Egypt. J. Soil Sci. **Vol. 61,** No. 3, pp. 255 – 365 (2021)

Egyptian Journal of Soil Science

http://ejss.journals.ekb.eg/

Integrated Management of K -Additives to Improve the Productivity of Zucchini Plants Grown on a Poor Fertile Sandy Soil

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Abstract

Three eco-friendly approaches were investigated for their effects onimproving K-uptake by zucchini plants; hence, increasing shoot growth and fruit productivity. These approaches were: (1) amending soil with biochar (0 and 5g kg^{-1}), (2) spraying plants with *Amphora* extract (0 and 1g L^{-1}) and (3) substituting inorganic-K fertilizers partially with organic ones. In this concern, five levels of compost (0, 1.5, 3, 4.5 and 6 g kg^{-1}) were applied to a poor fertile sandy soil (98.5% sand) in complementation with inorganic NPK-fertilizers to bring their concentrations, even in the control treatment, to the recommended levels. This investigation was conducted under the greenhouse conditions during the summer season of 2020. Results obtained herein reveal that application of either of biochar or *Amphora* extract exhibited positive effects on soil available-K (20 and 6.5% respectively), K-concentrations in fruits and total K-uptake by the aboveground plant parts. Furthermore, these two amendments raised considerably the dry weights of both zucchini shoots and fruits. On the other hand, compost could partially substituteinorganic-K fertilizers when it was applied at a rate not exceeding 3gkg^{-1},recording significant improvements in all the investigated parameters. Nevertheless application of high compost doses reduced significantly fruit yield. Generally, there existed a highly significant linear relation between the total K-uptake by plants and fruit dry weights. Accordingly, treatments that improved considerably K-uptake by plants(the combination between foliar application of amphora extract + 5 g kg^{-1} biochar + 0-3 gkg^{-1} compost)recorded the highest improvements in productivity of zucchini plants.

Keywords: Potassium; Zucchini; *Amphora*extract; Biochar; Compost

1. Introduction

Zucchini *(Cucurbita pepo* L.) is a highly polymorphic vegetable crop (Kathiravan *et al.*, 2006) that can be grown during the summer seasons (Shah *et al.*, 2008). It is one of the most significant crops of the Cucurbitaceae family (Galal, 2016). The total cultivated area in Egypt was estimated by24923 hectare in 2016, producing about 471,571.000 Ton (mega-grams) according to Ministry of Agriculture and Land Reclamation (2016). Fruits of this crop are suitable as a low-calorie diet (Verdone et al., 2018)beside of their high contents of bioactive components including antioxidants, flavonoids, vitamins and minerals such as K, Mg, P, Ca and Fe (Tamer et al., 2010).

Potassium (K) is one of the major macronutrients needed for crop development(Wang et al., 2019), achieving high yield, quality, and stress tolerance (Zörb et al., 2014). Its content varies significantly in crop tissues (0.4 to 4.3 %) according to the location, year, crop species and fertilizer application (Askegaard et al., 2004). Probably,

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Rceived: 5/10/2021; Accepted: 25/10/2021
DOI: 10.21608/ejss.2021.99643.1472

differences in root structure such as root density, rooting depth and root hair lengths might account for such variances (Nieves-Cordones et al., 2014). Generally, plants take up K via root hairs (Jungk, 2001) from (1) the water-soluble K in soil which is immediately accessible to plants and microorganisms; yet, this K-formis susceptible to leaching (Rosolem et al., 2018) and (2) the exchangeable K which is electrostatically attached to the surfaces of clay minerals and humic substances as an outer-sphere complex (Barré et al., 2008). It is worthy to mention that up to 98 % of soil-K was found unavailable for plant uptake (Meena *et al.*, 2016). Accordingly, farmers depend on commercial inorganic fertilizers to satisfy plant needs for K (Meena et al., 2016Marzouk et al., 2020 and Elzemrany and Faiyad, 2021); however the efficiency of these fertilizers may increase when applied in combination with organic additives (Qaswar et al., 2020, Emam et al., 2020andAbou Hussien*et al*., 2021) such as manure and compost (Sánchez et al., 2015). Moreover, organic additives may effectively substitute inorganic K-fertilizers (Jiang et al., 2019) to sustain soil and crop productivity (Meena *et al.*, 2016). This is because some soil components such as clay content may fix K (Simonsson et al., 2009), especially within the arid zone (Najafi-Ghiri and Abtahi, 2013). On the other hand, K is not assimilated into organic matter (Ho and Tsay, 2010); thus organic applications may considerably enrich soils with available K to satisfy the nutritional needs of plant growth. In particular, compost is an eco-friendly approach to supply plants with K (Basak, 2018; Farid et al., 2018and Mohamed and Rashad, 2020). Also, biochar which is a carbon rich product produced via pyrolysis of organic wastes (Abdelhafez et al., 2014; Bassouny and Abbas, 2019; Abdelhafez et al., 2020 and 2021), can retain soil nutrients and reduce the need for artificial fertilizers (Ippolito et al., 2012; Lehmann and Joseph, 2015 and Rafique et al., 2020). Its application at a rate of 10% may causemajor increases in K content in leaves, stem and root (Liu et al., 2015). Accordingly, the usage of organic additives is recommended for zucchini production under low-fertile soil conditions because these additives regulate soil physicochemical characteristics and nutrient availability (Alharbi et al., 2021).

The current study investigates to what extent organic additives (compost and/or biochar) can integrate with commercial inorganic K-fertilizers to increase zucchini productivity grown on a poor fertile sandy soil. In this concern, this soil type has a very limited capability to reserve exchangeable K (Meena et al., 2016); yet it is subjected to leaching from the top soil. Therefore, the colloidal particles amended via organic additives may effectively reserve exchangeable soil-K and consequently increase its availability in soil. Specifically, we anticipate that compost can partially substitute inorganic fertilizers in production of zucchini (hypothesis 1). Moreover, biochar application can raise the efficiency of this combined application under the conditions of light textured soils (hypothesis 2).It is worthy to mention that the algal extracts are rich in various elements (macro and micro) such as N, P, K, Ca, Cu, Fe, Mg, Mn and Zn which can play vital roles in plant physiological processes, inducing photosynthesis, cell divisions and cell elongation (Gollan and Wright, 2006). Diatoms such as *Amphora coffeaeformis* are thought to be a source of a variety of bioactive chemicals, namely carotenoids, sulfated polysaccharides, polyunsaturated fatty acids, vitamins C and E and - β-glucans (El-Sayed et al., 2018a). So, we assume that spraying plants with Amphora extract may have direct and indirect impacts on increasing plant capability to absorb and utilize soil-K; thus, increase its productivity (hypothesis 3).

