

## Physiological Effect of Some Bioregulators on Vegetative Growth, Yield and Chemical Constituents of Yellow Maize Plants

M.S.A. Abd El-Wahed, A.A. Amin and El-Sh. M. Rashad

Botany Department, National Research Centre, Dokki, Cairo, Egypt

**Abstract:** A field study was conducted to estimate the effect of salicylic acid (1, 2 and 3 mM), sitosterol as well as putrescine concentrations (0.05, 0.10 and 0.15 mM) on vegetative growth characters, yield and its components and grain biochemical constituents of yellow maize (*Zea mays* L.) at elongation and milky stages. The application of bioregulators led to significant increases of vegetative growth characters such as plant height, leaf area, leaf area index, dry weight/plant, specific leaf weight, crop growth rate and net assimilation rate except plant height, which significantly reduced with increasing salicylic acid concentration. Increasing vegetative character values were obtained at salicylic acid (3 mM), sitosterol or putrescine (0.15 mM) at elongation and milky stages of yellow maize plants. Yield and its components, i.e. ear length, ear diameter, grain yield/plant, grain yield/feddan, crop index and 100-grain weight of yellow maize were significantly increased at certain level of applied bioregulators application. Salicylic acid (3 mM), sitosterol (0.15 mM) and putrescine (0.15 mM) gave the highest values of the previous yield components. Bioregulators varied of their effect on grain biochemical constituents of yellow maize plant. Sitosterol (0.15 mM) was more effective on crude protein and total carotenoids while putrescine (0.15 mM) was also more effective on total sugars and oil content of grains. Grain yield/feddan showed highly significant and positive correlation with the majority of growth parameters under sitosterol and putrescine application but not with salicylic acid treatments.

**Key words:** Bioregulators • yellow maize • growth • grain yield

### INTRODUCTION

Salicylic acid is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plant, such as stomatal closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance [1, 2]. The effect of salicylic acid on the physiological processes is variable, promoting some processes and inhibiting others depending on its concentration, plant species, developmental stages and environmental conditions [3]. Low salicylic acid doses enhanced growth of wheat and maize [2, 4].

The diamine putrescine occurred widely in the higher plants. It was suggested to be involved in a variety of growth and developmental processes such as cell division [5], fruit set and growth [6] and senescence [7]. The interaction of polyamines with the macromolecules was responsible for physiological effects on plant growth and development [8]. Polyamines were effective on inhibiting RNase and protease activities [9].

Also, Serafini-Fracassini [10] found that polyamines are activators of protein process that was related to genes encoding [11].

Sitosterol is the major constituent of steroids in plant that plays a critical role in membrane function [12]. Sterols have a main role in plant development. Brassinosteroids have been found to evoke both cell elongation and cell division resulting in elongation, swelling, curvature and splitting of the internode [13]. Physiological functions proposed for Brassinosteroids included cell elongation, cell division, leaf bending, vascular differentiation, proton pump-mediated membrane polarization, sink/source regulation, responses [14]. In addition, brassinosteroids caused changes in enzymatic activities, membrane potential, DNA, RNA, protein synthesis, photosynthetic activity and changes in the balance of endogenous phytohormones [15]. Particular interest in sterols was elicited by enhanced growth characters and yield of maize and soybean plant [16, 17]. Recently, these studies provided strong evidence that sterols could be essential for normal plant growth and development [18].

The aim of present work was to study the effect of the three bioregulators (Salicylic acid, sitosterol and putrescine) on growth, yield and some biochemical constituents of yellow maize plants.

## MATERIALS AND METHODS

Grains of yellow maize cultivar (Three Way Hybrids TW-3062 pioneer) sown on 15 and 18 May 2004 and 2005, respectively at the experimental station of National Research Centre at Shalakan, Kalubia Governorate. The plot area was 10.5 m<sup>2</sup> (3.5 x 3 m) in rows 60 cm apart and 20 cm apart between hill along the row. The experiments were arranged as a complete randomized block design with six replicates. The plants were sprayed at elongation stage (45 days after sowing) with the following bioregulators: salicylic acid (C<sub>7</sub>H<sub>6</sub>O<sub>3</sub>) (1,2 and 3 mM), sitosterol (stigmasta-5-en-3 $\beta$ -ol: (24 R)-24 ethylcholest-5-en-3ol) and putrescine (NH<sub>2</sub>(CH<sub>2</sub>)<sub>4</sub>NH<sub>2</sub>) (0.05, 0.10 and 0.15 mM). Control treatment sprayed with distilled water at the same period. Pre-sowing at rate of 100 kg/fed. Calcium superphosphate (15.5 % P<sub>2</sub>O<sub>5</sub>) was applied to the soil. Nitrogen fertilizer as ammonium nitrate (33.5 % N) was added at a rate of 120 kg. N/feddan in two equal doses the 1st half at 21 and the 2nd at 36 days after sowing.

