J. Plant Production, Mansoura Univ., Vol. 9 (10): 821 - 831, 2018

Performance of Faba Bean Plants under different Irrigation Regimes and Foliar Application of Certain Growth Regulators in Toshka Area, Egypt

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ABSTRACT

In order to water deficit has become the major limiting factor on the productivity and sustainability of agriculture, especially in arid and semi-arid regions. It could be achieved through two field experiment were carried out during 2016-17 and 2017-18 seasons at the agricultural experimental station farm of Water Studies & Research Complex (WSRC), National Water Research Center, located in Toshka at Abu-Simbel Region, to investigate out the impact of irrigation water regimes (Ir_1=60, Ir_2=80 and Ir_3=100 % of ETc, which were applied using a sprinkler irrigation system) with the foliar applications of indole acetic acid (IAA) application (In_1=0, In_2=50 and In_3=75 ppm) and kinetin (Kn_1=0, Kn_2=20 and Kn_3=40 ppm) on growth, seed yield and quality of faba bean plants (Nubaria 1) as well as the water crop productivity (WCP). The experiment was laid out in strip-split plot design with 3 replications.The obtained results could be summarized as follows: Increasing the applied amount of irrigation water from 1458 (Ir_1) to 2430 m^3 fed^{-1} (Ir_3) gave the highest values of all growth characters, except plant height in average values of both seasons. Nevertheless, the application of 100 % ETc (Ir_3) resulted in increases in the values of yield and its attributes as well as P and K contents of seeds. The highest values of (WUE), (WCP) and seed quality (protein content) occurred with 60 % ETc (Ir_1) of irrigation water level. The growth traits, yield and its attributes, as well as chemical composition of faba bean values and water parameters increased with increasing IAA and kinetin concentrations to 75 and 40 ppm, respectively. With respect to the interaction of the three studied factors, Ir_3 (100 % ETc), In_3 (75 ppm) and Kn_3 (40 ppm) gave the highest values for plant height, leaf area index, total chlorophyll and No. of branches $plant^{-1}$.Seed yield was positively significantly and correlated to the leaf area index, total chlorophyll, root length, plant fresh and dry weights, No. of branches and leaves $plant^{-1}$, No. of pods $plant^{-1}$, 100-seed weight and pod yield $plant^{-1}$ whereas, the plant height was significantly negatively correlated to seed yield.Therefore, it is recommended to grow faba bean plants (Nubaria 1) with applying 2430 m^3 fed^{-1} of irrigation water and foliar spraying indole acetic acid (IAA) and kinetin at levels 75 and 40 ppm, respectively to obtain high seed yield and quality of faba bean.

Keywords: Faba bean, Irrigation, Growth regulators, yield, Chemical composition, WCP.

INTRODUCTION

Faba bean (Vicia faba L.) is a diploid species with 2n=12 chromosomes and member of the Fabaceae family. It is considered as one of the most important nutritive food legume winter crops in the world as well as Egypt. The total cultivated area of faba bean in Egypt was 83356 fed in 2015/2016 according to the Egyptian Ministry of Agriculture. Faba bean is consumed as a vegetable, either green or dried, fresh or canned and plays an important role in human nutrition as a cheap source of protein (25-40 %) especially in the diet of low-income people.

Uses of sustainable irrigation water have certainly become a global issue, to ensure a rapid growth of food crops, feed 9 billion people by 2050 (Mancosu *et al*., 2015). Egypt is located in the North of Africa which considered as an arid region, the average annual water availability levels have dropped to less than 700 m^3 $capita^{-1}$, and the issue of agricultural water uses has become a crucial one (Mohamed, 2018). Water is the most restricting normal source for the agricultural production in arid and semi-arid regions. Irrigation levels play an essential role in water utilization and consequently yield and quality of crops. The agriculture consumes about 80 - 90 % of the total water supply in Egypt. If it is used Surface freshwater adequately, the problem of water shortage would be alleviated. Faba bean plants are more sensitive to water deficit than other seed legumes including common bean, pea and chickpea (Abdellatif *et al*., 2012 and Ammar *et al*., 2014). Thus, water deficit limits its growth and production. The reduction in faba bean seed yield was positively related to the level of water reduction and reach down to 50 % (Ammar *et al*., 2014). Understanding the drought tolerance physiological mechanisms in faba bean are substantial to identify characters that are correlated with drought tolerance which they can be selected in breeding programs.

Therefore, recent genetic and breeding efforts have resulted in improved faba bean plant that are adapted to environmental stresses, high yield protein and seed free from major anti-nutritional factors (Alghamdi, 2009). The application of 0.60 ETc led to reducing vegetable growth traits, biological and seed yield as well as the seed quality while the same level of irrigation gave the highest values of WUE and WCP (Hegab *et al*., 2014 and Saleh *et al*., 2018).

Plant growth regulators (PGRs) help plants to adapt with changing environments, via mediating plant growth and development of nutrient allocation and source-sink transitions. Moreover, it is an important way in reducing flower abscission as well as completing formation processes. The plant response to PGRs may vary with species, varieties, environmental conditions, physiological and nutritional status, development stage and endogenous hormonal balance (Naeem *et al*., 2011). Plant growth regulators can affect the plant growth and development when it is used with a low concentration but inhibit the modified physiological process of the plant at high concentration (Atiia and Jaddoh, 1999). Indole acetic acid (IAA) has a wide range of effects on many processes such as cell division and plant growth by enlarging and increasing photosynthetic activities in plants (Naeem *et al*., 2004). It also activates the translocation of carbohydrates during their synthesis (Sadak *et al*., 2013). Spraying faba bean (*cv*. Nubaria 1) with IAA increased plant height, No. of branches $plant^{-1}$, No. of shedding flower, shedding percentage, No. of pods $plant^{-1}$, No. of seeds pod^{-1}, No. of seeds $plant^{-1}$, 100-seed weight, seed yield $plant^{-1}$ and seed yield (Kandil *et al*., 2011; Sadak *et al*., 2014; Mahdy and Abd El-Rheem, 2017 and Sharief and El-hamady 2017).

Foliar spraying of kinetin is a well-known process which improves plant growth and development, including cell division, nutrient mobilization, vascular differentiation, chloroplast biogenesis and anthocyanin production even grown under environmental stress (Davies, 2004 and El-Nasharty *et al*., 2017).

Furthermore, foliar application of kinetin enhances flowering and delays leaf senescence (Shah, 2007). Sadak *et al*., (2013) reported that the foliar application of 75 mg L^{-1} kinetin on faba bean plants led to an increase in plant height, No. of branches $plant^{-1}$, No. of shedding flowers, shedding percentage, No. of pods $plant^{-1}$, No. of seeds pod^{-1}, No. of seeds $plant^{-1}$, 100-seed weight, seed yield $plant^{-1}$, protein percentage and seed yield fed^{-1}.

This study aims to investigate the effect of three irrigation regimes and foliar spray of three IAA and/or kinetin concentrations on growth, biochemical constituents, yield and its components, of faba bean (Nubaria 1) to recommend the best treatments under the environmental conditions of Toshka, Egypt.

