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The Impact of Some Growth Regulators on Growth and Productivity of Faba bean Plant Grown under Newly Reclaimed Soil Conditions

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ABSTRACT

Two field experiments were conducted during two winter successive seasons 2019/2020 and 2020/2021 at the National Research Centre Research and Development Station, Noubaria Area, Behira Governorate, Egypt. The purpose of the study was to investigate the link between vegetative development, yield, yield components, and numerous metabolic variables components of the "Giza 716" Egyptian faba bean cultivar (*Vicia faba* L.) to foliar application of three growth regulators; paclobutrazol (PBZ; 30, 60 and 90 ppm), mepiquat chloride (MC; 500, 1000 and 1500 ppm) and baritone (AGR; 400, 600 and 800 ppm). The foliar application of PBZ, MC, and AGR had positive effects on all growth and yield parameters. On the other hand, the three growth regulators reduced plant height, fresh and dry weights of branches and leaves/plant, fourth leaf area and leaf area index, specific leaf weight, crop growth rate, net assimilation rate, relative growth rate, and yield (number of pods per plant, number of seeds per pod, pod weight/plant, seed and straw yield/plant, seed and straw yield/feddan, seed index), and harvest index), when used in high concentrations. By boosting total carbs, crude protein, total free amino acids, nitrogen, phosphate, and potassium, PBZ, MC, and AGR considerably boosted total photosynthetic pigments content in leaves and improved seed quality and nutritional value. Generally, foliar application of PBZ, MC, and AGR When used at low quantities, it had a favorable impact on growth parameters, photosynthetic pigments, seed yield and yield components, as well as several biochemical components of the faba bean seeds yield.

Keywords: *Vicia faba;* paclobutrazol (PBZ); mepiquat chloride (MC); agritone (AGR); growth; photosynthetic pigments; yield.

1. Introduction

The faba bean (*Vicia faba* L.), a member of the (Fabaceae) family, is a key source of plant protein for humans and animals all over the world. (Cazzato *et al*., 2012). Faba bean seeds contain 51-68% total carbohydrates (Nachi and Guen, 1996) and 28-30% protein (Burbano *et al*., 1995), which are strong in lysine and arginine and may help to compensate for low levels in cereals. (Kumar *et al*., 2015). Faba bean is famous source of natural antioxidant according to their genotype. (Chaiebet *et al*., 2011). Faba bean able to fix nitrogen improves soil humus and is used in crop rotation (Peyvast, 2002). Faba bean provides an alternative to soybean meal for animal feed in developing countries, which is especially essential in more industrialised countries (Gous, 2011). In Egypt, the productivity of faba bean is low in newly reclaimed soils with the low setting present, low number, and weight of seeds per plant. Taking into account both the high agricultural and industrial potential of this pulse crop, it is found desirable to improve the productivity of faba beans in the newly reclaimed soils .The one of the important uses of plant growth regulators (PGRs) that, to control plant physiology and improving agronomic productivity, particularly growth retardants like Paclobutrazol (PBZ) and mepiquat chloride (MC), which maintains internal-hormonal balances and efficient sink–source interactions (Singh *et al*., 1987)The inter-nodal length reducing and thus decreasing plant height and stimulating photosynthates translocation to

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reproductive sink (Kumar *et al*. 2005) and thus, enhanced crop productivity, Internal hormonal balances and efficient sink-source connections must be maintained (Singh *et al*., 1987). [2RS,3RS)-1-(4-Chlorophenyl)-4,4dimethyl-2-(1H-1,2,4-triazol-1-yl)pentan-3-ol] Paclobutrazol [2RS,3RS)-1-(4-Chlorophenyl)-4,4dimethyl-2-(1H-1,2,4-triazol-1-yl)pentan-3-ol is a member of the triazole family of compounds. that is part of the synthetic plant growth regulators which inhibits biosynthesis of sterol and gibberellin (Khan *et al*., 2009) and found to protect many cultivars against various environmental stresses (Kan *et al*., 2009; Orabi and coll., 2010), through modulating phytohormone levels and changing photosynthetic rate (Kim *et al*., 2012),increasing the photosynthetic pigments, uptake of nutrients, retardation of senescence and flowering and seed yield improvement (Davis *et al*.,1988 and Amin, 2007). It inhibits ent-kaurene oxidase activity, in the GA biosynthetic pathway, an enzyme catalyses the oxidation of ent-kaurene to ent-kaurenoic acid (Kondhare *et al*., 2014). Due to their negative effect on abiotic stresses, which mitigating innate potential to reduce adverse effects on plant growth and development, paclobutrazol has a multifactor stress protection impact by enzymatic and non-enzymatic antioxidants, osmolytes, and regulating hormones levels (Kuai *et al*., 2016; Kamran *et al*., 2018). Mepiquat chloride (1,1-dimethylpiperidinium chloride) (Reddy *et al*., 1990), that known as Pix, inhibition excessive growth of plant by decreasing heigh of plant, the nodes number, length of branch and leaf and thus, enhances the development of reproductive organs (Dippenar *et al*., 1990). In some circumstances, MC is also utilised to regulate growth for greater flowering benefits (Biles and Cothren, 2001), improve crop earliness (Kerby, 1985), and boost seed yields (Biles and Cothren, 2001). MC is an anti-gibberellin that inhibits gibberellin biosynthesis in plants by preventing the cyclization of geranylgeranyl pyrophosphate to copalyl pyrophosphate and the subsequent transformation of gibberellic acid biosynthesis to ent-kaurene (Halmann, 1990). Gibberellins are fundamentally in charge of cell elongation control and the shoots and stems growth in length (Sperry and Chaney, 1999). It stimulates cell division and expansion (De Lucas *et al*., 2008; Feng *et al*., 2008). Low levels of GA affect cell movement by lowering cell wall relaxation, reducing cell wall plasticity, and raising cell wall rigidity (Potter and Fry, 1993, Yang *et al*., 1996). The increased friction between cells obstructs elongation and replication, resulting in a reduction in plant height. On the other hand, agritone is the trade name for a plant growth bioregulator (PGB) product used to induce fruit set. It consists of 0.45% α-naphthyl acetic acid, 1.2% α-naphthyl acetamide, 1.3% adjuvants and 97.05% inert.

