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Morphological and Productivity Characteristics of Tobacco Varieties as Influenced by Potassium Humate (k-humate) and Sorbitol under Drought Stress Conditions

Majd Darwish [a++*], Rabie Zaine [b#], Nizar Moalla [a++] and Haneen Mohamed [a†]

[a] *Department of Field Crops, Faculty of Agricultural Engineering, Tishreen University, Lattakia, Syria.*
[b] *Agricultural Scientific Research Center, Lattakia, Syria.*

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment was carried out in a completely randomized block design (RCBD) with three replications, at the Scientific Agricultural Research Station (Setkhiris-Latakia), using seedlings of three tobacco varieties (Virginia VK51- Burley R21 - Katrina) and treating them with concentrations

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++ Associate Professor (PhD);
 # Researcher (PhD);
† Postgraduate student (PhD);
**Corresponding author: Email: majds26@yahoo.com;*

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(0- 5- 15 %) of polyethylene glycol (PEG-600) and foliar spraying with a concentration of 0.5 g/L of potassium humate (k-humate) and sorbitol. The aim of this research was to determine the response of some morphysiological and productivity characteristics under the effect of the most harmful level of drought stress induced by PEG-600 and spraying with potassium humate and sorbitol. The drought stress (PEG 5 %), as well as foliar spraying with 0.5 g/L of potassium humate and sorbitol, led to a significant increase in plant height (cm), plant leaves area PLA (cm^2/plant), leaf area index (LAI), crop growth rate CGR (g/m^2/day) and weight of dry leaves (g/plant). While drought stress (PEG 15 %) caused a significant decrease in the values of all the studied traits. A significant increase in the studied traits compared to the PEG 5 and 15 % treatments alone was recorded when plant foliar sprayed with potassium humate and sorbitol. Thus, it can suggested application treatment with PEG 5 %, foliar spraying with potassium humate (k-humate) or sorbitol at a concentration of 0.5 g/L to stimulate plant growth and reduce the damaging effects of drought stress.

Keywords: Tobacco; drought stress; potassium humate; sorbitol.

1. INTRODUCTION

Tobacco is considered one of the most important industrial crops in the world, and its importance in the Syrian Arab Republic is due to its role in the country's internal and external trade and to support the state budget. There are also thousands of farmers, workers, technicians and engineers who work in the field of tobacco production and manufacturing [1]. Tobacco belongs botanically to the Solanaceae family, and to *Nicotiana* genus, which includes about 70 different species of plants, of which only two species are of industrial importance: *Nicotiana tabacum* L. and *Nicotiana rustica* L. [2]. Tobacco is characterized by its great tendency to grow and adapt in a variety of environmental conditions, especially those related to soil conditions and nutritional factors. It also responds with high sensitivity to any, even if it was slight, change in these conditions, which made its cultivation spread in large areas of the world with variation in the productivity and quality of the dry crop of leaves [3].

Drought stress affects the growth of the tobacco plant at its various growth stages (seedling, vegetative growth, flowering, and maturity). The worst effect on yield and quality is in the vigorous growth stage. The importance of tobacco depends largely on the quantity of the crop and the quality of its leaves, both of which are affected by the photosynthesis process. Drought affects not only cell structure and leaf function, but also light energy capture, light absorption, electron transfer, and heat dissipation, and thus affects the photosynthesis. Increasing the efficiency of leaf photosynthesis under the influence of drought is important for tobacco production [4]. It was found that slight water stress from polyethylene glycol PEG this substance reduces the water stress of the environment without being absorbed by the plant, thus simulating the effect of drought on the plant for one day increases the plasticity of leaf cell walls by reducing their content of ferulic and diferulic acids, which increase the rigidity of cell walls, compared to non-stressed plants [5].

