J. of Soil Sciences and Agricultural Engineering, Mansoura Univ., Vol 11 (12):893 - 900, 2020

Journal of Soil Sciences and Agricultural Engineering

Journal homepage: www.jssae.mans.edu.eg
Available online at: www.jssae.journals.ekb.eg

Influence of Potassium Humate and Micronutrients Foliar Nutrition on Sesame Productivity and Quality under Alluvial Soils of Nile Delta

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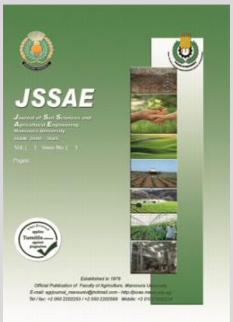

ABSTRACT

Two field experiments were conducted at a private farm on Gadila Village, Mansoura City , Dakahlia Governorate , Egypt under alluvial soils of Nile delta, during 2017 and 2018 summer growing seasons as sake of studying the effect of potassium humate (KH) sprayed singly or in dual,triple and quadruple combinations (9 mixtures) with some micronutrients(Fe , Mn and Zn)on leaves photosynthetic pigments ; yield and yield attributes as well as nutritive and biochemical contents of sesame seeds. KH and micronutrients were sprayed; once , at 21 days after sowing (DAS) ; twice, at 21 and 35 DAS and triple, at 21 , 35 and 50 DAS. So ,a split plot arrangement with three replications was used , where number of foliar spraying times for both KH and micronutrients were allocated in the main plots however , nine treatments of different combinations of KH and micronutrients were randomly distributed in the sub – plots . The highest values for all traits mentioned before were attained upon foliar spraying of sesame plants, triple compared to those sprayed twice and once, respectively. Spraying KH and micronutrients simultaneously in a quadruple combination i.e.(KH + Fe + Zn + Mn)also gave the best values followed by their additions in triple ,dual combinations however, spraying of KH alone achieved the least values . Therefore , spraying sesame plants with(KH + Fe +Zn +Mn)three times achieved the highest increments for all criteria under investigation related to the quantity and quality of sesame .

***Keywords* :** Potassium humate (KH) , Micronutrients , Sesame , Productivity , Quality.

INTRODUCTION

The sesame production area in Egypt has decreased from 41214 feddan , in 2011 to 24639 feddan , in 2013 while the productivity increased from 578 to 586 kg fed $^{-1}$ (Bulletin Agricultural Statistics , 2013 and 2014) . In a view of population growth , the requirement of edible oil is increasing with high in demand than the production. So , it's production should be increased considerably to fulfill the increasing demand. The production may be increased either by increasing cropping area under oil crops or increasing yield per unit area. Hence, it is a general consensus that increasing yield per unit area is most reasonable way to increase total production of sesame through using numerous improved technologies and practices . Among them, the proper balanced supply of both macro-and micronutrients as well as the natural and organic substances is considered the most important factors to get the highest yield of sesame and improve its quality characteristics (Bedigian and Harlan , 1986).

Sesame (*Sesamum indicum* L.) is one of the most ancient and important oilseed crops in tropical and subtropical regions around the world. Seeds are chemically composed of 44–57% oil, 18–25% protein, 13–14% carbohydrates (Borchani *et al.,* 2010). Sesame oil has excellent nutritional, medical, domestic and cooking qualities for which it is known as "the queen of oilseeds" . Due to the presence of potent antioxidants, sesame seeds are called as " the seeds of immorality " . It also has a very high level of unsaturated fatty acids, which is assumed to have reducing effect on plasma cholesterol and heart disease. In Egypt, sesame is considered a food crop rather than oilseed crop because most of its seeds production is used for snacks, dessert, bakery products, tehena and halawa purposes. Sesame oil is also used for illumination as well as manufacture of margarine, soap, paint, drugs, and perfumery products and as dispersing agent for different kinds of insecticides.

Humic substances (HS) are recognized as "auxin-like effects" which are a result of the induction of ATPase activity in the plasma membrane (Zandonadi *et al* . , 2007) . The underlying mechanisms are generating a wider electrochemical gradient by ATPase induction and accelerating the nutrients uptake rate, which can also be confirmed by the overexpression of the transporter genes (Nunes *et al* ., 2019) . HS also interferes with secondary metabolism by altering gene expression and changing the content of chemical compounds in plant cells, such as related to the Krebs cycle, metabolism of nitrate and phosphorus, glycolysis, and photosynthesis (Roomi *et al.*, 2018). In this respect, Neri *et. al.*, (2002) reported that foliar spraying of humic acid enhanced growth, nutrients uptake and yield as well as improved the quality of the production of some crops. Eisa (2011) also reported that the highest yields of peanut and sesame seeds achieved upon treating by soil gypsum application and foliar spray by humic acid. These increases in yields were attributed to the enhancing of easily nutrients release into soil solution and to encourage their penetration through plant roots and leaves. The above-mentioned treatment also increased chlorophyll concentration which leading to higher degree of photosynthesis. This makes crops much green and leads to more accumulation of the dry matter and subsequently increasing both seed nutrients contents and

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DOI: 10.21608/jssae.2020.170646

biochemical constituents (protein and oil) and crop yield. Similar conclusion was also suggested by Nasef, (2004), Borhamy, (2005) and Nasef , (2010) . Moreover, Singaravel *et. al.,* (2002) stated that humic acid contains auxins which influence cell division and stem that gave the cell wall the ability to expand . So, humic acid can cantribute in increasing sesame seed yield and improving its protein and oil contents.

