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Influence of Water Deficit and Gibberellic Acid Treatments on Vegetative Growth of Tomato

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Abstract
Tomato plants (Lycopersicon esculentum Mill. cv. Rio Grand*) grown in plastic bags were exogenous treated by gibberellic acid (GA_3) (0, 50 and 100 ppm) under water deficit (WD) treatments (0, 20, 40 and 60%) during vegetative stage. The results showed that significantly increased in fresh and dry weight of leaves (FWL and DWL), the plant height (PH) and leaf number (LN) with increased concentration of GA_3 treatment regardless of the percentage of the WD applied. The treatment of 60% WD and 100 ppm GA_3 has resulting in the appearance of FWL, PH and LN values comparable to the effect of the control treatment of WD and GA_3. The treatment with GA_3 (100 ppm) has ameliorated the value of leaf area (LA) under the effect of the applied WD. The GA_3 treatments resulted in a relative increase in the water content (WC) and relative water content (RWC) with all the WD percentages used. The specific leaf weight (SLW) and the content of chlorophyll in the leaves were increased as a result of increased concentrations of GA_3 regardless of the percentage of the WD applied. There was no significant change in the percentage of protein in the leaves as a result of the application of the GA_3 treatments, whereas 60% of WD has decreased the protein percentage. The treatment with GA_3 led to maintaining or reducing the severity of the reduction effect of WD on the content of nitrogen, phosphors and potassium (NPK) nutrients in varying proportions. The addition of GA_3 has reduced the effect of WD as the plant promotes water absorption and its translocation to the leaves and other parts of the plant, as well as mechanisms to regulate growth under the influence of WD.*

Key words: *Tomato; Lycopersicon esculentum* Mill.; *Water deficit; Gibberellic acid; Vegetative growth.*

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I. Introduction

The water deficit(WD) caused by water stress is one of the most important types of abiotic stresses that limit agricultural production in arid and semi-arid regions of the world. The loss due to WD in crop yields may exceed the losses from all other causes, because the severity and the duration of the water stress are crucial (Farooq *et al.*, 2009). Pokluda *et al.* (2010) showed that there was a significant decrease in the leaf area of tomato plants due to water stress. Severe water stress can causing a decrease in the total water stock to minimum levels, thus stopping or slowing down some biological functions such as photosynthesis and stomatal conductance as well as the effect on the general metabolism processes (Turner, 1979). WD or water stress affects the functioning of photosynthesis systems and leads to reduced leaf content of chlorophyll pigments (Holaday *et al.*, 1992). The application of water stress during the phase of fruiting growth has a slight effect on the productivity of tomatoes (Boon, 1973). The effect of water stress is reflected in reducing the rate of cell division and elongation in plants (Torrecillas *et al.*, 1995). In several studies, showed that the contents of IAA and GA_3 in leaves decreased as the water stress increased, whereas the contents of ABA increased significantly under water stress conditions(Zhang *et al.*, 2002).

The researches indicated that it is possible to reduce the damage caused by water stress by increasing plant growth activity under stress conditions (Li and van Staden, 1998), as adding substances that promote growth may have a positive effect in this regard, among the fertilizer materials and compounds, especially nitrogenous fertilizer and growth regulators such as auxins, gibberellins and cytokinins (Rimski-Korsakov *et al.*, 2009; Ashraf *et al.*, 2011). The role of growth regulators in increasing plant growth is known for specialists in this field, while their combined effect and relationship to water stress may provide a solution that reduces the water stress problem in many areas with many plant species. Gibberellins are considered growth regulators that are important in increasing plant growth activity under several conditions, they stimulate the division and elongation of cells in sub-apical of stems, which increases the vegetative growth of the plant. Gibberellins promote the germination of dormant seeds as well as extend the stem and flowering in plants, and the gibberellins in turn preserve the chlorophyll of separated leaves and also promote the formation of seedless tomato fruits (Misra and Biswal, 1980; Sawhney, 1984; Bewley, 1997).