The plant growth regulators impact effective on plant structure and function in different areas has forced several researchers to apply them to many crop plants in order to improve agronomic productivity. Paclobutrazol application inhibited height of plant, enhanced diameter of stem, and number of leaves, reformed root architecture and enhanced photosynthetic rates (Pal *et al*., 2016), directly participated to increase of yield and the lodging case indirectly decreased (Syahputra *et al*., 2016). The use of paclobutrazol effectively decreased rice plant vegetative growth and increased content of chlorophyll. Application of Rice seedlings with PBZ assigned less vegetative growth photosynthesis; assigned more seed evolution photosynthesis compared to non-treated plants or plants treated with gibberellin (Dewi *et al*., 2016). Under drought stress, the use of 50 ppm paclobutrazol enhanced maize yields and average 1000 seed weight. (Bayat and Sepehri, 2012), maintains the endogenous amount of cytokine, stabilizes the capacity for leaf water and contributes to an increased leaf and epidermal thickness (Sankar *et al*., 2013). Regulation of free proline and glycine betaine as main osmo-protectants (Hajihashemi and Ehsanpour, 2014) as well as the promotion antioxidant activities enzymes and non-enzymes and reducing the drought stress toxicity (Hajihashemi and Ehsanpour, 2014; Jungklang *et al*., 2016). MC application not only offers the potential of the decreasing area of new leaves, (Stuart *et al*., 1984), but it increases CO_2 fixation in leaves near the fruiting branches with consequent improvement in biomass production and yield (Kerby *et al*., 1980). Plants treated with MC, are mostly prevented in their length of growth and with thicker, more callous, and more resistant stems to lodging (Reddy *et al*., 1992). In cotton, MC treatment in one variety increased the number of bolls and in the other (Reddy *et al*., 1992). In soyabean, MC foliar application significantly improved absolute growth rate, relative growth rate, net assimilation rate, and growth rates of crop (Patil, 1994 and Amin, 2003). In chickpea, MC treatment (50 ppm) increased leaf area, number of pods/plant, weight of pods and seeds/plant yield/m due to higher levels of chlorophyll content which provided photosynthates higher production of photosynthates, utilized for grain yield due to larger sink resulting from increased branching and more number of pods only in BG 384 variety, but no such effect was observed in Pusa 261 variety (Wasnik and Bagga, 1996). In pea plants (*Pisum sativum* L.), MC at 25-100 g ha^{-1} significantly increased number of pods/plant, number of seeds / pods, yielded seed, total biomass and harvest index (Elkoca and Kantar, 2006). On the other hand, the magnitude of response to NAA appears to be related to the application dose and growth stage of the crop at the time of application. In cotton, A foliar spray of NAA at 10 ppm increased crop growth rate, relative growth rate, sympodial branches/plant, and seed yield by 19.7% over control (Sharma and Dungarwal, 2004), and a foliar spray of 20 ppm NAA at 90 DAS increased plant height, number of (nodes on the main stem, and seed yield by 19.7% over control (Sharma and Dungarwal, 2004). symposia, and bolls/plant), boll weight, and seed cotton yield, which was 43% higher than control (Kumar *et al*.,2006). The highest cotton When NAA was given at a rate of 20 ppm (22.13 percent), then 15, 25, 10, and 5 ppm (17.28, 16.84, 12.97, and 7.25 percent), yield was higher than control. (Sawan *et al*., 1998). Two foliar sprays of NAA at 20 and 30 ppm gave significantly higher seed cotton yield than control (Brar *et al*., 2001; Turkhede *et al*., 2003) also, three foliar application of NAA at 40 ppm significantly increased seed cotton yield and boll weight (Pothiraj *et al*., 1995). Four sprays of 1% NAA solution significantly increased cotton yield and yield components, as well as varied growth factors, chlorophyll levels, and yield components (Parveen *et al*., 2017). In faba bean, maximum increments in root length, number of (nodules, branches, and leaves/plant), plant height, total leaf area/plant, and dry weights of root, stem, and leaves were obtained at 200 and 100 ppm NAA compared to the control (Ismaeil and Abd El-All, 2011). Because of several positive effects of growth regulators in improving the yield of several crops. Thus, the aim of this study was to investigate the effect of spraying faba bean (*Vicia faba* L.) cv. Giza 716 cv. with paclobutrazol, mepiquat chloride, On some physical features, yield, and metabolic seed components, as well as agritone.