Micronutrients are essential for plant growth and play important roles in crop production. The beneficial influence of micronutrients might by due to the activation of various enzymes, and efficient utilization of applied nutrients resulting in increasing yield components. Micronutrients also play important roles in cell division and development of meristematic tissues; stimulate photosynthesis, respiration, energy and nucleotide transfer reactions and fasten the plant maturity (Marschner, 1998 and Shanker *et al.,* 1999) however, their deficiencies can cause a great disturbance in the physiological and metabolic processes in the plant (Bacha *et al.,*1995). In recent years, soil micronutrients have been reduced due to intensive agriculture without balanced fertilization . Thus, foliar nutrition is an option when nutrients deficiencies cannot be corrected by their application to the soil (Babaeian *et al.* , 2011). The role of different micronutrients has been well established in plant metabolism. Zn is involved in the biosynthesis of auxins, indole-3-acetic acid and participate in the metabolism of plant as an activator of several enzymes. Reduced growth hormone production in Zn-deficient plants causes shortening of internodes and leaves resulting on malformation of fruit with little or no yield. Mn is essential to photosynthesis reactions, enzyme activation and root growth. Fe performs important functions in the metabolic processes like DNA synthesis, respiration and photosynthesis, necessary for the servicing of chloroplast structure and function and is considered cofactor constitutive for several enzymes (Samaranayke *et al.*, 2012).Therefore, the present study was undertaken as sake of raising the productivity of sesame seed yield and improving its quality through foliar spraying of potassium humate and micronutrients. Number of their foliar spraying times was also taken into consideration.

MATERIALS AND METHODS

Two field experiments were conducted at a private farm on Gadila Village (5 Km north –east to Mansoura) , Mansoura City , Dakahlia Governorate , Egypt (31^0 03 ` 40 ` N latitude and 31^0 24` 53` E) during the summer growing seasons of 2017 and 2018 . The main target of the present investigation is studying the impact of potassium humate (KH) adding as foliar spraying alone or in dual , triple and quadrant combinations includes 9 mixtures with some micronutrients (Fe , Mn and Zn) at different physiological stages of sesame on seed , stover , biological yields and harvest index as well as some seed quality characteristics . So, each experiment included twenty seven treatments in a split - plot design where the main plots were assigned to the number of foliar spraying times of KH and micronutrients combinations as the following :

I - Once , at 21 days after sowing (DAS) during Vegetative stage .

II - Twice , at 21 and 35 DAS during Vegetative and beginning of flowering stages .

III - Triple , at 21 , 35 and 50 DAS during Vegetative , beginning of flowering and early of capsules formation stages .

Each main plot was randomly divided into nine sub - plots represent the foliar spraying treatments of KH adding singly or in dual , triple or quadrant combinations with (Fe , Mn and Zn) micronutrients as follows :

1- Untreated (without foliar spray) .
2- Potassium humate (KH).
3- KH + Fe
4- KH + Mn
5- KH + Zn
6- KH + Fe +Mn
7- KH + Fe + Zn
8- KH + Mn + Zn
9- KH + Fe +Mn +Zn

KH (10 % K_2O) was foliar sprayed at 20 ml L^{-1} . However , micronutrients were sprayed at a rate of 0.3 g L^{-1} for each , in chelating forms (EDTA). The foliar solution volume was 300 L fed^{-1} and spraying was done by hand sprayer (for all experimental plots) until saturation point.

KH (10 % K_2O) was obtained from Plant Nutrition and Soil Fertility Res. Department ; Soil , Water and Environment Res. Institute ; ARC ; Giza ; Egypt . Whilst , Certified Sesame (*Sesamum indictum* L.) seeds variety Sohag 1 were attained from the Oil Crops Res . Department; Field Crops Res . Institute ; ARC; Giza ; Egypt .

For the two seasons, soils were clay loam , their mechanical and chemical analyses as well as nutritive contents are presented in Table (1 a , b and c). Soils mechanical and chemical characteristics were determined according to USDA (2014) and Jackson (1973) . However, soil nutritive contents were determined according to Chapman and Pratt (1978).

Table 1. Some mechanical and chemical analyses as well as contents of available nutrients of the soils under investigation .

a) Mechanical analysis :

Season	Particle size distribution (%)				Texture class
	Coarse sand	fine sand	Silt	Clay	
1 st	2.10	31.62	36.43	29.85	Clay loam
2 nd	2.08	31.78	36.39	29.75	Clay loam

b) Chemical analysis :

Season	$CaCO_3$ (%)	EC (dSm^{-1}) (1:5)	PH (1:2.5) soil suspension	O.M (%)	Soluble ions meq.L^{-1} (1:5 soil : water extract)							
					Cations				Anions			
					Na^+	K^+	Ca^{++}	Mg^{++}	CO_3^{--}	HCO_3^-	Cl^-	SO_4^{--}
1 st	2.87	0.88	8.04	1.68	2.55	0.27	3.43	2.50	0.00	1.05	2.74	4.96
2 nd	2.89	0.89	7.83	1.78	2.57	0.37	3.40	2.51	0.00	1.04	2.83	4.98

c) Nutritive contents :

