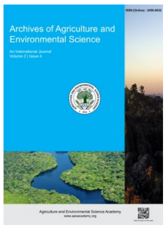
Archives of Agriculture and Environmental Science 5(2): 89-96 (2020)
https://doi.org/10.26832/24566632.2020.050202

e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



ORIGINAL RESEARCH ARTICLE

CrossMark

Foliar-applied Amcoton® and potassium thiosulfate enhances the growth and productivity of three faba beans varieties by improving photosynthetic efficiency

Salah M. Emam[1*] and **Wael M. Semida**[2]

[1]Department of Agronomy [2]Department of Horticulture, Faculty of Agriculture, Fayoum University, EGYPT
[*]Corresponding author's E-mail: sme00@fayoum.edu.eg

ARTICLE HISTORY

Received: 15 May 2020
Revised received: 23 May 2020
Accepted: 15 June 2020

Keywords

Amcoton®
Faba beans
Growth and productivity
Photosynthetic efficiency
Potassium thiosulfate

ABSTRACT

Amcoton® [a mixture of 0.45% naphthalene acetic acid and 1.25% naphthalene acetamide] and potassium thiosulfate (KTS) play a crucial role in growth and productivity enhancement of faba beans plants. The current study aimed to evaluate the potential impact of Amcoton® and KTS foliar application on growth, yield, and photosynthetic efficiency in three faba beans varieties (i.e. Giza-843, Nubaria-3, and Sakha-4) during 2016-17 and 2017-18 seasons. Results exhibited that Amcoton® and/or KTS significantly increased growth indices (e.g., plant height, number of leaves and branches, leaves area, shoot dry weight), yield component, and chlorophylls contents and photosynthetic efficiency in comparison with untreated control plants. Giza-843 showed significantly higher growth and productivity when compared to Nubaria-3 and Sakha-4. Seed yield significantly positive correlated with leaves area, chlorophyll content, plant height, number of branches, pods and seeds per plant, pod dry weight and biological yield. Results obtained through this study highlighted the potential impact of Amcoton® and/or KTS on enhancing the growth and productivity of faba beans plants by improving leaf chlorophylls contents and photosynthetic efficiency.

Citation of this article: Emam, S.M. and Semida, W.M. (2020). Foliar-applied Amcoton® and potassium thiosulfate enhances the growth and productivity of three faba beans varieties by improving photosynthetic efficiency. *Archives of Agriculture and Environmental Science*, 5(2): 89-96, https://dx.doi.org/10.26832/24566632.2020.050202

INTRODUCTION

Legumes are one of the most important nutritional groups for humans. It is considered as an essential meal in the dietary pattern for the poor and middle classes because of its high nutritional value. Beans and legumes are an excellent vegetable source of protein which is considered an alternative to animal protein in addition to increasing the fertility of the soil by increasing its content of nitrogen (Jeyabal and Kuppuswamy, 2001; Tharanathan and Mahadevamma, 2003). Faba bean are considered the first legume seed crop in Egypt in terms of the cultivated area, where green, dry seeds as well as pods are consumed. The annual production during the last 5 years was 138,239 tons in average (FAOSTAT, 2019).
The percentage of self-sufficiency of faba bean in Egypt in 2015 reached 30%, and Egypt imports 70% of its needs of faba bean, which are about 399 thousand tons (Amin and Attia, 2019). Therefore, attention must be paid to the cultivation of varieties that are acceptable to different environmental conditions in the old and new lands, and to follow all agricultural processes that contribute to increasing the yield of faba beans to bridge the gap between production and consumption under Egyptian conditions. The genetics installation of cultivated varieties plays an important role in expressing itself in different agricultural environments, so a number of varieties of Egyptian faba bean chosen to determine their productivity under arid region conditions in the Mediterranean basin region. Many researchers found a great influence of varieties on many growth and yield characteristics Saber (2016), Mohamed *et al.* (2018) and Abdel-Baky *et al.* (2019) confirmed the differences among genotypes under different conditions.
Bio-regulators such as naphthalene acetic acid (NAA) and naphthalene acetamide (NAD) have been used for the enhancement of growth and productivity of many crops (Bakhsh *et al.*, 2011;

Parveen *et al*., 2017; Rademacher, 2015; Taghipour *et al*., 2011). NAA and NAD belong to synthetic forms of Auxins, which play a key role in cell elongation, vascular tissue differentiation, root initiation, fruit setting and flowering (Vanneste and Friml, 2009). NAA, in comparison with other natural auxin, enhanced growth and productivity of cotton (Abro *et al*., 2004), rice (Zahir *et al*., 1998), wheat (Alam *et al*., 2002) and cereals (Lilani *et al*., 1991). Yield and quality of summer squash was positively affected when a mixture of NAA and NAD was foliarly applied for several time (Suleiman and Suwwan, 1990).

Potassium thiosulfate (KTS) contains 25% K_2O and 17% S and can be applied by drip, sprinkler or flood irrigation as well as a foliar treatment. Potassium (K) is well recognized as a key nutrient for enhancing productivity of field crops as well as vegetables and its content in vegetables has significant positive relationship with quality attributes (Behairy *et al*., 2015; Jifon and Lester, 2011). Potassium has a significant contribution in photosynthesis, enzyme activation, cell turgor maintenance and ion homeostasis (Bhandal and Malik, 1988). Imbalanced nutrition with K is becoming an important constraint to crop production in the developing countries. Depletion of plant-available K in soils results in a variety of negative impacts, including preventing optimum utilization of applied nitrogen and phosphorus fertilizers, decreasing farmers' income, threatens the yields of the cropping systems (Cakmak, 2010).

Following the literature reviewed, very limited information is available about the interactive effect of Amcoton® and KTS at a multiple years, large-scale field study and there potential role in enhancing growth and productivity of cultivated crops. Therefore, the main objective of the current study was to evaluate the effect of Amcoton® and/or KTS on growth and productivity of three faba beans varieties.