MATERIALS AND METHODS

1- Location and Objective:

Tw field experiments were carried out in the Agricultural Experimental Station farm of Water Studies & Research Complex (WSRC), National Water Research Center, located at Abu-Simbel Toshka region, during two successive winter seasons of 2016-17 and 2017-18. The experiments aimed to evaluate the influence of irrigation regimes, some growth regulators and their interaction on growth, seed yield and quality of faba bean, Nubaria 1 cultivar.

Physical and chemical soil and water characteristics (Tables 1 and 2) respective were determined according to Chapman and Pratt (1982), Page *et al*. (1982) and Klute (1986).

Meteorological data which were obtained from Meteorological WSRC station, National Water Research Center, Abu Simbel Toshka, Egypt during the two growing seasons are shown in Table 3.

Table 1. Some physical and chemical properties of the experimental soil.

Soil Depth (cm)	Sand	Silt	Clay	Soil texture	OM (%)	$CaCO_3$ (%)	pH (1:1) soil extract	EC (dS m^{-1}) (1:1) soil extract
		%						
0-20	87.28	8.22	4.50		0.40	4.73	7.65	0.50
20-40	87.35	5.30	7.36	Loamy sand	0.48	3.70	7.91	0.43
40-60	87.22	6.50	6.28		0.31	2.35	7.93	0.39
Soil	Soluble cations and anions (meq L^{-1})							
Depth (cm)	Na^+	K^+	Ca^{+2}	Mg^{+2}	Cl^-	CO_3^{--}	HCO_3^-	SO_4^{--}
0-20	1.6	0.23	1.8	1.07	1.7	0.0	2.0	1.02
20-40	1.5	0.22	1.6	0.55	1.4	0.0	1.8	0.67
40-60	1.4	0.21	1.7	0.67	1.3	0.0	1.64	1.02

Table 2. Some chemical analysis of the irrigation water.

pH	EC dS m^{-1}	Ions (meq L^{-1}) Na^+	K^+	Ca^{++}	Mg^{++}	Cl^-	CO_3^{--}	HCO_3^-	SO_4^{--}	SAR
6.70	0.80	3.4	0.1	2.6	1.8	3.2	1.8	1.6	1.3	2.30

Table 3. Meteorological data of Toshka region averaged for 2016-17 and 2017-18 seasons.

Month	Combined data of 2016-17 and 2017-18 seasons					
	Temperature (C°) Max.	Temperature (C°) Min.	Relative Humidity (%)	Wind speed (m sec^{-1})	Sunshine (hour)	ETo (mm day^{-1})
November	29.24	9.45	33.34	2.05	10.90	4.75
December	30.40	5.30	38.84	2.56	10.60	5.22
January	24.76	10.08	43.92	2.77	10.70	4.55
February	29.75	11.93	29.90	3.72	11.17	7.01
March	31.11	14.44	26.12	2.95	11.70	7.32
April	37.70	20.33	11.65	3.10	12.25	9.48

Max = maximum, Min = minimum Eto = Reference evapotranspiration (mm day^{-1})

2- Experimental Design and Treatments:

The experiments were laid in a randamized complete block design (RCBD) using strip-split plot arrangement with three replication. Irrigation regime (Ir) at three levels (I_{r1}=60, Ir_2=80 and Ir_3=100 % ETc of total amount of water applied 1458, 1944 and 2430 m^3 fed^{-1}, respectively) were represented in the vertical plots, and IAA concentrations (In_1=0, In_2=50 and In_3=75 ppm) were allocated in the horizontal plots. On the other hand, the subplots were devoted to Kinetin (Kn) concentrations (Kn_1=0, Kn_2=20 and Kn_3=40 ppm). Table 4 presents the chemical formula, molecular weight and solubility of growth regulators used in the study.

Table 4. Characteristics of growth regulators.

Name	Chemical formula	Molecular weight	Solubility
Indole-3 acetic acid (IAA)	$C_{10}H_9NO_2$	175.2	IN NaOH/96% ethanol
Kinetin	$C_{10}H_9N_5O$	203.3	IN NaOH/IN HCL, heat lightly
IAA and kinetin was obtained from Lab Egypt Supplies company, Egypt			

The plot area was 10.5 m^2 (3 meter × 3.5 meter with 60 cm apart between rows). Certified seeds of faba bean (cv. Nubaria 1) obtained from Legumes Crops Research Department, Agriculture Research Center, Giza, Egypt were sown (2 to 3 seeds in a hole) on one side of the ridge with 20 cm spacing. Seeds were grown in 20^{th} November at the rate of 60 kg fed^{-1} during the two growing seasons. After germination, the plants were thinned to two plants $hill^{-1}$ after 15 days from planting. Phosphorus and potassium fertilizers in the form of calcium superphosphate (15.5 % P_2O_5) and potassium sulfate (48 % K_2O), respectively were added during the seedbed preparation at the level of 31 and 24 kg fed^{-1}, respectively, moreover N fertilizer as ammonium nitrate (33.5 % N) was added at the level of 80 kg N fed^{-1} in two equal doses, the first dose was applied after 15 days from sowing and the second one after 25 days from sowing.

Fixed sprinkler irrigation system was used with the use of cubic meter calculator to estimate amounts of irrigation water.

The preceding summer crop was maize in both seasons. The plants were sprayed twice at 45 and 70 days from sowing with freshly prepared solutions of IAA and kinetin at different levels individually. Meanwhile, untreated plants were sprayed with distilled water to serve as a control. All the cultural practices for growing faba bean were adopted as they were recommended by the Ministry of Agriculture in the region of the study except the factors under study.

3- Sampling and data recorded:

1- **Vegetative growth characters:** Five plants were randomly chosen from the central row of each plot after 85 days from sowing in the two respective seasons to estimate the mean value of some characters such as plant height (cm), leaf area index, root length (cm), number of branches $plant^{-1}$, number of leaves $plant^{-1}$, plant fresh weight (g) and plant dry weight (g).
2- **At the same stage (85 days after sowing):** The total chlorophyll content was estimated using a chlorophyll meter (SPDS), Model SPAD 402 according to Mielke and Schaffer (2010).
3- **At harvest (120 days after sowing)** a sample of ten random guarded plants from each plot were used to record yield and yield components characters i.e. numbers of pods $plant^{-1}$, pods yield $plant^{-1}$ (g) and 100-seed weight (g). The whole plot was harvested to determine seed yield (ton fed^{-1}).
4- **For chemical constituents**, after the harvest process seeds were dried in open air avoiding sunlight to evaluate their contents of N, P and K. Total N and P contents were determined using the micro Kjeldahl method and colorimetrically using spectrophotometer, respectively, according to by Cottenie (1980). Crud protein was calculated from the total N × 6.25. Potassium content was determined by flame photometer method (Chapman and Pratt, 1982).
5- **Crop-irrigation efficiencies:**

The total amount of irrigation water and crop evapotranspiration (ET_{crop}) for faba bean plants was calculated according to Allen *et al.* (1998) as follow.

$$IR = (ET_o \times K_c) + LR \times 4.2 / Ea \quad (m^3\ fed^{-1}\ day^{-1})$$

Where: **ET_o= reference evapotranspiration mm day^{-1} (ET crop using weather data from the laboratories unit in Toshka), IR= irrigation requirement for faba bean m^3 fed^{-1} day^{-1}, K_c= crop coefficient for faba bean (0.5 for initial, 1.15 for developmental, 0.30 for maturity stages) by Penman-Monteith method equation (Allen *et al.*, 1998), LR= leaching requirement (assumed 20 % of the total applied water) and Ea=irrigation efficiency (75 %). The lengths of faba bean development stages for various planting periods and climatic region, which were 20, 30, 35 and 15 days for initial, development, mid and maturity, respectively. Irrigation frequency was carried out every other day throughout sprinkler irrigation system.**

The total amount of irrigation water applied was 1458, 1944 and 2430 m^3 fed^{-1}, calculated as 60, 80 and 100 % of evapotranspiration, respectively.

