, Kadawa (11° 38′ 40.3″ N, 8° 25′ 53.9″ E) 498 m elevation above sea level during 2011/2012 and 2012/2013 dry seasons to study the effect of antitranspirants on the yield attributes of moisture stressed tomato. The treatments consisted of two Antitranspirant (Salicylic acid and Benzoic acid) at four concentrations each (0, 200, 400 and 600 ppm) and three moisture stress stages (vegetative, flowering and fruit setting), factorially combined and laid out in a split-plot design replicated three times. Antitranspirant and moisture stress constituted the main plot and concentrations as sub-plot treatment. 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 rows. Data were taken on fruit diameter, number of fruits plant^{-1}, average fruit weight, marketable fruit yield, weight of marketable fruit yield and total fruit yield. Data generated were analysed using Statistical Analysis Software (SAS). The results revealed that, application of 200 and 400 ppm of antitranspirant produced plants with larger fruit diameter, more number of fruits plant^{-1} and total fruit yield. On various stages considered, imposing stress at vegetative stage gave significantly higher total fruit yield than other stages implying that flowering and fruiting stages were found to be the critical growth stages for moisture stress of tomato. Study on the antitranspirants revealed that, foliar application of 400 ppm of Salicylic acid at fruit setting stage statistically appeared to promote tomato yield in the study area. The study concluded that salicylic acid performed better than benzoic acid. It was recommended that farmers should be encouraged to use salicylic acid in order to reduce irrigation frequency and to increase yield.

Keywords: Benzoic acid, Marketable attributes, Moisture stress, Salicylic acid, Tomato.

INTRODUCTION
Tomato (*Solanum lycopersicon* **L.**) belongs to the family *Solanaceae*. The Spaniard introduced tomato into Europe in the early 16th century (Harvey *et al.*, 2002) and subsequently to Africa through Gibraltar and Morocco. The cultivated tomato reached its present status after a long period of domestication and it is now grown throughout the temperate and tropical climates (Harvey *et al.*, 2002).The area of major production is the Northern part of the country, between latitude 8^0 – 13^0N, but the greatest market is mostly in the South and other neighbouring countries (Amans *et al.*, 1986). One most well-known benefit of tomato is its lycopene content. Lycopene is a vital anti-oxidant that helps in the fight against cancerous cell formation as well as other kinds of health complications and diseases (Balasundram *et al.*, 2006). Tomato requires a relatively cool dry climate for high yield and premium quality. However, it is adapted to a wide range of climatic conditions from cool temperate to hot humid tropical areas.

The optimum temperature for most varieties lies between 21– 24°C. The crop can survive a range of temperatures but the plant tissues are damaged below 10°C and above 38°C (Tindall, 1983). Shortage of water is an important limiting factor for irrigated crop production. In areas of water scarcity, irrigation strategies need to be devised to save irrigation water with marginal yield reduction. Drought stress during vegetative or early reproductive growth stage usually reduces growth characters and yield by reducing the number of fruits, fruit size and quality. Water deficit on plant inhibits leaf expansion, stem and root elongation and this can slow down or stop the growth of the affected plant (Younis *et al*., 2000).

Water deficit often causes reduction in plant growth by inhibiting leaf and stem elongation and by reducing the nutrient uptake by plants. In addition, water deficit affects negatively the process of flowering in many plant species by reducing the fertility of newly formed flowers. Under such drought conditions, actively growing plants transpire a weight of water equal to their leaf fresh weight each hour if water is adequately supplied (Younis *et al*., 2000). One way to achieve this goal is by reducing the transpiration rate using Antitranspirant materials to minimize the amount of irrigation water. Film forming antitranspirants when sprayed on to plants supposedly form a continuous layer over the leaf surfaces which are permeable to gases for example carbon dioxide and oxygen but impermeable to water vapour. The reduced transpiration enhances plant survival especially under hot climatic conditions with reduced soil water potential.

