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ORIGINAL ARTICLE

Determination if type of potassium salt affects growth and yield of *Capsicum annuum* and *Capsicum chinense* under drought stress

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Pepper (*Capsicum* spp.) growth and yield are reduced because of its susceptibility to water shortage which may be improved by application of potassium salts. Effects of concentrations of K2SO4 and KNO3 on growth and some yield parameters of *C. annuum* L. and *C. chinense* L. under artificially initiated drought were studied. Growth parameters like fresh and dry weights, Leaf Area Ratio, Leaf Weight Ratio, Relative Growth Rate and Net Assimilation Rate were determined at harvest. Yield parameters like number of flowers, number of fruit, fruit length, fruit diameter, fruit fresh weight and fruit dry weight were determined. There was a significant interaction of salt types, water levels and pepper types on all the growth, yield and biomass parameters studied.

Key words: Capsicum spp., drought, pepper, photosynthesis, seed, water

Drought induced reduction in yield of crops is an important factor for loss in food production worldwide (Debaeke and Aboudrare, 2004, Pennisi, 2008). Potassium as a macronutrient is required by plants for normal growth, development and yield formation. Limitation in growth and yield of crops under water deficit could be improved by increasing amounts of potassium (Cakmak, 2005; Damon, 2007; Damon and Rengel 2007). Potassium is involved in charge balance, transport process, metabolic process and turgor pressure (Dorais *& al*., 2001; Mengel and Kirkby, 2001). Fruit shape and reduction of ripening disorder is improved by application of potassium to plants under drought. Development of red coloration in some plants is primarily due to carotenoid biosynthesis as a result of increasing the potassium concentration (Amhakhian, 2010).

Pepper (*Capsicum* spp.) is sensitive to water level (Gonzalez-Dugo *& al*., 2007, Okunlola *& al*., 2017). Varying water application results in differences in growth, yield and physiology of the plants. Several works have reported that for improved yield of pepper, an adequate supply of water is important during its entire life cycle (Dorji *& al*., 2005; Sezen *& al*., 2006; Gonzalez-Dugo *& al*., 2007). The total fresh weight of fruit is reduced by a continuous water shortage. To ensure an improved yield, it is therefore important to determine if potassium species ameliorates the effects of drought in pepper.

MATERIALS AND METHODS

Seed of *C*. *annuum* and *C*. *chinense* were obtained from the Institute of Agricultural Research and Training, Ibadan, Oyo State, Nigeria. The physical and chemical properties of the soil used for development of seedlings were analyzed at the Department of Soil and Land Resource Management, Faculty of Agriculture, Obafemi Awolowo University, Ile-Ife, Nigeria. The soil was air-dried and transferred into 72 plastic pots (21 cm dia, 24 cm tall) with holes at the bottom for drainage. The experiment was conducted in a screenhouse in the Department of Botany. Mean daily temperature of the screen house was 29.5°C. The seedlings were treated with 0.2 $mL{\cdot}L^{-1}$ of DD force® to control insects. Thirty-five days after sowing, seedlings were already fully established, and the pots were divided into 12 groups of 6 pots each. The first six groups of plants had *C. chinense* while the other 6 groups of plants had *C. annuum*. Nutrient solution was prepared in accordance with the modified Long Ashton formula (Okunlola *& al*., 2015). The concentrations of potassium salts were modified and divided into treatments following the methods of Okunlola *& al*. (2016): 200 mL of water twice daily (W_0), this represents the control; 200 mL of water twice at a 2 day interval (W_1); 200 mL of 0.01 mol K_2SO_4 in the morning and 200 mL of water in the evening at a 2 day interval (W_2); 200 mL of 0.02 mol K_2SO_4 in the morning and 200 mL of water in the evening at a 2 day interval (W_3); 200 mL of 0.01 mol KNO_3 in the morning and 200 mL of water in the evening at a 2 day (W_4); and 200 mL of 0.02 mol KNO_3 in the morning and 200 mL of water in the evening at a 2 days interval (W_5). Treatments were replicated 6 times and applied to plants from the 35th day after sowing until 102 days after planting when the fruit were fully red and were harvested. Harvest growth and physiological measurements were then obtained.