Due to the importance of vegetable crops in many regions of the world, especially in our country, where the domestic consumption of various types of vegetables increases steadily annually, it is imperative that those working in the field of agriculture increase interest in ways and means to increase production and raise its quality. Perhaps the most important and most widespread vegetable is tomato (*Lycopersicon esculentum* Mill.), where it follows Solanaceae family. The global cultivated area is about 4.7 million hectares of tomatoes and its global production is about 182 million tons annually (FAO, 2018), and it is one of the most important vegetable crops in the Mediterranean countries, including Libya. Tomato is considered to be the most consumed, and due to its economic importance, researchers in the field of agriculture have paid great attention to studies that lead to develop and increase its productivity. Despite the limited water resources available to invest in expanding agricultural sector, the spread of tomato cultivation is increasing in a significant way.

Perhaps one of the ways in order to increase production and reduce its degradation is the availability of complete water needs for the plant. This will only come with practical solutions to the WD problem caused by drought. Therefore, the development of any strategy that leads to reducing this problem will necessarily lead to improving the water situation in relation to the plant, which is reflected in the improvement of the quantity and quality of production.

Therefore, the present study aimed to research the effects of gibberellic acid on the growth and development of tomato plants during the vegetative phase under conditions of water deficiency applications.

II. Materials and Methods

The experiment was carried out by cultivating the tomato plants (*Lycopersicon esculentum* Mill. CV. Rio Grand)in the research farm of the Faculty of Agriculture - University of Benghazi, seeds were sawing in a substrate consisting a 1:1:1 ratio of soil, sand and an organic matter in 30 litres plastic bags, a fertilization program has been applied by addition the essential nutrients during the growth and development stages of the plant. Plants were grown under a plastic canopy to avoid reach of rainfall in case of precipitation, at 14h photoperiod, photosynthetic active radiation reached a daytime peak value of 1200 $\mu mol.m^{-2}.s^{-1}$, the temperature and relative humidity ranged to 31/19°C and 42/76% during day/night periods, respectively.

Treatments were initiated when the plants reached the first leaf stage with a vary levels of water deficit (WD) and concentrations of gibberellic acid (GA_3). Plants were gradually exposed to WD by reducing the amount of irrigation water by 0, 20, 40 and 60%. In reverse, WD was done by hydrating plants with 100, 80, 60 and 40% of field capacity. The plants were foliar sprayed by GA_3 solution (0, 50 and 100 ppm), three times and every other days at beginning of WD treatment during vegetative stage. Amount of irrigation water was adding according to the needs of the plant and the change in the daily temperature with respecting the increase in the size of the plant due to growth. The amount of irrigation water was calculated according to modified method of Sibomana *et al.* (2013) by determining the difference in plant weight with the substrate before and after each irrigation. So it has been taken into consideration the gradual increase in the amount of irrigation water needed by the plant to reach the whole percentage indicated of field capacity. Treatments have been continued until the beginning of the flowering stage.

Plants designated for these measurements were cut off at the end of the vegetative stage; the leaf number (LN) of the plant was calculated, the plant height (PH) and leaf area (LA) were also measured. Fresh weight of leaf (FWL) were measured for each treatment, these plants were dried three days in an oven at 65 °C (until there was no decrease in weight) for determination the dry weight of leaf (DWL).

The midday water content (WC) and relative water content (RWC) were measured using leaves, which were immediately weighed to obtain a leaf fresh weight. Leaves were placed in a beaker with the petioles submerged in water overnight in the dark at 4 °C, so leaves could become fully hydrated. Leaves were reweighed to obtain turgid weight and dried at 70 °C for 3 days to obtain dry weight. The WC was calculated as $[(FW–DW)\times FW^{-1}]\times 100$, while the RWC was calculated as $[(FW–DW)\times(TW–DW)^{-1}]\times 100$ according to Barrs and Weatherley (1962) and Morgan (1984), where FW is the leaf fresh weight, TW is the turgid weight and DW is the dry weight. The specific leaf weight (SLW) was determined by dividing values of leaf dry weight by leaf area.