1) **Water use efficiency (WUE, kg m^{-3} water applied):** for the examined treatments reflects the capability of water applied in producing the crop yield according to Jensen (1983) as follows.

$$WUE = \frac{\text{seeds yield } (kg\ fed^{-1})}{\text{water applied } (m^3\ fed^{-1})}$$

2) **Water crop productivity (WCP, kg m^{-3} consumed water)** from irrigation unit (WCP) for seeds was calculated according to FAO, (2012) as follows:

$$CWP = \frac{\text{seeds yield } (kg\ fed^{-1})}{\text{seasonal consumptive use } (m^3\ fed^{-1})}$$

4- Statistical analysis:

Data were subjected to the analysis of variance (ANOVA) and after confirmation of errors homogeneity, the combined analysis over the two seasons was according to Gomez and Gomez (1984) and the least significant differences test (LSD) between treatments were done at 0.05 level of probability. All means were verified according to waller and Duncan (1969). Simple correlation coefficients between seed yield and agronomic parameters were computed according to the method described by Steel and Torrie (1980).

RESULTS AND DISCUSSION

A- Effect of irrigation regime:

Tables 5 to 8 showed significant influences of irrigation regime on plant height, root length, total chlorophyll, No. of branches $plant^{-1}$, No. of leaves $plant^{-1}$, plant fresh weight and plant dry weight of faba bean as averages of the two seasons. The irrigation at 100 % of ETc (Ir_3) gave the lower plant height, longer root, greater leaf area index, more total chlorophyll, more No. of branches accompanied with more No. of leaves $plant^{-1}$ and the higher weight fresh and dry of plant in both seasons compared to the irrigation at 60 % of ETc (Ir_1). It exhibited mean values of 14.20 cm for root length, 4.37 for leaf area index, 57.81 for total chlorophyll, 5.15 for No. branches $plant^{-1}$, 96.62 for No. of leaves $plant^{-1}$, 327.24 g for plant fresh weight and 153.59 g for plant dry weight. On the other hand, the lowest values of growth parameters were more pronounced when 60 % of ETc was applied to Nubaria 1 variety. The increase in growth attributes at 100 % ETc may be due to the increase in soil moisture availability which in turn increase the absorption of water and the uptake of nutrients leading to an increase in the photosynthetic rate which resulted in growth increases (Gunes *et al.*, 2008). Faba bean irrigated with 100 % ETc might be a suitable treatment for achieving efficient faba bean crop. The total chlorophyll was significantly reduced with decreasing the irrigation regime in both growing seasons, which mainly might be due to the production of reactive oxygen species that deteriorate the chloroplasts (Gill and Tuteje, 2010). Similar findings were also reported by Hegab *et al*. (2014); El- Harty (2016), El-Shiekh *et al*. (2016); Gupta *et al*. (2017) and Sarkar *et al*. (2017).

Yield parameters such as No. of pods plant^{-1}, pods yield plant^{-1}, 100-seed weight and seed yield of faba bean significantly affected due to irrigation regims (Tables 9 and 10). Irrigation regime Ir_3 (100 % ETc) recorded the maximum No. of pods plant^{-1} (20.24 pod), pods yield plant^{-1} (58.27 g), 100-seed yield (91.30 g) and (1.23 ton fed^{-1}) for seed yield. It was followed by Ir_2 treatment (80 % ETc) and the minimum values of these characters were found under the irrigation regime Ir_1 (60 % ETc). This could be attributed to the fact that the increased amount of applied water during the vegetative and reproductive growth of faba bean enhances the photosynthesis resulting in more synthesis and accumulation of food material which leads to higher yield and its components.

These results are in an agreement with those reported by Erdem *et al*. (2006) who explained that increasing the available soil moisture contributed to the increasing various physiological processes, better of nutrient uptake, higher rates in the photosynthesis which might be reflected on higher values of yield and its components. Similar results were also reported by Hegab *et al*. (2014), El-Harty (2016), El-Shiekh *et al*. (2016), Gupta *et al*. (2017) and Sarkar *et al*. (2017).

The irrigation regime exhibited significant differences for all chemical composition of seed faba bean plants except P % that had no significant effect (Tables 11 and 12). The highest contents of N (4.97 %) and protein (31.06 %) were at irrigation regime of 60 % ETc (Ir_1) followed by 80% ETc (Ir_2) but the lowest N values were obtained using 100 % ETc (Ir_3). However P and K concentrations in seeds increased significantly with increasing irrigation regime especially under the 100 % ETc treatment (Ir_3), their values were 0.34 % for P and 1.42 % for K in faba bean seeds. The plants irrigated with the lowest irrigation water regime (60 %ETc) had the lowest percentage of P and K at 0.31 and 1.20 %, respectively.

There were increases in the mean values of N and protein percentage of seeds with the lowest water supply i.e. seeds of 60 % ETc (Ir_1) and 80%ETc had more N and protein % compared with 100 % ETc (Ir_3) treatment that might be due to the fact that plants under the 60 and 80 % ETc treatments had lower seeds plant^{-1} than those of 100 % ETc high-level irrigation regime. High photosynthetic among plants is expected when irrigated with 100%ETc compared to the plants irrigated with 60 and 80 %ETc regimes. The seeds of these plants are also expected to have lowest N and protein values. These results are in harmony with Salem (2009), Siam *et al*. (2016), Megawer *et al*. (2017) and Saleh *et al*. (2018).

B- Effect of indole acetic acid (IAA):

Spraying of 75 ppm of IAA as the foliar application had a significant effect on growth attributes of faba bean plants (Tables 5 to 8). The treatment of 75 ppm IAA gave high values of growth parameters of faba bean which were 58.04 cm for plant height, 13.31cm for root length, 4.18 for leaf area index, 50.81 for total chlorophyll, 4.48 for No. of branches plant^{-1}, 85.37 leaf for No. of leaves plant^{-1}, 221.31 g for plant fresh weight and 92.72 g for plant dry weight. On the contrary, the lowest values of growth parameters were found for the control treatment (0.0 ppm IAA). These increases in growth attributes are due to the application of IAA that may cause an elongation in the primary cells of the young tissues, enlarging leaves and increasing photosynthetic activities (Naeem *et al*., 2004). These increments in growth parameters under the influence of IAA treatments are similar to those reported by Ibrahim *et al*. (2007) on faba bean, Fawzy *et al*. (2011) on snap bean, Eleiwa *et al*. (2013) on barley, Kaya *et al*. (2013) on maize and Sharief and El-hamady (2017) on faba bean.