2. Materials and Methods

Surface soil sample (0-30 cm) was collected from the experimental farm at the Research and Production Station EL-Nobaria, BeharaGovernorate, Egypt. This sample was air dried, crushed and sieved to pass through a 2-mm sieve; afterwards, soil was analysed for its physical and chemical characteristics as outlined by Klute (1986) and Sparks et al. (1996), respectively. Soils physical and chemical characteristics are presented in Table 1.

TABLE 1. Physical and chemical properties of the investigated soil

Property	Value	Property	Value
Sand, %	98.5	pH*	7.7
Silt, %	1.0	EC**, dS m^{-1}	0.6
Clay, %	0.5	Available-N, mg kg^{-1}	10.3
Textural class	Sand	Available P, mg kg^{-1}	7.3
Organic matter, g kg^{-1}	3.0	Available-K, mg kg^{-1}	188

*pH was determined in 1:2.5 (soil:water) suspension, **EC was determined in soil paste extract, available NPK were extracted by K_2SO_4 (1%), $NaHCO_3$ (0.5*N*, pH 8.5) and ammonium acetate (1*N*, pH 7) methods, respectively.

Seeds of zucchini *(Cucurbitepepo* cultivar Jamila F1*)* were brought from HM. CLAUSE SAS Company, France. Amphora (*Amphora coffeaeformis)* extract was obtained from the Algae Biotechnology Unit, NRC, Cairo, Egypt. This extract contained (per liter) 54.1gN, 13.2gP, 6.3gK, 78.9gFe, 11gMn, 135gZn and 4.6 g Cu. Rice straw was collected from private fields at EL-DakahliaGovernorate, North Egypt. Half of these residues underwent pyrolysis under limited oxygen conditions for 5h using a traditional pyrolysis unit in New Borg El Arab City (SRTA-City, 21934), Alexandria while the other half underwent composting for 145 days until maturity in presence of 15% farmyard manure, 15kg NH_4SO_4 (20.6 g N kg^{-1}), 3 kg CaH_2PO_4 (6.7 g P kg^{-1}) and 15 kg calcium carbonate ($CaCO_3$) per mega-gram (ton).For preparation of co-composted biochar, extra 10% of biochar was added to the aforementioned additives while composting. Properties of the used organic additives are presented in Table 2.

TABLE 2. Chemical properties of biochar and compost used in the study

Parameter	Compost	Biochar	Co-composted biochar
pH *	6.94	9.53	7.34
EC*	4.46	6.10	5.11
Total N (g kg^{-1})	17.30	9.19	14.00
Total-P (g kg^{-1})	9.10	5.20	5.90
Total-K (g kg^{-1})	20.30	46.20	21.50
C/N ratio	11.38	48.30	12.20

*EC and pH were determined in 1:10 extract

2.2. Greenhouse experiment

A pot experiment was carried out under the greenhouse conditions (natural light and ambient temperature) at EL-DkahliaGovernment(31°15´38" N 31° 25' 44"E), North Egypt during the summer season of 2020, comprising three factors with three replicates each: (a) biochar at two different rates i.e., 0 and 5g kg^{-1}, (b) foliar application of *Amphora*extract at two different rates (0 and 1gL^{-1}) and (c) organic fertilization with compost at five rates of0 (K_1), 1.5 (K_2), 3.0(K_3), 4.5 (K_4) and 6.0 g kg^{-1} (K_5). Supplementary doses of inorganic NPK fertilizers were added to all treatments, even to the control one, to standardize the level of NPK applications among treatments and raise NPK levels in soil to the optimum concentrations (0.27g kg^{-1} ammonium nitrate (33.5% N), 0.15g kg^{-1} calcium super phosphate(8.5 % P)and 0.35g kg^{-1} potassium sulphate (40% K)). Twenty kilograms of air dried soil was uniformly packed in plastic pots (30 cm in diameter × 25 cm in depth) then planted with 6 seeds of zucchini (*Cucurbitepepo)* on the 15th of May, 2020. At the secondtrue-leaf stage, plants were thinned to two plants per pot and at the physiological maturity stage (80 days after planting), the aboveground plant parts were harvested , washed several times with tap water then distilled water . Plant materials were then oven dried at 70˚C for 48 h and their weights were recorded. Soil samples were also collected from the rhizosphere of each treatment to determine their available contents of K.

2.3. Harvesting and measurement of K

Plant portions (equivalent to 0.4g) were acid digested using a mixture of H_2SO_4:$HClO_4$ (4:1v/v) according to Cottenie et al. (1982) and the total contents of potassium in these extracts were determined by flame photometer (model Jenway PFP7). Available soil potassium was extracted by ammonium acetate method in 1:5 (soil: ammonium acetate, v/v) according to Hesse (1971) then shacked for 30 min and filtered. Afterwards, available potassium was determined in the filtrate using flame photometer.

2.4. Statistical analysis

Data were statistically analyzed using Costat software of variance and the mean values were compared using Duncan multiple range test at $P\leq0.05$. Figures were plotted using SigmaPlot 10.

3. Results and Discussion

3.1. Soil available potassium

Application of biochar raised significantly the available content of K in the sandy soil by 20% versus the non-amended one. These results are in agreement with the findings of Gao et al. (2017) who recorded significant increases in soil available K owing to application of biochar. Maybe, biochar stimulated the activities of K-dissolving bacteria (Zhang et al., 2020). Likewise, spraying plants with Amphora extract led to significant increases in soil available K by 6.5%. Probably, these extracts induced root growth (Supraja et al., 2020), which in turn increased the root exudates (Neumann, 2007). These exudates took part in increasing the availability of soil-K (Wang et al., 2011 and Zörb et al., 2014). Amending soils with compost (up to 3 g kg^{-1}) raised significantly available potassium in soil, while higher application rates lessened this content in soil. In this concern, the rate K_3 recorded the highest avail- K content (208.5mgkg^{-1}), followed bythe rate K_2 (193mgkg^{-1}) while the rate K_5(155.1 mgkg^{-1}) recorded the leastavailable K value. Compost may increase P availability in soil (Litaor et al., 2017)by enhancing plant roots to secret more exudates (Sun et al., 2020) and also stimulate the activities of in-situ K-dissolving bacteria (Sahoo et al., 2013). Concerning the combination between the foliar application of amphora, biochar and organic vs inorganic fertilizer treatments, K_3 recorded the highest values of available potassium in soil when combined with soil application of biochar and the foliar spray of Amphora extract (Table 3).