Season	Soil Nutritive contents (mg kg^{-1})					
	Macro			Micro		
	N	P	K	Fe	Mn	Zn
1 st	53.8	4.72	180.2	3.24	1.40	0.64
2 nd	50.5	4.60	187.8	3.10	1.56	0.64

The experimental fields were well prepared by the two plowing leveling , compaction , division and then divided to the experimental units. Each plot included five ridges, each of 60 cm apart and 3.5m long. So, the plot area was 10.5 m^2 (1/400 fed). Sesame seeds variety Sohag 1 were sown at hills 20 cm apart on 25th and 28 th of the April for the first and Second seasons, respectively. The plots were irrigated immediately after sowing . Plants were thinned to one plant $hill^{-1}$ at 15 days after sowing and before the first irrigation . Monocalcium phosphate (15.5 % P_2O_5) was applied during soil preparation at a level of 150 kg fed^{-1}. However, N-fertilization was applied at a level of 30kg N fed^{-1} as ammonium nitrate (33.5 % N) in three equal doses, the first, after thinning and before the 1st irrigation ; the second, before the 2 nd irrigation and the third portion was applied before the 3 rd irrigation . All other recommended agricultural practices for sesame crop were followed according to the Oil Crops Res. Department, Field Crops Res. Institute; A. R. C.; Giza, Egypt.

For the two growing seasons , at 70 days after sowing , five plants were taken randomly from each plot to determine the concentrations of chlorophyll a , b and carotene (mg g^{-1} fresh weight) in the fourth leaf according to the method described by Gavrilenko and Zigalova (2003).

At harvest (120 days after sowing) , a random sample of five guarded plants was taken from each sub - plot to determine plant height , number of branches and capsules $plant^{-1}$, seed weight (g) $plant^{-1}$, seed index (1000- seed weight) , Seed and Stover yields (Kg fed^{-1}) and harvest index,which was calculated as the following :

$$\text{Harvest index (\%)} = \frac{\text{Seed yield}}{\text{Biological } yield \text{ (Seed yield + Stover yield)}} \times 100$$

Concentrations of NPK (%) and micronutrients (mg Kg^{-1}) in sesame seeds were determined in wet digested extract using the methods described by Chapman and Pratt (1978). Then , seed macro- and micronutrients contents (uptake) were also estimated as Kg and g fed^{-1}, respectively. In addition, both seed protein and oil percentages were determined according to A.O.A.C. (2000). Then , values were converted to protein and oil yields (Kg fed^{-1}).

All obtained data were statistically analyzed according to the technique of analysis of variance (ANOVA) for the Split- plot design according to Gomez and Gomez (1984). Least Significant Difference (L.S.D.) method was used to test the differences between treatments means at 5% level of probability.

RESULTS AND DISCUSSION

Results attained herein for the two summer seasons of 2017 and 2018 were statistically analyzed as the mean values of the two growing seasons and presented in Tables 2 , 3 and 4 . The main target of the current investigation was maximizing the productivity of sesame seed yield and improving its quality through foliar nutrition of potassium humate (KH) in different mixtures with some micronutrients (Fe , Mn and Zn) , once , twice or triple as well as impact of their possible combinations on the leaves photosynthetic pigments , yield and yield components as well as seed nutritive and biochemical contents .

I-Effect of treatments on leaves photosynthetic pigments:

Data in Table (2) revealed that foliar application of potassium humate (KH) singly or in combination with micronutrients significantly increased the concentrations of photosynthetic pigments in sesame leaves at 70 days age . In this concern , foliar spraying with KH and micronutrients , three times , at vegetative , beginning of flowering and early of capsules formation stages recorded the highest increments of chlorophyll a , b , a+b and carotene followed by the treatments sprayed twice and once , in a descending order.

Table 2. Impact of number of foliar spray times for mixtures of potassium hamate and micronutrients as well as their interactions on leaves photosynthetic pigments at 70 days after sowing*.