The importance of using alcoholic sugar in agricultural applications has also emerged recently, as growth stimulants that helping improve plant nutritional conditions, as these compounds act as diffusion and adsorption factors that contribute to increasing the absorption of nutrients during foliar spraying, in addition to their role in stimulating the absorption of nutrients and many others [6]. Sugar alcohols are produced endogenously in plants, and these products can participate in cellular metabolism as photoproducts and act as transporters to promote nutrient migration in plants [7,8]. Sorbitol sugar, as a carbohydrate compound ($C_6H_{14}O6$), was discovered in 1996 AD as a natural component and major and minor mineral elements within the phloem tissue of the plant. The movement of this element leads to increase in growth [9] and yield [10]. This component has a role in activating many enzymes and regulating osmotic pressure when it accumulates inside the plant, leading to improving the plant's absorption of water and nutrients from the soil for use in increasing the plant's vegetative growth, and thus increasing the rate of photosynthesis [11]. The results showed the importance of sorbitol in stimulating the absorption of nutrients by treating peanut plants with sorbitol at concentrations (1.6-2.4 g/L), as the yield of pods, the number of seeds, and the weight of 100 seeds, sugar content of the seeds increased [12].

Regarding humic acid, as a natural organic polymer compound, it is potential resource that can be used to improve plant growth, supply it with nutrients, and increase yield [13]. As a plant biostimulant, humic acid is produced mainly through the biodegradation of lignin, which contains plant organic materials [14].

Dorneanu et al. [15] reported that foliar spraying of humate enhances the penetration of nutrient ions into the leaves, stimulates the formation of some physiologically active metabolites, and activates the ability of the roots to absorb nutrients, especially N and K, which increases the number of chloroplasts per cell in addition to improving the efficiency of photosynthesis and increasing the content of sugar [16].

The process of adding potassium (K) to humic acid improved the speed and efficiency of its absorption in large quantities by most plants, and because it is a second source of potassium that is absorbed by the plant, which makes this nutrient more concentrated in plant tissues after nitrogen, whether by addition to the soil or foliar application methods [17]. Spraying plants with k-humate increased the permeability of plant membranes, stimulated cell division, and thus increased productivity [18]. In a study on the effect of nitrogen fertilization and the addition of potassium humate on growth standards, productivity, and nutrient absorption of the local tobacco variety (Shak Al-Bint), it was found that foliar spraying with potassium humate at a concentration of 2 g/L with nitrogen fertilization of 21 kg/1000 m^2 gave the highest yield of air-dried leaves, reaching 289.6 kg/1000 m^2 [19].

An increase in the accumulation of chlorophyll, sugar, and amino acids in plant tissues was observed as a result of spraying plants with k-humate, which was positively reflected in the absorption of nutrients and thus the plant's productivity in terms of quantity and quality, due to the effect of this compound resembling the plant hormone and as a result of increasing the efficiency of the photosynthesis process [20].

Due to the low productivity and shrinkage of the cultivated area of the Burley, Virginia and Katrina tobacco varieties in the country, given their relatively large water requirements, and their low qualitative and technological characteristics as they are filler varieties, and to the importance of increasing tobacco tolerance to drought stress, and the lack of previous studies on the effect of foliar spraying with sorbitol and potassium humate in the growth and development of the tobacco plant, the research aimed to study some morphological and production indicators of some tobacco varieties (Virginia VK51- Burley R21- Katrina) to determine the extent of their sensitivity to the effect of potential stress induced by polyethylene glycol (PEG-600), and spraying with sorbitol and potassium humate under conditions of the most harmful level of drought stress.

2. MATERIALS AND METHODS

The experiment was carried out at the Scientific Agricultural Research Station (Setkhiris- Lattakia) and in the scientific research laboratory of the Field Crops Department at the Faculty of Agricultural Engineering- Tishreen University, during the period extending from mid-May to the end of August of the year 2022. Seedlings, through seed obtained from the General Organization of Tobacco (G.O.T)- Lattakia, of three tobacco varieties (Virginia VK51- Burley R21- Katrina), which are American varieties, were used. These varieties are grown at low altitudes and characterized by high productivity and low nicotine content. The soil was prepared for cultivation by autumn cleaning and plowing with the addition of fermentable organic fertilizers at a rate of 20 t/h, and slow-release mineral fertilizers at a rate of 20 kg for each of urea fertilizer (46 %) and potassium sulphate (50 %), which represents the minimum recommended by G.O.T, because the soil is poor in these two elements, but phosphorus was not added that the soil is rich in it, as shown in Table (1), and then the operations of leveling and smoothing were carried out and the land was divided into experimental plots with a space of (4×3) m^2 for one plot, Leaving 1 m of passage between each plot.