The total content of nitrogen (N) and percentage of protein in leaves were determined by the micro-Kjeldahl method. Phosphorus (P) was determined choloremeterically, meanwhile potassium (K) content in dry matter were measured by flame photometer. Also content of chlorophyll a, b and total were determined choloremeterically according to Moran (1982).

The data presented are representative the mean of two independent experiments. The experimentation was conducted in four replicates, using factorial experimental 4×3 in completely randomized design, with the treatments of WD and GA_3. Data were subjected to analysis of variance using a two-way ANOVA. Differences among means of treatments were compared by Duncan's multiple range test at the 0.05 confidence level.

III. Results and Discussion

The water deficiency (WD) treatments resulted in a decrease in the values of the fresh (FWL) and dry (DWL) weights of the leaves, as the rate of decline was increased with increasing the percentage of the applied WD and reaching about half the weight (from 17.5 and 3.0 to 9.6 and 1.4 grams, respectively) (Table 1.). Significantly increased in leaf weight with increased concentration of GA_3 regardless of the percentage of the WD applied, as the treatment of 60% WD and 100 ppm GA_3 resulting in the appearance of FWL value comparable to the effect of the control treatment of WD and 0 GA_3 (Table 1.). The treatment also resulted in 60% WD and 100 ppm GA_3 to produce values for the plant height (PH) and leaf number (LN) comparative to the treatment of control WD and 0 ppm GA_3 (Table 1.). The treatment (control or 20% WD with 100 ppm GA_3) resulted in a higher value for the leaf area (LA), as the treatment with GA_3 reduced the severity of the low value of the LA due to the effect of the applied WD (Table 1.).

Table 1. Influence of water deficit (WD) and gibberellic acid (GA_3) treatments (ppm) on fresh weight of leaf (FWL), dry weight of leaf (DWL), plant height (PH), leaf number (LN) and leaf area (LA) of tomato plants.

Treatments		Measurements				
WD %	GA_3	FWL	DWL	PH	LN	LA
		(g/plant)		cm	no.	cm^2
Control	0	17.5^{cd}	3.0^{ab}	35.7^{abc}	13.3^{bc}	271^{bc}
	50	18.6^{c}	2.2^{bc}	35.3^{abcd}	17.5^{a}	313^{ab}
	100	28.7^{a}	3.8^{a}	40.3^{a}	19.0^{a}	474^{a}
20%	0	16.9^{cde}	2.2^{bc}	32.5^{bcd}	12.7^{bc}	234^{cde}
	50	17.6^{c}	3.2^{ab}	32.6^{bcd}	14.3^{b}	268^{bcd}
	100	21.7^{b}	3.6^{a}	38.0^{ab}	18.7^{a}	340^{a}
40%	0	10.8^{fg}	1.9^{c}	23.2^{e}	12.0^{bc}	231^{cde}
	50	13.1^{fg}	1.4^{c}	28.3^{de}	11.0^{c}	233^{cde}
	100	14.2^{ef}	1.7^{c}	29.3^{cde}	12.7^{bc}	271^{bc}
60%	0	9.6^{g}	1.4^{c}	23.1^{e}	10.3^{c}	173^{e}
	50	12.0^{fg}	1.7^{c}	23.0^{e}	11.5^{bc}	199^{e}
	100	14.5^{def}	2.2^{bc}	30.0^{bcde}	12.3^{bc}	217^{de}

Each value represents mean of four replicates. Means followed by the same letter in each column are not significantly different by Duncan's multiple range test at 5% level.

Several studies have pointed to the adverse effect of WD on plant growth, particularly the number, weight and area of leaves, as well as the height of the plant (Nemmar, 1983; Torrecillas *et al.*, 1995; Wahb-Allah *et al.*, 2011). The effect on growth may be directly proportional to the severity of the plant's WD (Farooq *et al.*, 2009). The results of our study indicate a gradual reduction in leaf weight as a result of exposure to a WD of up to 60% compared to the treatment of control (Table 1.). We note that the low weight value has reached about 50%, while the WD value has also reached about half (60%). Remarkably, the reduction in growth resulting from exposure to WD has been offset by an equal proportion of the applied WD.