Tables 9 and 10 indicated that the IAA application of In_3 significantly increased the yield and its components of faba bean plants *i.e*., 15.87 pods for No. of pods plant^{-1}, 58.27g for pod yield plant^{-1}, 91.30g for 100-seed weight and 1.08 ton fed^{-1} for seed yield than the control treatment (In_1). Therefore, the highest values of yield and its components were obtained by 75ppm of IAA (In_3), followed by (In_2). Generally, the obtained increase of the seed yield due to the foliar spraying of IAA could be attributed to the more increases in growth characteristics (Tables 5 to 8), which might provide more vegetative area and increases in pod set %, reduction in abscission % and increases in the No. of seeds pod^{-1}. Thus, the increase in all substances and bio-constituents synthesis and their translocation from leaf and different organs of plants up to seed production (Zewail, 2011). Similar conclusions were reported by Ibrahim *et al*. (2007), Fawzy *et al*. (2011), Kandil *et al*. (2011), Sadak *et al*. (2013), Sharief and El-hamady, (2017).

Results presented in (Tables 11 and 12) revealed that the seeds produced from the plants treated with IAA at 75 or 50 ppm treatments had significant increases in N, P, K and protein contents compared to those obtained from the untreated plants. The seeds produced from plants treated with IAA at 75 ppm treatments possessed the highest values of 4.84 % for N, 29.86 % for protein, 0.37 % for P and 1.39 % for K as averages of both seasons. Thereby, the increase in chemical composition of seeds due to applying the IAA may be due to its role on regulating ions and modifying the uptake movement and metabolism of nutrients within the plant tissues, besides activating the photosynthetic process through their effect on some enzymatic actions, leading to the increase in protein accumulation. Foliar application different growth regulators to snap bean with led to an obvious increase in the endogenous content of nutrients and chemical composition (Fawzy *et al*., 2011). Similar results were obtained by Bardisi, (2004) on pea as well as Ibrahim *et al*. (2007), Sadak *et al*. (2013), Mahdy and Abd El-Rheem, (2017) and Sharief and El-hamady, (2017) on faba bean.

C- Effect of kinetin:

Regarding the applied effect of kinetin as a foliar spray on growth parameters of faba bean, significant increases in the growth parameters occurred compared to the control treatment, results are presented in (Tables 5 to 8).

Generally, it might be stated that spraying faba bean plants with kinetin at a level of 40ppm significantly exceeded plant height by 9.85 %, root length by 59.87 %, leaf area index by 33.97 %, total chlorophyll by 5.34 %, No. of branches plant^{-1} by 8.9 %, No. of leaves plant^{-1} by 7.50 %, plant fresh weight by 8.06 % and plant dry weight by 11.41% over the control treatment as averages of both seasons. Conversely, the lowest values of growth parameters were obtained from the control treatment (0.0 ppm Kinetin). The increments in growth parameters such as plant height, plant fresh and dry weight of faba bean plants (cv. Nubaria 1) may be due to the role of kinetin in increasing cell division in apical meristems and cambium and stimulating xylem differentiation. Therefore, more absorption of water and nutrients from the soil, which is reflected on these characters. Plant height, No. of branches plant^{-1}, No. of leaves plant^{-1} and earliness significantly enriched with the foliar spraying of 75 mg L^{-1} kinetin (Sadak, 2013). In this respect, other researchers reported that faba bean growth characters increased due to foliar spraying of kinetin as reported by Shah, (2007), El-Nasharty *et al*. (2017), Mahdy and Abd El-Rheem, (2017) and Sharief and El-hamady, (2017).

Increasing the kinetin concentration from 0.0 to 40 ppm led to increasing yield and yield components (Tables 9 and 10). However, kinetin foliar spray significantly influenced all the parameters of faba bean yield and its components. The Kn_3 treatment (40 ppm) gave high values of 14.81 pod for No. of pods plant^{-1}, 47.97g for pod yield plant^{-1}, 86.97g for 100-seed weight and 1.05 ton fed^{-1} for the seed yield of faba bean plants. These results might be a reflection of the promotive effect of kinetin on growth parameters (Tables 5 to 7), which could lead to increase in the yield of faba bean. In this respect, the capacity of the kinetin to regulate the source-sink relationship may play an important role in greater crop yield, by setting pods, the individual weight of the seeds and increasing dry matter accumulation in the grains during the phenological phase (Passos *et al*., 2011). The obtained results of kinetin foliar spray treatments are in harmony with those of Shah (2007), Ammanullah *et al*. (2010), Sadak *et al*. (2013), El-Nasharty *et al*. (2017), Mahdy and Abd El-Rheem, (2017) and Sharief and El-hamady, (2017).

Tables 11 and 12 revealed that the seeds produced from the plants treated with kinetin at 40 and 20 ppm treatments had significant increases in N, P, K and protein contents compared to those obtained from the untreated plants. The seeds produced from plants treated with kinetin at 40 ppm treatments possessed the highest values of 4.76 % for N, 29.75 % for protein, 0.34 % for P and 1.33 % for K as averages of both seasons. Thereby, the increase in chemical composition of seeds due to applying the kinetin may be due to its role on regulating ions and modifying the uptake movement and metabolism of nutrients within the plant tissues, besides activating the photosynthetic process through their effect on some enzymatic actions, leading to the increase in protein accumulation. Foliar application different growth regulators to snap bean with led to an obvious increase in the endogenous content of nutrients and chemical composition (Fawzy *et al*., 2011). Similar results were obtained by Bardisi, (2004) on pea as well as Ibrahim *et al*. (2007), Sadak *et al*. (2013), Mahdy and Abd El-Rheem, (2017) and Sharief and El-hamady, (2017) on faba bean.

D- Effect of interaction:

The results of this work indicated that interaction of irrigation regime × IAA had a significant effect on vegetative growth characteristics (Tables 5 to 8). The highest growth parameters of faba bean plants were recorded using 100 % ETc with the application of 75 % IAA, with mean values of 14.85cm for root length, 4.79 for leaf area index, 60.01 for total chlorophyll, 5.89 for No. of branches plant^{-1}, 101.77 for No. of leaves plant^{-1}, 342.56 g for plant fresh weight and 168.38g for plant dry weight. Concerning the interaction effect of Ir×Kn, results presented in (Tables 5 to 8) showed that the highest average values of leaf area index (4.72), total chlorophyll (58.96), No. of branches plant^{-1} (5.42), No. of leaves plant^{-1} (99.38), plant fresh weight (332.25 g) and plant dry weight (159.48 g) were resulted from using 100 % ETc (Ir_3) and foliar spraying of kinetin at 40ppm (Kn_3). Conversely, the lowest averages of these characters produced from the $Ir_1 \times Kn_1$ treatment. The interaction of the foliar spray of IAA and Kinetin concentrations results (Tables 5 to 8) revealed that plant height, leaf area index, total chlorophyll, No. of branches plant^{-1} and fresh and dry weight plant^{-1} significantly affected as averages of both seasons. However, the results showed non-significant effect due to the In×Kn interaction on the No. of leaves plant^{-1}. All the values of the vegetative growth characters surpassed due to the $Ir_3 \times In_3 \times Kn_3$ interaction except plant height. In general, it can be noted that the highest mean values of vegetative growth parameters were obtained from interaction of 100 % ETc (Ir_3), 75 ppm IAA (In_3) and 40ppm kinetin (Kn_3).