MATERIALS AND METHODS

Farm site and experimental layout

Two field experiments were carried out consecutively at Dar-Ramad experimental farm of the Faculty of Agriculture, Fayoum University, Egypt during the winter seasons of 2016-17 and 2017-18 to study the effect of 1.25 g/L Amc® and/or 3.75 cm^3/L KTS foliar application on growth and productivity of three faba beans varieties i.e., Giza-843, Nubaria-3, and Sakha-4. Soil physical and chemical characteristics were assessed according to the procedures described by Page *et al.* (1982) and Klute and Dirksen (1986) as shown in Table 1. The experimental layout was a split-plot system based on Randomized Complete Blocks design (RCBD) with three replications. Faba bean cultivars randomly occupied the main plots and Amcotone® and/or KTS foliar application were randomly allocated to the sub-plots.

Treatments

Amcotone® and/or KTS foliar application was performed at 35 and 50 days after sowing (DAS). The sub-plots area was 10.5 m^2 (3.0 × 3.5 m) and contained 5 ridges 60 cm in width. Experiment comprised of 12 treatments in total, which were the combinations of three *Vicia faba* varieties (Giza-843, Nubaria-3, and Sakha-4) and four foliar application treatments (Control, Amc® = 1.25 g/L Amcoton, KTS = 3.75 cm^3/L KTS, and Amc® + KTS). Healthy seeds of faba bean were sown on 1 and 6 November for the 1st and 2nd seasons respectively. Faba bean varieties were obtained from the Field Crop Research Institute, Agricultural Research Centre, Giza, Egypt, and were sown at the equivalent of 95 kg ha^{-1} to achieve the recommended planting density (22-25 plants/m). Calcium super phosphate (15.5% P_2O_5) fertilizer was applied as recommended. Faba bean seeds were planted in hills 25 cm apart in both ridge sides and prior to planting irrigation, a simulative dose of N (48 kg N ha^{-1}, ammonium nitrate 33.5% N) was added and seeds were inoculated with rhizobium as recommended. The preceding crop was sesame (*Sesamum indicum* L.) in the first season and maize (*Zea mays* L.) in the second one. This preceding crop may be influenced many nutrients availability in the soil. All other recommended agricultural practices for faba bean production were adopted throughout the growing seasons according to the bulletin of Egyptian Ministry of Agriculture (1210/2010).

Growth traits and yield measurements

Ninety-days-old plants (n=12) were removed carefully from each experimental plot, gently shaken to remove all adhering soil particles and plant height, numbers of leaves and branch $plants^{-1}$, and leaves and stem DW $plants^{-1}$ were measured. Leaves areas were determined using leaf area – leaf weight relationship as illustrated by (Semida *et al*., 2017). At harvesting, dry pods $plant^{-1}$ as well as biological yield from each experimental plot was weighted. Then dry seeds of faba bean were extracted and weighed to calculate seed yield, and 100-seed weight average.

Chlorophyll *a* fluorescence and photosynthetic pigments measurements

Chlorophyll fluorescence (*Fv/Fm*, F_v/F_0, and PI) was determined according to Maxwell and Johnson (2000) and Clark *et al.* (2000) using (Handy PEA, Hansatech Instruments Ltd, Kings Lynn, UK). Chlorophyll 'a', chlorophyll 'b', total chlorophyll and carotenoid concentrations were determined (in mg g^{-1} FW) according to the procedure given by Arnon (1949). Fresh leaf samples (0.2 g) were ground in mortar with 80% aqueous acetone. The extraction was filtered through center glass funnel, and then the filtrate was made up a known volume with acetone 80%. The optical density of the filtrate was measured at 663, 645 and 470 nm using a UV- 160A UV Visible Recording Spectrometer, Shimadzu, Japan.

Statistical analysis

The analysis of variance (ANOVA) technique for the split-plot arrangement was used to statistically analyzed all data as published by Gomez and Gomez (1984) using GenStat 12th edition software. LSD test was applied to test the treatment means differences at 5 and 1% probability level.

Table 1. Some initial physico-chemical properties of the experimental soil.

Properties	Unit	Value
Sand	%	10
Silt		20
Clay		20
Texture class		Clay
pH [at a soil: water (w/v) ratio of 1:2.5]		7.76
ECe (soil–paste extract)	dS m^{-1}	1.85
Organic matter	%	1.50
$CaCO_3$		4.30
Bulk density	g cm^{-3}	1.40
K_{sat}	Cm h^{-1}	1.2
FC	%	34.33
WP		19.73
AW		14.60

K_{sat}=Hydraulic conductivity FC=Field capacity, WP = wilting point, and AW= Available water.

RESULTS AND DISCUSSION

Effects of Amcoton® and/or potassium thiosulfate on growth traits of three faba beans varieties

Plant height, number of branches and leaves plant^{-1}, leaves and stem dry weight plant^{-1} as affected by cultivars, Amcoton® and/or KTS and their interaction were presented in Table 3. Giza-843 significantly exceeded the other cultivars in most previous traits except plant height in both seasons and number of branches plant^{-1} in the second one. Sakh-4 in the first season and Nubaria-3 in the second season gave the highest plant. Giza-843 cultivar produced the highest number of leaves and leaf area per plant and the heaviest dry weight of leaves and stem per plant, this trend was occurred in both seasons followed by Sakha-4. These results agree with the results obtained by Khafaga *et al.* (2009) under saline conditions and Abdellatif *et al.* (2012) who mentioned that the variety 'Giza 843' was the most drought tolerant variety among 8 genotypes as well as Abdel-Baky *et al.* (2019) who reported that Sakha-4 surpassed Nubaria-2 in all growth parameters.

Results of this study cleared that (Amc®+ KTS) was significantly higher than those other treatments. This treatment were excited control treatment by 38.03, 156.18, 73.90, 124.18, 130.45, and 188.77 % for plant height, number of branches and leaves per plant, leaf area plant^{-1} and dry weight of leaves and stem per plant in the first season respectively. These percentages were 53.08, 167.31, 103.79, 110.89, 144.80 and 123.04 % for the same characters in the second year respectively. Similar results was obtained by Mady (2009) who mentioned that foliar application with yeast extract significantly increased many growth aspects as number of leaves per plant, dry weights of both stems and leaves per plant and total leaf area as well, at 75 and 95 days after sowing during the two seasons as compared with the control treatments. In addition, Khafaga *et al.* (2009) stated that the effect of growth regulators (Thidiazuron, paclobutrazol and salicylic acid significantly recorded the highest growth parameters as compared to control. Data presented in Table 3 and Figure 1 showed that the interaction between the two factors under study was significant in leaves and stem dry weight plant^{-1} in both seasons and leaf area plant^{-1} in the first one. The cultivar Giza-843 recorded the highest values when treated by both Amc®+ KTS. Results are in the same line of those reported by Khafaga *et al.* (2009).