Treatments		Ch. a (mg g^{-1} FW)	Ch. b (mg g^{-1} FW)	Ch. a+b (mg g^{-1} FW)	Carotene (mg g^{-1} FW)
(A) Number of foliar spraying times :					
Once		0.755	0.517	1.273	0.277
Twice		0.763	0.525	1.289	0.286
Triple		0.770	0.530	1.300	0.294
LSD 0.05		0.002	0.003	0.002	0.006
(B) Treatments of foliar spraying:					
Untreated **		0.683	0.456	1.139	0.194
KH ***		0.706	0.473	1.179	0.217
KH + Fe		0.762	0.525	1.287	0.285
KH + Mn		0.745	0.507	1.252	0.263
KH + Zn		0.726	0.490	1.217	0.240
KH + Fe + Mn		0.819	0.575	1.395	0.353
KH + Fe + Zn		0.801	0.558	1.359	0.332
KH + Mn + Zn		0.781	0.541	1.323	0.308
KH + Fe + Mn + Zn		0.840	0.593	1.433	0.376
LSD 0.05		0.004	0.003	0.005	0.004
(C) Interaction:					
Once	Untreated	0.673	0.449	1.122	0.183
	KH	0.700	0.466	1.166	0.209
	KH + Fe	0.757	0.518	1.275	0.277
	KH + Mn	0.738	0.501	1.239	0.255
	KH + Zn	0.719	0.483	1.202	0.231
	KH + Fe + Mn	0.811	0.568	1.379	0.346
	KH + Fe + Zn	0.794	0.551	1.345	0.324
	KH + Mn + Zn	0.773	0.535	1.308	0.299
	KH + Fe + Mn + Zn	0.832	0.586	1.418	0.367
Twice	Untreated	0.684	0.457	1.141	0.196
	KH	0.707	0.474	1.181	0.218
	KH + Fe	0.763	0.526	1.289	0.286
	KH + Mn	0.746	0.508	1.254	0.263
	KH + Zn	0.727	0.492	1.219	0.241
	KH + Fe + Mn	0.820	0.576	1.396	0.353
	KH + Fe + Zn	0.802	0.558	1.360	0.333
	KH + Mn + Zn	0.782	0.542	1.324	0.309
	KH + Fe + Mn + Zn	0.840	0.594	1.434	0.376
Triple	Untreated	0.693	0.461	1.154	0.204
	KH	0.712	0.479	1.191	0.225
	KH + Fe	0.767	0.530	1.297	0.293
	KH + Mn	0.750	0.512	1.262	0.270
	KH + Zn	0.733	0.496	1.229	0.249
	KH + Fe + Mn	0.827	0.582	1.409	0.361
	KH + Fe + Zn	0.808	0.565	1.373	0.340
	KH + Mn + Zn	0.789	0.547	1.336	0.316
	KH + Fe + Mn + Zn	0.848	0.599	1.447	0.384
	LSD 0.05	0.006	0.006	0.009	0.006

*** Mean values of the two investigated seasons **Untreated = without foliar spray ***KH = potassium Humate**

Plants sprayed with (KH + Fe + Mn + Zn) gave the maximum increments followed by those sprayed with (KH + Fe + Mn) , (KH + Fe + Zn) , (KH + Mn + Zn) , (KH + Fe) , (KH + Mn) and (KH+ Zn), respectively . Then, plants sprayed with KH singly achieved the least increments compared to the untreated ones. Data in Table (2) also showed the interaction effect between the number of foliar spray times of KH and micronutrients and their mixtures on leaves chlorophyll fractions . The highest concentrations of photosynthetic pigments were obtained upon spraying the plants , three times , with (KH + Fe + Mn + Zn) whilst the lowest values were recorded with the control treatment .

The beneficial impact of KH on the leaves photosynthetic pigments could be explained on the basis of that humic substances can directly or indirectly affect the physiological process of plant growth by promoting the uptake of macro- and micronutrients , affecting the biochemical substances , carrying nutrients and growth regulators and acting as hormones like substances (Verlindern *et al.,* 2009). Yet , Ismail *et al.,* (2017) and Dawood *et al.*,(2019) attributed the enhancement effect of KH to the beneficial function of potassium on osmoregulation photosynthesis , transpiration, and translating of assimilates into sink organs . As a result, growth characteristics improve (Vani *et al.,* 2017) .

The positive effects of micronutrients on photosynthetic pigments in sesame leaves could be explained on the basis of the essential roles of Fe in the synthesis , metabolism and activation of chlorophylls , plant growth regulators and many other hime proteins such as different cytochromes , which participate in different functions in the plant metabolism (Al-Bamarny *et al.,* 2010) . Fe also improves photosynthesis and assimilates transportation to sinks and finally increased seed yield (Alvarez-Fernandez *et al.,* 2006) and it also has an important role in carbohydrate production , cell respiration and chemical reduction of nitrate (Mousa *et al.*,2010). Mengel and Kirby (2006) also stated that spraying the plants with micronutrients especially Mn (contribute in plant component systems) is involved in the reaction of electron transfer and production of chlorophyll and it is also necessary in photosystem II .

II-Effect of treatments on sesame yield productivity and yield components :

Data presented in Table (3) clearly show that seed and stover yields of sesame as well as the investigated seed yield components namely; number of branches and capsules plant $^{-1}$, capsules and seeds weight plant^{-1} and seed index (1000 - seed weight) were all significantly increased as raising the number of foliar spray applications for both KH and micronutrients , up to three times

Table 3. Impact of number of foliar spray times for mixtures of potassium hamate and micronutrients as well as their interactions on sesame seed , stover yields and harvest index as well as seed yield components*.