The No. of pods plant^{-1}, pod yield plant^{-1}, 100-seed weight significantly influenced by the Ir×In interaction, while this effect was not significant on seed yield (Tables 9 and 10). The highest values of 22.77 pods for No. of pods plant^{-1}, 63.09 g for pod yield plant^{-1} and 98.52 ton fed^{-1} for 100-seed weight were obtained from plants treated with 100 % ETc and foliar sprayed with IAA at a concentration of 75 ppm ($Ir_3 \times In_3$). On the other hand, the lowest averages of these characters were obtained using $Ir_1 \times In_1$ treatment in average of the both seasons.

The 100-seed weight was also affected by the Ir×Kn interaction. Moreover, the highest value of 100-seed weight (97.85 g) was recorded using 100 % ETc and kinetin addition at a level of 40 ppm ($Ir_3 \times Kn_3$). On the other hand the lowest 100-seed yield (76.72 g) was obtained using 60 % ETc and without adding kinten ($Ir_1 \times Kn_1$). The interaction influences of irrigation regimes, IAA and kinetin were illustrated in Tables 9 and 10. All the values of yield and yield components were not significant from the Ir×In×Kn interaction.

The results of all interactions had no statistically significant influence on N, P, K and protein contents except Ir × In interaction for N and protein % was significant as average of both seasons. ETc 60 % with IAA spraying at a concentration of 75 ppm gave the highest values (5.15 and 31.96 %) for N and protein % respectively ($Ir_1 \times In_3$) while the lowest values 4.50 and 28.13% respectively were obtained by ETc 100 % and without IAA addition (Fig.1).

Table 5. Plant height (cm) and root length as affected by irrigation regime, indole acetic acid, kinetin and their interaction (combined data of 2016-17 and 2017-18 seasons).

Irrigation regime (Ir)	IAA (ppm) (In)	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In
		Plant height (cm)				Root length (cm)			
Ir_1 60 %	0.0	56.33	57.00	61.00	58.11	8.18	11.96	12.19	10.78
	50	60.33	62.67	64.00	62.33	8.43	12.31	12.68	11.14
	75	66.00	68.33	70.67	68.33	8.79	13.61	13.88	12.09
Mean of Ir_1		60.89	62.67	65.22	62.92	8.47	12.63	12.92	11.34
Ir_2 80 %	0.0	46.67	47.67	52.00	48.78	8.90	13.18	13.75	11.94
	50	53.00	57.00	58.00	56.00	9.11	14.02	14.59	12.57
	75	53.00	57.00	58.67	56.22	9.30	14.51	15.13	13.01
Mean of Ir_2		50.89	53.89	56.22	53.67	9.10	13.90	14.49	12.50
Ir_3 100 %	0.0	42.00	44.67	46.00	44.22	9.63	15.08	16.02	13.58
	50	44.00	46.00	49.33	46.44	10.08	15.94	16.51	14.17
	75	45.67	49.67	53.33	49.56	10.15	17.17	17.22	14.85
Mean of Ir_3		43.89	46.78	49.55	46.74	9.95	16.06	16.58	14.20
Mean of In × Kn	0.0	48.33	49.78	53.00	50.37	8.91	13.41	13.99	12.10
	50	52.44	55.22	57.11	54.92	9.21	14.09	14.59	12.63
	75	54.89	58.33	60.89	58.04	9.41	15.10	15.41	13.31
Mean of (Kn)		51.89	54.45	57.00	54.45	9.17	14.20	14.66	12.68
$LSD_{0.05}$	Ir: 1.30	In: 2.56	Kn:0.56	Ir×In:1.19		Ir: 0.07	In: 0.08	Kn:0.41	Ir×In:0.22
	Ir×Kn: 1.13	In×Kn: 1.13	Ir×In×Kn: 1.96			Ir×Kn: NS	In×Kn: NS	Ir×In×Kn: NS	

Table 6. Leaf area index and total chlorophyll as affected by irrigation regime, indole acetic acid, kinetin and their interaction (combined data of 2016-17 and 2017-18 seasons).

Irrigation regime (Ir)	IAA (ppm) (In)	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In
		Leaf area index				Total chlorophyll			
60 %	0.0	2.22	2.45	2.51	2.39	29.57	31.52	33.81	31.64
	50	2.30	2.97	3.72	3.00	34.57	36.01	36.78	35.79
	75	2.67	4.11	4.23	3.67	38.32	39.62	40.83	39.59
Mean of Ir_1		2.39	3.18	3.49	3.02	34.16	35.72	37.14	35.67
80 %	0.0	2.83	3.37	3.70	3.30	42.34	44.83	46.59	44.59
	50	3.17	4.22	4.43	3.94	49.63	51.40	51.66	50.90
	75	3.17	4.38	4.86	4.14	52.18	52.84	53.49	52.84
Mean of Ir_2		3.06	3.99	4.33	3.79	48.05	49.69	50.58	49.44
100 %	0.0	3.72	4.21	4.41	4.11	54.68	55.75	56.69	55.71
	50	3.82	4.40	4.63	4.28	57.58	57.62	58.62	57.94
	75	4.15	4.90	5.14	4.97	58.78	59.69	61.57	60.01
Mean of Ir_3		3.90	4.50	4.72	4.37	57.01	57.69	58.96	57.81
Mean of In × Kn	0.0	2.92	3.34	3.54	3.27	42.20	44.04	45.70	43.98
	50	3.10	3.86	4.26	3.74	47.26	48.35	49.02	48.21
	75	3.33	4.46	4.74	4.18	49.76	50.72	51.96	50.81
Mean of (Kn)		3.12	3.89	4.18	3.73	46.41	47.70	48.89	47.67
$LSD_{0.05}$	Ir: 0.37	In:0.23	Kn:0.50	Ir×In:0.56		Ir:0.25	In:0.27	Kn:0.26	Ir×In:0.83
	Ir×Kn:0.87	In×Kn:0.87	Ir×In×KN:1.50			Ir×Kn:0.46	In×Kn:0.46	Ir×In×KN:0.79	

Table 7. Number of branches plant⁻¹ and number of leaves plant⁻¹ as affected by irrigation regime, indole acetic acid, kinetin and their interaction (combined data of 2016-17 and 2017-18 seasons).

