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Mitigation of Moisture Stress in Sweet Pepper (*Capsicum annuum* L.) by Foliar Application of Salicylic Acid in Sudan Savanna Agro-Ecology, Nigeria

Y.M. Bakundi and S.U. Yahaya
Department of Agronomy, Bayero University Kano, Nigeria

Correspondence: suyahaya.agr@buk.edu.ng

Abstract

Field experiment was conducted to study the influence of salicylic acid in the mitigation of moisture stress in sweet pepper. Treatments consisted of four rates (0, 0.2, 0.4 and 0.6gL-1) of salicylic acid and three moisture stress stages (vegetative, flowering and fruit setting). These were laid out in split plot design with three replications. Results of the study revealed that exogenous application of salicylic acid significantly ($p < 0.05$) decreases canopy temperature in sweet pepper. This however, increases the number of fruits per plant, average fruit weight and fresh fruit yield irrespective of the rate applied. The yield and yield components were also higher from plants that were subjected to moisture stress at vegetative stage and the control. Based on the existing findings, moisture stress in sweet pepper could be mitigated by foliar spray of salicylic acid at the vegetative stage. Further investigation is thus recommended to justify the best rate to apply.

Key words: Foliar application, Moisture stress, Salicylic acid, Sweet pepper.

Introduction

Sweet pepper (*Capsicum annuum* L.) belongs to the family Solanaceae and genus *Capsicum* (Anonymous, 2012)). This crop is used when green and may be eaten as cooked or raw, as well as in salad (Andrews, 1984). Sweet pepper is relatively non–pungent with thick flesh. It is the world's second most important vegetable after tomato (Anon, 1989). The crop was discovered to be a good source of medicinal preparation against vomiting and paralysis (Islam et al., 2010). Salicylic acid (SA) is a hormone-like substance, which plays an important role in regulating a number of physiological processes such as growth, photosynthesis, nitrate metabolism, ethylene production, heat production and flowering (Raskin, 1992; Hayat and Ahmad, 2007). SA is an endogenous growth regulator, phenolic in nature, which regulates stomatal closure, transpiration and drought tolerance (Shakirova et al., 2013. Salicylic acid also provides protection against biotic and abiotic stresses such as salinity in plants (Kaya et al., 2002), drought and heat (El-Tayeb, 2005). Exogenous application of salicylic acid was reported to significantly mitigate the adverse effects of drought stress in some plant species (Sadia et al., 2016).

Lack of adequate moisture leading to water stress is a common occurrence in rain-fed areas (Wang et al, 2006). Water deficit often causes reduction in plant growth by inhibiting leaf and stem elongation (Younis et al., 2000) as well as reducing nutrient uptake by plants. In addition, water deficit negatively affects the process of flowering in many plant species by reducing the fertility of newly formed flowers (Slawinska and Obendorf, 2001). As water becomes more limiting, its use efficiency is posing threats to production in many areas of the sub-Saharan Africa, particularly the drylands where both rain and underground water is restrictive.

Since water loss normally occurs through the stomata pores via transpiration, conservation of water is therefore necessary for agricultural expansion particularly in arid and semi-arid regions where water deficit and high temperature negatively affect plant growth and productivity (Taiz and Zeiger, 2010). Most of the water available to plants is lost through transpiration, which is effectively reduced by closure of stomata. Several ways can be practiced to achieve this objective, the most obvious of which is the use of salicylic acid. This will aid to conserve soil water and thereby reduce irrigation frequency and optimize the available water use for sweet pepper production. It is most likely that this would consequently lead to saving more water to irrigate larger area for increased production. This experiment was aimed at mitigating moisture stress in sweet pepper with exogenous application of salicylic acid.