Effects of Amcoton® and/or potassium thiosulfate on chlorophyll *a* fluorescence and photosynthetic pigments of three faba beans varieties

The results in Table 4 showed that Giza-843 cultivar in the first season and Nubaria-3 cultivar in the second one avoid any abiotic stresses and consequently gave the highest values of F_v/F_m, F_v/F_0, and PI Whereas, Giza-843 cultivar was significantly transcend the other cultivars in both seasons for chlorophyll (a), chlorophyll (b), total chlorophyll and carotenoids contents. Giza 843 cultivar may be superior other cultivars due to the genetic composition which potential to withstand the environmental conditions in the cultivation area (Table 2). These results are in agreement with those obtained by Mohamed *et al.* (2018) and Abdel-Baky *et al.* (2019).

There is a highly significant effect of foliar spray of Amc® and/or KTS on photosynthetic efficiency (F_v/F_m, F_v/F_0, and PI) and pigments content of faba beans plants (Table 4). The combination between Amc® and KTS gave the highest leaf pigments content as compared to control treatment or Amc® and KTS alone (Table 4). It appears that this combination between the two compounds had a great influence on the leaf pigments content and plant performance index. These findings are in line with Khafaga *et al.* (2009) who mentioned that foliar spraying with yeast extract and Mohamed *et al.* (2018) who mentioned that foliar application by amino acid increased photosynthetic pigments. Table 4 and Figure 2 presented the interaction effect of cultivars and spraying treatments on faba bean plant. This interaction effect was significant on chlorophyll (a) and carotenoids content in the first season and chlorophyll (b) content in the second one. While, total chlorophyll content was significantly affected in both seasons. Mohamed *et al.* (2018) found that the interaction effect was significant on chlorophyll a and b while, carotenoids content was not affected.

Table 2. Source and pedigree of tested *Vicia faba* Egyptian cultivars.

Cultivars	Source	Pedigree
Nubaria-3	Egypt	Selected from Ahnacia line
Giza-843	FCRI	Cross-461 x cross-561
Sakha-4	FCRI	Sakha-1 x Giza-3

FCRI = Field Crops Research Institute, Agricultural Research Center, Giza, Egypt.

Table 3. Effect of Amcoton® (Amc®) and/or potassium thiosulfate (KTS) foliar application on growth characteristics of three faba beans varieties during 2016-17 (SI) and 2017-18 (SII) seasons.

Treatments	Plant height (cm)	No of branches plant^{-1}	No of leaves plant^{-1}	Leaves area plant^{-1} (cm^2)	Leaves DW plant^{-1} (g)	Stem DW plant^{-1} (g)
			SI			
Varieties (Var.)	*	ns	*	*	ns	ns
Nubaria-3	119.92b	2.92a	48.17b	1491.55b	35.02a	67.93a
Giza-843	117.33b	3.25a	61.17a	2146.59a	50.68a	83.76a
Sakha-4	127.42a	3.33a	53.33ab	1737.91ab	39.20a	80.30a
Treatments (T)	**	**	**	**	**	**
Control	100.22c	1.78d	37.89c	1026.03d	23.15d	38.74d
Amc®	120.44b	2.67c	48.78b	1688.57c	40.58c	67.95c
KTS	127.22b	3.67b	64.33a	2153.28b	49.46b	90.76b
Amc® + KTS	138.33a	4.56a	65.89a	2300.18a	53.35a	111.87a
Var. X T	*ns*	*ns*	*ns*	*	**	**
			SII			
Varieties (Var.)	ns	ns	*	*	**	*
Nubaria-3	121.25a	2.83a	46.00b	1488.34b	34.93b	58.12b
Giza-843	115.25a	3.17a	61.08a	2084.69a	48.12a	85.21a
Sakha-4	118.33a	2.67a	51.08ab	1696.40b	38.73b	75.95ab
Treatments (T)	**	**	**	**	**	**
Control	90.22c	1.56d	32.44c	1043.97c	23.35d	44.97d
Amc®	119.00b	2.33c	48.44b	1681.12b	37.05c	63.64c
KTS	125.78b	3.50b	63.89a	2099.20a	44.81b	83.46b
Amc® + KTS	138.11a	4.17a	66.11a	2201.62a	57.16a	100.30a
Var. X T	*ns*	*ns*	*ns*	*ns*	**	*

In each column, means followed by the same letter are not significantly different according to the LSD test ($P \leq 0.05$). ** and * indicate differences at $P \leq 0.05$ and $P \leq 0.01$ probability level respectively, and "ns" indicates not significant difference.

Table 4. Effect of Amcoton® (Amc®) and/or potassium thiosulfate (KTS) foliar application on photosynthetic efficiency (F_v/F_m, F_v/F_0, and PI) and pigments of three faba beans varieties during 2016/17 (SI) and 2017/18 (SII) seasons.