TABLE 3. Soil available-K (mg kg^{-1}) within the rhizosphere of zucchini plants as affected by biochar application, alga extract foliar application and compost, either solely or different in combinations

		K_1	K_2	K_3	K_4	K_5	Mean
	-Alga	169.1hi	141.8m	158.8k	176.4fg	141.3m	157.5B
-Biochar	*+Alga*	167.1i	182.1e	177.6ef	151.1l	161.7jk	167.9 C
	Mean	168.1 D	162.0 FG	168.2 D	163.7 EF	151.5 H	**162.7B**
	-Alga	177.9ef	233.6b	221.8c	158.8k	153.4l	189.1 B
+Biochar	*+Alga*	180.8ef	214.4d	275.7a	172.3gh	164.2ij	201.5 A
	Mean	179.3 C	224.0 B	248.8 A	165.5 DE	158.8 G	**195.3A**
	Grand means	**173.7 C**	**193 B**	**208.5 A**	**164.6 D**	**155.1 E**	
		Main effects of algal inoculation					
	-Alga	173.5 D	187.7 C	190.3 C	167.6 E	147.4 G	**173.3 B**
	+Alga	174.0 D	198.2 B	226.6 A	161.7 F	162.9 F	**184.7 A**

K_1 to K_5 treatments: rates of compost appliedto the sandy soil *i.e.*, 0, 1.5, 3.0, 4.5 and 6.0 g kg^{-1} plus supplementary doses of inorganic K fertilizers (potassium sulphate) to raise K-content in soils of all treatments to 0.14g K kg^{-1}. Similar letters indicate no significant variations among treatments. **Bold letters are the grand means.**

3.2. The above-ground biomass of zucchini plants

Dry weights of zucchini shoot and fruits increased significantly owing to the application of biochar (Fig 1). These results agree with the findings of Amin and Eissa (2017) who attributed such increases to the concurrent improvements in nutrient use efficiencies by plants grown on a soil amended with biochar. Also, foliar application of amphora extract increased plant shoot and fruit dry weights by 16.3 and 43.5%, respectively. This extract probably played significant roles in increasing plant height, number of leaves (per plant), leaf area and chlorophyll a&b (Mogazy et al., 2020). Regarding the effect of organic and inorganic fertilizers on leaves and fruit dry weights, it was found that compost applied at a rate ofK_3 recorded the highest significant increases (72.6g plant^{-1}) in shoot dry weights whilethe rate K_1 (58g plant^{-1}) recorded the highestsignificant increases in fruit dry weights. The significant role of compost treatments on enhancing the growth characteristics of plants such as dragonhead is well known and these results may be attributed to the role of macro- and micro-nutrients provided by compost as well as the improvements in soil conditions, beside of stimulating metabolic processes, encouraging growth and increasing the synthesis and accumulation of more metabolites in plant tissues (Wahby et al., 2006).

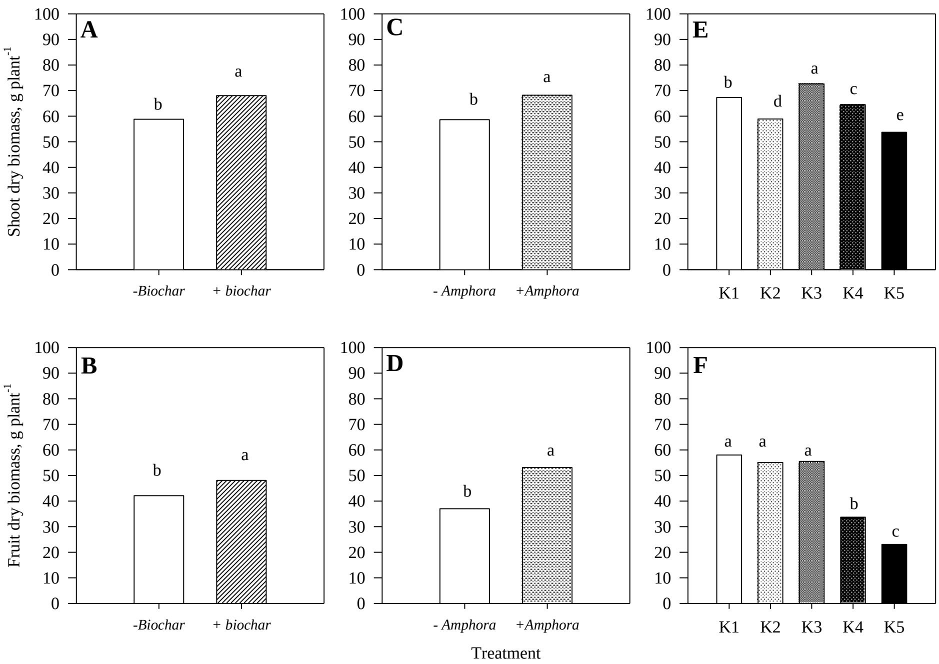

Fig 1. **Grand means of shoot and fruit dry weights of zucchini plants grown on a poor fertile light textured soil as affected by biochar application, algal extract foliar application and organic fertilizers (compost), either solely or in combinations. For treatments from K_1 to K_5: see footnote ofTable 3. Similar letters indicate no significant variations among treatments**

Yet, application of high dose of compost might not be a suitable option to attain high fruit productivity because high doses of compost led to concurrent significant reductions in shoot and fruit yields.In this concern, the application of compost at a rate of 3 g kg^{-1} seemed to be acceptable to attain the highest increases in plant growth and fruit yield.

Concerning the interactions among the three factors under investigation, it was found that the highest increases in shoot and fruit dry weights were recorded for either of K_1 or K_3 treatments in presence of biochar +*Amphora* foliar spray, with no significant variations betweenthese two treatments (Fig 2). In soil amended with higher rates of organic additives (6 g kg^{-1} compost and 5 g kg^{-1} biochar), shoot and fruit dry weights seemed to be relatively low, especially for plants not sprayed with *Amphora*extract.