**Growth characteristics:** The following growth characters were measured at elongation stage (60 days after sowing) and milky stage (90 days after sowing). The vegetative growth characters were plant height, number of leaves/plant, stem diameter, dry weight/plant, Leaf area/ cm<sup>2</sup> according to Bremner and Taha [19], leaf area index [20], specific leaf weight [21], crop growth rate [22] and net assimilation rate [23].

**Yield and its components characteristics:** Yield and its components such as ear length, ear diameter, number of row/ear, number of grains/row, grain weight/plant, grain yield/fed., crop index, 100-grain weight and shelling percentage were determined at maturity stage.

**Chemical analysis of grains:** Grain samples were dried at 70°C for constant weight and ground to determine the chemical constituents such as crude protein [24], total sugars [25], oil percentage [26] and total carotenoids [27].

**Statistical analysis:** The data were statistically analysed in randomized complete block design according to Snedecor and Cochran [28] and then combined analysis as well as simple correlation coefficients

between growth characters and yield attributes were done according to Gomez and Gomez [29]. The treatments means were compared using LSD test at 5% of significant.

## RESULTS AND DISCUSSION

**Growth characters:** Data presented in Table 1 show that vegetative growth characters of yellow maize such as plant height, leaf area/plant, stem diameter, leaf area index, dry weight/plant, specific leaf weight, net assimilation rate and crop growth rate significantly increased at elongation or milky stages as a result to foliar application of salicylic acid, sitosterol and putrescine bioregulators. However, number of leaves/plant was insignificantly affected by bioregulators application. Plant height significantly decreased with increasing salicylic concentration up to 3 mM. This mean that salicylic acid might be cause an inhibitory effect plant elongation, while, sitosterol and putrescine bioregulators were more effective on all vegetative growth characters. The maximum values of these characters were obtained by the concentration (3 mM) of all bioregulators at elongation and milky stages. It appeared from the results that sitosterol was more effective substance on yellow maize growth than the others. This effect could be attributed to bioregulators effect on physiological processes in plant such as, ion uptake, cell elongation, cell division, sink/source regulation, enzymatic activities, protein synthesis and photosynthetic activity. Our results are in agreement with Shehata *et al.* [4] they revealed that low salicylic acid doses led to significant increases in growth characters of maize. Similar results were obtained by Khan *et al.* [1] on corn and soybean and Shakirova *et al.* [2] of wheat. Also, El-Mergawi and Abd El-Wahed [3] found that the types of plants varied in their response to salicylic acid application as a result to genotype variation. Whereas, steroids have a role on cell elongation, cell division, leaf bending and enzymatic activities of plant [14, 18]. Consequently, the results of putrescine effect on vegetative growth of yellow maize are similar with those obtained by Abd El-Wahed [30] on maize, Abd El-Wahed and Gamal El-Din [31] on chamomile.

**Yield and its components:** Data in Table 2 show that yield and its components such as ear length, ear diameter, 100-grain weight, grain yield/plant, grain yield/fed., crop index and shelling percentage were significantly enhanced with foliar application of bioregulators (salicylic acid, sitosterol and putrescine)

Table 1: Effect of some bioregulators on vegetative growth of yellow maize plant c.v. pioneer 3062 at elongation stage (60 days after sowing)  
(Average of two seasons, 2004 and 2005)