MATERIALS AND METHODS

The experiment was conducted at the Agricultural Research Station Farm, Kadawa (11° 38′ 40.3″ N, 8° 25′ 53.9″ E) 498 m elevation above sea level during dry seasons of 2011/2012 and 2012/2013 to study the effects of salicylic and benzoic acids on the marketable yield of moisture stressed tomato. 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). These were factorially combined and laid out in a split-plot design with three replications.

The gross plot size was 3.6m x 3.0m (10.8m^2) consisting of 6 rows of 3m length, while the net plot size was 1.2 m x 1.8 m (2.16 m^2) consisting of 2 inner rows. The experimental site was ploughed, 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. Seedlings were transplanted at a spacing of 60 cm x 60 cm. 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. All plots received full rates of P and K (20 and 37 Kg ha^{-1}, respectively) in form of single super phosphate (SSP) and muriate of potash (MOP) after land preparation. The first rate of N (45 Kg N ha^{-1}), in form of urea was applied one week after transplanting. The remaining balance of 45 Kg N ha^{-1} was applied in form of urea in two split applications at three and six weeks after transplanting through banding method of application. Agronomic practices required for successful production of tomato were carried out. Data were collected on fruit diameter, number of fruits plant^{-1}, average fruit weight, marketable fruit yield, weight of marketable fruit yield and total fruit yield. All data collected were subjected to analysis of variance using SAS and means were separated using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Results of antitranspirants and moisture stress on fruit diameter and average fruit weight of tomato are presented in Table 1. There was no significant difference between the antitranspirants as well as the stress stages on fruit diameter of tomato in both seasons and combined. However, concentration of antitranspirant had significant effect on fruit diameter of tomato in both seasons and combined, where application of 400 ppm recorded the highest (92.81 mm) fruit diameter although statistically at par with 200 ppm (83.87 mm), 600 ppm (86.03 mm) while the control had the lowest (71.95mm) in 2012 season. In 2013 season, application of 200 ppm of Antitranspirant recorded the highest (99.45mm) fruit diameter while the control had the lowest (77.31 mm) although statistically at par with 400 ppm (83.05 mm) and 600 ppm (85.18 mm). Combined seasons on the other hand, application of 200 ppm of Antitranspirant recorded the highest (91.66 mm) fruit diameter although statistically at par with 400 ppm (87.93 mm) and 600 ppm (85.74 mm) but statistically better than the control (74.63 mm). Interaction between antitranspirant and stress on fruit diameter of tomato was significant only in 2012 season (Table 1).

The study further revealed a significant difference between the two antitranspirants on average fruit weight of moisture stressed tomato in 2012 season only, where plants sprayed with Salicylic acid recorded the heaviest average fruit (66.84 g) than those that were sprayed with Benzoic acid (56.66 g). Statistically, no significant difference was observed between the stress stages on average fruit weight and fruit diameter of moisture stressed tomato. On the different concentrations used, the results showed a significant effect on the average fruit weight in 2012 season only, where application of 200 ppm produced plants with the heaviest average fruit (70.32 g) than the other rates. Control on the other hand, produced plants with the lightest average fruit weight (56.66 g), although statistically at par with 400 ppm (60.23 g) and 600 ppm (59.80 g). Interactions between the factors were significant in both seasons and combined. The non-significant difference between the antitranspirants in both seasons on fruit diameter of tomato indicated that the antitranspirants had no effect on this measured parameter. However, the significant difference between antitranspirants on average fruit weight plant^{-1} could be due to the differences in the formulation of active ingredient.

The active ingredient in Benzoic acid was 0.3 kg a.i while that of Salicylic acid was 0.95 kg a.i (Table 1). This result is in contrast with the findings of MacDonald *et al*. (2010) who reported that pre-conditioning of tomato with Amboil increased number of fruit plant^{-1} by 65.1 %. Del-Amor *et al.* (2006) had reported that, the use of vapour guard at 1 % increased average fruit weight by 9.5%. Application of 200 ppm of the antitranspirant recorded plants with larger fruit diameter than the other levels. This could be attributed to the effect of the treatment on fruit which followed similar trend throughout the study period. High phytotoxicity was associated with higher concentrations of antitranspirant as reported by El-Kobbia and Ibrahim (1986).