	Treatments	Plant height (cm)	Branches number plant^{-1}	Capsules number plant^{-1}	Capsules weight (g plant^{-1})	Seeds weight (g plant^{-1})	Seed index (g)	Yield (kg fed^{-1}) Seed	Yield (kg fed^{-1}) Stover	Harvest index (%)
(A) Number of foliar spraying times :										
	Once	155.1	4.54	117.9	35.98	18.56	2.757	665	2248	22.79
	Twice	160.9	4.86	123.1	36.60	18.83	2.865	678	2267	22.96
	Triple	164.4	5.15	127.2	37.03	19.06	2.966	686	2280	23.08
	LSD 0.05	0.40	0.09	0.24	0.18	0.11	0.022	4.62	2.70	0.14
(B) Treatments of foliar spraying:										
	Untreated**	150.7	4.00	111.0	31.41	15.90	2.455	572	2090	21.50
	KH***	156.6	4.33	114.9	32.73	16.63	2.518	599	2132	21.92
	KH + Fe	161.0	4.94	122.3	36.75	18.88	2.852	680	2270	23.04
	KH + Mn	159.1	4.67	119.4	34.12	17.40	2.662	626	2178	22.33
	KH + Zn	157.7	4.53	117.4	35.37	18.11	2.713	652	2232	22.61
	KH + Fe + Mn	164.8	5.40	130.7	38.95	20.26	3.070	726	2350	23.59
	KH + Fe + Zn	162.8	5.21	128.7	40.28	20.93	3.204	753	2395	23.93
	KH + Mn + Zn	161.7	5.07	126.4	37.77	19.60	2.936	701	2302	23.35
	KH + Fe + Mn + Zn	166.8	5.51	133.8	41.46	21.61	3.354	778	2434	24.22
	LSD 0.05	1.19	0.11	0.39	0.08	0.25	0.032	5.41	8.06	0.15
(C) Interaction:										
Once	Untreated	149.2	3.83	109.2	31.03	15.69	2.379	565	2074	21.41
	KH	151.1	3.98	111.3	32.19	16.34	2.431	588	2114	21.76
	KH + Fe	155.9	4.63	117.1	36.28	18.62	2.763	670	2254	22.91
	KH + Mn	153.2	4.32	115.0	33.63	17.12	2.573	616	2163	22.17
	KH + Zn	152.4	4.17	113.5	34.85	17.82	2.617	642	2237	22.30
	KH + Fe + Mn	159.2	5.10	124.6	38.14	20.02	2.967	710	2334	23.32
	KH + Fe + Zn	157.2	4.89	122.3	39.87	20.69	3.049	745	2376	23.87
	KH + Mn + Zn	156.3	4.75	120.6	36.82	19.34	2.842	683	2263	23.19
	KH + Fe + Mn + Zn	161.6	5.23	127.9	40.99	21.35	3.189	769	2413	24.17
Twice	Untreated	151.0	4.00	111.0	31.38	15.89	2.436	572	2092	21.47
	KH	157.6	4.36	115.3	32.74	16.64	2.522	599	2136	21.90
	KH + Fe	161.8	4.93	122.8	36.76	18.89	2.854	680	2273	23.02
	KH + Mn	160.7	4.70	119.8	34.19	17.44	2.663	628	2177	22.39
	KH + Zn	158.1	4.57	117.2	35.39	18.12	2.707	652	2224	22.67
	KH + Fe + Mn	165.7	5.40	131.2	39.13	20.26	3.057	729	2353	23.65
	KH + Fe + Zn	163.4	5.22	129.2	40.28	20.93	3.238	753	2394	23.93
	KH + Mn + Zn	162.2	5.09	127.0	38.06	19.63	2.936	707	2318	23.37
	KH + Fe + Mn + Zn	167.4	5.51	134.4	41.50	21.64	3.374	779	2434	24.24
Triple	Untreated	151.8	4.18	112.9	31.81	16.12	2.549	580	2104	21.61
	KH	161.1	4.65	118.1	33.27	16.92	2.602	609	2147	22.09
	KH + Fe	165.3	5.25	127.1	37.22	19.14	2.939	689	2284	23.18
	KH + Mn	163.4	5.00	123.4	34.53	17.63	2.749	635	2195	22.44
	KH + Zn	162.7	4.86	121.6	35.87	18.38	2.815	662	2235	22.85
	KH + Fe + Mn	169.5	5.69	136.4	39.59	20.51	3.185	738	2363	23.80
	KH + Fe + Zn	167.7	5.53	134.6	40.69	21.16	3.324	762	2414	23.99
	KH + Mn + Zn	166.7	5.38	131.7	38.42	19.83	3.031	714	2325	23.49
	KH + Fe + Mn + Zn	171.3	5.80	139.1	41.88	21.84	3.498	786	2454	24.26
	LSD 0.05	2.23	0.20	0.74	0.14	0.07	0.061	9.38	13.96	0.26

*** Mean values of the two investigated seasons **Untreated = without foliar spray ***KH = potassium Humate**

Combined foliar application of KH and micronutrients , triple produced the highest seed yield by 35.5%, Stover yield by 16.6% and harvest index by 12.3% over the untreated treatment .