Treatments	F_v/F_m	F_v/F_0	PI	Chlorophyll 'a' (mg g^{-1} FW)	Chlorophyll 'b' (mg g^{-1} FW)	Total chlorophyll (mg g^{-1} FW)	Carotenoids (mg g^{-1} FW)
				SI			
Varieties (Var.)	ns	ns	ns	*	*	*	*
Nubaria-3	0.829a	4.87a	4.27a	10.41b	3.72b	17.23b	1.60b
Giza-843	0.833a	5.05a	5.70a	14.67a	4.82a	22.85a	2.18a
Sakha-4	0.818a	4.59a	4.29a	12.89ab	4.15b	19.81b	1.81b
Treatments (T)	**	**	**	**	**	**	**
Control	0.812b	4.38bc	2.98c	9.86d	3.38c	16.11d	1.49c
Amc®	0.821b	4.64bc	3.68c	12.03c	4.20b	19.48c	1.83b
KTS	0.832a	4.98b	5.33b	13.40b	4.25b	20.70b	1.97b
Amc® + KTS	0.842a	5.35a	7.02a	15.34a	5.09a	23.55a	2.17a
Var. X T	*ns*	*ns*	*ns*	**	*ns*	*	*
				SII			
Varieties (Var.)	ns	ns	ns	**	*	**	**
Nubaria-3	0.832a	5.02a	4.92a	10.29b	3.57b	16.41b	1.42b
Giza-843	0.831a	4.96a	4.91a	14.46a	4.35a	21.45a	1.98a
Sakha-4	0.826a	4.79a	4.36a	13.12a	3.57b	18.62b	1.65b
Treatments (T)	**	**	**	**	**	**	**
Control	0.813c	4.39c	2.80b	9.69d	3.07d	15.40d	1.44c
Amc®	0.828b	4.82b	3.82b	11.84c	3.56c	17.73c	1.59c
KTS	0.837ab	5.13a	4.01b	13.92b	3.75b	19.61b	1.75b
Amc® + KTS	0.842a	5.33a	7.28a	15.03a	4.95a	22.57a	1.96a
Var. X T	*ns*	*ns*	*ns*	*ns*	**	**	*ns*

In each column, means followed by the same letter are not significantly different according to the LSD test ($P \leq 0.05$). ** and * indicate differences at $P \leq 0.05$ and $P \leq 0.01$ probability level respectively, and "ns" indicates not significant difference.

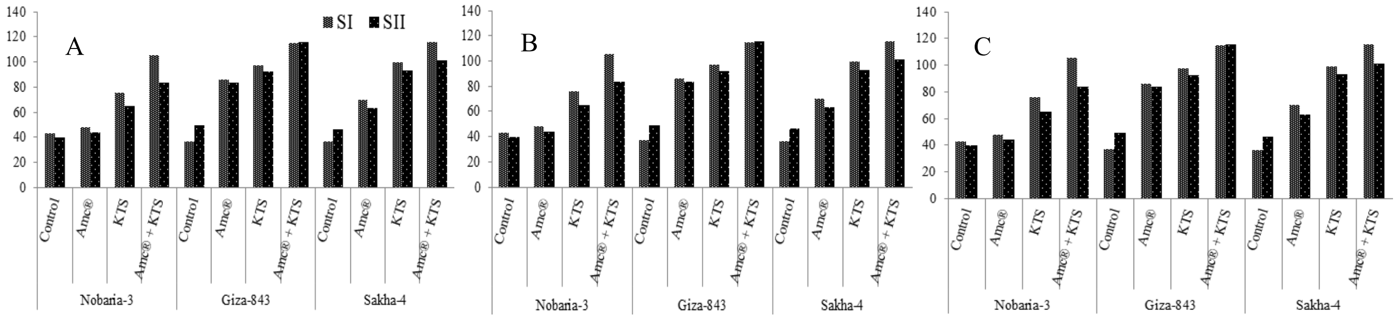


Figure 1. *Interactive effects of Amcoton® (Amc®) and/or potassium thiosulfate (KTS) foliar application on leaves area (A), leaves (B) and stem (C) dry weight of three faba beans varieties during 2016/17 (SI) and 2017/18 (SII) seasons.*