Irrigation regimes (Ir)	IAA (ppm) (In)	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In
		No. of branches $plant^{-1}$				No. of leaves $plant^{-1}$			
Ir_1 60 %	0.0	2.40	2.50	2.50	2.50	38.21	42.67	47.12	42.67
	50	2.87	2.57	2.93	2.79	55.65	61.01	64.03	60.23
	75	2.83	3.03	3.07	2.98	68.40	69.26	72.00	69.89
Mean of Ir_1		2.70	2.70	2.83	2.74	54.09	57.65	61.05	57.60
Ir_2 80 %	0.0	3.43	3.10	3.43	3.32	71.65	73.25	75.43	73.44
	50	3.97	4.13	4.03	4.04	77.53	79.45	79.69	78.89
	75	4.10	4.37	5.23	4.57	83.00	85.60	84.74	84.45
Mean of Ir_2		3.83	3.87	4.23	3.98	77.39	79.43	79.95	78.93
Ir_3 100 %	0.0	4.53	4.47	4.47	4.49	85.00	93.00	96.00	91.33
	50	4.77	4.87	5.53	5.06	93.87	98.47	97.98	96.77
	75	5.50	5.90	6.27	5.89	97.60	103.56	104.16	101.77
Mean of Ir_3		4.93	5.08	5.42	5.15	92.16	98.34	99.38	96.62
Mean of In×Kn	0.0	3.46	3.36	3.47	3.44	64.95	69.64	72.85	69.15
	50	3.87	3.86	4.17	3.96	75.68	79.64	80.57	78.63
	75	4.14	4.43	4.86	4.48	83.00	86.14	86.97	85.37
Mean of (Kn)		3.82	3.88	4.16	3.96	74.54	78.41	80.13	77.69
$LSD_{0.05}$	Ir:0.33	In:0.50	Kn:0.20	Ir×In:0.36		Ir:4.68	In:2.13	Kn:2.41	Ir×In:4.72
	Ir×Kn:0.34	In×Kn:0.34	Ir×In×KN:0.59			Ir×Kn:4.47	In×Kn: NS	Ir×In×Kn: NS	

Table 8. Plant fresh weight (g) and plant dry weight (g) as affected by irrigation regime, indole acetic acid, kinetin and their interaction (combined data of 2016-17 and 2017-18 seasons).

Irrigation regimes (Ir)	IAA (ppm) (In)	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In
		Plant fresh weight (g)				Plant dry weight (g)			
Ir_1 60 %	0.0	96.65	106.10	133.47	112.07	33.17	43.15	47.80	41.37
	50	157.29	179.65	187.90	174.95	51.70	58.33	64.33	58.12
	75	201.67	220.23	224.31	215.40	67.90	76.14	80.74	74.93
Mean of Ir_1		151.87	168.66	181.89	167.47	50.92	59.21	64.29	58.14
Ir_2 80 %	0.0	225.20	243.12	250.51	239.61	93.78	96.27	102.61	97.55
	50	257.48	268.17	279.53	268.39	103.22	113.73	117.45	111.47
	75	293.13	297.74	301.07	297.32	119.25	122.71	126.28	122.75
Mean of Ir_2		258.60	269.68	277.04	268.44	105.42	110.91	115.45	110.59
Ir_3 100 %	0.0	306.32	312.73	317.68	312.25	133.31	138.19	146.21	139.24
	50	322.67	327.30	330.77	326.91	148.07	153.20	158.20	153.16
	75	336.03	343.33	348.30	342.56	163.04	168.07	174.03	168.38
Mean of Ir_3		321.67	327.79	332.25	327.24	148.14	153.15	159.48	153.59
Mean of In × Kn	0.0	276.94	287.10	291.23	285.09	116.73	122.31	127.02	122.02
	50	245.81	258.37	266.07	256.75	101.00	108.42	113.33	107.58
	75	209.39	220.65	233.89	221.31	86.75	92.54	98.87	92.72
Mean of (Kn)		244.05	255.38	263.73	254.38	101.49	107.76	113.07	107.44
$LSD_{0.05}$		Ir:7.49	In:5.01	Kn:2.55	Ir×In:4.86	Ir:2.13	In:1.16	Kn:0.85	Ir×In:0.61
		Ir×Kn:4.42	In×Kn:4.42		Ir×In×KN: NS	Ir×Kn: NS	In×Kn: NS		Ir×In×KN: NS

Table 9. Number of pods plant^{-1} and pods yield plant^{-1} (g) as affected by irrigation regime, indole acetic acid, kinetin and their interaction (combined data of 2016-17 and 2017-18 seasons).

Irrigation regimes (Ir)	IAA (ppm) (In)	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In
		No. of pods plant^{-1}				Pods yield plant^{-1} (g)			
Ir_1 60 %	0.0	6.86	7.60	8.02	7.49	23.90	28.53	29.80	27.41
	50	7.66	7.87	8.78	8.01	31.64	32.86	34.41	32.97
	75	8.95	9.78	10.83	9.85	37.21	38.56	40.23	38.67
Mean of Ir_1		7.82	8.41	9.21	8.48	30.91	33.32	34.81	33.02
Ir_2 80 %	0.0	11.34	11.91	12.65	11.97	42.10	42.24	44.38	42.91
	50	13.00	13.88	14.88	13.92	46.43	47.54	50.34	48.10
	75	14.63	14.82	15.69	15.05	51.27	52.57	53.45	52.43
Mean of Ir_2		12.99	13.53	14.41	13.64	46.60	47.45	49.39	47.81
Ir_3 100 %	0.0	16.76	17.96	18.78	17.84	53.36	54.47	55.30	54.38
	50	19.86	19.79	20.72	20.12	56.23	57.63	58.13	57.33
	75	22.82	22.59	22.90	22.77	60.40	63.18	65.68	63.09
Mean of Ir_3		19.82	20.11	20.80	20.24	56.66	58.43	59.70	58.27
Mean of In × Kn	0.0	11.65	12.49	13.15	12.43	39.79	41.75	43.16	41.57
	50	13.51	13.84	14.79	14.05	44.76	46.01	47.63	46.14
	75	15.47	15.73	16.47	15.89	49.62	51.43	53.12	51.39
Mean of (Kn)		13.54	14.02	14.81	14.12	44.73	46.40	47.97	46.36
$LSD_{0.05}$		Ir: 0.52	In:0.24	Kn:0.27	Ir×In:0.48	Ir: 0.73	In: 0.86	Kn:0.77	Ir×In:1.34
		Ir×Kn: NS	In×Kn: NS		Ir×In×KN: NS	Ir×Kn: NS	In×Kn: NS		Ir×In×KN: NS

Table 10. 100-Seed weight (g) and seed yield (ton fed^{-1}) as affected by irrigation regime, indole acetic acid, kinetin and their interaction (combined data of 2016-17 and 2017-18 seasons).

Irrigation regimes (Ir)	IAA (ppm) (In)	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In
		100-seed weight (g)				Seed yield (ton fed^{-1})			
Ir_1 60 %	0.0	72.70	74.48	75.42	74.20	0.77	0.78	0.84	0.80
	50	76.59	77.80	79.52	77.97	0.81	0.82	0.87	0.83
	75	80.88	81.75	82.65	81.76	0.85	0.86	0.92	0.88
Mean of Ir_1		76.72	78.01	79.20	77.98	0.81	0.82	0.88	0.84
Ir_2 80 %	0.0	82.77	83.88	85.80	84.15	0.88	0.89	0.92	0.90
	50	86.89	87.59	89.40	87.15	0.92	0.94	0.95	0.94
	75	91.68	93.86	95.37	93.64	1.01	1.06	1.12	1.06
Mean of Ir_2		87.12	88.44	90.19	88.58	0.94	0.96	1.00	0.97
Ir_3 100 %	0.0	95.00	95.50	96.80	95.77	1.17	1.18	1.18	1.18
	50	97.41	97.56	98.12	97.70	1.20	1.22	1.23	1.22
	75	98.83	98.08	98.64	98.52	1.22	1.23	1.44	1.30
Mean of Ir_3		97.08	97.05	97.85	91.30	1.20	1.21	1.28	1.23
Mean of In × Kn	0.0	83.49	84.62	86.01	84.71	0.94	0.95	0.98	0.96
	50	86.97	87.65	89.02	87.88	0.98	0.99	1.02	1.00
	75	90.46	91.23	92.22	91.30	1.03	1.05	1.16	1.08
Mean of (Kn)		86.97	87.83	89.08	87.96	0.98	1.00	1.05	1.01
$LSD_{0.05}$		Ir: 0.86	In: 0.79	Kn:0.28	Ir×In:0.72	Ir: 0.07	In: 0.06	Kn: NS	Ir×In:NS
		Ir×Kn:0.48	In×Kn: NS		Ir×In×KN: NS	Ir×Kn: NS	In×Kn: NS		Ir×In×KN: NS

Table 11. Nitrogen % and protein% as affected by irrigation regime, indole acetic acid, kinetin and their interaction (combined data of 2016-17 and 2017-18 seasons).