The role of GA_3 in influencing the growth and development of plants is much mentioned in many research and may lead to an increase or decrease in growth, depending on its concentration and at what stage of development is applied (Heller and Lance, 2000; Petter, 2005). The results of table 1 indicate that the treatment of tomato plants with GA_3 has led to the maintenance of the FWL, DWL, PH and LN of the plant under WD condition. Also, from the results, we note that the values of the growth measures were comparable to the values resulting from the effect of the control treatment. In more detail, treatment with GA_3, especially concentration of 100 ppm, seems to have significantly reduced the adverse effect of WD within the plant even with the highest rate applied (60%). On the other hand, the treatment with GA_3 (100 ppm) did not limit the deterioration of the value of the LA under the influence of WD by 60%, while the effect of the treatment with GA_3 with a 20% WD was limited to giving more LA than other treatments (Table 1.). The effect of WD in the LA has been shown by reducing the number and size of cells, while GA_3 improves cell growth (Alhadi *et al.*, 1999). It is clear that the effect of GA_3 on plant growth continues and is effective even under WD conditions, in the sense that GA_3 has acted as a compensatory agent and stimulant for the growth process under stress conditions, particularly WD conditions.

The desired effect of GA_3 treatment on plant growth can be the result of an increased capacity of the plant to absorb water from the soil. Where Kaya *et al.* (2006) reported that the GA_3 has increased cell membrane permeability, and possibly increasing cell retention capacity too. The cells of the developing plant tissue are clearly known to act as a gathering sink of the water, allowing them to continue to grow. In any case, the GA_3

appears to have maintained the level of growth of the cells and their expansion to a degree that the plant has adapted to and maintained its level of development despite the application of a WD.

The application of the WD treatment resulted in a relative decrease in the values of the water content (WC) and the relative water content (RWC), while the treatment with GA_3 resulted in a relative increase with all the concentrations used (Table 2.). The specific leaf weight (SLW) values increased as a result of increased concentrations of GA_3 regardless of the percentage of the WD applied (Table 2.). There was a decrease in the content of chlorophyll *a*, *b* and total (*t*) due to the applied WD, where the rate of decline increased with the raise in the percentage of WD, in contrast the treatment of GA_3 increased the content of chlorophyll in the leaves to levels exceeding the values obtained with the control treatment (Table 2.). There was no significant change in the protein% in the leaves as a result of the application of the WD and the treatment of GA_3, exception has been appeared when the WD rate reached to the lowest level (60%), where the protein% decreased without any effect from the treatment of GA_3 has been registered (Table 2.).

Table 2. Influence of water deficit (WD) and gibberellic acid (GA_3) treatments (ppm) on water content (WC), relative water content (RWC), specific leaf weight (SLW), chlorophyll content (Chl.*a*, Chl.*b* and Chl.*t*) and protein percentage of tomato plants.