Journal of Agripreneurship and Sustainable Development (JASD)
Volume 4, Number 3, September, 2021
ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

Table 1: Effects of Antitranspirants on Fruit Diameter (mm) and Average Fruit Weight (g) of Moisture Stressed Tomato at Kadawa in 2012, 2013 Dry Seasons and Combined

Treatments	Kadawa					
	Fruit Diameter (mm)			Average Fruit Weight (g)		
	2012	2013	Combined	2012	2013	Combined
Antitranspirants (A):						
Benzoic acid	80.32	86.02	83.17	56.66b	47.07	51.87
Salicylic acid	87.14	86.48	86.81	66.84a	49.24	58.04
Level of significance	NS	NS	NS	*	NS	NS
SE$\pm$	7.130	5.400	4.590	2.610	2.840	3.240
Stress (S):						
Vegetative	92.39	88.49	90.44	61.73	49.23	55.48
Flowering	86.14	85.08	85.61	62.67	47.73	55.20
Fruit setting	72.66	85.17	78.91	60.85	47.50	54.18
Level of significance	NS	NS	NS	NS	NS	NS
SE+	7.130	5.400	4.590	2.610	2.840	3.240
Concentrations ppm (C):						
0	71.95b	77.31b	74.63b	56.66b	45.44	51.05
200	83.87a	99.45a	91.66a	70.32a	46.64	58.48
400	92.81a	83.05b	87.93a	60.23b	51.05	55.64
600	86.03a	85.18b	85.74a	59.80b	49.49	54.65
Level of significance	*	*	*	*	NS	NS
SE$\pm$	5.410	3.420	3.750	2.380	2.140	2.650
Interactions (I):						
A x S	*	NS	NS	NS	NS	NS
A x C	NS	NS	NS	NS	NS	NS
S x C	NS	NS	NS	NS	NS	NS
A x S x C	NS	NS	NS	NS	NS	NS

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

The result as presented in Table 2 showed that, Antitranspirants had no significant effect on number of fruits plant^{-1} and weight of marketable fruit yield of the moisture stressed tomato. The effect of stress was observed to be significant on both number of fruits plant^{-1} and weight of marketable fruit yield but only in 2013 season where plants that were stressed at fruiting stage had more number of fruitsplant^{-1} (9.20) while those stressed at flowering stage (7.42) had recorded few number of fruits plant^{-1}, respectively. However, plants that were stressed at flowering stage recorded the heaviest marketable fruit (2.71 t ha^{-1}) although statistically at par with those plants stressed at fruiting stage (2.39 t ha^{-1});and those that were stressed at the vegetative stage had the lightest marketable fruit weight (2.00 t ha^{-1}). Application of 400ppm resulted into plants with higher number of fruits plant^{-1} throughout the study period. Control plot on the other hand, recorded fewer number of fruits plant^{-1} throughout the period under study. Significant interaction was observed between antitranspirants and concentration on number of fruits plant^{-1} in 2012 season and between stress and concentration in 2013 season. Similarly, application of 400 ppm of the concentration produced plants with heaviest weight of marketable fruit (2.57 t ha^{-1}) although statistically at par with application of 200 ppm (2.50 t ha^{-1}) and 600 ppm (2.43 t ha^{-1}) while the control recorded plants with the lightest weight of marketable fruits (1.97 t ha^{-1}). Similar trend was observed in 2013 season and the combined

Journal of Agripreneurship and Sustainable Development (JASD)
Volume 4, Number 3, September, 2021
ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

seasons. Significant interaction on weight of marketable fruits was observed only in 2012 season.