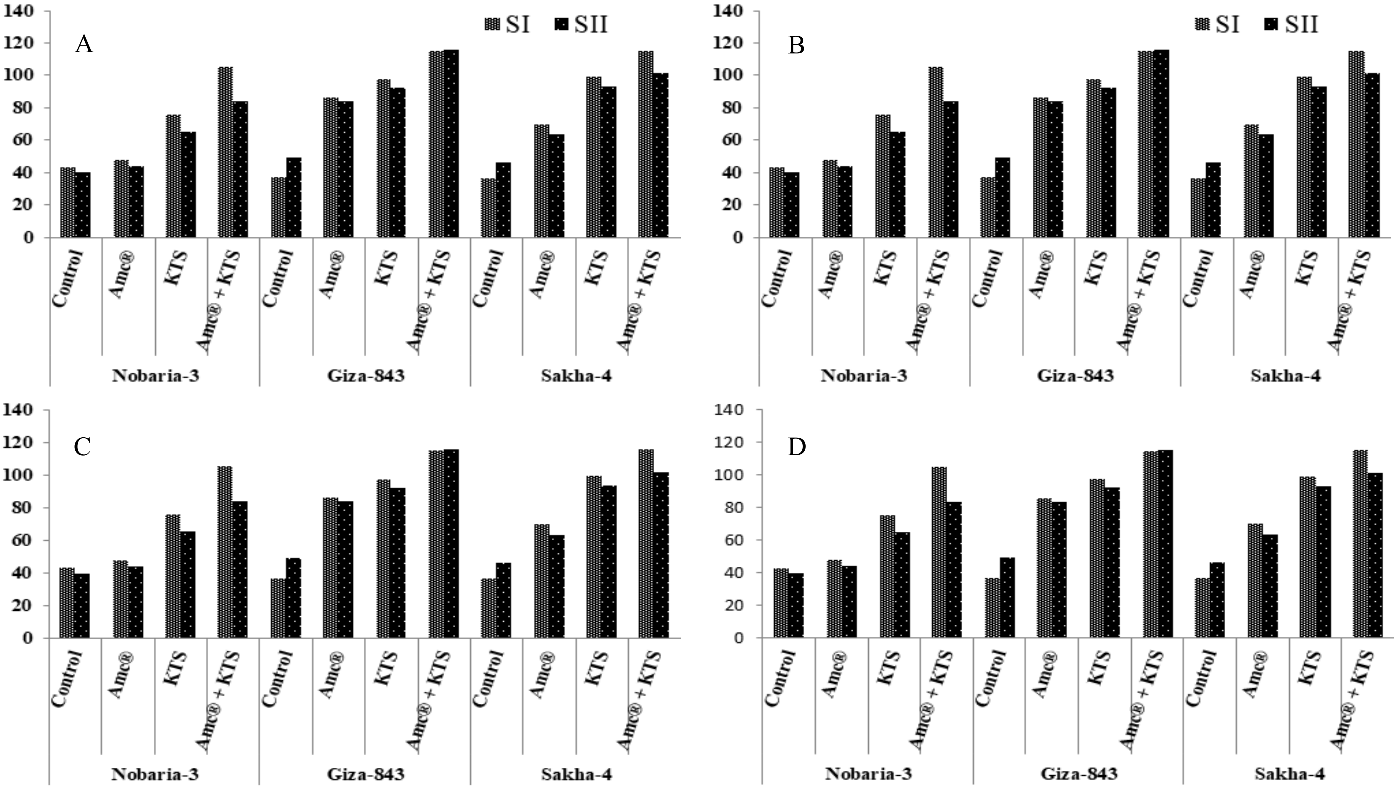


Figure 2. *Interactive effects of Amcoton® (Amc®) and/or potassium thiosulfate (KTS) foliar application on chlorophyll a (A), chlorophyll b (B), total chlorophyll (C), and carotenoids (D) of three faba beans varieties during 2016/17 (SI) and 2017/18 (SII) seasons.*

Effects of Amcoton® and/or potassium thiosulfate on yield and its components of three faba beans varieties

At maturity, faba bean traits i.e., number of pod plant^{-1}, pod dry weight plant^{-1}, number of seeds plant^{-1}, seed yield plant^{-1}, biological yield ha^{-1}, seed yield ha^{-1} and 100-seed weight as affected by Amc® and KTS foliar spraying were presented in Table 5. Except seed index, Giza-843 variety recorded the highest value of number of pods plant^{-1} (28.58 and 26.33), pod dry weight plant^{-1} (75.78 and 75.54 g), number of seeds plant^{-1} (71.08 and 69.42), seed yield plant^{-1} (63.63 and 59.73 g), biological yield (9.53 and 9.40 ton ha^{-1}) and seed yield ha^{-1} (5233.87 and 4686.19 kg ha^{-1}) in the two seasons, respectively. Sakha-4 variety significantly exceeded Nubaria-3 variety in seed yield. While, Nubaria-3 variety gave the heaviest 100-seed weight (105.37 and 101.62 g) in the first and second season, respectively. The variation among genotypes was noticed by many investigators among them Khafaga *et al.* (2009), Sharifi (2014), Saber (2016), and Mohamed *et al.* (2018). In addition, Abdel-Baky *et al.* (2019) found that Sakha-4 significantly transcend Nubaria-2 variety in seed yield. On the other hand, Bakry *et al.* (2011) and Hendawey and Younes (2013) in sandy soils, found that Giza-843 variety recorded the lowest seed yield and its components as compared by other varieties.

The data in Table 5 indicated that Amc® + KTS foliar spraying treatment exceeded all other treatments for yield and yield component traits at the two seasons. The increase percentage over control were (119.46 and 79.74), (64.80 and 62.60), (51.50 and 55.12), (89.90 and 99.71), (38.70 and 79.44), (33.61 and 36.07), and (5.78 and 14.43) for number of pod plant^{-1}, pod dry weight plant^{-1}, number of seeds plant^{-1}, seed yield plant^{-1}, biological yield ha^{-1}, seed yield ha^{-1} and 100-seed weight in the two seasons respectively. These results were in full agreement with those obtained by Khafaga *et al.* (2009) and Mady (2009). In addition, Mohamed *et al.* (2011) found that foliar application with potassium di-hydrogen orthophosphate had the greatest stimulatory effect on number of pods/plant seed yield/plant and seed index as well as biological and seed yield. Also, Saber (2016) stated that foliar application with mixture of both GA_3 and IAA treatments had positive effect on seed yield.

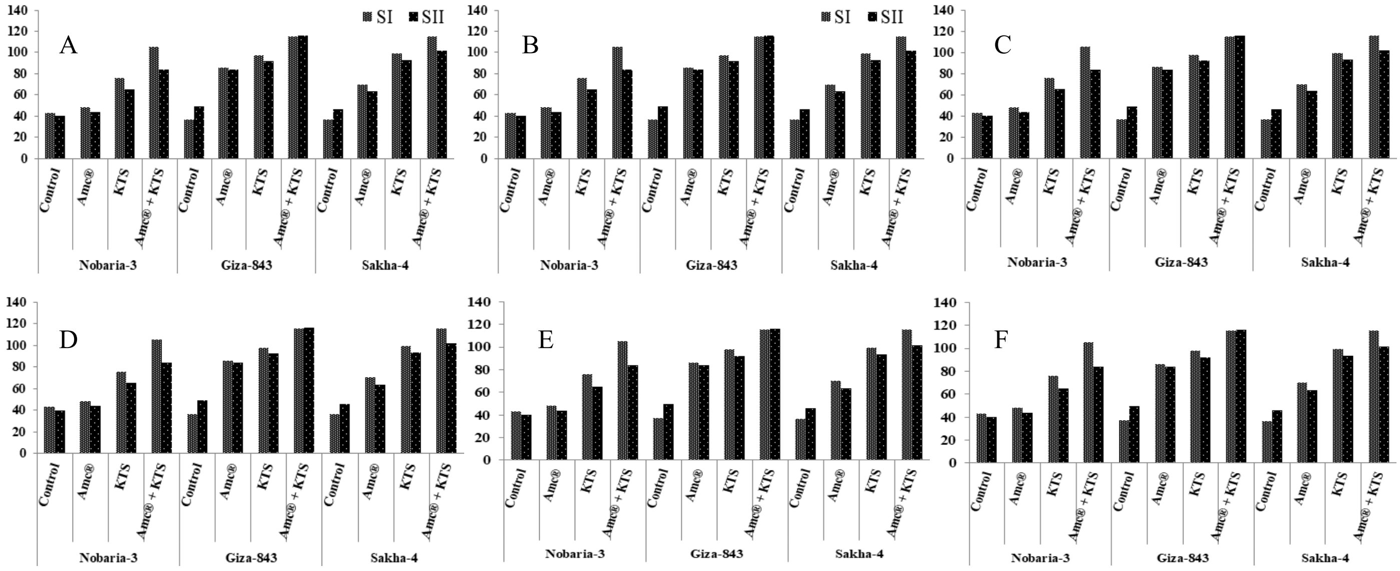


Figure 3. *Interactive effects of Amcoton® (Amc®) and/or potassium thiosulfate (KTS) foliar application on no. of pods (A), no of seeds (B), 100 seed weight (C), seed yield plant^{-1} (D), biological yield (E), and seed yield ha^{-1} (F) of three faba beans varieties during 2016/17 (SI) and 2017/18 (SII) seasons.*

Table 5. Effect of Amcoton® (Amc®) and/or potassium thiosulfate (KTS) foliar application on yield and its components of three faba beans varieties during 2016/17 (SI) and 2017/18 (SII) seasons.