Treatments		Measurements						
WD %	GA_3	WC (%)	RWC (%)	SLW (g/cm^2)	Chl.*a* (mg/100g FW)	Chl.*b* (mg/100g FW)	Chl.*t* (mg/100g FW)	Protein (%)
Control	0	80.6^{e}	80.2^{def}	0.044^{c}	45^{d}	20^{bcd}	65^{cd}	18.9^{ab}
	50	86.0^{ab}	83.4^{bc}	0.045^{c}	55^{bc}	24^{bc}	79^{b}	19.5^{a}
	100	85.2^{abc}	86.8^{a}	0.056^{ab}	59^{ab}	26^{ab}	85^{b}	19.6^{a}
20%	0	81.8^{de}	79.5^{ef}	0.045^{c}	42^{d}	19^{cde}	61^{de}	17.3^{abc}
	50	81.9^{de}	82.2^{cde}	0.051^{abc}	60^{ab}	24^{bc}	84^{b}	18.0^{abc}
	100	85.6^{abc}	85.8^{ab}	0.060^{a}	65^{a}	32^{a}	97^{a}	18.3^{ab}
40%	0	82.6^{cde}	78.4^{fg}	0.046^{bc}	22^{f}	17^{def}	39^{g}	14.6^{abc}
	50	87.9^{a}	81.7^{cde}	0.049^{bc}	47^{cd}	10^{g}	57^{de}	14.9^{abc}
	100	88.2^{a}	82.6^{cd}	0.056^{ab}	62^{ab}	13^{efg}	75^{bc}	15.2^{abc}
60%	0	83.8^{bcd}	76.0^{g}	0.051^{abc}	16^{f}	10^{g}	26^{h}	13.1^{c}
	50	84.3^{bcd}	79.6^{def}	0.056^{ab}	32e	13^{efg}	45^{fg}	13.9^{bc}
	100	84.8^{bcd}	81.5^{cde}	0.056^{ab}	41^{de}	12^{fg}	53^{ef}	15.8^{abc}

Each value represents mean of four replicates. Means followed by the same letter in each column are not significantly different by Duncan's multiple range test at 5% level.

Several researches have indicated that the effect of water stress (water deficit) is reflected in a decrease in both WC and RWC in tomato plant tissue (Rahman *et al*., 2002; Yuan *et al*., 2010; Nahar and Ullah, 2012). The reduction in the content of water in the plant is an expected result under the applicable WD (Table 2.). On the other hand, the treatment with GA_3 has resulted in the preservation of the WC and RWC in proportions compatible with the rate of WD to which the plant has been exposed. The exogenous treatment of GA_3 can increase the permeability of cell membranes, allowing it to grow easily and expand, thus attract a quantity of water commensurate with its growth rate (De La Guardia and Benlloch, 1980). The effect of the GA_3 is also clearly reflected in the increase in the SLW (Table 2.), although the LN has decreased (Table 1.), in the sense that although few leaves are thicker as a result of the interaction influence of both the WD and GA_3 treatments on the growth and development of the leaves. Perhaps, exogenous application of GA_3 has improved the water stress tolerance in plants such increasing cuticle layer thickness of leaf (Zhu *et al*., 2019). Treatment with GA_3 has had an adverse effect compared to the effect of WD on the leaf content of chlorophyll a, b and total (Table 2.), as confirmed by the relevant studies, the treatment with GA_3 increases the leaf content of chlorophyll (Kaya *et al*., 2006; Kazemi, 2014). The low level of chlorophyll can be caused by a disturbance in the concentration of some cations within plant tissues due to exposure to the WD condition (Alhadi *et al*., 1999). It clearly shows that the percentage of protein in the leaves of the plant has often been preserved as a result of treatment with GA_3 under water deficiency (Table 2). Maintaining the level of growth of several measures under the applied WD predicts that the components responsible for growth have been preserved and continued to be active by an influential factor, GA_3. The known role of GA_3 in influencing plant growth and development can be in its regulation of biological processes within plant tissues (Heller and Lance, 2000; Petter, 2005).

Figure 1 presents the effect of the treatments applied on leaves content of some macro nutrients. The application of the WD resulted in a decrease in the leaf content of the nutrients, nitrogen, phosphors and potassium (NPK), while the treatment with GA_3 led to maintaining or reducing the severity of the decrease in the content of some nutrients in varying proportions. As the P content improved with the treatment of GA_3 better than the improvement in the N content, while the treatment with GA_3 raised the severity of the decrease in the K content resulting from the effect of the applied WD.