Table 2: Effects of Antitranspirants on Number of Fruits Plant^{-1} and Weight of Marketable Fruits Yield (t ha^{-1}) of Moisture Stressed Tomato at Kadawa in 2012, 2013 Dry Seasons and Combined

Treatments	**Kadawa**					
	Number of Fruits Plant^{-1}			**Weight of Marketable Fruit Yield (t ha^{-1})**		
	2012	**2013**	**Combined**	**2012**	**2013**	**Combined**
Antitranspirants (A):						
Benzoic acid	8.26	9.08	8.67	2.20	2.25	2.37
Salicylic acid	10.78	7.66	9.22	2.16	2.20	2.18
Level of significance	NS	NS	NS	NS	NS	NS
SE+	2.091	0.574	0.711	0.285	0.184	0.191
Stress (S):						
Vegetative	9.46	8.50ab	8.98	2.28	2.00b	2.14
Flowering	10.04	7.42b	8.73	2.23	2.71a	2.47
Fruit setting	9.04	9.20a	9.12	2.03	2.39a	2.21
Level of significance	NS	*	NS	NS	**	NS
SE+	2.091	0.574	0.711	0.285	0.184	0.191
Concentrations ppm (C):						
0	7.06c	6.86b	6.96c	1.35b	1.97b	1.66b
200	11.00a	8.26b	9.63ab	2.51a	2.50a	2.50a
400	11.11a	10.03a	10.57a	2.58a	2.57a	2.57a
600	8.90b	8.35b	8.62b	2.28a	2.43a	2.35a
Level of significance	**	*	**	**	*	
SE+	0.873	0.481	0.580	0.185	0.207	0.156
Interactions (I):						
A x S	NS	NS	NS	**	NS	NS
A x C	*	NS	NS	*	NS	NS
S x C	NS	*	NS	**	NS	NS
A x S x C	NS	NS	NS	NS	NS	NS

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

Tomato crop stressed at the fruiting stage resulted in higher number of fruits plant^{-1} than when the crop was stressed at the vegetative and flowering stages. This could probably be attributed to the higher number of branches and leaf area recorded by the crop at this stage. High leaf area means higher photosynthetic rate which enhanced both growth and yield characters of the crop as reported by (Sharp, 1996). This result supported the findings of Nuruddin *et al.* (2003) who reported that plants stressed only during the flowering stage showed fewer but bigger fruits. Stress imposed at the fruiting stage had plants with higher marketable fruit yield than tomato stressed at vegetative and flowering stages. This could be attributed to the effect of the treatment on total number of fruits plant^{-1} (Table 2).

Table 3 shows the effect of antitranspirants and moisture stress on marketable fruits yield and the total fruits yield of moisture stressed tomato. There result revealed a significant difference between the two antitranspirants on marketable fruits yield as well as the total fruits yield. The result further indicated that plants sprayed with Salicylic acid recorded the highest

Journal of Agripreneurship and Sustainable Development (JASD)
Volume 4, Number 3, September, 2021
ISSN (Print): 2651-6144; ISSN (Online): 2651-6365

marketable fruits yield (8.80 t ha^{-1}) than those sprayed with Benzoic acid (7.31 t ha^{-1}). Plants sprayed with Benzoic acid recorded the highest total fruits yield (3.76 t ha^{-1}) than those sprayed with Salicylic acid (3.06 t ha^{-1}). Stress on the other hand indicated a significant effect on marketable fruits yield only in 2012 season, where plants stressed at flowering stage recorded the highest marketable fruit yield (9.54 t ha^{-1}); and those stressed at flowering stage recorded the lowest marketable fruit yield (9.54 t ha^{-1}) although statistically at par with those stressed at vegetative stages (7.51 t ha^{-1}).