Materials and Methods

The experiment was conducted during the 2015/2016 dry season at the Teaching and Research Farm of Faculty of Agriculture, Bayero University Kano (Latitude 110 58' N, Longitude 080 25 E') 475m elevation and the National Horticultural Research Institute (NIHORT), Progeny Orchard Kadawa (Latitude 110 48' N, Longitude 080 34' E) both located in the Sudan savanna agro-ecology in Nigeria. Treatments consisted of four rates of salicylic acid (0, 0.2, 0.4 and 0.6gL-1) and four moisture stress stages (no stress, vegetative, flowering and fruit setting). These were laid out in a split-plot design with three replications. Moisture stress stage was assigned to the main plot while the salicylic acid occupies the sub-plots. Seeds were sown shallowly in nursery beds, broadcast in rows of 20 cm apart. Seedbeds were protected against direct sun by covering them with rice straw. Complete fertilizer was applied at 20%N: 20%P: 20% K plus essential micro nutrients in two equal portions. The first application was done during the seedling stage while the second application at the beginning of flowering. The experimental field was ploughed and harrowed to a fine tilth. This was prepared into plots of slightly sunken beds (12m2) as comprised of 4 rows of 3m long. Four weeks old seedlings were transplanted at 30 x 60cm spacing. Manual hoe weeding was done to eradicate competing weeds at 3 and 6 weeks after transplanting (WAT). Insect pests were controlled by spraying the fields with cypermethrin at 1liter ha-1 at growth, flowering and fruiting stages. Salicylic acid was sprayed on the foliage using a hand sprayer at vegetative, flowering and fruit setting stages at the rates of 0.2, 0.4 and 0.6 g L-1 while the control was sprayed with water. Sweet pepper was harvested at four successive pickings when fruits were still green.

Data Collection and Analysis

Canopy temperature was measured at 6, 9 and 12 weeks after transplanting (WAT), using infrared thermometer (Benetech GM300). Similarly, number of fruits per plant were pooled from the net plots at four successive harvests, while the average fruit weight was determined from average weights of five randomly selected (tagged) fruits of each net plot. The fresh fruit yield was determined from the weights (in grams) of the harvested net plots, pooled from four successive harvests and extrapolated to kilogram per hectare. All data obtained were analyzed using Genstat 17th Edition (Reference?). Significant treatment means were compared using Tukey HSD at 5% level of significance.

Results and Discussion

The effects of moisture stress and salicylic acid (SA) on canopy temperature (CT) in sweet pepper at Bayero University, Kano (BUK) and Kadawa are presented in Table 1. Results of the study revealed significant ($p<0.047$) effect of stress on canopy temperature only at 9 and 12 weeks after transplanting (WAT) in BUK, while this was only significant ($p< 0.039$) during 12 WAT in Kadawa. At BUK, significantly ($p< 0.044$) higher CT was recorded from plants that were stressed at the stages of development. This was slightly different at Kadawa, in which higher CT was recorded from plants that were stressed at flowering and fruiting stages. This is an indication of the effect of moisture stress in raising leaf temperature due to decreased evapotranspiration. Water is a heat sink in plants; hence the slightest water deficit results in increased

leaf temperature. Similar observation was recorded for the effect of SA on CT in both locations (Table 1). Significantly (p<0.037 higher CT was noticed from plants that were sprayed with 0.2g L-1 and the control treatments at BUK. Lowest CT was also recorded from plants that received 0.4 and 0.6g L-1 of SA; thus, indicating a decrease in CT with increase in the rate of applied SA. The effect of SA on CT was only significant ($p< 0.034$) at 12 WAT in Kadawa. This showed that `higher CT was obtained from 0.2g L-1 and the control treatments. In general, there was decrease in CT with every increased rate of applied SA. Interaction of stress with SA on the canopy temperature was however, not significant in this study. The result of the investigation corroborates with the work of Sadia et al. (2016) who reported pronounced reduction in transpiration rate, stomatal conductance and water use efficiency at both flowering and pod formation stages in mung bean. They further affirmed improved transpiration rate under normal and stressful condition during these stages with exogenous application of SA and potassium or in combination. As transpiration increases, cooling effect tends to be higher resulting in decreased canopy temperature.

Table 2 shows the influence of stress and SA on some yield components and fruit yield of sweet pepper at BUK and Kadawa. The number of fruits per plant was significantly (p< 0.029 influenced by stress in both locations. Plants that were stressed at vegetative stage and control recorded the highest number of fruits while those stressed at flowering and fruiting stages had the least number of fruits per plant. The results further revealed significant effect of SA on number of fruits per plant at BUK only. All the applied SA rates recorded the highest effect, which also differed with the control. At Kadawa however, number of fruits per plants was not significantly influenced by the applied SA. Interaction of SA with stress period on number of fruits per plant was not significant in this study.