2. Materials and Methods

During the winter seasons of 2019/2020 and 2020/2021, two field tests were conducted at the Research and Production Station of the National Research Centre in Noubaria, Behira Governorate, Egypt. In both seasons, seeds of faba bean (*Vicia faba* L.) Giza 716 cultivar were seeded in sandy soil on October 25th. According to Chapman and Pratt, Table 1 lists the physical and chemical parameters of the soil (1978). The experimental design was a ten-factor randomized complete block design. The plot measured 10.5 m^2 (3.0 m 3.5 m) and was divided into five rows, each 70 cm apart, with hills spaced 25 cm apart. In both seasons, a foliar spray with three growth regulators, paclobutrazol (PBZ; 30, 60, and 90 ppm), mepiquat chloride (MC; 500, 1000, and 1500 ppm), and agritone (AGR; 400, 600, and 800 ppm), faba bean plants were treated twice during the elongation stage (45 and 60 days after seeding) (DAS), in addition to control plants, which were sprayed with faba bean plants were irrigated and maintained utilizing a spray irrigation system up to 100% of crop evapotranspiration potential (in 15 successive irrigations) during the growing season. The suggested good agricultural methods, such as insect control, for growing faba bean in sandy soil were followed. The soil was pre-sown with calcium superphosphate (15.5 % P_2O_5) at a rate of 50 kg/fed. Before the first and second irrigations, nitrogen in the form of ammonium nitrate (33.0% N) was delivered in two equal doses at a rate of 100 kg/fed. At 21 and 35 days after sowing, 30 kg/fed potassium sulphate (48 % K_2O) was applied to the soil in two equal dosages.

Table 1: Some mechanical and chemical characters of the tested soil.

Character	Value	Character	Value
% Sand	87.0	K	10.20
% Silt	5.00	Ca mg/100g	92.10
% Clay	7.25	Mg	18.40
Texture	Sandy	Na	12.40
pH (1: 2.5 water)	8.82	Fe	8.90
E.C (mmhos/cm) (1:2.	0.13	Mn mg/kg	8.30
% $CaCO_3$	4.70	Zn	0.132
% O.M	0.23	Cu	0.11
		P	0.24

2.1. Data recorded

Plant samples were collected, after 80 and 105 DAS Plant height (PH), branch number (BN), and leaf number (LN) are all measured using green yield (LN), branches fresh weight (BFW), leaves fresh weight (LFW), branches dry weight (BDW), leaves dry weight (LDW) plant^{-1}, According to Vivekanadan *et al*. (1972), fourth leaf area (4-LA) (cm2 plant1) calculated using the leaf disc method on a dry weight basis, specific leaf weight (SLW) (mg cm2) calculated by Radford (1967), and crop growth rate (CGR) (mg/cm2/days) calculated by Abdel-Gawad *et al* (1980), Watson (1958) calculated the net assimilation rate (NAR) (mg/cm^2/day) and the leaf area index (LAI) 15 days after each spray, while Abdel-Gawad *et al*. (1980) calculated the relative growth rate (mg/g/day) (RGR).

At 80 and 105 DAS, the amount of photosynthetic pigments Fresh leaves were also tested for [chlorophylls (Chl) a, b, and carotenoids, as well as total photosynthetic pigments (TPP)]. (Lichtenthaler and Wellburn, 1983). The mean values of yield and its related parameters were determined at harvest time (115 DAS), including plant height (PH), number of pods/plant (PN/P), Seed and straw yields/plant (SY/P; StY/P), seed and straw yields/fed (SY/F; StY/F), number of seeds/plant (SN/P), weight of pods/plant (PW/P), seed and straw yields/fed (SY/F; StY/F), Seed index (SI), and harvest index (HI). Seeds from each treatment were harvested and dried for 48 hours until a constant dry weight was attained in an electric oven with a drift fan at 70°C.Total carbohydrate percent in seeds (CP) was calculated using dry seed samples (Dubois *et al*., 1956). Plummer's (1978) to calculate total free amino acids, a method was utilized (FAA). Wet digestion was performed on the dry powder samples. According to Chapman and Pratt's procedure (1978). The nitrogen, phosphorus, and potassium content of the acid digested plant materials were determined using the following methods: The modified Micro-Kjeldahl technique was used to determine total nitrogen. The crude protein was calculated by multiplying the total N values by 6.25. Percentage (CPP) (AOAC, 1988). According to Carpena *et al*., (1990) phosphorus was measured using an atomic absorption spectrophotometer. Brown and Lilliland (1946) recommended using a flame photometer by Jenway (atomic spectrum AAS vario 6) to assess potassium content. Mineral content was measured in milligrams per 100 grammes of DW seed tissue.

According to Snedecor and Cochran (1980), using the MSTATC (1989) programme in conjunction with the "MSTAT-C" computer software package, the average of two seasons was statistically assessed as a randomized full block design, and the least significant difference (L.S.D.) for each was calculated at the 0.05 level of probability.