An analysis of the soil to be cultivated was conducted to determine its texture and content of nutrients, after samples were taken from different places on the ground at a depth of 10-30 cm. They were air-dried and sifted to pass through a sieve with 2 mm holes and were subjected to laboratory analysis to determine some of their physical and chemical properties, which are shown in Table (1). The soil is non-salted limestone clay, poor in nitrogen, potassium, and organic matter (OM) with moderate phosphorus content, slightly alkaline, and has a good exchange capacity [21].

Table 1. Physical and chemical analysis of the soil site (Setkhiris- Lattakia)

Mechanical analysis (%)			Total content N (%)	Content (ppm)		Total content %		EC ds/cm	*p*H	Exchange capacity Millieq/100g soil
clay	Silt	sand		P	K	OM	$CaCO_3$			
38	18	44	0.19	18.9	63.8	0.88	49.7	0.124	7.6	46.11

The experiment was a factorial experiment in which a randomized complete block design (RCBD) was used, with three replications for each treatment, so the number of treatments reached (12). The experimental plot was divided into 4 lines, and transplanting was carried out at a rate of 7 plants per line, with a planting distance of: 100 cm between the lines and 40 cm between them. Plants on one line, achieving a planting density of 2.5 plants/m^2. These types of tobacco are grown at a plant density of 2.25-2.50 plants/m^2.

2.1 Studied Treatments

Drought stress treatments:

- Control (CON): Spray plants with fresh water only.
- PEG 5 %: 5% PEG (W/V) is equivalent to an osmotic pressure of -0.18 MPa.
- PEG 15 %: 15% PEG (W/V) equivalent to an osmotic pressure of -0.54 MPa.

Potassium humate treatment (H):

Spraying plants with a solution containing potassium humate at a concentration of 0.5 g/L.

Sorbitol treatment (S):

Spraying plants with a solution containing sorbitol at a concentration of 0.5 g/L.

Interactions:

- HPEG 5 %: 5 % PEG (W/V) equivalent to an osmotic pressure of -0.18 MPa. Spray the plants with a solution containing potassium humate at a concentration of 0.5 g/L.
- SPEG 5 %: 5 % PEG (W/V), equivalent to an osmotic pressure of 0.18 MPa, and spraying the plants with a solution containing sorbitol at a concentration of 0.5 g/L.
- HPEG 15 %: 15 % PEG (W/V) equivalent to an osmotic pressure of -0.54 MPa, and spraying the plants with a solution containing potassium humate at a concentration of 0.5 g/L.
- SPEG 15 %: 15% PEG (W/V) equivalent to an osmotic pressure of -0.54 MPa, and spraying the plants with a solution containing sorbitol at a concentration of 0.5 g/L.

2.2 Studied Qualities and Characteristics

Two weeks after the last humate and sorbitol spraying treatment (about two months after transplanting), five plants were randomly marked from the two middle lines of each experimental plot to measure some growth and qualities and characteristics:

Plant height (cm): This was done by measuring the plant height (cm) of the plants of each experimental treatment before the plants enter the inflorescence formation stage.

Plant leaf area PLA (cm^2/plant): The total leaf area of the plant was calculated with the formation of the flower inflorescence (i.e., about two months after transplanting) from the following equation:

PLA (cm^2/plant) = sum of the space of all leaves of a plant.

Leaf area (cm^2) was measured according to the equation: leaf length (cm) × leaf width (cm) × 0.6443 [22].

Leaf area index (LAI): The leaf area index was calculated after knowing the total leaf surface area and the area occupied by the plant on the soil according to the researcher's equation [23]:

LAI = leaf space of the plant (cm^2)/space of land occupied by the plant (cm^2).

Crop growth rate CGR (g/m^2/day): This indicator was determined according to the researcher [24].