Growth regulators treatments mM	Plant height (cm)	Number of leaves/plant	Stem diameter (cm)	Dry weight (g/plant)	Leaf area (cm <sup>2</sup> )	Leaf area index (LAI)	Specific leaf weight (mg/cm <sup>2</sup> )
Control	206.15	14.60	1.72	153.80	507.34	2.96	6.49
Salicylic acid							
1 mM	200.60	14.68	1.99	182.46	523.41	3.44	7.04
2 mM	197.57	14.90	2.14	195.27	621.41	3.80	7.65
3 mM	195.10	15.17	2.46	202.52	635.76	3.88	8.51
Sitosterol							
0.05 mM	215.44	14.77	1.92	177.94	585.98	3.62	7.91
0.10 mM	218.49	15.08	1.97	189.28	619.13	4.02	8.04
0.15 mM	234.41	15.16	2.15	200.97	692.88	4.22	8.58
Putrescine							
0.05 mM	211.52	14.83	1.95	170.38	576.85	3.55	7.95
0.10 mM	217.95	15.17	2.03	195.39	597.78	4.03	8.38
0.15 mM	232.39	15.07	2.15	204.66	647.78	4.31	8.76
LSD at 5%	12.80	NS	0.34	12.76	2.64	0.63	0.96

Table 1: (Continue) Effect of some bioregulators on vegetative growth of yellow maize plant c.v. pioneer 3062 at milky stage (90 days after sowing)  
(Average of two seasons, 2004 and 2005)

Growth regulators treatments mM	Plant height (cm)	Number of leaves/plant	Stem diameter (cm)	Dry weight (g/plant)	Leaf area (cm <sup>2</sup> )	Leaf area index (LAI)	Specific leaf weight (mg/cm <sup>2</sup> )	Net assimilation rate (mg/cm <sup>2</sup> /day) (60-90 days)	Crop growth rate (mg/cm <sup>2</sup> /day) (60-90 days)
Control	270.52	14.98	2.00	216.01	591.54	3.72	8.43	3.04	4.80
Salicylic acid									
1 mM	266.83	15.76	2.32	258.56	620.29	4.53	8.20	3.57	5.74
2 mM	263.39	15.13	2.51	276.31	640.88	4.71	9.04	3.21	6.04
3 mM	256.57	15.38	2.65	281.21	659.70	4.94	10.02	3.79	6.35
Sitosterol									
0.05 mM	273.32	15.27	2.25	257.21	693.18	4.34	9.83	3.95	5.16
0.10 mM	277.78	15.59	2.40	259.83	711.54	5.05	10.19	4.07	6.19
0.15 mM	282.86	15.88	2.51	275.10	755.76	5.31	11.07	4.35	6.44
Putrescine									
0.05 mM	269.09	15.60	2.07	232.47	689.86	4.62	9.94	3.15	5.72
0.10 mM	284.12	15.46	2.35	273.09	708.52	5.21	10.79	4.37	6.12
0.15 mM	289.38	15.98	2.44	283.91	746.67	5.38	11.23	4.32	6.39
LSD at 5%	6.45	NS	0.22	17.65	76.43	0.97	1.31	0.57	1.03

Table 2: Effect of some bioregulators on yield and its components of yellow maize plant c.v. pioneer 3062 (Average of two seasons, 2004 and 2005)

Growth regulators treatments mM	Ear length (cm)	Ear diameter (cm)	Number of rows/ear	Number of grains/row	100-grain weight (g)	Grain yield/plant (g)	Grain yield (ton/fed.)	Crop index	Shelling %
Control	20.81	3.53	12.97	41.64	39.78	207.01	3.12	0.45	70
Salicylic acid									
1 mM	22.52	3.90	13.75	42.58	41.16	233.58	3.37	0.47	76
2 mM	23.31	4.01	14.11	42.90	43.19	242.86	3.42	0.48	78
3 mM	21.43	4.28	14.67	43.31	43.46	260.37	3.92	0.48	80
Sitosterol									
0.05 mM	21.63	3.66	13.91	42.80	41.52	245.83	3.96	0.46	79
0.10 mM	22.63	3.92	13.97	43.42	42.48	252.79	4.11	0.48	80
0.15 mM	24.05	4.02	14.20	44.14	44.06	266.46	4.56	0.52	83
Putrescine									
0.05 mM	21.33	3.74	13.86	42.76	40.91	237.36	3.87	0.50	79
0.10 mM	22.56	3.89	14.01	43.27	42.33	248.15	4.26	0.48	82
0.15 mM	23.40	3.98	14.54	43.52	43.90	256.1	4.4	0.52	86
LSD at 5%	1.18	0.38	NS	NS	2.59	28.52	0.74	0.10	36