Data presented in Table (3) also indicated that spraying sesame plants with KH together with micronutrients achieved values better than those attained upon the application of KH singly, concerning seed and stover yields as well as seed yield attributes. Application mixture of KH and micronutrients simultaneously in a quadruple treatment i.e.(KH + Fe + Zn + Mn) attained the highest values for all traits(plant height, yields and yield components), mentioned previously followed by their applications in triple and binary mixtures then, the control treatment recorded the lowest values . Data concerned the interaction effect of KH and micronutrients foliar sprayed once , twice and triple on seed and stover yields as well as seed yield components are also presented in Table (3) . The superiority impact was observed upon foliar spray of KH together with micronutrients three times. Similar conclusion was also suggested by Nasef , (2004) , Borhamy , (2005) , Nasef , (2010) and Eisa (2011) whose attributed the beneficial effect of the previous interaction to the enhancing sufficient quantities of micronutrients and to encouraging of their penetration through plant leaves as well as increasing chlorophyll concentration which leading to higher degree of photosynthesis . This makes crops much green and leads to more accumulation of the dry mater and subsequently increases the crop yield . Porass *et al.,* (2010) also found that the applicalion of half of the recommended dose of nitrogen combıned with humic acid led to the highest increases in number of branches and capsules plant^{-1}, 1000 - seed weight, seed yield and oil content of Giza 32 and Shadwell 1 sesame genotypes.

Foliar application of micronutrients had significant positive effects on yield components viz. plant height , number of branches and capsules plant^{-1}, number of seeds and capsules plant^{-1},1000 - seed weight as well as seed , stover and biological yields ; harvest index and oil content (Shanker *et al.,* 1999 and Babaeian *et al.,* 2011) . They attributed the beneficial influence of micronutrients on yield and its attributes to their positive effects on the activation of various enzymes, transłocation efficient utilization of applied nutrients , activation of photosynthetic enzymes and encouragement of chlorophyll formation . Thus , plant growth , seed yield and yield components will be increased . Moreover, Singaravel *et al.,*(2002) reported that the combined application of Zn and Mn in soil produced the highest number of capsules plant^{-1} by 59 % and number of seeds capsule^{-1} by 57 % over the control . Application of Zn alone as soil or foliar increased the yield from 592 to 611 Kg ha^{-1}. Zn and Mn increased growth , yield components and their availability and uptake . Kobraee *et al.,* (2011) also noted that Zn foliar application particularly at vegetative growth stage increased soybean seed yield and its attributes. Yet, Maghsud *et al.,* (2014) found that foliar application of Fe , Zn and Mn simultaneously had statistically significant impact on the yield and yield components of safflower , at 1% level and had no significant effect on the thousand grain weight.

III – Effect of treatments on nutritive contents and biochemical constituents of sesame seeds :

Data in Table (4) revealed the nutrients contents (macro - and micronutrients) and biochemical constituents (protein and oil yields fed^{-1}) of sesame seeds as influenced by foliar application of KH separately or in dual , triple and quadruple combinations with micronutrients under different times of their foliar spraying . Data obtained showed clearly that foliar spray of KH in combined with micronutrients had significant positive impacts on the contents of seed macro- and micronutrients as well as biochemical constituents better than those observed upon spraying of KH alone. In this respect, foliar spray of KH together with all investigated micronutrients i.e. (KH + Fe + Zn + Mn) attained the superiority effects for all above - mentioned parameters followed by their additions in triple and binary combinations , respectively however , the addition of KH alone achieved the lowest increments. Among the triple combinations, (KH + Fe + Zn) recorded the highest values whereas, (KH + Fe) gave the best values among the binary ones . In this connection , spraying the sesame plants with KH and all tested micronutrients three times attained the maximum values of nutrients and biochemical contents compared to their foliar additions twice and once, respectively. Interaction of combined foliar applications of KH and micronutrients three times produced the highest seed N-content by 72.7 % , P-content by 52% , K-content by 102.1% , protein yield by 72.5% , oil yield by 63.1% over the untreated treatment . The results attained herein were parallel with those obtained by Singaravel *et al.,* (2002) who stated that humic acid contains auxins which influence cell division and stem that gave the cell walls the ability to expand . So, humic acid can contribute in increasing sesame seed yield and improving both its protein and oil contents. Significant increases in the contents of both seed nutrients and biochemical constituents (protein and oil) were observed upon gypsum application and foliar spray by humic and amino acids (Eisa , 2011).

Concerning the enhancing effect of micronutrients foliar spray on the nutritive contents and biochemical constituents , Chapłot *et al.,* (1992) revealed that the combined application of 25 and 5 kg ha^{-1} for $ZnSO_4$ and $MnSO_4$, respectively was significantly superior to NPK treatment in enhancing the growth , yield and nutrients uptake of sesame . Also, Singaravel *et al.,*(2002) noted that foliar application of Zn and Mn raised the absorption of NPK , harvest index ,yield components and seed yield of sesame. In addition , Potarzycki and Grzebisz (2009) reported that Zn exerts a great influence on basic plant life processes , such as (I) Nitrogen uptake and metabolism as well as protein quality (II) photosynthesis and chlorophyll synthesis as well as carbon anhydrase activity. Narimani *et al.,* (2010) also indicated that foliar application of Fe , Zn , Mn and Mg significantly increased growth parameters , yield of durum wheat and improved the effectivness of macronutrients . Moreover , Dehnovi *et al.,* (2008) also found that foliar application of Zn and Mn significantly increased palmitic and oleic acids percentages in safflower seeds ,whereas linoleic percentage was decreased .

Table 4. Impact of number of foliar spray times for mixtures of potassium hamate and micronutrients as well as their interactions on nutritive contents and biochemical constituents of sesame seeds* .