CGR= (1/A) * (W2-W1/T2-T1)

Where:

A = the space of land occupied by the sample plants in m^2

W2 = dry weight of plant sample in period T2
W1 = dry weight of plant sample in period T1

The crop growth rate was measured 55 days after planting until physiological maturity, using eight readings.

Weight of dry leaves (g/plant): The yield of dry leaves was measured upon reaching maturity, that is, about three months after transplanting.

Statistical analysis: Statistical analyses were performed with the R statistical software using an ANOVA with Tukey's test. The results are displayed as means ± SE and are considered significant at *P<0.05*.

3. RESULTS AND DISCUSSION

3.1 The Effect of Treatment with Potassium Humate (k-humate) and Sorbitol under Drought Stress Conditions on Plant Height (cm)

The data in Table (2) showed that there were significant differences (*P<0.05*) between the studied treatments in terms of plant height (cm) for the three varieties. Drought stress induced by polyethylene glycol (PEG 15 %) caused a significant decrease in plant height, reaching values of 101, 100 and 114 cm for the three varieties Virginia VK51, Burley R21 and Katrina, respectively, while treatment with a diluted concentration of polyethylene glycol (PEG 5 %) led to a significant increase in plant height. The three varieties recorded values of 155, 145 and 158 cm, respectively, compared to the control for the studied varieties (110, 115 and 119 cm, respectively). Foliar spraying with potassium humate led to a significant increase (*P<0.05*) in plant height. The maximum plant height was recorded for the Virginia VK51 variety, which reached 131 cm, compared to the two varieties Burley R21 (100 cm) and Katerina (125 cm). Spraying with the sugar alcohol sorbitol also improved the plant height characteristics of the three varieties reached 142, 120 and 132 cm, respectively.

Our results are consistent with many researchers, as they confirmed the role of sorbitol in manufacturing hormones (auxin and cytokine), which lead to elongation and cell division and thus increase plant growth indicators, especially plant height [25].

As for the treatment of polyethylene glycol with 5 %, an increase in plant height was observed under spraying conditions with potassium humate and sorbitol compared to the control. The highest increase in this indicator was recorded about 9-30 % in Virginia VK51 variety, followed by 16-17 and 6-9 % at Burley R21 and Katrina, respectively, compared to the values of this trait when treated with PEG 5 %. When treated with PEG 15 % stress under spraying conditions with potassium humate and sorbitol, an increase in plant height values was also observed compared to the PEG 15 % treatment alone. The increase rate reached about 28-42 % for Virginia VK51 variety, and then 23-32 and 9-19 % for Burley R21 and Katrina, respectively.

This positive effect of potassium humate (k-humate) in increasing plant height in the tobacco varieties used is due to the prominent role played by the potassium element in all the physiological and metabolic processes taking place in the plant, such as photosynthesis, transpiration, and respiration, and Sorbitol, as it is a mobile nutrient that contributes to plant growth by transporting the products of the photosynthesis process between plant organs and their storage, in addition to its importance in the aquatic system and the exchange and storage of basic compounds for growth such as carbohydrates [26].

Reported data are obtained from five replicates, n= 5. Different letters indicate significant difference within each treatment according to an ANOVA-Tukey test at the 95 % confidence level.

3.2 The Effect of Treatment with Potassium Humate (k-humate) and Sorbitol under Conditions of Drought Stress on the Plant Leaf Area PLA (cm^2/plant)

Data of Table (3) indicated that there were significant differences (*P<0.05*) between the studied treatments in terms of plant leaf area (cm^2/plant) for the three varieties. Drought stress with polyethylene glycol (PEG 15 %) caused a significant decrease in plant leaf area, reaching values of 15798, 11266 and 12061 cm^2 for the three varieties Virginia VK51, Burley R21 and Katerina, respectively, while treatment with a concentration of polyethylene glycol (PEG 5 %) led to a significant increase in this indicator, the three varieties recorded values of 36534, 24427 and 28154 cm^2, respectively, compared to the control for the studied varieties (20830, 14251 and 18492 cm^2).