Irrigation regimes (Ir)	IAA (ppm) (In)	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In
		N %				protein %			
Ir_1 60 %	0.0	4.78	4.83	4.86	4.82	29.88	30.19	30.38	30.15
	50	4.95	4.97	5.00	4.97	30.94	31.06	31.25	31.08
	75	5.09	5.10	5.15	5.11	31.81	31.88	32.18	31.96
Mean of Ir_1		4.94	4.97	5.00	4.97	30.88	31.04	31.27	31.06
Ir_2 80 %	0.0	4.50	4.53	4.60	4.55	28.13	28.31	28.75	28.40
	50	4.52	4.59	4.64	4.58	28.25	28.69	29.00	28.63
	75	4.57	4.65	4.73	4.65	28.56	29.06	29.56	29.06
Mean of Ir_2		4.53	4.59	4.66	4.59	28.31	28.69	29.10	28.70
Ir_3 100 %	0.0	4.42	4.47	4.61	4.50	27.63	27.94	28.81	28.13
	50	4.48	4.56	4.62	4.55	28.00	28.50	28.88	28.46
	75	4.48	4.59	4.63	4.57	28.00	28.69	28.94	28.54
Mean of Ir_3		4.46	4.54	4.62	4.54	27.88	28.38	28.88	28.38
Mean of In × Kn	0.0	4.57	4.61	4.69	4.62	28.56	28.81	29.31	28.89
	50	4.65	4.71	4.75	4.70	29.06	29.44	29.69	29.40
	75	4.71	4.78	4.84	4.78	29.44	29.88	30.25	29.86
Mean of (Kn)		4.64	4.70	4.76	4.70	29.02	29.38	29.75	29.38
$LSD_{0.05}$		Ir: 0.16	In: 0.09	Kn: NS	Ir×In:0.10	Ir: 0.98	In: 0.56	Kn: NS	Ir×In:0.61
		Ir×Kn: NS	In×Kn: NS	Ir×In×KN: NS		Ir×Kn: NS	In×Kn: NS	Ir×In×KN: NS	

Table 12. Phosphorus % and K% as affected by irrigation regime, indole acetic acid, kinetin and their interaction (combined data of 2016-17 and 2017-18 seasons).

Irrigation regimes (Ir)	IAA (ppm) (In)	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In	(Kn) Kentein (ppm) 0.0	20	40	Mean of Ir×In
		P %				K %			
Ir_1 60 %	0.0	0.22	0.25	0.27	0.25	1.07	1.09	1.13	1.10
	50	0.31	0.33	0.33	0.32	1.17	1.20	1.22	1.20
	75	0.35	0.37	0.39	0.37	1.25	1.29	1.33	1.29
Mean of Ir_1		0.29	0.32	0.33	0.31	1.16	1.19	1.23	1.20
Ir_2 80 %	0.0	0.22	0.26	0.27	0.25	1.08	1.12	1.18	1.13
	50	0.31	0.34	0.34	0.33	1.22	1.28	1.31	1.27
	75	0.36	0.37	0.39	0.37	1.31	1.33	1.38	1.34
Mean of Ir_2		0.30	0.32	0.33	0.32	1.20	1.24	1.29	1.25
Ir_3 100 %	0.0	0.27	0.28	0.30	0.28	1.29	1.33	1.34	1.32
	50	0.35	0.36	0.38	0.36	1.36	1.38	1.42	1.39
	75	0.38	0.39	0.40	0.39	1.48	1.56	1.62	1.55
Mean of Ir_3		0.33	0.34	0.36	0.34	1.38	1.42	1.46	1.42
Mean of In × Kn	0.0	0.24	0.26	0.28	0.26	1.15	1.18	1.22	1.18
	50	0.32	0.34	0.35	0.34	1.25	1.29	1.32	1.29
	75	0.36	0.37	0.39	0.37	1.35	1.39	1.44	1.39
Mean of (Kn)		0.31	0.32	0.34	0.32	1.25	1.29	1.33	1.29
$LSD_{0.05}$		Ir: NS	In: 0.02	Kn:0.04	Ir×In:NS	Ir: 0. 09	In: 0.02	Kn:0.02	Ir×In:NS
		Ir×Kn: NS	In×Kn: NS	Ir×In×KN: NS		Ir×Kn: NS	In×Kn: NS	Ir×In×KN: NS	

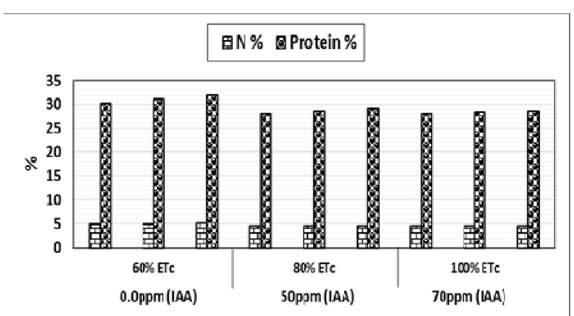

Fig. 1. Nitrogen and protein % as affected by the interaction among irrigation regime and IAA (combined data of 2016-17 and 2017-18 seasons).

E- Crop Irrigation Efficiency and productivity:

The effect of irrigation regime, IAA, kinetin and their interaction on the water use efficiency (WUE) and water crop productivity (WCP) of faba bean plants is shown in Fig 2. The reduction in the amount of applied water and actual crop evapotranspiration positively influenced WUE and WCP. The lowest irrigation regime (60 % of ET) resulted in the highest values of WUE and WCP, of 0.57 and 0.77 kg m^{-3}, respectively. Generally, the trends of the WUE and WCP that were related to the amount of applied water and the production of seed yield for the various treatments exhibited that the lower the amount of applied water received, the higher the WUE and WCP as averages of the two seasons. It could be due to fact that the increase in seed yield was not conformable with the increase in the amount of applied water and consumptive use of water. Saleh *et al*. (2018) showed that the values of WUE of green bean could be arranged in the descending order of 6.33>5.68>4.33 g L^{-1} for 60, 80 and 100 % treatments respectively. These results corroborated with the findings of Hegab *et al*. (2014), Gupta *et al*. (2017) and Siam *et al*. (2017).

The effect of IAA on WUE and WCP values was significant (Fig 2). Increasing the IAA concentration from 0.0 to 75ppm increased WUE and WCP (kg m^3) for all irrigation treatments as averages of the two seasons. The effect of kinetin and all interactions had not significant effects on WUE and WCP as averages of both seasons.