3. Results

3.1. Parameters for growth

The data in Tables 2 and 3 show that foliar spraying paclobutrazol (PBZ) at 30, 60 and 90 ppm mepiquat chloride (MC) at 500, 1000 and 1500 ppm and Agritone (AGR) at 400, 600 and 800 ppm promoted almost all growth criteria of faba bean (Giza 716) cultivars except plant height compared with that of control (untreated plants). In most situations, the increment in growth parameters (branches and leaves number, In the majority of cases, fresh and dry weight/plant of branches and leaves, area of fourth leaf and leaf area index (LAI), specific leaf weight (SLW), crop growth rate (CGR), net assimilation rate (NAR), and relative growth rate (RGR), as compared with untreated control plants, were highly significant. Data also show the most effectiveness treatments were AGR at 400 and 600 ppm followed by PBZ at 30 ppm for all growth parameters. Foliar application of PBZ up to 60 ppm, significantly increased the area of fourth leaf (4th LA), leaf area index (LAI), specific leaf weight (SLW), crop growth rate (CGR), net assimilation rate (NAR), and relative growth rate (RGR) compared with relevant untreated control units. Similar significant increases in some growth parameters were achieved with up to 1000 ppm concentration of MC. During the two stages of growth, the MC treatment at 500 ppm promoted growth parameters (Tables 2 and 3). Furthermore, AGR was most effective than PBZ and MC in promoting faba bean vegetative growth during the two stages (Table 2 and Table 3). The growth characters increment (i.e., BN, LN, BFW, LFW, BDW, LDW, 4th LA, LAI, SLW, CGR, NAR and RGR was greatest with 400 ppm AGR whereas SLW recorded an insignificant response at 105 DAS compared with control plants.

Table 2: Effect of growth regulators Paclobutrazol, Mepiqquat chloride and Agritone on growth characters of faba bean (*Vicia faba* L.) (cv. Giza 716) at (A) 80 and (B) 105 days from sowing (Combined analysis of two seasons).

Treatments (ppm)	Characteristics of vegetative growth													
	Plant height (cm) (PH)		No. of branches /plant (BN)		Leaves No./plant (LN)		Branches F.W. (g/plant) (BFW)		Leaves F.W. (g/plant) (LFW)		Branches D.W. (g/plant) (BDW)		Leaves D.W. (g/plant) (LDW)	
	A	B	A	B	A	B	A	B	A	B	A	B	A	B
Control 0.0	78.9	89.9	4.2	5.8	37.4	39.1	90.5	92.2	59.1	60.1	23.9	24.7	9.2	8.2
Paclobutrazol30	70.8	85.8	6.9	6.8	53.9	56.4	118.6	122.4	68.2	67.8	30.1	32.2	11.9	9.9
Paclobutrazol 60	67.7	81.6	5.8	6.7	50.8	53.3	100.0	114.6	64.8	63.9	28.8	31.4	9.7	8.1
Paclobutrazol 90	64.6	76.4	5.7	5.9	41.7	49.7	98.7	106.5	60.2	61.7	26.7	29.8	9.1	7.8
MC 500	65.8	84.8	5.6	5.6	50.5	54.5	112.3	120.7	67.2	65.8	30.5	31.6	10.6	9.3
MC 1000	64.5	80.7	5.5	5.5	48.8	52.6	99.8	110.4	63.1	62.6	27.4	30.4	9.5	7.4
MC 1500	62.4	72.4	5.4	4.4	40.6	44.2	89.2	98.8	59.2	61.5	26.5	28.7	8.4	6.5
Agritone 400	76.7	87.9	7.9	7.7	59.6	64.8	125.1	132.6	69.9	71.4	31.6	33.1	12.9	10.6
Agritone 600	75.8	85.6	7.2	7.3	58.5	60.9	114.3	126.4	66.3	68.3	29.3	31.5	10.2	8.7
Agritone 800	66.9	81.3	7.1	6.7	56.8	59.1	109.5	122.3	62.9	62.5	28.1	30.5	9.5	8.0
L.S.D. at 5%	3.41	3.2	1.0	0.8	3.1	2.9	3.9	5.2	3.4	4.1	1.7	2.4	2.0	1.2

A: at 80 days from sowing; and B: at 105 days from sowing. Agritone: (0.43% NAA+ 1.18% NAD) MC: Mepiqquat chloride

Table 3: Effect of growth regulators: Paclobutrazol, Mepiqquat chloride and Agritone on growth characters of faba bean (*Vicia faba* L.) (cv. Giza 716) at (A) 80 and (B) From sowing to harvest, it takes 105 days (Combined analysis of two seasons).