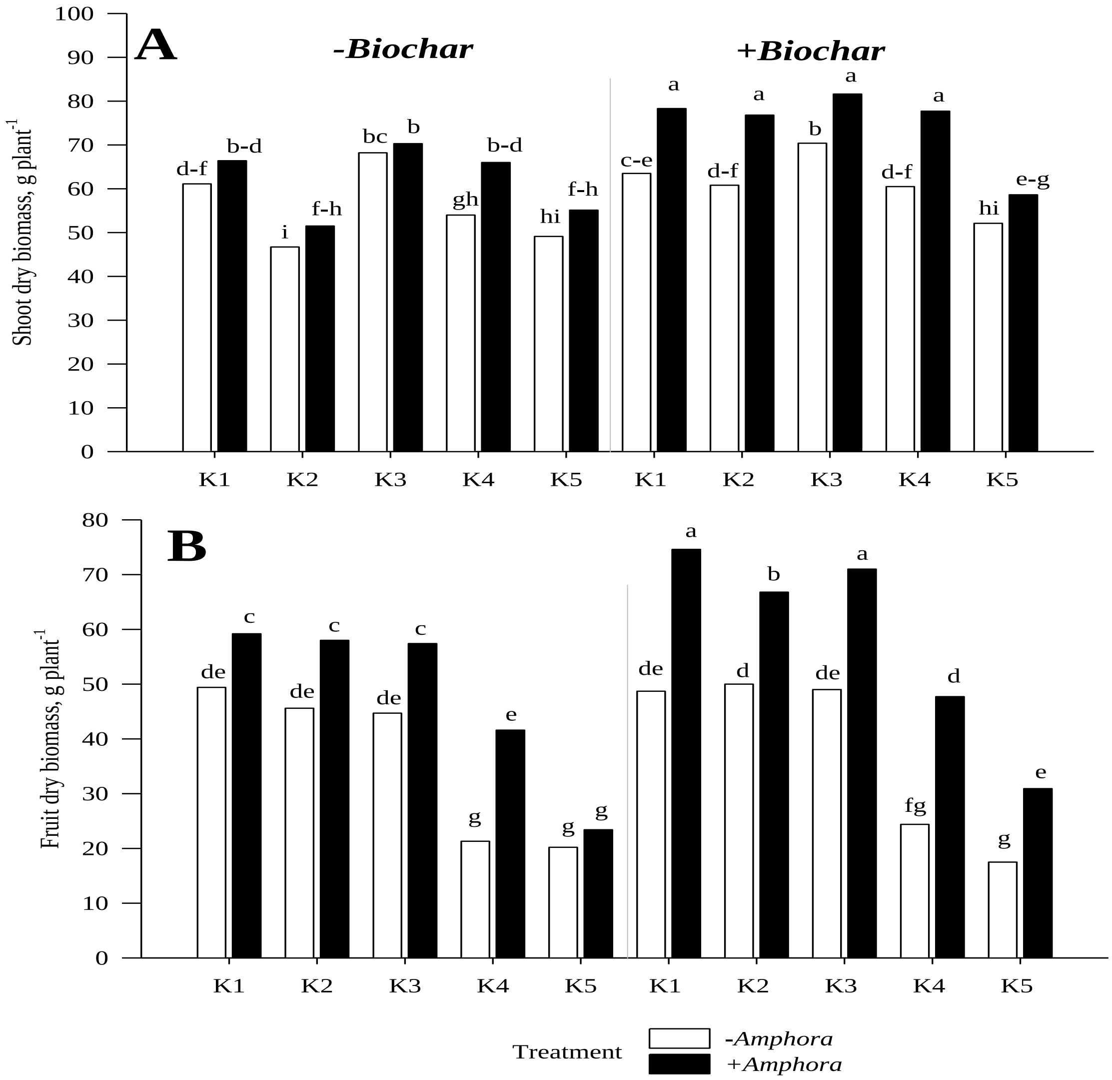

Fig 2. Shoot and fruit dry weights of zucchini grown on a poor fertile light textured soil as affected by biochar application, algal extract and compost, either solely or in different combinations. For treatments from K_1 to K_5: see footnoteof Table 3. Similar letters indicate no significant variations among treatments

3.3. Potassium concentrations and uptake in the aboveground plant tissues

Application of either biochar or *Amphora*extract raised significantly K-content in fruits as well as the total K uptake by the above ground parts; yet K-content in shoots did not vary significantly owing to the these two amendments (Table 3). In this concern, amending soils with biochar or spraying plants with the algal extract recorded 16. 7 and 36.4% increases, respectively in total K-uptake by the aboveground plant parts while the corresponding increaseswereonly 5.6% corresponding to K-content in fruits. Probably, K in biochar (Elshony et al., 2019)and algal extract took part in plant nutrition (Mutale-Joan et al., 2020). Relating to the effect of organic (compost) vs inorganic fertilizers on the concentration and uptake of K by plants, K_3 and to some extent K_4, was the most effective treatment that increased potassium concentration and uptake by plants while K_5 seemed to be the least effective one.

TABLE 4. K content within shoots and fruits of zucchini plants grown on a light textured soil as affected by biochar application, algal extract and compost, either solely or in different combinations

		K_1	K_2	K_3	K_4	K_5	Mean
Concentration of K in shoot, gkg^{-1}							
-Biochar	*-Alga*	18.7cd	19.4bc	20.8a-c	23.8ab	21.7a-c	20.9AB
	+Alga	22.6a-c	21.0 a-c	22.6a-c	23.6ab	22.3a-c	22.4A
	Mean	20.7A-C	20.2BC	21.6A-C	23.7A	22.0A-C	**21.6A**
+Biochar	*-Alga*	23.8ab	20.8a-c	22.4a-c	22.7a-c	21.4a-c	22.2A
	+Alga	14.8d	18.4cd	20.0 a-c	22.1a-c	24.5a-c	19.9B
	Mean	19.3C	19.6C	21.2A-C	22.4A-C	23.0AB	**21.1A**
	Grand means	**20.0B**	**19.9B**	**21.4AB**	**23.0 A**	**22.5A**	
Main effects of algal inoculation							
	-Alga	21.2A-C	20.1BC	21.6A-C	23.2A	21.5A-C	**21.5A**
	+Alga	18.7C	19.7BC	21.2A-C	22.8AB	23.4A	**21.2A**
Concentration of K in fruit, gkg^{-1}							
	-Alga	55.1c-e	54.7c-f	54.1d-f	52.1ef	50.0f	53.2C
-Biochar	*+Alga*	56.5a-e	58.6a-d	60.3ab	53.7d-f	55.3b-e	56.9B
	Mean	55.8 BC	56.6 AB	57.2 AB	52.9 C	52.6 C	**55.0B**
	-Alga	55.7b-e	58.3a-d	57.4a-d	59.6a-c	53.9d-f	57.0B
+Biochar	*+Alga*	59.2a-c	60.2ab	61.1a	59.3a-c	56.7a-e	59.3A
	Mean	57.4AB	59.2A	59.3A	59.4A	55.3BC	**58.1A**
	Grand means	**56.6AB**	**57.9A**	**58.2A**	**56.1AB**	**53.9B**	
Main effects of algal inoculation							
	-Alga	55.4 C	56.5 C	55.8 C	55.8 C	51.9 D	**55.1B**
	+Alga	57.8 A-C	59.4 AB	60.7 A	56.5 C	56.0 BC	**58.1A**
Uptake of K by the aboveground plant parts, g plant^{-1}							
-Biochar	*-Alga*	3.8fg	3.4gh	3.8fg	2.3jk	2.1 k	3.1D
	+Alga	4.8cd	4.4c-e	5.1 bc	3.8fg	2.5jk	4.1B
	Mean	4.3C	3.9D	4.4BC	3.1E	2.3F	**3.6B**
+Biochar	*-Alga*	4.2ef	4.1ef	4.3d-f	2.8ij	2.1 k	3.5C
	+Alga	5.5ab	5.4ab	5.9a	4.5c-e	3.2hi	4.9A
	Mean	4.9A	4.8AB	5.1A	3.6D	2.6F	**4.2A**
	Grand means	**4.6AB**	**4.3B**	**4.8A**	**3.3C**	**2.6D**	
Main effects of algal inoculation							
	-Alga	4.1 C	3.7C	4.1C	2.6D	2.1E	**3.3B**
	+Alga	5.2AB	4.9B	5.5A	4.1C	2.8D	**4.5A**