Table 3: Effect of some bioregulators on some biochemical constituents of yellow maize plant c.v. pioneer 3062 (Average of two seasons, 2004 and 2005)

Growth regulators treatments mM	Crude protein %	Total carbohydrate %	Oil %	Total carotenoids mg/g (D.W)
Control	8.30	73.52	5.52	60.23
Salicylic acid				
1 mM	8.95	80.65	5.83	73.57
2 mM	9.01	81.30	6.66	76.83
3 mM	9.84	79.08	6.59	81.40
Sitosterol				
0.05 mM	9.21	80.82	6.05	74.77
0.10 mM	10.55	79.75	7.60	82.59
0.15 mM	11.37	76.01	6.55	89.07
Putrescine				
0.05 mM	8.91	83.53	6.07	77.10
0.10 mM	10.55	78.92	6.87	80.90
0.15 mM	11.26	74.90	7.79	89.00
LSD at 5%	1.65	4.90	1.01	6.73

Table 4: A simple correlation between grain yield (ton/fed.) and some growth characters under putrescine application

Characters	Grain yield (ton/fed.)	Ear length	Ear diameter	No. of rows/ear	No. of grains/ear	100-grains weight	Grain yield/plant	Shelling %	Crop index
Grain yield (ton/fed.)	1	0.742**	0.798**	0.719**	0.563	0.535	0.937**	0.916**	0.635*
Ear length	0.742**	1	0.523	0.551	0.301	0.648*	0.733**	0.568	0.575
Ear diameter	0.798**	0.523	1	0.703*	0.401	0.470	0.807**	0.834**	0.552
No. of rows / ear	0.719**	0.551	0.703*	1	0.154	0.413	0.740**	0.788**	0.228
No. of grains/ear	0.563	0.301	0.401	0.154	1	0.330	0.507	0.531	0.515
100-grains weight	0.535	0.648*	0.470	0.413	0.330	1	0.434	0.498	0.225
Grain yield/plant	0.937**	0.733**	0.807**	0.740**	0.507	0.434	1	0.897**	0.691*
Shelling %	0.916**	0.568	0.834**	0.788**	0.531	0.498	0.897**	1	0.593*
Crop index	0.635*	0.575	0.552	0.228	0.515	0.225	0.691*	0.593*	1

Table 4 (Cont.): A simple correlation between grain yield (ton/fed.) and some growth characters under sitosterol application

Characters	Grain yield (ton/fed.)	Ear length	Ear diameter	No. of rows/ear	No. of grains/ear	100-grains weight	Grain yield/plant	Shelling %	Crop index
Grain yield (ton/fed.)	1	0.799**	0.656*	0.303	0.732**	0.460	0.928**	0.922**	0.590*
Ear length	0.799**	1	0.736**	0.414	0.573	0.630*	0.734**	0.641*	0.575
Ear diameter	0.656*	0.736**	1	0.454	0.278	0.592*	0.603*	0.569	0.767**
No. of rows / ear	0.303	0.414	0.454	1	0.456	0.456	0.339	0.192	0.281
No. of grains/ear	0.732**	0.573	0.278	0.456	1	0.183	0.740**	0.623*	0.201
100-grains weight	0.460	0.630*	0.592*	0.456	0.183	1	0.314	0.416	0.401
Grain yield/plant	0.928**	0.734**	0.603*	0.339	0.740**	0.314	1	0.892**	0.576
Shelling %	0.922**	0.641*	0.569	0.192	0.623*	0.416	0.892**	1	0.639*
Crop index	0.590*	0.575	0.767**	0.281	0.201	0.401	0.576	0.639*	1

Table 4 (Cont.): A simple correlation between grain yield (ton/fed.) and some growth characters under salicylic acid application