Treatments (ppm)	Growth Characters								
	Fourth leaf area (cm^2)		Leaf area index		Specific leaf Weight ($mg/cm^2/day$)		Crop growth rate ($mg/cm^2/day$)	Net assimilation rate ($mg/cm^2/day$)	Relative growth rate (mg/g/day)
	A	B	A	B	A	B	A-B		A-B
Control 0.0	1351.36	1560.62	2.90	3.44	3.01	4.11	1390.61	0.360	2.29
Paclobutrazol30	1452.50	1764.65	3.89	4.55	4.86	4.90	1658.67	0.471	3.70
Paclobutrazol 60	1370.80	1651.56	3.76	3.63	4.66	4.75	1649.74	0.442	2.43
Paclobutrazol 90	1349.39	1592.70	2.81	3. 51	3.74	3.69	1568.58	0.423	1.33
MC 500	1409.31	1634.90	3.94	3.75	4.82	4.88	1579.49	0.404	2.47
MC 1000	1356.43	1559.83	3. 67	3.60	3.78	4.72	1487.30	0.385	1.60
MC 1500	1329.76	1566.47	2.54	3. 48	3.63	3.44	1476.72	0.366	1.56
Agritone 400	1733.81	1851.38	4.87	4.91	4.95	4.96	1781.08	0.487	3.79
Agritone600	1566.70	1762.29	4.72	4.89	4.69	4.81	1762.92	0.470	3.68
Agritone800	1409.90	1670.43	4.03	4.47	3.80	3.70	1630.83	0.462	2.59
L.S.D. at 5%	33.51	60.41	0.46	0.16	0.19	n.s	36.01	0.062	0.11

A: at 80 days from sowing; and B: at 105 days from sowing. Agritone: (0.43% NAA+ 1.18% NAD) MC: Mepiqquat chloride n.s= not significant at L.S.D. 5%

3.2. Yield

Presented data in Table (4) explain that, treated with PBZ increased yield of faba bean (i.e., No. of Pods/plant (PN), No. seeds/Pods (SN), Weight of pods (g/plant) (PW), Seed Yield (g)/plant (SY/P), Seed Yield (ton)/fed. (SY/F), Straw Yield (g)/plant (StY/P), Straw Yield (ton)/fed. (StY/F), Seed index (g) (SI) and Plants with a higher harvest index (HI) than control plants. The results for SY/F were the most promising., StY/F and SI (increased 133.33, 66.54 and 28.14% more than their controls, respectively) when used 30 ppm of PBZ.

The mepiquat chloride was less effective than PBZ and AGR in increasing bean yield characters. MC at 500 ppm increased SY/F, StY/F and SI by 127.66, 45.72 and 20.64% more than the controls, respectively. In this respect, the increments in SY/P and StY/P were often non-significant at 1500 ppm MC in comparison with untreated controls (Table 4). Furthermore, bean yield was more sensitive to agritone. The greatest i ncrease in bean yield (SY/F, StY/F, SI and HI increased 136.17, 73.23, 31.06 and 9.87% more than control, respectively) were obtained by foliar application of 400 ppm (Table 4).

Table 4: Effect of growth regulators: Paclobutrazol, Mepiqquat chloride and Agritone on yield and its components of faba bean (*Vicia faba* L.) (cv. Giza 716) at 115 days from sowing (Combined analysis of two seasons).

Treatments (ppm)	Yield and its components									
	Plant height (cm) PH	No. Pods/plant	No. seeds/ Pod (SN/P)	Weight of pods/plant (PW)	Yield/plant (g)		Yield/fed (ton)		Seed index	Harvest index
					Seed	Straw	Seed	Straw		
Control 0.0	118.44	26.49	3.29	6.93	50.60	86.21	1.41	2.69	76.01	45.6
Paclobutrazol30	112.70	32.50	5.69	8.56	64.38	98.76	3.29	4.48	97.40	46.7
Paclobutrazol 60	100.60	30.65	4.97	7.90	61.79	96.68	2.62	3.78	94.59	45.8
Paclobutrazol 90	91.12	29.70	4.81	7. 62	59.55	89.74	2.59	3.64	88.66	41.6
MC 500	109.03	31.28	5.68	8.11	56.68	89.70	3.21	3.92	91.70	45.7
MC 1000	98.94	29.37	4.77	7.60	53.76	87.88	2.62	3.71	87.38	44.8
MC 1500	90.68	27.44	4.57	7.19	51.82	86.57	2.56	3.60	84.49	39.9
Agritone 400	113.35	34.84	6.86	9.86	67.91	99.49	3.33	4.66	99.62	50.1
Agritone 600	108.62	32.93	5.94	8.64	64.09	96.85	3.14	3.89	96.33	46.7
Agritone 800	96.53	30.42	5.89	7. 78	62.62	94.87	3.01	3.80	94.51	45.9
L.S.D. at 5%	5.41	1.39	0.67	0.62	3.92	5.61	0.73	0.21	2.92	2.34

Agritone: (0.43% NAA+ 1.18% NAD) MC: Mepiqquat chloride.

3.3. Photosynthetic Pigments

Table (5) shows that the maximum value of Chlorophyll (Chl.) a, b, carotenoids, and total photosynthetic pigments (TPP) in faba leaves was reached at 105 days. after sowing (DAS). In addition, foliar spraying of all concentrations to PBZ, MC, or AGR resulted in significantly increment of the Chl. a, b, carotenoids and consequently the TPP at 80 and 105 DAS more than control and the most efficient treatments were PBZ, MC, and AGR at 30, 500, and 400 ppm, respectively during both vegetative stages. Foliar spraying plants of faba bean with PBZ at 30, 60 and 90 ppm Compared to untreated plants, there was a considerable increase in photosynthetic pigments (Table 5). Giza 716 cultivar leaves have the highest value of Chl a, b, carotenoids, and TPP. were recorded by 30 ppm PBZ at the two stages of growth, whereas MC up to 1500 ppm was less effective in increasing these pigments (Table 5). Moreover, in the leaves of Giza 716 cultivar plants, AGR up to 800 ppm enhanced the levels of Chl a, b, carotenoids, and TPP. significantly during the two growth stages compared with control (Table 5) and the most effective treatment was 400 ppm of AGR.