Relative water content (RWC) was determined by weighing leaves of plants from treatments to determine fresh weight (FW). Tissues were floated on distilled water for 12 h and the turgid weight (TW) measured. The turgid plants were dried in a convection oven (model OV-160, Gallenkamp BS, London, UK) at 80°C for 48 h, and the dry weight (DW) was measured. The RWC was calculated by the modified method of Barrs and Weatherley (1962).

At the beginning, and end of the experiment, plants were randomly uprooted from each of treatment and roots washed with distilled water to remove soil. The plant fresh weight was determined, and tissues dried in a convection oven (Gallenkamp BS) at 80°C until a constant weight was achieved. After cooling, dry weights of the plants were determined. The dried plants were separated into leaves, shoots and roots and their individual weights determined.

Leaf area ratio (LAR), Leaf Weight Ratio (LWR), Relative Growth Rate (RGR), Net assimilation rate

(NAR), were calculated using the formulae of Okunlola *& al*. (2017). The Root Shoot Ratio (RSR) was determined by dividing the root dry weight by the shoot dry weight. Number of flowers, fruit, and aborted flowers per treatment was determined on the tagged plants in each pot. Fruit length and diameter were measured. Fresh fruit weight was determined. Fruit were dried in a convection oven (Gallenkamp) at 80°C for 48 h and after cooling weighed.

Data were subjected to analysis of variance in SAS (ver. 9.1, SAS Institute, Cary, NC). If the interaction was significant it was used to explain results. If the interaction was not significant means were separated with Least Significant Difference.

RESULTS AND DISCUSSION

Analysis of variance showed that, there were no significant effects of salt types on all the parameters studied, except on relative growth rate, number of flowers and fruits dry weight (Table1 and Table 2). Relative growth rate, number of flowers and fruit dry weight of pepper species subjected to drought is dependent on the types of potassium salt applied (KNO_3 or K_2SO_4). Leaf weight ratio, leaf area ratio and relative water contents of the pepper plants are dependent on the different water levels applied to the plants (Table 1). Other parameters studied were not significantly affected by the different water levels (Table 1). Leaf dry weight, root dry weight, leaf area ratio, leaf weight ratio, relative water content, relative growth rate (Table 1) , fruit number, fruit lengths and fruit diameter (Table 2) were significantly affected by the pepper types(*C. annuum* or *C. chinense*). Species of pepper did not have any significant effects on the other parameters studied. There was a significant interaction between the salt types and the water level on the leaf weight ratio and the relative water content (Table 1), number of flower, number of fruits, fruit fresh weight and fruit dry weight (Table 2). The effects of salt types on these parameters are dependent on the water levels applied to the plants. There was a significant interaction of salt types and pepper types only on the leaf weight ratio of the plant (Table 1). The other growth parameters (Table 1) and all yield parameters studied were not significantly affected by the interaction of salt types and pepper types (Table 2). Leaf weight ratio and net assimilation rate were significantly affected by the interaction of water levels and pepper types (Table 1).There was however no significant interaction of water levels and pepper types on all the yield parameters studied (Table 2). *C. annuum* and *C. chinense* plants subjected to application of W_5 and W_3 recorded significantly higher relative water content than those of the water stressed plants without potassium application, W_1 (Table 3). However, these values were not significantly higher than those recorded by the control plants (W_0) (Table 3). This is an indication that the water stressed plants subjected to this concentration of K_2SO_4 and KNO_3 benefited from application of potassium. The relative growth rate of water stressed *C. annuum* and *C. chinense* plants subjected to W4 was also significantly higher than the control plants (W_0) (Table 6). However, in *C. annuum* and *C. chinense* subjected to K_2SO_4 applications, there was no significant difference in the RGR of all the plants (Table 4). *Capsicum annuum* and *Capsicum chinense* plants treated with W_5 and W_3 had more relative water contents than the plants subjected to other treatments. There was a significant interaction among the salt types, water levels and pepper types on all the parameters studied (Table 1, 2).