Treatments	No. of Pods plant^{-1}	Pods DW plant^{-1} (g)	No. of seeds plant^{-1}	Seed yield plant^{-1} (g)	Biological yield (ton ha^{-1})	Seed yield (kg ha^{-1})	100 Seed weight (g)
				SI			
Varieties (Var.)	**	*	*	*	*	**	**
Nubaria-3	19.17c	60.22b	56.25b	45.65b	7.60b	3912.26b	105.37a
Giza-843	28.58a	75.78a	71.08a	63.63a	9.53a	5233.87a	88.33c
Sakha-4	22.58b	69.85a	60.83ab	55.70ab	8.12b	4983.04a	96.97b
Treatments (T)	**	**	**	**	**	**	**
Control	13.67d	48.81c	48.33c	36.72c	6.90c	4040.74d	93.84d
Amc®	22.44c	68.28b	60.33b	48.49b	8.00b	4530.13c	96.63c
KTS	27.67b	76.94a	68.00a	65.04a	9.19a	4869.21b	97.82b
Amc® + KTS	30.00a	80.44a	73.22a	69.73a	9.57a	5398.81a	99.26a
Var. X T	*	*	*ns*	**	**	**	**
				SII			
Varieties (Var.)	**	**	**	**	*	*	**
Nubaria-3	18.42c	58.88c	54.33c	43.84c	7.10b	3773.49b	101.62a
Giza-843	26.33a	75.54a	69.42a	59.73a	9.40a	4686.19a	88.13b
Sakha-4	21.08b	68.40b	65.42a	50.05b	7.78b	4127.46b	93.20b
Treatments (T)	**	**	**	**	**	**	**
Control	15.89d	51.63d	49.78d	34.34d	5.40c	3460.00c	86.01c
Amc®	19.89c	62.07c	59.22c	45.81c	7.90b	4118.20b	95.92b
KTS	23.44b	72.78b	66.00b	56.09b	9.40a	4496.51a	96.91ab
Amc® + KTS	28.56a	83.95a	77.22a	68.58a	9.69a	4708.15a	98.42a
Var. X T	**	*ns*	**	**	*	*ns*	*

In each column, means followed by the same letter are not significantly different according to the LSD test ($P \leq 0.05$). ** and * indicate differences at $P \leq 0.05$ and $P \leq 0.01$ probability level respectively, and "ns" indicates not significant difference.

Concerning the interaction, the data in Table 5 and Figure 3 show that the interaction between the two factors under study was significant for number of pod plant^{-1}, seed weight plant^{-1}, biological yield ha^{-1} and 100-seed weight in the two seasons. The significant effect was also observed for pod dry weight plant^{-1} and seed yield ha^{-1} only in the first season and number of seeds plant^{-1} in the second one. Similar results were reported by Khafaga *et al.* (2009), Saber (2016) and Mohamed *et al.* (2018). Who noticed a significant interaction between varieties and foliar substances for seed yield, While Mohamed *et al.* (2018) found no significant interaction for the number of branches and pods per plant as well as seed index.

Simple coefficients of correlation among seed yield traits in 2016/2017 and 2017/2018 seasons are given in Table 6. In both seasons, seed yield significantly positive correlated with LA plant^{-1}, chlorophyll traits, plant height, number of branches, pods and seeds per plant, pod dry weight and biological yield ha^{-1}. These results are in concordance with those reported by ALGhamdi (2007), Tadesse *et al.* (2011), and Sharifi (2014) who found significant positive correlation between faba bean seed yield and yield components. Table 7 showed that, there are two traits, i.e., total chlorophyll content and pod dry weight plant^{-1} in the 1st season and two ones, i.e., chlorophyll (a) content and biological yield ha^{-1} in the second one, were significantly (*P≤ 0.001*) contributed to variation in seed yield. Data revealed that 78.30% of the total seed yield ha^{-1} variations could be linearly related total chlorophyll content and pod dry weight plant^{-1} in 1st season and 80.60 % of chlorophyll (a) content and biological yield ha^{-1} in 2nd season.

Table 6. Simple correlation coefficient matrix in 2016/2017 (SI) (above diagonal line) and 2017/2018 (SII) (below diagonal line) of thirteen agronomic characters.

		LA	Chl. a	Chl. b	T. Chl.	Car.	PH	Bra. #	Pods #	Pods DW	Seeds #	Seed Y/P	Bio. yield	Seed yield
								SI						
LA	SII		0.806**	0.738**	0.847**	0.784**	0.688**	0.868**	0.947**	0.938**	0.915**	0.899**	0.812**	0.806**
Chl. a		0.833**		0.717**	0.947**	0.871**	0.545**	0.808**	0.846**	0.868**	0.866**	0.871**	0.825**	0.845**
Chl. b		0.695**	0.754**		0.878**	0.692**	0.490**	0.692**	0.774**	0.679**	0.686**	0.682**	0.704**	0.706**
T. Chl.		0.816**	0.940**	0.893**		0.924**	0.530**	0.813**	0.881**	0.861**	0.872**	0.860**	0.832**	0.853**
Car.		0.659**	0.758**	0.655**	0.872**		0.402*	0.725**	0.799**	0.817**	0.848**	0.805**	0.751**	0.788**
PH		0.665**	0.559**	0.609**	0.590**	0.409*		0.669**	0.688**	0.738**	0.589**	0.642**	0.537**	0.465**
Bra. #		0.825**	0.851**	0.796**	0.884**	0.733**	0.569**		0.852**	0.859**	0.834**	0.863**	0.767**	0.818**
Pods #		0.888**	0.894**	0.857**	0.927**	0.741**	0.594**	0.860**		0.942**	0.892**	0.889**	0.838**	0.805**
Pods DW		0.887**	0.905**	0.701**	0.860**	0.694**	0.691**	0.818**	0.866**		0.922**	0.911**	0.814**	0.840**
Seeds #		0.794**	0.887**	0.779**	0.885**	0.707**	0.627**	0.821**	0.888**	0.855**		0.924**	0.749**	0.784**
Seed DW		0.909**	0.894**	0.849**	0.918**	0.721**	0.695**	0.863**	0.954**	0.899**	0.885**		0.755**	0.791**
Bio. yield		0.861**	0.852**	0.760**	0.858**	0.689**	0.691**	0.860**	0.874**	0.859**	0.828**	0.882**		0.716**
Seed yield		0.812**	0.877**	0.734**	0.871**	0.729**	0.619**	0.819**	0.856**	0.832**	0.784**	0.840**	0.848**	