Similarly, the average fruit weight per plant was significantly ($p < 0.049$) affected by moisture stress at BUK only. Highest average fruit weight was recorded from plants that were stressed at vegetative stage and the control, while the least weight was recorded from plants that were stressed at flowering and fruiting stages. The average fruit weight was not affected by applied SA as all the rates recorded the same effect in both locations. Interaction between stress and SA on average fruit weight was not significant in this study. The results of the study further revealed significant ($p < 0.039$) effects of stress and applied SA on the fresh fruit yield in both locations. This showed that highest fruit yield was observed from plants that were stressed at vegetative stage and control. The lowest fruit yield was also observed from plants that were stressed at flowering and fruiting stages. Furthermore, plants treated with SA recorded the highest fruit yield irrespective of the rate applied in both locations. The control treatment also gave the lowest fruit yield. It was generally observed that all the yield components and the yield of sweet pepper were higher in plants subjected to stress at vegetative stage and the control. The decrease in number of fruits per plant at flowering and fruiting stages were because of the stress imposed, which resulted in poor bud and flower formation, flower abortion and consequent poor fruit development (Slawinska et al., 2001). Birhanu and Tilahum (2010) and Zotarelli et al. (2009) also reported similar findings for decrease in number and size of tomato fruits subjected to moisture stress at flowering and fruiting stages.

Several authors (Ehret et al., 2012., Proietti and Antognozzi, 1996., Zegbe et al., 2006) also reported significant increase in fruit size and weight due to increased fruit water content, active cell division due to water availability and amount of irrigation water applied at flowering and fruiting stages. Increase in these parameters could also translate to increased yield. Similarly, the increase in fresh fruit yield and its yield components in sweet pepper observed in this study could be attributed to the role of SA in the regulation of physiological processes and abiotic stress tolerance in plants. Khodary (2004) and El-Tayeb (2005) reported wide range of responses to appear after exogenous application of SA in plants. This might be due to increase in vegetative growth as reported by Zaghlool et al (2001). In another study, Abdel-Waheed et al. (2006) and Gharib (2006) also reported that foliar application of SA significantly increases yield and its components in maize.

Conclusion

The results of this investigation suggest that moisture stress in sweet pepper could be mitigated with foliar spray of SA at vegetative stage of development. However, more work is needed to justify the best rate of SA required for improved sweet pepper production with restrictive moisture.

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Table 1: Canopy temperature (0C) in sweet pepper as influenced by moisture stress and salicylic acid at Bayero University Kano and Kadawa during 2015/2016 dry season.

	BUK			Kadawa		
	Weeks After Transplanting					
Treatment	6	9	12	6	9	12
Stress (S)						
No stress	22.1	22.0b	23.9b	24.6	27.7	28.4b
At Vegetative	22.6	26.5a	26.9a	24.7	27.4	28.4b
At Flowering	22.3	26.8a	27.2a	24.6	27.5	32.4a
At Fruiting	22.4	26.9a	26.6a	24.2	27.4	34.7a
SE±	0.24	0.30	0.52	0.21	0.25	0.44
Salicylic acid (g L-1)						
0	22.4	26.9a	26.2a	24.5	27.4	32.4a
0.2	22.3	25.0a	27.3a	24.5	27.4	33.0a
0.4	22.2	22.8b	23.1b	24.5	27.6	28.7b
0.6	22.3	22.6b	22.2b	24.5	27.5	28.3b
SE±	0.06	0.11	0.74	0.03	0.11	0.78
Interaction						
S*A	ns	ns	ns	ns	ns	ns

Means followed by the same letter among treatments are not significantly different using Tukey HSD. BUK: Bayero University. ns: not significant

Table 2: Yield components and fruit yield in sweet pepper as influenced by moisture stress and salicylic acid at Bayero University Kano and Kadawa during 2015/2016 dry season.

Treatment	BUK			Kadawa		
	No. of Fruits/ Plant	Av. Fruit Weight (grm)	Fresh Fruit Yield Kg ha-1	No. of Fruits/ Plant	Av. Fruit Weight (grm)	Fresh Fruit Yield Kg ha-1
Stress (S)						
No Stress	56.0a	139.8a	4776a	52.0a	138.0	6229a
At Vegetative	55.0a	139.5a	4141a	52.0a	138.3	6869a
At Flowering	34.0b	133.4b	2853b	46.0b	139.5	5629b
At Fruiting	35.0b	133.4b	3464b	45.0b	139.6	5742b
SE±	4.57	3.241	68.641	5.33	3.112	65.162
Salicylic acid (gL-1)						
0	47.0b	159.0	3708b	54.0	187.3	6264b
0.2	57.0a	185.8	4956a	57.0	176.5	6887ab
0.4	56.0a	172.9	4592ab	55.0	178.1	6633ab
0.6	54.0a	189.2	4979a	60.0	181.5	7589a
SE±	5.12	3.324	65.641	6.10	3.42	76.491
Interaction						
A*S	ns	ns	ns	ns	ns	ns

Means followed by the same letter(s) within columns are not significantly different using Tukey HSD. ns: not significant.