In *Capsicum chinense*, the root to shoot ratio of plant treated with W3 was significantly reduced in comparison to plant treated with W_1. This was in agreement with the findings of Okunlola *& al*., 2017 who reported a higher root shoot ratio in drought treated plants. Plants devote fewer of their photo assimilates in leaves compared to roots when subjected to drought condition, thereby leading to higher root shoot ratio than in control plants

In *C. annuum* treated with different concentrations of KNO_3, the fruit length, fruit diameter, fruit fresh weight and fruit dry weight of plants treated with W_4 and W_5 were significantly more than those of water stressed plants without potassium application (W_1) (Table 5). Number of flowers and fruits of water stressed *C. chinense* subjected to KNO_3 application were significantly higher than those of water stressed plants without K application (Table 5). Fruit length and fruit diameter of W5 treated plants were significantly higher than those of control plants (Table 5). Water stressed *C. chinense* plants subjected to W_4 treatment had significantly higher fruit fresh weight and fruit dry weight than those water stressed plants without K application (W_1) and control plants (W_0) (Table 5). Water stressed *C. annuum* plants subjected to K_2SO_4 applications recorded a significantly higher fruit length than the ones that were water stressed without any K_2SO_4 application (Table 6). However the control plants (W_0) had the significantly highest fruit length (Table 6). The control plants (W_0) also recorded the highest fruit diameter and fruit fresh weight compared to the other treatments (Table 6). According to Colpan *& al*. 2013, fruit size, diameters of fruits, number of fruits per plant and fruit weight increased with the application of K in tomato.

Table 1: Analysis of variance for growth and biomass accumulation as affected by salt type, water level and pepper type.

Source	Dry weight				Ratio			Rate
	Plant	Leaf	Root	Shoot	Leaf area	Root:Shoot	Leaf weight	RWC
Salt type (S)	Ns	ns	Ns	Ns	ns	ns	ns	ns
Water level (W)	Ns	ns	Ns	Ns	*	ns	*	*
Pepper type (P)	Ns	*	*	Ns	*	ns	*	*
S×W	Ns	ns	Ns	Ns	ns	ns	*	*
S×P	Ns	ns	Ns	Ns	ns	ns	*	ns
W×P	Ns	ns	Ns	Ns	ns	ns	*	ns
S×W×P	*	*	*	*	*	*	*	*

ns, * not significant or significant at $p<0.05$, ANOVA.
RWC = relative water content.

Table 2: Analysis of variance for yield as affected by salt type, water level and pepper type.

Source	Number			Fruit		
	Flowers	Fruit	Length	Diameter	Fresh weight	Dry weight
Salt type (S)	*	ns	Ns	ns	ns	*
Water level (S)	Ns	ns	Ns	ns	ns	ns
Pepper type (P)	Ns	*	*	*	ns	ns
S×W	*	*	Ns	ns	*	*
S×P	Ns	ns	Ns	ns	ns	ns
W×P	Ns	ns	Ns	ns	ns	ns
S×W×P	*	*	*	*	*	*

ns, * not significant or significant at $p < 0.05$, ANOVA.
Values in columns with the same letter are not significantly different, $p>0.05$, LSD

Table 3: Effects of potassium nitrate on growth parameters of *Capsicum annuum* and *C. chinense* under water stress