Table 5: Effect of growth regulators: Paclobutrazol, Mepiqquat chloride and Agritone on photosynthetic pigments contents (mg/g fresh weight) in the leaves of faba bean (*Vicia faba* L.) (cv. Giza 716) at 80 and 105 days from sowing (Analysis of two seasons combined).

Treatment (ppm)	80 days following sowing				105 days following sowing			
	Chl. A	Chl.b	Carotenoids	Total pigments	Chl. a	Chl. b	Carotenoids	Total pigments
Control 0.0	1.26	0.81	1.31	3.38	1.41	0.97	1.44	3.82
Paclobutrazol30	1.69	1.16	1.47	4.32	2.29	1.27	1.58	5.14
Paclobutrazol 60	1.58	1.12	1.41	4.11	2.09	1.21	1.56	4.86
Paclobutrazol 90	1.49	1.04	1.39	3.92	1.82	1.13	1.52	4.47
MC 500	1.67	1.09	1.42	4.18	1.77	1.29	1.55	4.61
MC 1000	1.56	1.06	1.39	4.01	1.71	1.16	1.53	4.40
MC 1500	1.40	1.01	1.35	3.76	1.59	1.18	1.51	4.28
Agritone 400	1.76	1.16	1.43	4.35	2.39	1.24	1.57	5.20
Agritone 600	1.67	1.13	1.43	4.23	2.34	1.21	1.54	5.09
Agritone 800	1.64	1.10	1.38	4.12	2.01	1.15	1.48	4.64
L.S.D. at 5%	0.11	0.03	0.02	0.17	0.07	0.04	0.03	0.20

Agritone: (0.43% NAA+ 1.18% NAD) MC: Mepiqquat chloride.

3.4. Chemical Constituents

Data in Table (6) explain that, all concentrations of PBZ, MC or/and AGR recorded significantly increase in the total carbohydrates (%TC), crude protein (%CP), total free amino acids contents (mg

100/g ^{DW} (FAA), nitrogen (%N), P and K contents (mg 100/g DW) in Giza 716 seeds in contrast to control at 115 DAS (i.e., the harvest time). The most successful application in increasing the chemical constituents in seeds at the harvest date were 30, 500, and 600 ppm of PBZ, MC, and AGR, respectively. In addition, the findings show that the highest level of TC, CP, FAA, N, P, and K in seeds was obtained from 400 ppm AGR, followed by 30 ppm PBZ, then 500 ppm MC (Table 6).

Table 6: Effect of growth regulators: Paclobutrazol, Mepiqquat chloride and Agritone on chemical constituents in seeds of faba bean (*Vicia faba* L.) (cv. Giza 716) (Combined analysis of two seasons).

Treatments (ppm)	Chemical constituents in seeds					
	Total carbohydrate (%)	Crude protein	Total amino acids (mg/100g DW)	N %	P	K
					(mg/100 g DW)	
Control 0.0	43.51	32.09	1.21	4.38	1.36	1.39
Paclobutrazol30	48.49	36.70	2.34	6.60	2.77	2.71
Paclobutrazol 60	46.69	35.66	2.22	5. 76	2.51	2.65
Paclobutrazol 90	45.81	34.45	2.02	5.45	1.48	2.51
MC 500	45.67	35.87	2.29	6.09	2.69	2.62
MC 1000	45.59	34.51	2.11	5.46	1.56	2.57
MC 1500	44.62	33.40	1.39	4.66	1.47	2.46
Agritone 400	48.68	37.82	2.41	6.71	2.79	2.80
Agritone 600	47.77	35. 60	2.23	5. 89	2.66	2.70
Agritone 800	47.59	35.80	2.09	5.80	2.46	2.67
L.S.D. at 5%	1.96	1.09	0.23	0.11	0.07	0.05

Agritone: (0.43% NAA+ 1.18% NAD) MC: Mepiqquat chloride.