Table 2. Effect of treatment with potassium humate (k-humate) and sorbitol under drought stress conditions on plant height (cm)

Treatments	Varieties		
	Virginia VK51	Burley R21	Katrina
CON	110 ± 1.30^{g}	115 ± 2^{i}	119 ± 1.30^{f}
PEG 5 %	155 ± 2^{c}	145 ± 3^{d}	158 ± 1.50^{c}
PEG 15 %	101 ± 2.7^{h}	100 ± 4^{g}	114 ± 3^{g}
H	131 ± 2^{e}	120 ± 2^{h}	125 ± 1^{f}
S	142 ± 1.5^{d}	120 ± 3^{f}	132 ± 2^{e}
HPEG 5 %	169 ± 2.39^{b}	168 ± 4^{b}	168 ± 3^{b}
SPEG 5 %	202 ± 6.80^{a}	169 ± 2^{b}	173 ± 1.60^{b}
HPEG 15 %	129 ± 2.44^{e}	123 ± 3^{f}	124 ± 3^{f}
SPEG 15 %	143 ± 2.60^{d}	132 ± 4^{e}	136 ± 2^{e}

Table 3. Effect of treatment with sorbitol and potassium humate (k-humate) under drought stress conditions on plant leaf area PLA (cm^2/plant)

Treatments	Varieties		
	Virginia VK51	Burley R21	Katrina
CON	20830 ± 680^{ij}	14251 ± 990^{k}	18492 ± 1531^{j}
PEG 5 %	36534 ± 2964^{e}	24427 ± 1123^{hi}	28154 ± 2110^{h}
PEG 15 %	15798 ± 1655^{k}	11266 ± 1062^{l}	12061 ± 2968^{k}
H	27975 ± 3721^{e}	16301 ± 1090^{ef}	20532 ± 1633^{ef}
S	32357 ± 2721^{g}	18402 ± 1176^{d}	24256 ± 1798^{e}
HPEG 5 %	47198 ± 5220^{b}	35653 ± 2584^{f}	32968 ± 1934^{g}
SPEG 5 %	52672 ± 7088^{a}	45118 ± 3349^{c}	41472 ± 2346^{d}
HPEG 15 %	20726 ± 1590^{j}	15308 ± 2755^{k}	18911 ± 1568^{j}
SPEG 15 %	23786 ± 1727^{i}	22850 ± 1016^{i}	24867 ± 1917^{i}

Foliar spraying with potassium humate led to a significant increase (*P<0.05*) in the plant leaf area. The maximum leaf area was recorded in Virginia VK51, reaching 27975 cm^2, compared to the two varieties Burley R21 (16301 cm^2) and Katerina (20532 cm^2). The spraying treatment with the alcoholic sugar sorbitol also improved the plant leaf area of the three varieties; its values reached 32357, 18402 and 24256 cm^2, respectively.

Our results are consistent with the results of a study conducted by Darwish et al. [27] to study the effect of foliar spraying with different concentrations (0-0.5-1-1.5 g/L) of alcoholic sugar sorbitol on some morphological indicators of three tobacco varieties (Virginia VK51, Burley R21, Katerina), the spray concentration of 0.5 g/L gave the best values for plant height (cm) and leaf space (cm^2/plant) for the three studied varieties. This may be due to the role of sorbitol in activating all the physiological processes occurring in the plant, including photosynthesis process, and thus a greater synthesis of primary metabolites and components necessary to activate cell division and increase their elongation, thus increasing the plant leaf area. These are the results achieved by researchers on the effect of spraying sorbitol sugar on cabbage and strawberry plants [28,29]. The positive effect of spraying with this compound is to stimulate the permeability of nutrient ions within the leaves and thus increase the synthesis of some active physiological metabolites necessary for the growth and division of plant cells, as humic compounds contribute to improving the properties of the leaves as a result of their role in stimulating and accelerating plant growth cell division [30].

Reported data are obtained from five replicates, n= 5. Different letters indicate significant difference within each treatment according to an ANOVA-Tukey test at the 95 % confidence level.
As for the treatment of polyethylene glycol with 5 %, the highest increase in the plant leaf area indicator was observed under the conditions of spraying with potassium humate and sorbitol, compared to the control, that recorded about 29-44, 45-84 and 17-47 % in Virginia VK51, Burley R21 and Katrina, respectively, as compared to the values of this trait when treated with PEG 5 %. When plant treated with PEG 15 % under spraying conditions with potassium humate and sorbitol, an increase in leaf area values was also observed compared to the PEG 15 % treatment

alone, and the increase rate reached about 31-50, 35-100 and 56-106 % in Virginia VK51, Burley R21 and Katrina, respectively.