Treatments	Relative Water Content (%)	Leaf Area Ratio (cm^2/g)	Leaf Weight Ratio	Root Shoot Ratio	Net Assimilation Rate	Relative Growth Rate
C. annuum						
W4	61.08b	351.72a	0.637a	0.212a	0.00151a	0.132a
W5	63.23a	461.78a	0.599a	0.188a	0.00096a	0.083b
W1	61.57b	240.23a	0.641a	0.217a	0.00097a	0.11ab
W0	60.76b	237.42a	0.609a	0.176a	0.00058a	0.065b
LSD	1.513	78.87	0.122	0.117	0.0012	0.045
CV (%)	7.06	95.38	15.90	47.99	94.49	38.04
C. chinense						
W4	59.68b	207.47	0.658ab	0.096a	0.00120a	0.12a
W5	62.65a	232.39a	0.669a	0.096a	0.00118a	0.09ab
W1	59.11a	254.44a	0.657ab	0.135a	0.00047ab	0.06bc
W0	58.32b	196.83a	0.596b	0.104a	0.00036b	0.04c
LSD	2.05	109.15	0.068	0.049	0.0008	0.047
CV(%)	6.81	39.81	8.505	37.39	50.29	50.50

Values in columns with the same letter are not significantly different, p>0.05, LSD

Table 4: Effects of potassium sulfate on growth parameters of *Capsicum annuum* and *C. chinense* under water stress

Treatments	Relative Water Content	Leaf Area Ratio	Leaf Weight Ratio	Root Shoot Ratio	Net Assimilation Rate	Relative Growth Rate
C. annuum						
W2	61.77b	290.68a	0.548a	0.548a	0.00047a	0.062a
W3	62.99a	318.98a	0.546a	0.182a	0.00076a	0.100a
W1	61.57b	240.23a	0.641a	0.217a	0.00097a	0.108a
W0	60.76b	237.42a	0.609a	0.176a	0.00058a	0.065a
LSD	1.11	233.33	0.120	0.085	0.0005	0.053
CV (%)	8.23	66.76	16.56	37.59	63.22	51.02
C. chinense						
W2	59.24b	168.21a	0.634a	0.128ab	0.00053a	0.059a
W3	61.45a	166.28a	0.688a	0.090b	0.00041a	0.050a
W1	59.11a	254.44a	0.657a	0.135a	0.00047a	0.055a
W0	58.32b	196.83a	0.596a	0.104ab	0.00036a	0.035a
LSD	0.99	110.53	0.137	0.044	0.0005	0.029
CV(%)	9.37	45.72	17.22	30.96	88.66	44.86

Values in columns with the same letter are not significantly different, p>0.05, LSD

Table 5: Effects of potassium nitrate on yield parameters of *Capsicum annuum* and *C. chinense* under water stress

Treatments	Number of flowers	Number of fruits	Fruit length	Fruit Diameter	Fruit Fresh weight(g)	Fruit Dry Weight(g)
			C. annuum			
W4	9.00a	2.00	76.50a	10.00a	4.57a	0.54a
W5	9.00a	1.00a	67.00b	8.33b	4.44b	0.53a
W1	6.00b	1.00a	54.50d	7.62c	4.23d	0.44b
W0	7.00ab	1.00a	65.17c	8.32b	4.35c	0.46b
LSD	2.10	1.32	71.42	0.15	0.02	0.03
CV (%)	23.39	87.64	31.79	1.50	0.37	4.46
			C. chinense			
W4	18.00a	8.00a	25.31ab	26.24ab	6.71a	0.75a
W5	15.00a	6.00a	30.51a	29.89a	4.92ab	0.50b
W1	6.00b	2.00b	16.63bc	20.72ab	3.08b	0.30b
W0	5.00b	1.00b	12.67c	14.74b	2.84b	0.27b
LSD	8.17	2.47	11.57	13.94	2.41	0.24
CV(%)	62.46	49.60	44.19	49.46	44.64	42.4

Values in columns with the same letter are not significantly different, p>0.05, LSD

Table 6: Effects of potassium sulfate on reproductive and yield parameters of *Capsicum annuum* and *C. chinense* under water stress