4. Discussion

According to the findings of this investigation, the application of low concentrations of PBZ, MC, and AGR, reduced plant height by inhibiting GA_3 production and significantly increases plant vegetative and production of dry-matter by involvement in the auxin and/or cytokinin's synthesis, improvement in the division of cells and accumulated of Chl. Faba bean plants treated with PBZ, especially at 30 ppm were shorter and superior to control plants regarding plant development. In this connection, PBZ have promoted rooting in apple (Wang and Faust, 1986), significantly increased the root activity and root-bleeding sap flow in maize which due to higher root growth and root vigor compared to control (Kamran *et al*., 2018), in oleander leaves, leaf blade area were reduced and imparted a partially darker green color (Banon *et al*., 2001),suppressed shoot height and dry weight in wheat and tomato (Berova *et al*., 2002; Still and Pill, 2003) and reduced height and stem width, induced a darker green color leaves as well as increased photosynthetic rate, transpiration rate and water use efficiency in peony plants (Paeonialactiflora Pall; Xia *et al*., 2018). Reduced plants height which treated by PBZ may be related to its restrain action of GA biosynthesis, which is responsible for cell elongation (Grossmann, 1992). Application of paclobutrazol at 200 ~ 600 mg/L concentration during pre-anthesis, declined content of gibberellins in rice leaves compared to control (Syahputra *et al*., 2013). In faba bean plants, the use of 25 ppm PBZ resulted in a considerable reduction in plant height as well as an increase in the number of branches and blooms (Ibrahim *et al*., 2007). Fresh and dried weights per plant, leaf area, number of plant pods, seeds per pod, weight of 100 seeds, and seed output at 200 ppm all rose significantly (Khafaga *et al*., 2009) as well as a rise in the number of branches and leaves per plant, and dry leaves weight/plant at 10 ppm concentration in faba bean (Faba vulgaris Mill.) Cv. Gridley (Ismaeil and Abd El-All, 2011). Soil application of PBZ at low concentrations (75-100 mgl^{-1}) reduced height of plant accompanied by significant increase in branches thickening, number, and the dry matter accumulation in *Camelina sativa* stem. While, the high concentration of PBZ (125 mgl^{-1}) significantly decreased plant height (47.5% decrease), stem growth (25%), and branch number with respect to control (Sumit *et al*., 2012). Similarly, PBZ at 50 ppm reduced plant height and caused severe dwarfism in black rice (*Oryza Sativa* L.), (Dewi *et al*., 2016). MC has shown a lower capacity to encourage the growth and yield of faba bean plants than PBZ in this study. In addition, treatments of MC significantly reduced stem height and increased faba bean growth, especially at 500 ppm (Tables 2 and 3). MC act by inhibiting the biosynthesis of gibberellin (Yokota *et al*., 1991) which the main responsibility for cell elongation and increase in the length of the shoots and stems of plants (Sperry and Chaney, 1999). Lower concentrations of gibberellin affect movement among cells due to lower cell wall relaxation reduced plasticity of the cell walls and increased cell wall rigidity (Potter and Fry 1993; Yang *et al*., 1996). Increased the friction amount between cells hampers elongation and replication and thus, decreases plant height. In this respect, plants treated with MC are usually inhibited with their length of growth and their tines tend to be thicker, stiffer, and more robust (Reddy *et al*., 1992). The application of plant growth retardant in wheat has demonstrated comparable decreases in stem height and accommodations (Berry *et al*., 2000), cotton (Iqbal *et al*., 2004) and pea at a low dose (25 gha^{-1}) of MC. Higher doses of MC, however, did not lead to substantial decreases in stem height, increased lodging prevention and increased yield of seed compared to a 25gha^{-1} application dose (Elkoca and Kantar, 2006). In soybean, the foliar application of MC substantially increased its AGR, RGR, NAR, and CGR (Patil, 1994). MC treatment (50 ppm) increased the dry weight of leaf but had no effect on dry weights of root and stem, in two varieties of chickpea. However, leaf area, number of secondary and tertiary branches were increased only in BG 384 variety (Wasnik and Bagga, 1996). Moreover, AGR increased vegetative growth, the production of dry matter, and the seed yield of faba bean plants more efficiently than the treatments with PBZ and MC. In this connection, naphthalene acetic acid (NAA) has a stimulating effect on cell division and cell elongation, hence it could increase all vegetative growth and photosynthetic rates (Gutam Sridhar *et al*., 2009). In cotton, A foliar spray of NAA at 10 ppm boosted crop growth rate, relative growth rate, sympodial branches/plant, and seed production considerably yield by 19.7 % more than control (Sharma and Dungarwal, 2004) and increased plant height, number of (nodes on the main stem, symposia, and bolls/plant), boll weight, and seed cotton yield, which was 43% higher than control at 20 ppm NAA at 90 DAS (Kumar *et al*., 2006). In faba bean (*Faba vulgaris* Mill.) cv. Gridley, maximum increments in root length, number of (nodules, branches, and leaves/plant), plant height, total leaf area/plant and dry weights of root, stem, and leaves were obtained by applying 200 and 100 ppm of NAA compared to the control (Ismaeil and Abd El-All, 2011) while, NAA treatments at 25 and 50 ppm decreased plant height and flowers number in *Vicia faba* L. cv. Giza 716 (Ibrahim *et al*., 2007). Through improved photosynthesis, increased plant vegetative development, dry matter buildup, and hence greater translocation, as well as the accumulation of specific metabolites in plant tissues, application of PBZ, MC, or AGR increased yield (seed and straw yield/fed), SI, and HI of faba bean (Giza 716) cultivar. (Tables 3).