Treatments		Seed nutritive contents						Seed biochemical constituents (kg fed^{-1})	
		Macro (kg fed^{-1})			Micro (g fed^{-1})				
		N	P	K	Fe	Zn	Mn	Protein	Oil
(A) Number of foliar spraying times :									
Once		18.96	3.42	18.68	53.74	29.53	12.18	118.5	317.9
Twice		21.26	3.80	22.39	61.25	35.68	14.74	132.9	329.6
Triple		22.99	4.10	25.16	71.35	41.26	17.51	143.7	337.9
LSD 0.05		0.27	0.05	0.78	0.78	0.47	0.28	1.67	2.7
(B) Treatments of foliar spraying:									
Untreated**		15.54	2.97	14.47	51.28	28.81	11.40	97.12	249.7
KH ***		17.34	3.16	15.99	54.65	31.13	13.04	108.4	266.6
KH + Fe		21.14	3.77	21.85	63.90	34.85	14.16	132.1	329.9
KH + Mn		18.62	3.37	17.86	56.99	32.52	14.94	116.4	288.1
KH + Zn		19.88	3.57	19.70	58.84	35.51	13.89	124.3	308.6
KH + Fe + Mn		23.51	4.16	26.04	66.91	36.99	16.20	146.9	367.9
KH + Fe + Zn		24.93	4.39	28.30	69.90	39.95	15.38	155.8	388.3
KH + Mn + Zn		22.20	3.96	24.02	63.86	37.59	16.06	138.8	348.9
KH + Fe + Mn + Zn		26.47	4.59	30.43	72.69	42.06	18.23	165.5	408.1
LSD 0.05		0.39	0.05	0.68	0.77	0.49	0.35	2.42	4.94
(C)Interaction:									
Once	Untreated	14.40	2.68	11.50	44.53	23.75	9.27	90.03	242.9
	KH	15.44	2.84	13.28	47.10	25.94	10.65	96.50	256.3
	KH + Fe	18.90	3.42	18.23	55.07	29.07	11.56	118.1	318.7
	KH + Mn	16.80	3.04	15.27	49.43	26.99	12.29	105.0	279.1
	KH + Zn	17.83	3.24	16.11	51.16	29.83	11.46	111.4	298.9
	KH + Fe + Mn	20.94	3.77	22.12	57.67	30.31	13.28	130.9	355.1
	KH + Fe + Zn	22.52	4.00	24.72	60.74	33.45	12.68	140.8	378.1
	KH + Mn + Zn	19.72	3.54	19.85	54.53	30.94	13.08	123.3	333.8
	KH + Fe + Mn + Zn	24.10	4.22	27.01	63.41	35.52	15.33	150.7	398.5
Twice	Untreated	15.61	2.99	15.08	50.33	28.89	11.38	97.53	250.5
	KH	17.54	3.17	16.20	53.72	30.90	12.98	109.6	266.9
	KH + Fe	21.31	3.80	22.21	63.42	35.17	14.08	133.2	331.1
	KH + Mn	18.89	3.40	17.99	56.01	32.78	14.78	118.1	288.8
	KH + Zn	20.08	3.59	20.42	57.92	35.65	13.80	125.5	309.5
	KH + Fe + Mn	23.76	4.20	26.17	66.04	37.40	16.18	148.5	370.2
	KH + Fe + Zn	25.05	4.42	28.45	68.74	40.10	15.22	156.6	388.3
	KH + Mn + Zn	22.43	4.02	24.71	63.52	38.08	16.09	140.2	352.3
	KH + Fe + Mn + Zn	26.65	4.62	30.25	71.52	42.19	18.19	166.6	408.5
Triple	Untreated	16.60	3.25	16.84	58.99	33.79	13.54	103.8	255.8
	KH	19.05	3.46	18.49	63.14	36.55	15.49	119.0	276.7
	KH + Fe	23.20	4.10	25.10	73.20	40.31	16.83	145.0	340.0
	KH + Mn	20.16	3.68	20.32	65.53	37.80	17.76	126.0	296.3
	KH + Zn	21.74	3.87	22.58	67.44	41.05	16.42	135.9	317.3
	KH + Fe + Mn	25.82	4.51	29.82	77.01	43.27	19.13	161.4	378.3
	KH + Fe + Zn	27.21	4.75	31.74	80.21	46.31	18.23	170.0	398.6
	KH + Mn + Zn	24.46	4.32	27.49	73.53	43.76	19.01	152.9	360.7
	KH + Fe + Mn + Zn	28.66	4.94	34.04	83.14	48.47	21.18	179.1	417.2
	LSD 0.05	0.67	0.08	1.17	1.36	1.36	0.60	4.20	8.56

*** Mean values of the two investigated seasons **Untreated = without foliar spray ***KH = potassium Humate**

CONCLUSION

Finally, it can be concluded that foliar nutrition of both potassium humate (KH) and micronutrients , under investigation , simultaneously in a quadruple combination namely (KH + Fe + Zn + Mn) triple , at 21 , 35 and 50 days after sowing i.e. (at vegetative , beginning of flowering and early of capsules formation stages) achieved the superiority impacts on sesame yield productivity and its quality compared with the other treatments . At this treatment, the highest increments compared to the control treatment were 35.5 ,16.6 and 12.3 % for the seed yield , stover yield and harvest index , respectively . For the seed quality characteristics, the increments reached to 72.7 , 52.0 and 102.1 % for seed N , P and K contents . Yet , the increases for protein and oil yields were 72.5 and 63.1 % , respectively .