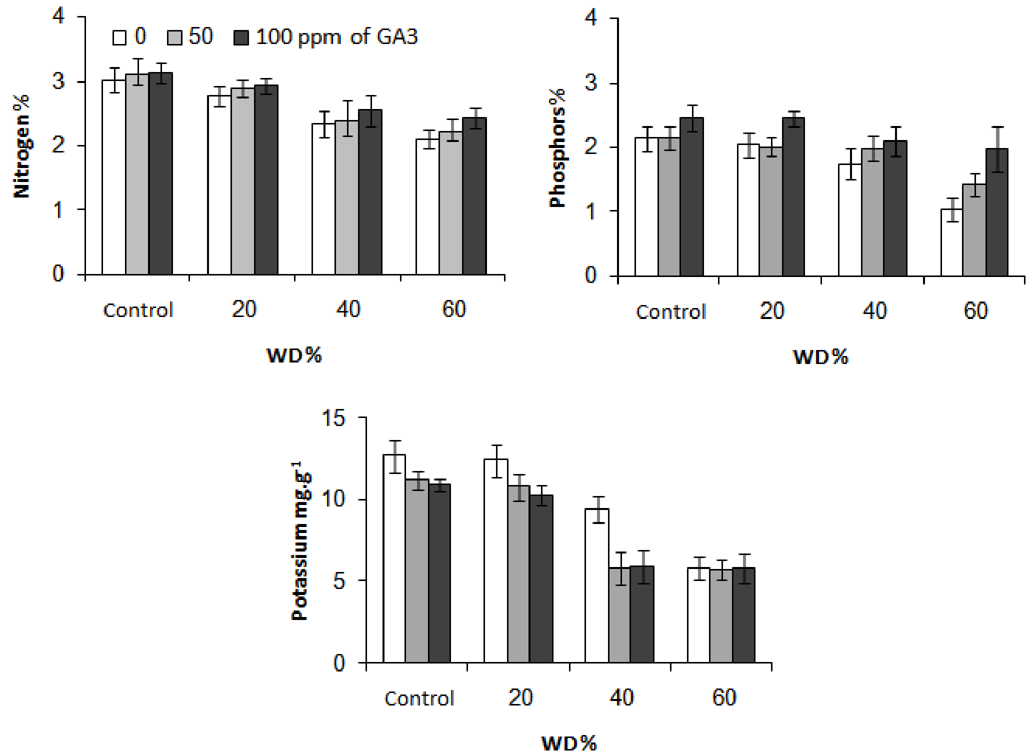

Figure 1. Influence of water deficit (WD) and gibberellic acid (GA_3) (ppm) treatments on content of nitrogen (N), phosphor (P) and potassium (K) in leaves of tomato.

Reduced leaf content of N, P and K nutrients (Figure 1.) is a realistic result under WD by reducing the amount of elements provided in a low amount of water requirements for the plant. Treatment with GA_3 has clearly improved the nutrients content of the leaves (Naeen *et al*., 2001; Khan *et al*., 2006). Although treatment with GA_3 resulted in a better level of nitrogen and phosphorus, it did not maintain a comparable level to control treatment. On the other hand, treatment with GA_3 did not maintain the potassium level, but rather it reduced in presence or absence of a WD condition. This result may not be considered specific to tomato plants during vegetable growth, which is difficult to explain. The role of potassium is important in increasing the capacity of plants exposed to biotic and abiotic stress in maintaining their growth balance (Wang *et al*., 2013). Some studies suggest the potassium has improved water stress tolerance by enhancing concentrations of some essential nutrients in leaves (Wang *et al*., 2013).

IV. Conclusion

The results indicated that exogenous GA_3 treatment can ameliorate the deleterious effects of WD by maintaining or improving growth measurements and water contents of plants. In contrast, a relative amelioration in chlorophyll levels, protein content and nutrients uptake, have been registered during vegetative stage of tomato plants. The application of GA_3 could offer an economical and simple treatment to the plants facing a WD periods in arid and semiarid zones caused by water stress. However, further studies are required in order to make some amelioration processes by applying other concentrations of GA_3 under conditions of WD, as well as to determine the efficiency of this method under natural field condition.

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