Characters	Grain yield (ton/fed.)	Ear length	Ear diameter	No. of rows/ear	No. of grains/ear	100-grains weight	Grain yield/plant	Shelling %	Crop index
Grain yield (ton/fed.)	1	-0.432	0.276	-0.078	-0.060	-0.156	0.109	0.007	0.211
Ear length	-0.432	1	0.491	0.392	0.627*	0.469	0.541	0.521	-0.072
Ear diameter	0.276	0.491	1	0.651*	0.589*	0.468	0.819**	0.732**	0.339
No. of rows / ear	-0.078	0.392	0.651*	1	0.046	0.677*	0.530	0.702*	0.011
No. of grains/ear	-0.060	0.627*	0.589*	0.046	1	0.083	0.626*	0.533	0.439
100-grains weight	-0.156	0.469	0.468	0.677*	0.083	1	0.407	0.612*	0.061
Grain yield/plant	0.109	0.541	0.819**	0.530	0.626*	0.407	1	0.864**	0.536
Shelling %	0.007	0.521	0.732**	0.702*	0.533	0.612*	0.864**	1	0.583*
Crop index	0.211	-0.072	0.339	0.011	0.439	0.061	0.536	0.583*	1

compared with control. However, number of rows/ear and number of grains/row had no significant increase by all bioregulators applications. Increasing yield and its components was related to bioregulators concentration up to 3 mM except ear length character. It appeared from the results that salicylic acid was more effective than sitosterol and putrescine application on ear diameter enhancement. Ear length, 100 grains weight, grain yield/plant and grain yield/fed. were also more affected by sitosterol than the other bioregulators. However, sitosterol and putrescine treatments did not show significant differences in their effect on crop index. The favourable effects of bioregulators were obtained at concentration of salicylic acid of 3 mM, sitosterol of 0.15 mM and putrescine of 0.05 mM. It might be due to bioregulators stimulation of physiological processes that were reflected on improving vegetative growth that followed by active translocation of the photosynthesis products from source to sink in yellow maize plant. The previous studies confirmed the present obtained positive responses of salicylic acid foliar application on soybean [32]. In addition, brassinosteroids increased peanut yield [33] as well as maize and chamomile yield after foliar or injection application of both stigmasterol or spermidine [16, 34]. Whereas, increasing or decreasing putrescine content controlled pistillate flower and pistillate differentiation [35].

**Chemical constituents:** Data in Table 3 indicated that foliar application of salicylic acid, sitosterol and putrescine bioregulators led to significant effect on some biochemical constituents of yellow maize seed. Crude protein, oil and total carotenoids content of yellow maize grain tended to increase while the total sugars content were decreased with enhancement bioregulators concentration. The maximum values of biochemical content in yellow maize seed were obtained by sitosterol treatment (0.15 mM) on crude protein and total carotenoids by putrescine (0.05 or 0.15 mM) on total sugars and oil. It appeared from the results that both sitosterol and putrescine are more effective on seed biochemical contents than salicylic acid. This effect might be due to these substances on enzymatic activity and translocation of the metabolites to yellow maize seed. These results are agreement with those obtained by Vardhini and Seeta [33] they found that the exogenous application of brassinosteroids enhanced levels of DNA, RNA, soluble proteins, various carbohydrate and fat content of peanut seed. Also, Abd El-Wahed *et al.* [16] and Abd El-Wahed [36] found that stigmasterol

or spermidine application increased the previous mentioned contents of maize seeds. This might be due to their conjugation with sugars and their effect on  $\alpha$ -amylase. So, putrescine or salicylic application promoted nitrate reductase activity that was positively correlated with total organic nitrogen of maize [37]. In this current study increasing carotenoids content may due to convert these substances to pyruvic acid that led to increase biosynthesis of two general classes of carotenoid pigments carotene and xanthophylls [38, 39].

**Correlation study:** Data in Table 4 show that grain yield (ton/fed.) recorded highly significant and positive correlation with each of plant height, stem diameter, ear length, grain yield/plant as well as, shelling percentage. Significant and positive correlation of grain yield was obtained with crop index and insignificant and positive correlation with 100-grains weight under sitosterol and putrescine application. On the other hand, grain yield (ton/fed.) showed insignificant and positive correlation with plant height, stem and ear diameter, grain yield/plant as well as, crop index. In addition, insignificant and negative correlation of grain yield with ear length, number of rows/ear, number of grains/ear and 100-grains weight under salicylic acid application are shown in Table 4. It appears that the improvement of growth reflected on increasing grain yield/fed. of maize that showed high significant correlation between grain yield, stem diameter, ear diameter, number of rows /ear and grain yield/plant under treating *Zea mays* with sitosterol and putrescine.