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تأثير التغذية الورقية بهيومات البوتاسيوم والعناصر الصغرى على إنتاجية محصول السمسم وتحسين جودته تحت ظروف الأراضى الطينية بدلتا النيل

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أجريت تجربتان حقليتان في مزرعة خاصة بقرية جديلة التابعة لمدينة المنصورة – محافظة الدقهلية – مصر خلال موسمي الزراعة الصيفيين 2017 ، 2018 بغرض دراسة تأثير الرش الورقي بهيومات البوتاسيوم وبعض العناصر الغذائية الصغرى (الحديد ، المنجنيز ، الزنك) على صبغات التمثيل الضوئي بالأوراق (عند عمر 70 يوم) ، ومحصولي البذور والعلف والمحصول البيولوجي ودليل الحصاد لنباتات السمسم وكذا مكونات محصول البذور ومحتوى البذور من العناصر الغذائية الكبرى والصغرى وبعض المكونات الحيوية الكيميائية كالزيت والبروتين كمؤشرين لجودة البذور .. وقد أضيفت معاملات الرش الورقى لهيومات البوتاسيوم والعناصر الغذائية الصغرى – موضوع الدراسة – مرة واحدة (بعد 21 يوم من الزراعة – مرحلة النمو الخضري) أو مرتين (بعد 21 ، 35 يوم من الزراعة – مرحلتي النمو الخضري وبداية التزهير) أو ثلاث مرات (بعد 21 ، 35 ،50 يوم من الزراعة – مراحل النمو الخضري وبداية التزهير وبداية تكوين الكبسولات) .. ومن ناحية أخرى أضيفت هيومات البوتاسيوم والعناصر الصغرى في تسع معاملات مختلفة : بدون ، هيومات البوتاسيوم بمفردها ، هيومات البوتاسيوم في ثلاثة مخاليط ثنائية ، ثلاثة مخاليط ثلاثية ، مخلوط واحد رباعي مع العناصر الصغرى .. لذلك صممت التجربتان في كلا موسمي الزراعة بنظام القطع المنشقة مرة واحدة في قطاعات كاملة العشوائية حيث رتبت عدد مرات الرش الورقي بالهيومات و العناصر الصغرى فى القطع الرئيسية بينما وزعت معاملات الهيومات و العناصر الصغرى التسع عشوائياً في القطع الشقية وبالتالي كانت عدد معاملات التجربة 3 × 9 = 27 معاملة ... وقد أشارت نتائج البحث إلى زيادة تركيزات صبغات التمثيل الضوئي بالأوراق ، المحصول الكمي للبذور والعلف وكذا المحصول البيولوجي ودليل الحصاد لنباتات السمسم وكذلك تحسين المحتوى الغذائي والحيوي للبذور (البروتين ، الزيت) نتيجة الرش الورقي للنباتات بهيومات البوتاسيوم والعناصر الصغرى وقد تفوقت معاملة الرش الثلاثية للهيومات والعناصر الصغرى (ثلاث مرات) عن رشهما مرتان ومرة واحدة على التوالي ومن ناحية أخرى أدى إضافة العناصر الصغرى لهيومات البوتاسيوم في مخاليط ثنائية وثلاثية ورباعية إلى تعزيز وزيادة التأثير الإيجابي المعنوي للهيومات على جميع مقاييس النمو والمحصول والجودة السابق الإشارة إليها .. وقد أدت إضافة العناصر الصغرى المختبرة مجتمعة بهيومات البوتاسيوم في معاملة واحدة (هيومات بوتاسيوم + حديد + منجنيز + زنك) إلى تحقيق أعلى الزيادات في المحصول الكمي للسمسم وتحسين جودته (محتوى البذور من المغذيات الكبرى والصغرى والزيت والبروتين) مقارنة بإضافة هيومات البوتاسيوم للعناصر الصغرى في مخاليط ثلاثية أو ثنائية أو إضافتها بمفردها .. بينما حققت معاملة الكنترول (بدون رش الهيومات أو العناصر الصغرى) أقل القيم لجميع المقاييس السابقة ... وقد كان للتأثير المشترك لعدد مرات رش هيومات البوتاسيوم والعناصر الصغرى ومعاملاتهما التسع أثر إيجابي في زيادة محصول السمسم وزيادة المحتوى الغذائي والحيوي للبذور... ومن ثم يمكن التوصية بأن إضافة هيومات البوتاسيوم والعناصر الصغرى - موضوع البحث - (الحديد ، المنجنيز ، الزنك) مجتمعة في معاملة واحدة ثلاث مرات خلال المراحل الحيوية الفعالة للسمسم (مراحل النمو الخضرى ، وبداية التزهير ، بداية تكوين الكبسولات) يكون له أعظم الأثر في زيادة المحصول الكمي لبذور السمسم ورفع قيمته الغذائية وتعزيز محتواه الحيوى من البروتين والزيت .