For treatments from K_1 to K_5: see footnote of Table 3. Similar letters indicate no significant variations among treatments. **Bold letters are the grand means.**

Based on the aforementioned results, compost can partially substitute inorganic K fertilizers to satisfy K-needs for zucchini, only when it is applied at relatively low rates (≤3 g kg^{-1}); consequently, it improves plant growth and productivity. Higher application doses of compost are not guaranteed to attain high crop production. These findings confirmed partially the first hypothesis. On the other hand, the combination between biochar and high doses of compost led to significant reductions in K availability and uptake by plants; subsequently lessened dry weights of both shoots and fruits. These results, of course, did not support the second hypothesis. It is worth mentioning that spraying plants with *Amphora* extract increased plant capability to absorb and utilize soil-K; thus improved plant growth and productivity. Therefore, we accept the third hypothesis. In this concern, algal extract foliar applications is recommended for inducing plant growth under drastic stress conditions (Abdel-Maguid et al., 2004; 2005; Shabaan et al., 2010; Tarraf et al., 2015;Enan et al., 2016; El-Sayed et al., 2018b;Anter and El-Sayed, 2020 and Reda et al., 2020) which may exists in sandy soils subjected to prolong irrigations.

3.4. *Correlation coefficients between zucchini fruit and shoot dry weights in relation with K-availability and uptake by plants*

All calculated correlation coefficient values amongst the studied traits were significant and positive (Table 5). In this concern, K- uptake was correlated significantly and positively with K-availability in soil (R^2=0.634). Likewise, K content in both shoots and fruits were correlated significantly and positively with K-uptake by the aboveground plantparts. Moreover, shoot and root dry weights were correlated positively and significantly with K-content in these plant parts. Results obtained herein highlighted the presence of very high correlations between fruit yield and shoot biomass (R^2≈1)

TABLE 5. Correlation coefficients between zucchini fruit and shoot dry weights in relation with K-availability and uptake by plants

	Shoot dry weight	Fruit dry weight	Available-K	K in shoot	K in fruits	Total K-uptake
Shoot dry weight						
Fruit dry weight	0.707**					
Available-K content in soil	0.585**	0.577**				
K in shoot	0.999**	0.707**	0.585**			
K in fruit	0.668**	0.680**	0.620**	0.668**		
Total K-uptake in the aboveground plant part	0.815**	0.974**	0.634**	0.815**	0.762**	

* Correlation is significant at the 0.05 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

It seems that the fruit yields of zucchini plants were highly correlated with total K uptake by plants. Therefore, a regression function was conducted between these two parameters (Fig 3A) to estimate the coefficient of determination (R^2= 0.949), which was high enough to indicates the presence of a linear relationship between zucchini fruit yield and the increase in total K-uptake by plants. A linear function was not applicable for the relation between the increases that occurred in total K-uptake by plants and zucchini shoot biomass (R^2= 0.666, Fig 3B). The regression relations between total zucchini shoot and fruit yields with available potassium content in soil were also not significant (R^2=0.334 and 0.333, respectively, Figs C and D), and this probably indicates that there were many other soil factors that affect the availability of soil-K; hence limit its uptake by plants, e.g. the release-fixation process of interlayer K. (Barré et al., 2008).

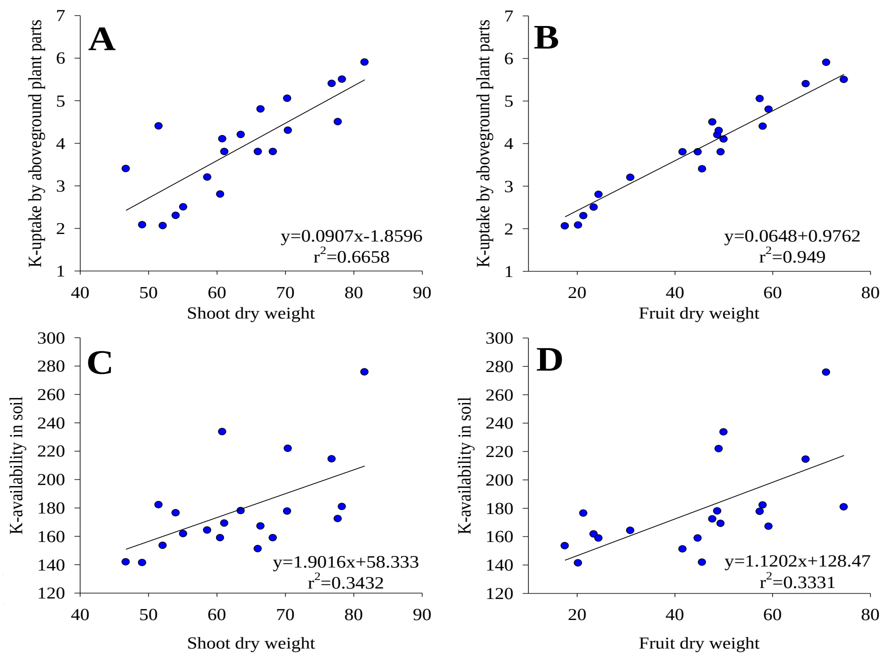

Fig 3. Regression relations between zucchini shoot and fruit dry weights in relation to total K-uptake by plants (A, B) and K-available content in soil (C, D)

Conclusion

Three eco-friendly approaches were investigated for their impacts on improving K-uptake by zucchini plants and consequentlyincreasingtheir growth and productivity. These approaches were: (1) amending soil with biochar, (2) spraying plants with *Amphora* extract and (3) substitutingpartially inorganic-K fertilizers with an organic one (compost). The first two approaches seemed to be approriate for improving total K-uptake by the aboveground plant parts; hence increasing shoot and fruit dry weights. Furthermore, the combinations between these two approaches were superior to each one when applied soley. On the other hand, compost could partially substitute inorganic K-fertilizers; yet its application at a rate exceeding 3 g kg^{-1} may considerably lessen available-K content and uptake by plants. This might take place via temporarely bio-immobilization in soils as a result of indution of soil microbial growth and activity through organic additives. In this concern, there existed a highly significant linear relationship between total K-uptake and fruit dry weights. Accordigly the application of high rates of compost to substitute partially inorganic fertilizers might not be the suitable choise to increase zucchini productivity.