3.3 The Effect of Treatment with Potassium Humate (k-humate) and Sorbitol under Conditions of Drought Stress on the Leaf Area Index (LAI)

The data in Table (4) showed that there were significant differences (*P<0.05*) between the studied treatments in terms of the leaf area index (LAI) of the three varieties. Drought stress with polyethylene glycol (PEG 15 %) caused a significant decrease in the LAI character, reaching values of 3.94, 2.81 and 3.01 for the three varieties Virginia VK51, Burley R21 and Katrina, respectively, while treatment with a concentration of polyethylene glycol (PEG 5 %) led to a significant increase in the LAI, where the three varieties recorded values of 9.13, 6.10 and 7.03, respectively, compared to the control for the studied varieties (5.20, 3.56 and 4.62).

Foliar spraying with potassium humate led to a significant increase (*P<0.05*) in the LAI characteristic, and the maximum value was recorded for the Virginia VK51 (6.99), compared to the two varieties Burley R21 (4.07) and Katrina (5.13). Spraying with the Alcoholic sugar sorbitol also improved the LAI character, and its values reached 8.08, 4.60 and 6.06, respectively.

Reported data are obtained from five replicates, n= 5. Different letters indicate significant difference within each treatment according to an ANOVA-Tukey test at the 95 % confidence level.

The treatment of polyethylene glycol 5 % conducted to an increase in the LAI, that was observed under the conditions of spraying with potassium humate and sorbitol compared to the control. The highest increase was recorded, about 41-125 % in Virginia VK51, 44-88 % in Burley R21 and 33-66 % in Katrina, compared to the values of PEG 5 % treatment alone. When plant treated with PEG 15 % under spraying conditions with potassium humate and sorbitol, an increase in LAI values was also observed compared to the PEG 15 % treatment alone, and the increase rate reached about 133-66, 50-125 and 125-75 % in Virginia VK51, Burley R21 an Katrina, respectively.

These results are similar to studies on wheat [31]; foliar spraying with humic acid increased the leaf area index. These results are also consistent with many studies indicating that all morphological characteristics and crop components were significantly increased by applying humate (HS) spraying [32].

3.4 The Effect of Treatment with potassium Humate (k-humate) and Sorbitol under Drought Stress Conditions on Crop Growth Rate (CGR) (g/m^2/day)

The data in Table (5) showed that there were significant differences (*P<0.05*) between the studied treatments in terms of crop growth rate (CGR) for the three varieties. Drought stress with polyethylene glycol (PEG 15 %) caused a significant decrease in CGR, reaching values of 0.35, 0.25 and 0.26 g/m^2/day for the three varieties Virginia VK51, Burley R21 and Katrina, respectively. In contrast, treatment with a concentration of polyethylene glycol (PEG 5 %) led to a significant increase in CGR, where this indicator recorded values for the three varieties of 0.65, 0.45 and 0.70 g/m^2/day, respectively, as compared to the control for the studied varieties (0.50, 0.35 and 0.30 g/m^2/day)

Foliar spraying with potassium humate led to a significant increase (*P<0.05*) in CGR. The maximum value was recorded in Virginia VK51 reached 0.70 g/m^2/day, compared to the two varieties Burley R21 (0.41 g/m^2/day) and Katerina (0.56 g/m^2/day). The spraying treatment with the alcoholic sugar sorbitol also improved the CGR value of the three varieties reached 0.80, 0.42 and 0.61 g/m^2/day, respectively.

Reported data are obtained from five replicates, n= 5. Different letters indicate significant difference within each treatment according to an ANOVA-Tukey test at the 95 % confidence level.