From the above mentioned results, it could be concluded that foliar application of sitosterol at 0.15 mM followed by putrescine at 0.15 mM, then salicylic acid at 3 mM to yellow maize TW 3062 pioneer plant at elongation stages improved growth, yield and its components as well as, some biochemical constituents of yellow maize plants.

## REFERENCES

1. Khan, W., B. Prithiviraj and D.L. Smith, 2003. Photosynthetic response of corn and soybean to foliar application of salicylates. J. Plant Physiol., 160: 485.
2. Shakirova, F.M., A.R. Sakhabutdinova, M.V. Berzukova, R.A. Fatkhutdinova and D.R. Fatkhutdinova, 2003. Changes in the hormonal status of wheat seedlings induced by salicylic acid and salinity. Plant Sci., 164: 317.

3. El-Mergawi, R.A. and M.S.A. Abdel-Wahed, 2004. Diversity in salicylic acid effects on growth criteria and different indole acetic acid forms among faba bean and maize. Egypt. J. Agron., 26: 49-61.
4. Shehata, S.A.M., S.I. Ibrahim and S.A.M. Zaghloul, 2001. Physiological response of flag leaf and ears of maize plant induced by foliar application of kinetin (kin) and acetyl salicylic acid (ASA) Ann. Agric. Sci. Ain Shams Univ. Cairo, 46: 435-449.
5. Bueno, M. and A. Matilla, 1992. Effect of spermine and abscisic acid on mitotic divisions in isolated embryonic axes of chick pea seeds (*Cicer arietinum* L.). Cytobiol., 71: 151-155.
6. Biasi, R., G. Costa and N. Bagni, 1991. Polyamine metabolism as related to fruit set and growth. Plant Physiol. Biochem., 29: 497-506.
7. Kao, C. H., 1994. Endogenous polyamine levels and dark-induced senescence of detached corn leaves. Bot. Bull. Acad. Sin., 35: 15-18.
8. Smith, T.A., 1985. Polyamines. Ann. Rev. Plant Physiol., 36: 117-143.
9. Kaur-Sawhney, R. and A.W. Galston, 1982. On the physiological roles of polyamines in higher plants. In: Sen sp. (Ed.) Recent developments in plant sciences. Today and Tomorrow's printers, New Delhi, pp: 129-144.
10. Serafini-Fracassini, D., 1991. Cell Cycle development changes in plant polyamine metabolism. In: Slocum, R.D. and H.E. Flores (Eds.). Biochemistry and physiology of polyamines in plants. CRC Press, Boca Raton, FL, pp: 159-171.
11. Imai, K., T. Matsuyama, Y. Hanzawa, T. Akiyama, M. Tamaoki, H. Saji, Y. Shirano and T. Takayama, 2004. Spermidine synthase genes are essential for survival of Arabidopsis. Plant Physiol., 135: 1565-1573.
12. Bloch, K.E., 1983. Sterol structure and membrane function. CRC Crit. Rev. Biochem., 14: 47-92.
13. Mandava, N.B., 1998. Plant growth promoting brassinosteroids. Ann. Rev. Plant Physiol. Mol. Biol., 39: 23-52.
14. Sasse, J.M., 1999. Physiological actions of brassinosteroids. In: Sakuria, A., T. Yokota and S.D. Clouse (Eds.). Brassinosteroids: Steroidal Plant Hormones. Springer. Verlag, Tokyo, pp: 137-161.
15. Steven, D.C. and M.S. Jenneth, 1998. Brassinosteroids: Essential regulators of plant, growth and development. Ann. Rev. Plant Physiol. Mol. Biol., 49: 427-451.
16. Abdel-Wahed, M.S., A.A. Amin and Z.A. Ali, 2000. Effect of different concentration of stigmasterol on growth, yield and its components of maize plants. J. Agric. Sci. Mansoura Univ., 25: 201-215.
17. Abdel-Wahed, M.S.A., 2005. Inoculation of *Rhizobium japonicum* and  $\beta$ -Sitosterol effect on growth, yield and some biochemical constituents of soybean plant. J. Agric. Sci., Mansoura Univ., 30: 5803-5818.
18. Özdemir, F., M. Bor, T. Dermiral and I. Türkan, 2004. Effect of 24-apibrassinolide on seed germination, seedling growth, lipid peroxidation, proline content and antioxidative system of rice (*Oryza sativa* L.) under salinity stress. Plant Growth Regul., 42: 203-211.
19. Bremner, P.M. and M.A. Taha, 1966. Studies in potatoes agronomy. 1. The effect of variety, seed size and spacing on growth, development and yield. Plant Physiol., 116: 189-196.
20. Watson, D.J., 1952. The physiological basis of variation in yield. Adv. Agron., 4: 101-145.
21. Pearce, R., G.E. Carlson, D.K. Barnes, R.H. Host and C.H. Hasson, 1969. Specific leaf weight and photosynthesis in alfalfa. Crop Sci., 9: 423-426.
22. Abdel-Gawad, A.A., K.A. El-Shouny, S.A. Saleh and M.A. Ahmed, 1980. The relation between the efficiency of leaf surface and the growth of some wheat cultivars in Egypt. Res. Bull. No. 751: 1412, Fac. Agric. Ain Shams Univ., pp: 1-17.
23. Watson, D.J., 1958. The dependence of net assimilation rate of leaf area index. Ann Bot. N.S., 22: 37-54.
24. Chapman, D.H. and P.F. Pratt, 1978. Methods of analysis for soils, plants and water. Univ. of California, Dep. Agric. Sci., Printed Publication 4034, pp: 12-19.
25. Dubois, M., K.A. Gilles, J.R. Hamilton, P.A. Rebers and F. Smith, 1956. Colorimetric method for determination of sugar and related substances. Anal. Chem., 28: 350-356.
26. A.O.A.C., 1988. Official Methods of Analysis. Association of Official Analytical Chemists, 21st Ed, Washington, DC., USA.
27. A.O.A.C., 1956. Association of official Agricultural Chemists. Official Methods of Analysis, pp: 178. Washington, DC., USA.
28. Snedecor, G.W. and W.G. Cochran, 1990. Statistical Methods. 8th Ed. Iowa State Univ. Press Ames, Iowa, USA.