Author Contributions: Conceptualization, All authors; methodology, Mona Tolba, Hanan S. Siam, Safaa A. Mohamed and Abo El-Kair B. El-Sayed; formalanalysis, all authors; resources and writing—original draft preparation, all authors; writing—review and editing, all authors.

Conflicts of interest

There are no conflicts to declare.

Formatting of funding sources

There is no fund

Acknowledgments

Deep thanks to Prof. Dr. Hassan H. Abbas, Soils and Water Department, Benha University for his help and valuable advices during the course of this study.

References

Abdelhafez, A.A., Li, J. and Abbas, M.H.H. (2014) Feasibility of biochar manufactured from organic wastes on the stabilization of heavy metals in a metal smelter contaminated soil. *Chemosphere* 117, 66–71. **Doi:**10.1016/j.chemosphere.2014.05.086

Abdelhafez, A.A., Zhang, X., Zhou, L., Zou, G., Cui, N., Abbas,.H.H. and Hamed, M.H. (2020) Introductory Chapter: Is Biochar Safe?. In Abdelhafez, A.A., Abbas, M.H.H. (eds), Applications of Biochar for Environmental Safety, Intech Open, pp 1-6. **Doi**:10.5772/intechopen.91996

Abdelhafez, A.A., Zhang, X., Zhou, L., Cai, M., Cui, N., Chen, G., Zou, G., Abbas, M.H.H., Kenawy, M.H.M., Ahmad, M., Alharthi, S.S. andHamed, M.H. (2021) Eco-friendly production of biochar via conventional pyrolysis: Application of biochar and liquefied smoke for plant productivity and seed germination,*Environmental Technology & Innovation*,22,101540. **Doi**: 10.1016/j.eti.2021.101540.

Abdel-Maguid, A.A.; El-Sayed, A.B. and Hassan, H.S.A. (2004). Growth enhancement of olive transplants by broken cells of fresh green algae as soil application. *Minufiya J. Agric. Res.* 29(3), 723-733.

Abdel-Maguid, A. A.; El-Fouly, M. M. and El-Sayed, A. B. (2005). Use of Algae on Plant Nutrition: a review article. The 3rd Conference of Agricultural and Biological Research Division, Prospects of the Recent Agriculture Research, April 21-23,2005, NRC, Cairo, Egypt.

AbouHussien, E., Nada, W., Mahrous, H. (2021). Improving chemical and microbial properties of calcareous soil and its productivity of faba bean (*Viciafaba* L.) plants by using compost tea enriched with humic acid and Azolla. *Egypt. J. Soil Sci*, 61(1), 27-44. **Doi:** 10.21608/ejss.2020.47611.1399

Alharbi, S., Majrashi, A., Ghoneim, A.M., Ali, E.F., Modahish, A.S., Hassan, F.A. and Eissa, M.A. (2021) A new method to recycle dairy waste for the nutrition of wheat plants. *Agronomy* 11, 840.**Doi:**10.1016/j.algal.2021.102200

Amin, A.E.-E.A.Z. and Eissa, M.A. (2017) Biochar effects on nitrogen and phosphorus use efficiencies of zucchini plants grown in a calcareous sandy soil. *Journal of Soil Science and Plant Nutrition* 17, 912-921.

Anter A.S. and El-Sayed A.B. (2020). Screening new sesame (*Sesamum indicum*L.) Lines at two levels of salinity incorporated with algae for salt tolerance. *Plant Archives* 20(2), 2271-227.

Askegaard, M., Eriksen, J. and Johnston, A.(2004) Sustainable management of potassium. Managing Soil Quality: Challenges in Modern Agriculture. CAB International 2004, 85-102.**Doi**: 10.1079/9780851996714.0085

Barré, P., Montagnier, C., Chenu, C., Abbadie, L. and Velde, B. (2008) Clay minerals as a soil potassium reservoir: observation and quantification through X-ray diffraction. *Plant Soil* 302, 213-220.**Doi**: 10.1007/s11104-007-9471-6

Basak, B.B. (2018) Recycling of waste biomass and mineral powder for preparation of potassium-enriched compost. *Journal of Material Cycles and Waste Management* 20, 1409-1415.**Doi**:10.1007/s10163-018-0699-4

Bassouny, M. and Abbas, M. (2019). Role of Biochar in Managing the Irrigation Water Requirements of Maize Plants: the Pyramid Model Signifying the Soil Hydro-physical and Environmental Markers. *Egypt. J. Soil Sci*, 59(2), 99-115. **Doi**: 10.21608/ejss.2019.9990.1252

Cottenie, A., Verloo, M., Kiekens, L., Velghe, G. and Camerlynck, R. (1982) Chemical analysis of plants and soils. Lab. Agroch. State Univ. Gent, Belgium 63.

El-Sayed, A.E.-K.B., Aboulthana, W.M., El-Feky, A.M., Ibrahim, N.E. and Seif, M.M.(2018a) Bio and phyto-chemical effect of *Amphora coffeaeformis* extract against hepatic injury induced by paracetamol in rats. *Molecular Biology Reports* 45, 2007-2023.**Doi**: 10.1007/s11033-018-4356-8

El-Sayed A.B., Shehata S.A., Sahar Taha, Hamouda H.A. and Youssef D.M . (2018b). Algae extract overcoming the adverse effects of saline stress of hydroponic tomato grown plants. *Journal of Food, Agriculture & Environment*. 16(2) 92-99.