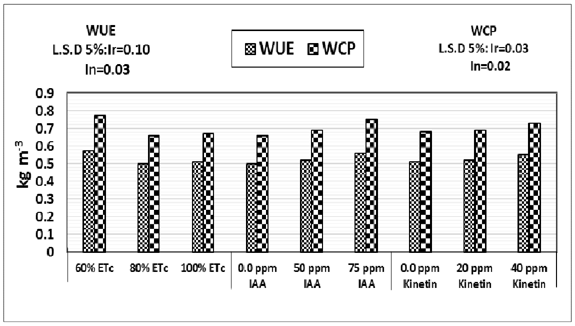

Fig. 2. Water use efficiency and water crop productivity as affected by irrigation regime, indole acetic acid, kinetin and their interaction (combined data of 2016-17 and 2017-18 seasons).

Correlation Analysis:

The simple correlation coefficient (r) is a most accepted way to measure the ratio among independent variables, such as agronomic parameters and seed yield are presented in (Table 13). The root length, leaf area index, No. of branches $plant^{-1}$, No. of leaves $plant^{-1}$, plant fresh weight (g), plant dry weight (g), total chlorophyll, No. of pods $plant^{-1}$, 100-seed weight (g) and pod yield $plant^{-1}$ were significantly and positively correlation with to faba bean seed yield fed^{-1} with correlation values of 0.54, 0.95, 0.94, 0.89, 0.94, 0.94, 0.96, 0.96 and 0.92, respectively in combined data of 2016-17 and 2017-18 seasons. However, the relationship was negatively significant among plant height and seed yield (r= -0.60). Increases in seed yield occurred specifically because of the increase in all agronomic parameters, as a result of the application of irrigation regime, foliar spray of IAA and kinetin, as shown in Table 13. These findings are in an agreement with those obtained by Passos *et al*. (2011) and El-Harty (2016).

Table 13. Correlation coefficients among some agronomic parameters with the production faba bean as affected by irrigation regime, IAA and kinetin concentrations on faba bean in combined data of 2016-17 and 2017-18 seasons.

Characters	Plant height (cm)	Root length (cm)	Leaf area Index	No. of branches $plant^{-1}$	No. of leaves $plant^{-1}$	Pant fresh weight(g)	Plant dry weight (g)	Total chlorophyll	No. of pods $plant^{-1}$	100-seed weight (g)	Pod yield $plant^{-1}$ (g)
Combined data of 2016-17 and 2017-18 seasons											
Seed yield (ton fed^{-1})	- 0.60 **	0.54 **	0.81 **	0.95 **	0.94 **	0.89 **	0.94 **	0.94 **	0.96 **	0.96 **	0.92 **

*** and ** donates significant at 5 and 1%, respectively, by the t-test**

CONCLUSION

It could be concluded that the highest values of growth, yield and chemical composition of faba bean plants were obtained using the maximum irrigation regime [(100 %=2430 m^3 fed^{-1} (Ir_3)] while the highest values of plant height, N (%), protein (%), WUE and WCP (kg m^3) were recorded with the application of irrigation regime of 60 %ETc. Foliar application of growth regulators i.e. IAA (up to 75ppm) and kinetin (up to 40ppm) increased the growth, yield, chemical composition of faba bean seeds and also increased WUE and WCP. Finally, the application of irrigation water volume of 2430 m^3 fed^{-1}(Ir_3), 75ppm IAA (In_3) and 40 ppm kinetin (Kn_3) is an effective strategy to enhance the production of faba bean plants grown on the sandy soil in Toshka region.

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أداء نبات الفول البلدى تحت نظم رى مختلفة والرش الورقى ببعض منظمات النمو في منطقة توشكا مصر

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لقد أصبحت عجز المياه هو العامل الرئيسي الذي يحد من الإنتاجية والإستدامة في الزراعة ، لا سيما في المناطق الجافة وشبه الجافة. ولذلك أقيمت تجربة حقلية فى مزرعة تجارب الأبحاث بمجمع الدراسات والبحوث المائية بأبى سمبل بتوشكى خلال الموسمين ٢٠١٦-٢٠١٧ ، ٢٠١٧-٢٠١٨ وذلك بهدف تقييم تأثير إستخدام مستويات مختلفة من مياه الرى وتركيزات مختلفة من منظمات النمو على النمو وإنتاجية الفول البلدى (صنف نوبارية ١) والتركيب الكيماوى للمحصول فى الأراضى الرملية تحت نظام الرى بالرش. تم إستخدام ٣ مستويات رى هى ٦٠ ، ٨٠ ، ١٠٠% من معدل البخر نتح مع ٣ تركيزات من أندول حمض الخليك هى (صفر ، ٥٠ ، ٧٥ جزء فى المليون) وثلاث تركيزات من الكينيتين هى (صفر ، ٢٠ ، ٤٠ جزء فى المليون) أضيف رشاً على النباتات. تم إستخدم تصميم الشرائح المتعامدة فى ثلاث مكررات. ويمكن تلخيص أهم النتائج كما يلى : أشارت النتائج إلى زيادة مستويات الري من ٦٠ إلى ١٠٠٪ ETc أدت إلى الحصول على أعلى قيم لجميع خصائص النمو ، ما عدا طول النبات في متوسط الموسمين. كما أدى إضافة ١٠٠٪ ETc إلى زيادة فى قيم المحصول ومكوناته وكذلك زيادة فى تركيز الفوسفور والبوتاسيوم ببذور الفول. وسجلت أعلى قيم لكفاءة إستخدام الماء و إنتاجية المحصول المائية وجودة البذور (محتواها من البروتين) عند إستخدام المستوى الأول ٦٠٪ ETc.أوضحت النتائج أن رش النباتات بأندول حمض الخليك عند تركيز ٧٥ جزء فى المليون وكذلك للكينيتين عند تركيز ٤٠ جزء فى المليون إلى زيادة صفات النمو والمحصول ومكوناته وكذلك التركيب الكيماوى للفول و قراءات المياه.أضهرت النتائج أن التفاعل بين العوامل الثلاثة المدروسة عند إستخدام المستويات العالية من ماء الرى ومنظمات النمو أعلى قيم لطول النبات ودليل مساحة الورقة والكلوروفيل الكلي وعدد الفروع لكل نبات لمحصول الفول البلدى.أرتبط محصول البذور للفول إرتباطاً إيجابياً ومعنويا مع دليل مساحة الورقة ، الكلوروفيل الكلي ، طول الجذر ، الوزن النباتي الطازج والجاف ، عدد الفروع والأوراق للنبات ، عدد نباتات القرون للنبات ، وزن ١٠٠ بذرو , بينما طول النبات أرتبط إرتباطاً سالباً ومعنوياً مع محصول البذور.توصى الدراسة : بزراعة الفول البلدى صنف نوبارية ١ تحت ظروف منطقة توشكا مع الرى عند مستوى مائى ٢٤٣٠ م^{3} للفدان والرش بأندول حمض الخليك عند تركيز ٧٥ جزء في المليون والكينيتين عند تركيز ٤٠ جزء فى المليون للحصول على إنتاجية وجودة عالية لمحصول الفول.