Treatments	Number of flowers	Number of fruits	Fruit length	Fruit Diameter	Fruit Fresh weight(g)	Fruit Dry Weight(g)
			C. annuum			
W2	6.00a	1.00a	58.00c	7.65b	4.33a	0.47a
W3	7.00a	1.00a	59.00b	7.78b	4.23b	0.43c
W1	6.00a	1.00a	54.50d	7.62b	4.23b	0.45bc
W0	7.00a	1.00a	65.17a	8.32a	4.35a	0.46ab
LSD	1.35	0.74	0.95	0.17	0.03	0.02
CV (%)	17.79	82.68	1.33	1.83	0.51	4.31
			C. chinense			
W2	8.00a	3.00a	28.69a	22.83a	4.97a	0.50a
W3	6.50a	2.00a	19.57ab	20.66a	3.47a	0.37a
W1	6.00a	2.00a	16.63ab	20.72a	3.08a	0.30a
W0	5.00a	1.00a	12.67b	14.74a	2.40a	0.27a
LSD	4.67	1.96	12.75	15.48	2.57	0.26
CV(%)	61.92	88.98	53.44	63.73	58.32	57.72

Values in columns with the same letter are not significantly different, p>0.05, LSD

The non-significant effects of K applications on the biomass accumulation in the two pepper species might be due to the low concentrations at which the KNO_3 and K_2SO_4 were applied. According to Egila *et al*., 2011, a sufficient supply of K can improve the plant dry matter better than a lower concentration of K can in soil under drought conditions. This might be as a result of the role of K^+ in the regulation of stomatal opening and the resultant effect of high rate of photosynthesis (Marschner, 2012). Application of potassium increases root growth as well as the root surface area under drought conditions, which ultimately enhances the water up take by plant cells (Römheld and Kirby, 2010). Water retention of plants under drought stress as well as the plant total dry mass is improved by potassium application. (Lindhauer, 1985). Previous studies have reported a reduction in relative growth rate of plants under water stress (Okunlola *et al*., 2017). However, the higher RGR of water stressed plants subjected to potassium application is an indication that potassium is important in ameliorating the effect water shortage causes in plants. High relative water content is a resistant mechanism to more osmotic regulation or less elasticity of tissue cell wall. It reduces closure of stomata and thereby increases the photosynthetic rate. The maintenance of high relative water content under drought condition is an indication of drought tolerance in plants (Okunlola *et al*., 2017). Plants with K^+ deficiencies are more vulnerable to drought than the plants which have sufficient K^+. These plants have better hydrated tissues than those having inadequate supply of K^+ (Mengel and Kirkby, 2001). Potassium plays an imperative role in the photosynthesis process and the subsequent carbohydrate translocation and metabolism, which eventually increase crop yield (Zorb *et al*., 2014; Lu *et al*., 2016). According to Saini and Lalonde (1998) , reduction in the number of fruits in water stressed crops could be attributed to the failure of plants to pollinate under such conditions. Hsiao (1993) noted the restricted plant size and reduction in assimilate availability at the time of fruit development and maturation in plants under water stress as important causes of reduction in fruit production. All these effects could be said to have been ameliorated by the application of potassium salts, hence, the improvement in the yield parameters of the potassium treated plants. Previous investigations on tomato indicated that K has important contribution to fruit weight, color, dry matter content and final yield (Anac *et al*. 1994). Adequate supply of K nutrition has also been associated with increased yield (Lester *et al*. 2005, Kanai *et al*. 2007) which further confirm our findings that K application to plants under drought favors improved yield in pepper. About two-thirds of the potassium uptake from the soil is allocated to the fruits (Hidetoshi, 2007). Hence, there exist a positive correlation between potassium supply and the fruit weights, number of flowers and number of fruits. One of the factors that influence the quality of vegetable crops is potassium.

CONCLUSION

It is concluded from this study that the growth and yield of the two pepper species used in this study is determined by the interaction of the potassium type and the level of water application. The two potassium salts used are important in the maintenance of the water status of the two pepper species under water stress and thereby improved the growth and yield of the crop.

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CONFLICTS OF INTEREST

The Authors declare that they have no competing interest.

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