As for the treatment of polyethylene glycol with 5 %, an increase in CGR was observed under the conditions of spraying with potassium humate and sorbitol compared to the control, where the highest increase was recorded; about 54-100, 22-33 and 21-57 % in Virginia VK51, Burley R21 and Katrina, respectively, as compared to the values of PEG 5 % treatment alone. When plant treated with PEG 15 % under spraying conditions with potassium humate and sorbitol, an increase in CGR values was also observed compared to the PEG 15 % treatment alone. The increase rate reached about 186-71 % in Virginia VK51, 40-60 and 131-246 % in Burley R21 and Katrina, respectively.

Table 4. The effect of treatment in potassium (K-Humate) and sorbitol under drought stress conditions on leaf area index (LAI)

Treatments	Varieties		
	Virginia VK51	**Burley R21**	**Katrina**
CON	5.20 ± 0.17^{f}	3.56 ± 0.24^{h}	4.62 ± 0.38^{f}
PEG 5 %	9.13 ± 0.74^{bc}	6.10 ± 0.28^{f}	7.03 ± 0.52^{d}
PEG 15 %	3.94 ± 0.41^{fg}	2.81 ± 0.26^{j}	3.01 ± 0.74^{i}
H	6.99 ± 0.93^{de}	4.07 ± 0.27^{f}	5.13 ± 0.40^{e}
S	8.08 ± 0.68^{d}	4.60 ± 0.29^{fg}	6.06 ± 0.44^{e}
HPEG 5 %	11.79 ± 1.30^{bc}	8.91 ± 0.64^{e}	8.24 ± 0.48^{c}
SPEG 5 %	13.16 ± 1.77^{a}	11.27 ± 0.83^{e}	10.36 ± 0.58^{b}
HPEG 15 %	5.18 ± 0.39^{ef}	3.82 ± 0.68^{g}	4.72 ± 0.39^{d}
SPEG 15 %	5.94 ± 0.43^{e}	5.71 ± 0.25^{fg}	6.21 ± 0.47^{c}

Table 5. Effect of treatment with potassium humate (k-humate) and sorbitol under drought stress conditions on crop growth rate CGR (g/m^{2}/day)

Treatments	Varieties		
	Virginia VK51	**Burley R21**	**Katrina**
CON	0.50 ± 0.04^{f}	0.35 ± 0.01^{h}	0.30 ± 0.08^{f}
PEG 5 %	0.65 ± 0.26^{bc}	0.45 ± 0.03^{f}	0.70 ± 0.10^{d}
PEG 15 %	0.35 ± 0.10^{fg}	0.25 ± 0.02^{j}	0.26 ± 0.06^{i}
H	0.70 ± 0.1^{de}	0.41 ± 0.04^{f}	0.56 ± 0.08^{e}
S	0.80 ± 0.07^{d}	0.42 ± 0.03^{fg}	0.61 ± 0.04^{e}
HPEG 5 %	1 ± 0.12^{bc}	0.55 ± 0.05^{e}	0.85 ± 0.11^{c}
SPEG 5 %	1.30 ± 0.42^{a}	0.60 ± 0.09^{e}	1.10 ± 0.22^{b}
HPEG 15 %	1 ± 0.14^{ef}	0.35 ± 0.03^{g}	0.60 ± 0.10^{d}
SPEG 15 %	0.60 ± 0.30^{e}	0.40 ± 0.04^{fg}	0.90 ± 0.20^{c}

Table 6. Effect of treatment with potassium humate (k-humate) and sorbitol under drought stress conditions on weight of dry leaves (g/plant)

Treatments	Varieties		
	Virginia VK51	**Burley R21**	**Katrina**
CON	242 ± 61^{d}	200 ± 18^{f}	180 ± 25^{f}
PEG 5 %	272 ± 62^{cd}	233 ± 20de	208 ± 19^{e}
PEG 15 %	223 ± 22de	137 ± 19^{g}	129 ± 41^{g}
H	330 ± 36^{c}	246 ± 21^{e}	230 ± 35^{e}
S	480 ± 55^{b}	300 ± 25^{d}	275 ± 52^{d}
HPEG 5 %	364 ± 23^{c}	282 ± 27^{d}	265 ± 50^{d}
SPEG 5 %	539 ± 79^{a}	347 ± 50^{c}	317 ± 23^{cd}
HPEG 15 %	265 ± 25^{d}	195 ± 28^{f}	215 ± 70^{d}
SPEG 15 %	298 ± 27^{cd}	237 ± 31^{d}	279 ± 41^{d}

Our results are consistent with the studies [33] that have shown that the humic acid can be used as a growth regulator to improve plant growth and enhance stress tolerance.