Table 3: Effects of Antitranspirants on Marketable Fruits Yield and Fruit Yield (t ha^{-1}) of Moisture Stressed Tomato at Kadawa in 2012, 2013 Dry Seasons and Combined

Treatments	Kadawa					
	Marketable Fruits Yield			Fruit Yield		
	2012	2013	Combined	2012	2013	Combined
Antitranspirants (A):						
Benzoic acid	7.31b	4.83	6.07	3.44	3.76a	3.60
Salicylic acid	8.80a	4.72	6.76	3.52	3.06b	3.29
Level of significance	*	NS	NS	NS	*	NS
SE+	0.424	0.620	0.773	0.329	0.152	0.266
Stress (S):						
Vegetative	7.51b	4.97	6.24	3.66	3.38	3.52
Flowering	9.54a	4.29	6.91	3.48	3.52	3.50
Fruit setting	7.11b	5.07	6.09	3.30	3.33	3.31
Level of significance	*	NS	NS	NS	NS	NS
SE+	0.424	0.620	0.773	0.329	0.152	0.266
Concentrations ppm (C):						
0	5.95c	3.76b	4.85c	2.62b	3.03	2.83b
200	8.03b	4.46ab	6.24b	3.74a	3.62	3.68a
400	9.61a	5.70a	7.65a	3.98a	3.57	3.77a
600	8.63ab	5.18ab	6.90ab	3.57a	3.43	3.50a
Level of significance	*	*	*	*	NS	*
SE+	0.417	0.468	0.631	0.225	0.174	0.217
Interactions (I):						
A x S	*	NS	NS	*	NS	NS
A x C	*	NS	NS	*	NS	NS
S x C	*	NS	*	NS	NS	NS
A x S x C	NS	NS	NS	*	NS	NS

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

However, as presented in Table 3, stress had no significant effect on total fruit yield. The result further showed a significant effect of concentration on the marketable fruit yield and total fruit yield. Application of 600 ppm resulted to plants with the highest marketable fruit yield of (7.51 t ha^{-1}) than the control (5.95t ha^{-1}). Similar trend was observed in 2013 season and the combined interaction between factors on marketable fruits yield was significant only in 2012 season and combined.

The effect of concentration on total fruits yield was significant only in 2012 season and the combined (Table 3). In 2012 season, application of 400 ppm produced plants with the highest total fruits yield $hectare^{-1}$ (3.98 t ha^{-1}), although statistically at par with 200 ppm (3.74 t ha^{-1}) and 600 ppm (3.57 t ha^{-1}) while the control recorded the lowest total fruits yield hectare⁻

^{1} (2.62 t ha^{-1}). The observed difference between the antitranspirants on marketable fruit yield and fruit yield could be associated with the effect of this treatment on characters like average fruit weight and fruit diameter which are all positively correlated with fruit yield. MacDonald *et al.* (2010) reported that preconditioning with 10 mg L^{-1} Amboil resulted in an increase of 65.1 % in number of tomatoes on each plant and 44 % in tomato mass (weight) which resulted to an increase of fruit yield by 143 %. Stress imposed at the vegetative stage had higher total fruit yield than those stressed at the flowering and fruit setting stages. This indicated that, the reproductive stage is the critical stage of water requirement in tomato. May and Gonzales (1994) reported that, 60% depletion of available moisture significantly reduced yields by 15 Kg ha^{-1}, 40% depletion reduced yields by 4 Kg ha^{-1} less than the 20% depletion treatment. They also reported that 20 to 60 days water stress before harvest during fruit development and ripening stage (late stress) resulted in similar reduction in yield. Tomato that received 400 ppm of the antitranspirant had higher number of fruits plant^{-1} than the other concentrations. This could be due to the fact that higher rates of antitranspirant usually results in phytotoxicity which reduces growth and yield of the crop as reported by El-Kobbia and Ibrahim (1986). This suggest that this rate of antitranspirant might have encouraged more moisture conservation and its use in production of more assimilate and its subsequent translocation to the fruit.

CONCLUSION AND RECOMMENDATIONS

From the results of the study obtained, it could be concluded that Salicylic acid performed better than Benzoic acid. Flowering and fruiting stages were found to be the critical growth stages for moisture stress of tomato. Salicylic acid was recommended to farmers in order to reduce the irrigation frequency thereby reducing cost of production and hence increased tomato fruit yield in the study area.

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