Elshony, M., Farid, I.M., Alkamar, F., Abbas, M.H. and Abbas, H. (2019) Ameliorating a sandy soil using biochar and compost amendments and their implications as slow release fertilizers on plant growth. *Egypt. J. Soil Sci* 59, 305-322.**Doi**:10.21608/EJSS.2019.12914.1276

Emam, M., Elsayed, T. andHamed, L. M.M. (2020).Sweet corn growth performance and rhizospheremicrobial densities in response to mineral and organic amendments. *Egypt. J. Soil Sci*, 60(1), 43-52. **Doi**: 10.21608/ejss.2019.19528.1324

Enan, S.A.A.M.; A. M. El-Saady and A. B. El-Sayed. (2016). Impact of foliar feeding with alga extract and boron on yield and quality of sugar beet grown in sandy soil. *Egypt. J. of Agron.* 38(2) 319-336.**Doi**: 10.21608/agro.2016.622

Elzemrany, H. and Faiyad, R. (2021). Maximizing use efficiency of mineral fertilizers using K fulvate and *Azotobacterchroococcum* DSM 2286 and their effect on wheat production and nutrients uptake.. *Egypt. J. Soil Sci*, 61(1), 13-25. **Doi:** 10.21608/ejss.2020.48114.1403

Farid, I.M., Abbas, M.H.H. and El-Ghozoli, A. (2018) Implications of humic, fulvic and K—humate extracted from each of compost and biogas manure as well as their teas on faba bean plants grown on TypicTorripsamments and emissions of soil CO_2. *Egypt. J. Soil Sci* 58 (3), 275-298. **Doi**:10.21608/ejss.2018.4232.1183

Galal, T.M. (2016) Health hazards and heavy metals accumulation by summer squash (Cucurbita pepo L.) cultivated in contaminated soils. *Environmental Monitoring and Assessment* 188, 434.**Doi**:10.1007/s10661-016-5448-3.

Gao, L., Wang, R., Shen, G., Zhang, J., Meng, G. and Zhang, J.(2017) Effects of biochar on nutrients and the microbial community structure of tobacco-planting soils. *Journal of soil science and plant nutrition* 17, 884-896.**Doi**: 10.4067/S0718-95162017000400004

Gollan, J.R. and Wright, J.T.(2006) Limited grazing pressure by native herbivores on the invasive seaweed Caulerpa taxifolia in a temperate Australian estuary. *Marine and Freshwater Research* 57, 685-694.**Doi**: 10.1071/MF05253

Hesse, P. (1971) A Textbook of Soil Chemical Analysis, Chemical Publishing Co. Inc, NewYork.

Ho, C.-H. and Tsay, Y.-F.(2010) Nitrate, ammonium, and potassium sensing and signaling. *Current Opinion in Plant Biology* 13, 604-610.**Doi**:10.1016/j.pbi.2010.08.005

Ippolito, J.A., Laird, D.A. and Busscher, W.J. (2012) Environmental benefits of biochar. *J Environ Qual* 41, 967-972. **Doi**:10.2134/jeq2012.0151

Jiang, N., Hu, B., Wang, X., Meng, Y., Chen, B. and Zhou, Z. (2019) Effects of crop residue incorporation and inorganic potassium fertilization on soil potassium supply power. *Archives of Agronomy and Soil Science* 65, 1223-1236.**Doi:**10.1080/03650340.2018.1562174

Jungk, A. (2001) Root hairs and the acquisition of plant nutrients from soil. *Journal of Plant Nutrition and Soil Science* 164, 121-129.

Kathiravan, K., Vengedesan, G., Singer, S., Steinitz, B., Paris, H.S. and Gaba, V.(2006) Adventitious regeneration in vitro occurs across a wide spectrum of squash (Cucurbita pepo) genotypes. *Plant Cell, Tissue and Organ Culture* 85, 285-295.**Doi:**10.1007/s11240-006-9079-1.

Klute, A.(1986) Part 1. Physical and mineralogical methods. ASA-SSSA-Agronomy, Madison, Wisconsin USA.

Lehmann, J. and Joseph, S.(2015) Biochar for environmental management: science, technology and implementation, 2nd edition. Routledge.

Litaor, M.I., Katz, L. and Shenker, M.(2017) The influence of compost and zeolite co-addition on the nutrients status and plant growth in intensively cultivated Mediterranean soils. *Soil Use and Management* 33, 72-80.**Doi**: 10.1111/sum.12324

Liu, L., Zhu, B. and Wang, G.-X.(2015) Azoxystrobin-induced excessive reactive oxygen species (ROS) production and inhibition of photosynthesis in the unicellular green algae *Chlorella vulgaris*. Environ Sci Poll Res 22, 7766-7775.**Doi**: 10.1007/s11356-015-4121-7.

Marzouk, N., Hassan, N., Fawzy, Z. and El-Ramady, H. (2020). Cassava cultivars response to different levels of potassium fertilization under drip irrigation and sandy soil conditions. *Egypt. J. Soil Sci*, 60(3), 317-334. **Doi**: 10.21608/ejss.2020.34054.1367

Meena, V.S., Bahadur, I., Maurya, B.R., Kumar, A., Meena, R.K., Meena, S.K. and Verma, J.P.(2016) Potassium-Solubilizing Microorganism in Evergreen Agriculture: An Overview. In: Meena, V.S., Maurya, B.R., Verma, J.P., Meena, R.S. (Eds.), Potassium Solubilizing Microorganisms for Sustainable Agriculture. Springer India, New Delhi, pp. 1-20.**Doi**: 10.1007/978-81-322-2776-2_1

Mogazy, A.M., Seleem, E.A. and Mohamed, G.F. (2020) Mitigating the harmful effects of water deficiency stress on white lupine (*Lupinus albus* L.) plants by using algae extract and hydrogen peroxide. Journal of Plant Production 11, 921-931.**Doi**: 10.21608/jpp.2020.123998

Mohamed, S. M. andRashad, R.T. (2020).Studying some characteristics of sandy soil amended by water hyacinth, bean straw, and compost. *Egypt. J. Soil Sci*, 60(1), 53-65. **Doi:** 10.21608/ejss.2019.18969.1322

Mutale-Joan, C., Redouane, B., Najib, E., Yassine, K., Lyamlouli, K., Laila, S. and Zeroual, Y. (2020) Screening of microalgae liquid extracts for their bio stimulant properties on plant growth, nutrient uptake and metabolite profile of *Solanum lycopersicum* L. *Scientific reports* 10, 1-12.**Doi**: 10.1038/s41598-020-59840-4

Najafi-Ghiri, M. and Abtahi, A.(2013) Potassium fixation in soil size fractions of arid soils. *Soil Water Res.* 8, 49-55.**Doi**:10.17221/52/2012-SWR

Neumann, G.(2007) Root Exudates and Nutrient Cycling. In: Marschner, P., Rengel, Z. (Eds.), Nutrient Cycling in Terrestrial Ecosystems. Springer Berlin Heidelberg, Berlin, Heidelberg, pp. 123-157.**Doi**: 10.1007/978-3-540-68027-7_5

Nieves-Cordones, M., Alemán, F., Martínez, V. and Rubio, F. (2014) K^+ uptake in plant roots. The systems involved, their regulation and parallels in other organisms. *Journal of plant physiology* 171, 688-695.**Doi**: 10.1016/j.jplph.2013.09.021