3.5 The Effect of Treatment with sorbitol and Potassium Humate (k-humate) under Conditions of Drought Stress on Weight of Dry Leaves (g/plant)

The data in Table (6) revealed significant differences (*P<0.05*) between the studied treatments in weight of dry leaves (g/plant) for the three varieties. Drought stress with polyethylene glycol (PEG15 %) caused a significant decrease in weight of dry leaves (g/plant), reaching values of 223, 137 and 129 g/plant for the three varieties Virginia VK51, Burley R21 and Katerina, respectively. In contrast, treatment with a reduced concentration of polyethylene glycol (PEG 5 %) resulted in significantly increases of this indicator, recording values of 372, 233 and 208 g/plant, respectively, compared to the control for the studied varieties (242, 200, and 180 g/plant).

Foliar spraying with potassium humate led to a significant increase (*P<0.05*) in weight of dry leaves (g/plant), and the maximum plant yield was recorded for the Virginia VK51, which reached 330 g/plant, compared to the two varieties Burley R21 (246 g/plant) and Katerina (230 g/plant). The spraying treatment with sorbitol also improved yield of dry leaves in the three varieties reached 480, 300 and 275 g/plant, respectively.

Reported data are obtained from five replicates, n= 5. Different letters indicate significant difference within each treatment according to an ANOVA-Tukey test at the 95 % confidence level.

As for the treatment of polyethylene glycol 5 %, an increase in weight of dry leaves (g/plant) was observed under the conditions of spraying with potassium humate and sorbitol compared to the control. The highest increase was recorded; about 34-98, 21-49 and 27-52 % in Virginia VK51, Burley R21 and Katrina, respectively, as compared to the values of PEG 5 % treatment alone. When plant treated with PEG 15 % under spraying conditions with potassium humate and sorbitol, an increase in weight of dry leaves values (g/plant) was also observed compared to the PEG 15 % treatment alone, where the increase rate reached; about 19-34, 42-73 and 67-116 % in Virginia VK51, Burley R21 and Katrina, respectively.

Our results are consistent with research conducted on the effect of treatment with humic acid in quantities (600-900-1200 kg/ha) on the productivity and quality of tobacco, where it was found that this component increased the plant's yield of leaves and their content of potassium, carbohydrates and sugars while maintaining an appropriate level of nicotine [34].

In a study by researchers Habib et al. [19] regarding the addition of potassium humate in the standards of growth, productivity, and nutrient absorption of the local tobacco variety (Shak Al-Bint), it was found that foliar spraying with potassium humate at a concentration of 2 g/L with nitrogen fertilization of 21 kg/1000 m^2 gave the highest yield of air-dried leaves, reaching 289.6 kg/1000 m^2.

4. CONCLUSIONS

Drought stress induced by polyethylene (PEG 15 %) led to a significant decrease in the plant height (cm/plant), the plant leaf area PLA (cm^2/plant), the leaf area index LAI, the crop growth rate CGR (g/m^2/day) and the weight of dry leaves (g/plant). While, the treatment with polyethylene (PEG 5 %), foliar spraying with potassium humate, or with sorbitol (0.5 g/L) conducted to a significant increase in most of the indicators and characteristics studied. A significant increase in the studied traits compared to the PEG 5 and 15 % treatments alone was recorded when plant foliar sprayed with potassium humate and sorbitol.

Taken together, it can suggested to use a treatment with PEG 5 %, foliar spraying with potassium humate (k-humate) or sorbitol at a concentration of 0.5 g/L, due to its physiological role in stimulating plant growth, reducing the effects of drought stress and increasing its tolerance, thus increasing the yield of tobacco dry leaves.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Authors (s) hereby declare that NO generative AL technologies, such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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