LA = Leaves area, Chl. a = Chlorophyll 'a', Chl. B = Chlorophyll 'b', T. Chl = Total chlorophyll, Car. = Carotenoids, PH = Plant height, Bra. # = No of Branches, Pods # =No of pods, Pods DW = Pods dry weight, Seeds # = No of seed, Seed Y/P = Seed yield/plant, Bio. Yield = Biological yield.
** and * indicate correlation is significant at the 0.01 level and at the 0.05 level respectively

Table 7. Correlation coefficient (r), coefficient of determination (R^2) and standard error of the estimates (SEE) for predicting seed yield (kg ha^{-1}) in 2016/2017 (SI) and 2017/2018 (SII) seasons.

Season	R	R^2	SEE	Sig.	Fitted equation
(SI)	0.885^b	0.783	405.64	**	Seed yield kg/ha^{-1}= 1811.39 + 112.56 Total chlorophyll + 81.79 pods dry weight $plant^{-1}$
(SII)	0.898^b	0.806	3.03.65	**	Seed yield kg/ha^{-1}= 1595.20 + 132.205 chlorophyll A + 115.14 biological yield ha^{-1}

Conclusion

Giza-843 exceeded other cultivars in most growth characteristics, chlorophyll content, and seed yield and its components, followed by Sakha-4 and finally Nubaria-3. Amcoton® and/or KTS foliar application had a significant effect on all studied characteristics compared to the control treatment. The best results were obtained when Amcoton® and KTS were applied together, followed by KTS or growth Amcoton® foliar application. There was a highly significant positive correlation between seed yield and many attributes studied. Data revealed that 78.30% of the total seed yield ha^{-1} variations could be linearly related to total chlorophyll content and pod dry weight $plant^{-1}$ in 1st season and 80.60 % of chlorophyll (a) content and biological yield ha^{-1} in 2nd season. Giza-843 variety gave the highest seed yield with Amcoton® and/or KTS foliar application. Furthermore, the results hint that Amcoton® and/or KTS may in future, find application as a potential growth and productivity enhancement of faba beans plants.

REFERENCES

Abdel-Baky, Y.R., Abouziena, H.F., Amin, A.A., El-Sh, M.R. and El-Sttar, A.A. (2019). Improve quality and productivity of some faba bean cultivars with foliar application of fulvic acid .*Bulletin of the National Research Centre*, 43: 1–11.

Abdellatif, K.F., El Sayed, A. and Zakaria, A.M. (2012). Drought stress tolerance of faba bean as studied by morphological traits and seed storage protein pattern .*Journal of Plant Studies*, 1: 47–54.

Abro, G.H., Syed, T.S., Unar, M.A. and Zhang, M.S. (2004). Effect of application of a plant growth regulator and micronutrients on insect pest infestation and yield components of cotton. *Journal of Entomology*, 1: 12–16, https://doi.org/10.3923/je.2004.12.16

Alam, S.M., Shereen, A. and Khan, M. (2002). Growth response of wheat cultivars to naphthalene acetic acid (NAA) and ethrel. *Pakistan Journal of Botany*, 2: 135–137.

ALGhamdi, S.S. (2007). Genetic behavior of some selected faba bean genotypes, in: African Crop Science Conference Proceedings. pp. 8:709-714.

Amin, S.T. and Attia, S.S. (2019). An economic study of the faba bean crop in Egypt (Beheira Governorate). *Journal of Agricultural Economics and Social Sciences* 10: 427– 436.

Arnon, D.I. (1949). Copper enzymes in isolated chloroplasts. Polyphenoloxidase in *Beta vulgaris*. *Plant Physiology*, 24: 1–15.

Bakhsh, I., Khan, H.U., Khan, M.Q. and Javaria, S. (2011). Effect of naphthalene acetic acid and phosphorus levels on the yield potential of transplanted coarse rice. *Sarhad Journal of Agriculture*, 27: 161–165.

Bakry, B.A., Elewa, T.A., El karamany, M.F., Zeidan, M.S. and Tawfik, M.M. (2011). Effect of row spacing on yield and its components of some faba bean varieties under newly reclaimed sandy soil condition .*World Journal of Agricultural Sciences*, 7: 68–72.

Behairy, A.G., Mahmoud, A.R., Shafeek, M.R., Ali, A.H. and Hafez, M.M. (2015). Growth , yield and bulb quality of onion plants (Allium cepa L.) as affected by foliar and soil application of potassium. *Middle East Journal of Agriculture*

Research, 4(1): 60–66.

Bhandal, I.S. and Malik, C.P. (1988). Potassium estimation, uptake, and its role in the physiology and metabolism of flowering plants. *International Review of Cytology*, 110: 205–254, https://doi.org/10.1016/S0074-7696(08)61851-3.

Cakmak, I. (2010). Potassium for better crop production and quality. *Plant and Soil*, 335: 1–2, https://doi.org/10.1007/s11104-010-0534-8

Clark, A.J., Landolt, W., Bucher, J.B. and Strasser, R.J. (2000). Beech (*Fagus sylvatica*) response to ozone exposure assessed with a chlorophyll a fluorescence performance index. *Environmental Pollution*, 109(3): 501–507.