Qaswar, M., Jing, H., Ahmed, W., Dongchu, L., Shujun, L., Lu, Z., Cai, A., Lisheng, L., Yongmei, X., Jusheng, G. and Huimin, Z. (2020) Yield sustainability, soil organic carbon sequestration and nutrients balance under long-term combined application of manure and inorganic fertilizers in acidic paddy soil. *Soil Till Res* 198, 104569.**Doi**: 10.1016/j.still.2019.104569

Rafique, M., Ortas, I., Rizwan, M., Chaudhary, H.J., Gurmani, A.R. and Munis, M.F.H.(2020) Residual effects of biochar and phosphorus on growth and nutrient accumulation by maize (*Zea mays* L.) amended with microbes in texturally different soils. *Chemosphere* 238, 124710.**Doi**: 10.1016/j.chemosphere.2019.124710

Reda, M., El-Sayed, A. and Almutairi, A., A, H. (2020). Fatty acid profiles and fuel properties of oils from castor oil plants irrigated by microalga-treated wastewater. *Egyptian Journal of Botany*, 60(3), 797-804. **Doi:** 10.21608/ejbo.2020.22970.1444

Rosolem, C.A., Almeida, D.S., Rocha, K.F. and Bacco, G.H.M. (2018) Potassium fertilisation with humic acid coated KCl in a sandy clay loam tropical soil. *Soil Research* 56, 244-251.**Doi**: 10.1071/SR17214

Sahoo, R.K., Bhardwaj, D. and Tuteja, N. (2013) Biofertilizers: A Sustainable Eco-Friendly Agricultural Approach to Crop Improvement. In: Tuteja, N., Singh Gill, S. (Eds.), Plant Acclimation to Environmental Stress. Springer New York, New York, NY, pp. 403-432.**Doi**: 10.1007/978-1-4614-5001-6_15

Sánchez A.,Artola, A., Font, X., Gea, T., Barrena, R., Gabriel, D., Sánchez-Monedero, M.Á., Roig, A., Cayuela, M.L. and Mondini, C. (2015) Greenhouse Gas from Organic Waste Composting: Emissions and Measurement. In: Lichtfouse E., Schwarzbauer J., Robert D. (eds) CO_2 Sequestration, Biofuels and Depollution. Environmental Chemistry for a Sustainable World, vol 5. Springer, Cham, pp. 33-70.**Doi**: 10.1007/978-3-319-11906-9_2

Shaaban, M.M.; El-Saady, A.M. and El-Sayed, A. B. (2010). Green microalgae water extract and micronutrients foliar treatments as promoters to nutrient balance and growth of wheat plants. Journal of American Science, 6(9):631-636.

Shah, P., Singh, N.K., Khare, N., Rathore, M., Anandhan, S., Arif, M., Singh, R.K., Das, S.C., Ahmed, Z. and Kumar, N.(2008) Agrobacterium mediated genetic transformation of summer squash (*Cucurbita pepo* L. cv. Australian green) with cbf-1 using a two vector system. *Plant Cell, Tissue and Organ Culture* 95, 363-371.**Doi**:10.1007/s11240-008-9450-5

Simonsson, M., Hillier, S. and Öborn, I.(2009) Changes in clay minerals and potassium fixation capacity as a result of release and fixation of potassium in long-term field experiments. *Geoderma* 151, 109-120.**Doi**: 10.1016/j.geoderma.2009.03.018

Sparks, D.L., Page, A.L., Helmke, P.A., Loeppert, R.H., Soltanpour, P.N., Tabatabai, M.A., Johnston, C.T. and Sumner, M.E. (1996) Methods of Soil Analysis Part 3—Chemical Methods. SSSA Book Series, Madison, WI.

Sun, C., Wang, D., Shen, X., Li, C., Liu, J., Lan, T., Wang, W., Xie, H. and Zhang, Y. (2020) Effects of biochar, compost and straw input on root exudation of maize (*Zea mays* L.): From function to morphology. *Agriculture, Ecosystems & Environment* 297, 106952.**Doi**: 10.1016/j.agee.2020.106952

Supraja, K.V., Bunushree, B. and Balasubramanian, P. (2020) Efficacy of microalgal extracts as biostimulants through seed treatment and foliar spray for tomato cultivation. *Industrial Crops and Products* 151, 112453.**Doi**: 10.1016/j.indcrop.2020.112453

Tamer, C.E., Incedayi, B., Yönel, S.P., Yonak, S. and Copur, O.U. (2010) Evaluation of several quality criteria of low calorie pumpkin dessert. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca* 38, 76-80.**Doi**: 10.15835/nbha3813557

Tarraf, S.S., Talaat, I.M., El-Sayed, A.B. and Balbaa, L.K. (2015). Influence of foliar application of algae extract and amino acids mixture on fenugreek plants in sandy and clay soils. *Nusanatar Bioscince*. 7(1) 33-37.**Doi:** 10.13057/nusbiosci/n070106

Verdone, M., Rao, R., Coppola, M. and Corrado, G.(2018) Identification of zucchini varieties in commercial food products by DNA typing. *Food Control* 84, 197-204.**Doi**: 10.1016/j.foodcont.2017.07.039.

Wahby, M., El-Sherbeny, S., Khalil, M., Naguib, N. and Aly, S. (2006) Growth characters and chemical constituents of *Dracocephalum moldavica* L. plants in relation to compost fertilizer and planting distance. *Scientia Horticulturae* 108, 322-331.**Doi**: 10.1016/j.scienta.2006.01.035

Wang, X., Mohamed, I., Ali, M., Abbas, M.H.H., Shah, G.M. and Chen, F.(2019) Potassium distribution in root and non-root zones of two cotton genotypes and its accumulation in their organs as affected by drought and potassium stress conditions. *J Plant Nutr Soil Sci.* 182,72-81. **Doi**: 10.1002/jpln.201800026

Wang, H.-Y., Shen, Q.-H., Zhou, J.-M., Wang, J., Du, C.-W. and Chen, X.-Q. (2011) Plants use alternative strategies to utilize nonexchangeable potassium in minerals. *Plant Soil* 343, 209-220.**Doi**:10.1007/s11104-011-0726-x.

Zhang, M., Riaz, M., Liu, B., Xia, H., El-desouki, Z. and Jiang, C. (2020) Two-year study of biochar: Achieving excellent capability of potassium supply via alter clay mineral composition and potassium-dissolving bacteria activity. *Sci Total Environ* 717, 137286.**Doi**: 10.1016/j.scitotenv.2020.137286

Zörb, C., Senbayram, M. and Peiter, E. (2014) Potassium in agriculture – Status and perspectives. *Journal of Plant Physiology* 171, 656-669.**Doi**:10.1016/j.jplph.2013.08.008