29. Gomez, K.A. and A.A. Gomez, 1984. Statistical Procedures for Agricultural Research. 2nd Ed., John Wiley Sons, Inc. New York, pp: 680.
30. Abdel-Wahed, M.S.A., 2000. Effect of stigmasterol, spermidine and sucrose on vegetative growth, carbohydrate distribution and yield of maize plants. Egypt. J. Physiol. Sci., 24: 225-239.
31. Abdel-Wahed, M.S.A. and K. M. Gamal El-Din, 2005. Effect of putrescine and Atonik on growth and some biochemical constituents as well as essential oil composition of chamomile plant. J. Agric. Sci. Mansoura Univ., 30: 869-882.
32. Gutierrez-Coronado, M.A., C. Trejo-Lopez and A. Karque-Saavedra, 1998. Effect of salicylic acid on the growth of roots and shoots in soybean. Plant Physiol. Biochem., 36: 563.
33. Vardhini, V.B. and R.R.S. Seeta, 1998. Effect of brassinosteroids on nodulation and nitrogenase activity in groundnut (*Arachis hypogaea* L.). Plant Growth Regul., 28: 165-167.
34. Abdel-Wahed, M.S.A. and K.M. Gamal El-Din, 2004. Stimulation of growth, flowering and biochemical constituents of chamomile plant (*Chamomilla recutita*, Rausch.) with spermidine and stigmasterol application. Bulg. J. Plant Physiol., 30: 48-60.
35. Lin, S., G.Z. Song, Z. Heng, H. Luo and X. Guan, 2001. Changes in endogenous hormones and polyamine during flowering of longan. In: Proceeding of the first international symposium on litchi and longan, Guangz-hou, China, 16-19 July 2000 Acta Hort., 588: 251-256.
36. Abdel-Wahed, M.S.A., 2001. Sitosterol stimulation of root growth, yield and some biochemical constituents of maize. J. Agric. Sci., Mansoura Univ., 26: 2563-2577.
37. Shankar, N.K., S.R. Khan and H.S. Srivastava, 2001. The response of nitrate reductase activity and nitrate assimilation in maize roots to growth regulators at acidic pH. Biol. Plant., 44: 599-601.
38. Martin-Tanguy, J., 2001. Metabolism and function of polyamines in plant. Plant Growth Regul., 34: 135-148.
39. Raskin, J., 1992. Role of salicylic acid in plants. Ann. Rev. Plant Physiol. Plant Mol. Biol., 43: 439-463.