FAOSTAT (2019). Food and agriculture data. Food and Agriculture Organization. https://doi.org//www.fao.org/faostat/en/#data/QC

Gomez, K.A. and Gomez, A.A. (1984). Statistical Procedures For Agricultural Research. John Wiley Sons Inc. pp 206-212.

Hendawey, M.H. and Younes, A.M.A. (2013). Biochemical evaluation of some faba bean cultivars under rainfed conditions at El-Sheikh Zuwayid. *Annals of Agricultural Sciences*, 58(2): 183–193, https://doi.org/10.1016/j.aoas.2013.07.010

Jeyabal, A. and Kuppuswamy, G. (2001). Recycling of organic wastes for the production of vermicompost and its response in rice-legume cropping system and soil fertility. *European Journal of Agronomy*, 15(3): 153-170, https://doi.org/10.1016/S1161-0301(00)00100-3

Jifon, J.L. and Lester, G.E. (2011). Effect of foliar potassium fertilization and source on cantaloupe yield and quality. *Better Crops*, 95(1): 13–15.

Khafaga, H.S., Raeefa, A.H., Hala, M.M. and Alaa, S.A. (2009). Response of two faba bean cultivars to application of certain growth regulators under salinity stress condition at siwa oasis. 1-Growth traits, yield and yield components. *Proceedings of the 4th Conference on Recent Technologies in Agriculture, Nov. 3-4, Cairo, Giza, Egypt*, pp: 236-249.

Klute, A. and Dirksen, C. (1986). Hydraulic conductivity and diffusivity. Laboratory methods. Methods soil Anal. - part 1. Phys. Mineral. methods 9: 687–734.

Lilani, A.T., Joshi, T. and Mishra, R.K. (1991). NAA-mediating growth and macro molecular changes in wheat primary leaf serial section. *Indian Journal of Plant Physiology*, 34: 311–318.

Mady, M.A. (2009). Effect of foliar application with yeast extract and Zinc on fruit setting and yield of faba bean (*Vicia faba* L) *Journal of Biological Chemistry and Environmental Sciences*, 4(2): 109–127.

Maxwell, K. and Johnson, G.N. (2000). Chlorophyll fluorescence - a practical guide. *Journal of experimental botany*, 51(345): 659–668.

Mohamed, H.Y., Mahmoud, A.A. and Abdel-Wahab, E.I. (2018). Influences of ridge width and foliar spraying of amino acids compounds on yield and quality of two faba bean cultivars. *Agricultural Sciences*, 9(12): 1629–1651, https://doi.org/10.4236/as.2018.912114

Mohamed, M.F., Mohamed, M.H., Hamouda, H.A. and Zeidan, M.S. (2011). Effect of urea foliar application and potassium dihydrogen orthophosphate on faba bean yield and quality in sandy soil *International Journal of Academic Research*, 3(6): 272–277.

Page, A.I., Miller, R.H. and Keeny, D.R. (1982). Methods of Soil Analysis, in: Part II. Chemical and Microbiological Methods, 2nd Ed. American Society of Agronomy, Madison, WI, USA, pp. 225–246.

Parveen, S., Iqbal, R.M., Akram, M., Iqbal, F., Tahir, M. and Rafay, M. (2017). Improvement of growth and productivity of cotton (*Gossypium hirsutum* L.) through foliar applications of naphthalene acetic acid. *Semina: Ciências Agrárias*, 38(2): 561–570, https://doi.org/10.5433/1679-0359.2017v38n2p561

Rademacher, W. (2015). Plant growth regulators: Backgrounds and uses in plant production. *Journal of plant growth regulation*, 34(4): 845-872, https://doi.org/10.1007/s00344-015-9541-6

Saber, R.A. (2016). Biochemical studies on the effect of GA3 and IAA on biochemical constituents of *Vici faba*. *International Journal of Approximate Reasoning*, 4: 871–877. https://doi.org/10.21474/ijar01/441

Semida, W.M., El-Mageed, T.A.A., Mohamed, S.E. and El-Sawah, N.A. (2017). Combined effect of deficit irrigation and foliar-applied salicylic acid on physiological responses, yield, and water-use efficiency of onion plants in saline calcareous soil. *Archives of Agronomy and Soil Science*, 63(9): 1227-1239, https://doi.org/10.1080/03650340.2016.1264579

Sharifi, P. (2014). Correlation and path coefficient analysis of yield and yield component in some of broad bean (*Vicia faba* L.) genotypes. *Genetika*, 46: 905–914, https://doi.org/10.2298/GENSR1403905S

Suleiman, F. and Suwwan, M. (1990). Effect of agritone on fruit set and productivity of summer squash (*Cucurbita pepo* L.) under plastic house conditions. *Advances in Horticultural Science*, 4: 83–89. doi:10.1400/13965.

Tadesse, T., Fikere, M., Legesse, T. and Parven, A. (2011). Correlation and path coefficient analysis of yield and its component in faba bean (*Vicia faba* L.) germplasm. *International Journal of Biodiversity and Conservation*, 3(8): 376–382.

Taghipour, L., Rahemi, M. and Assar, P. (2011). Thinning with NAA, NAD, ethephon, urea and by hand to improve fruit quality of "Gerdi" apricot. *Brazilian Journal of Plant Physiology*, 23(4): 279–284, https://doi.org/10.1590/S1677-04202011000400005

Tharanathan, R.N. and Mahadevamma, S. (2003). Grain legumes - A boon to human nutrition. *Trends in Food Science & Technology*, 14(12): 507–518, https://doi.org/10.1016/j.tifs.2003.07.002

Vanneste, S. and Friml, J. (2009). Auxin: A trigger for change in plant development. *Cell*, 136(6): 1005–1016. doi:10.1016/j.cell.2009.03.001.

Zahir, Z.A., Rahman, A., Asghar, N. and Arshad, M. (1998). Effect of an auxin precursor L-tryptophan on growth and yield of rice. *Pakistan Journal of Biological Sciences*, 1(4): 354–356.