Faba bean yield and the quantity of pods were significantly enhanced by PBZ; the PBZ positive effects on components of yield such as the larger mean of SY/F, StY/F and SI increased 133.33, 66.54, and 28.14% more than the control, respectively were obtained by foliar application of 30 ppm PBZ followed by 60 ppm PBZ for all parameters. In PBZ treated plants, the probable increase in the production of seeds may be due to improve in the canopy coverage, which in turn made it possible to grow a broader canopy increasing the light interception for better photosynthesis, the leaves were closed and held to plants longer than controls, which could account for an accumulation of stem and root dry matter, while the output of the plants is reduced (Pan *et al*., 2013). Increasing or extending photosynthetic rate per leaf area unit has been increased yield and enhancing crop biomass partitioning to the harvested product related to increment of the grain yield and slow leaves senescence which lengthen the seed development stage and maturation and as a result delayed the harvest time (Chenet *et al*., 2005). The further potential increase in grain yield is partly attributed to lower overland investment due to a relatively stronger PBZ canopy and an improved grain supply of treated plants due to an improved rooting system, which may increase water and nutrient uptake and consumption (Kamran *et al*., 2018).The soil application of PBZ increased the yield of seed by 3.91%, 8.53%, 16.58% and 74.23% at 25, 50, 75, and 100 g l^{-1}, respectively compared with control in Camelina (sumit *et al*., 2012) and average maize grain yields by 18.9%, 61.3% and 45.9% under seed soaking in 200, 300 and 400 mg L^{-1}, treatments, respectively. While, seed soaking at rate 1.5, 2.5 and 3.5 g kg^{-1} of PBZ increased yield of maize by 20.2%, 33.3% and 45.2%, respectively compared with control (Kamran *et al*., 2018). The application of PBZ has been reported to enhance grain yield associated with a significant increase in fertile tiller, altered phenology, and improved canopy (Tesfahun and Menzir, 2018). MC increased yield due to its promoting effect on many physiological processes which leads to the improvement of all performance components. MC at 500 ppm increased SY/F, StY/F, and SI by 127.66, 45.72, and 20.64% more than the control, respectively (Table 3). Manipulation of crop morphology using MC increased use of solar radiation and alterations in favor of seed growth is spread in order to minimize the height and lodging (Daniels *et al*., 1982). MC application improves the absorption and fixation of carbon dioxide on plant leaves, according to Gausmann *et al*. (1980). For stems, MC treatment increased xylem, likely growing water and nutrients in the plant's transportability (Elkoca and Kantar, 2006). Increased MC photosynthesis was also associated with increased total plant chlorophyll level (Nepomuceno *et al*., 1997), improved photosynthesis, increased flowering, retention of fruits, and yield of seed (Sawan *et al*., 1993). In two species of chickpea the amount of chlorides per plant, pods, and seed weight per plant, and yield m^{-2} increased at 50 ppm due to higher levels of chlorophyll which developed more photosynthesis for grain yield due to greater sink caused by increased branching and more pruning. However, in the case of Pusa 261, no such effect was observed. (Wasnik and Bagga, 1996). In cotton, MC increased the boll number in one variety and decreased it in the other (Reddy *et al*., 1992). Spraying pea (*Pisum sativum* L.) plants at the early blooming stage with MC at 25-100 g ha^{-1} substantially increased plant number, seed per pod, seed yield, total biomass yield, and harvest index in comparison to non-treated control (Elkoca and Kantar, 2006). In this study, AGR was the best treatment to increase the yield of faba bean (Giza 716) plants. The greatest increase in bean yield (SY/F, StY/F, SI, and HI increased 136.17, 73.23, 31.06, and 9.87% more than the control, respectively) were obtained by foliar application of 400 ppm followed by 600 ppm for all parameters. Similarly, NAA at 25 ppm significantly increased seed index (100-seed weight) and enhanced the mobilization of photo assimilates to filling seeds in *Vicia faba* L. cv. Giza 716 (Ibrahim *et al*., 2007). In cotton, When NAA was given at a rate of 20 ppm (22.13 percent), the maximum yield was obtained, followed by 15, 25, 10, and 5 ppm (17.28, 16.84, 12.97, and 7.25 percent) greater than control. (Sawan *et al*., 1998). Two foliar sprays of NAA at 20 and 30 ppm gave significantly higher seed cotton yield (Brar *et al*., 2001; Turkhede *et al*., 2003), three foliar applications of NAA at 40 ppm significantly increased seed cotton yield and boll weight (Pothiraj *et al*., 1995). Also, Different growth indices, chlorophyll levels, yield, and yield components of cotton were dramatically boosted after four sprays of a 1% NAA solution. (Parveen *et al*., 2017). PBZ, MC, and AGR were significantly enhanced through the application by increasing the metabolic rate of cells and shielding and avoiding chloroplast senescence, as well as decreasing Chl. breakdown and/or enhancing Chl. biosynthesis, can help to delay senescence. Chl. biosynthesis has been significantly enhanced through the application (Table 4). In the present trial, foliar use of PBZ increased in all concentrations more than control, Chl. a, b, carotenoids, and TPP considerably. Senescence was delayed in connected bean leaves by PBZ due to an increase in endogenous cytokinin levels as a result of chlorophyll degradation rates. (Fletcher *et al*., 2000). Nivedithadevi *et al*. (2015) report that more cytokinins was synthesized in plants treated with PBZ, which improved chloroplast differentiation and bio-synthesis of chloroplasts and prevented chlorophyll degradation. Dewi *et al*. (2016) worked on the black rice and showed that the 25 or 50 ppm greener leaves and late senescence of plants treated with PBZ have been shown to have the increasing activity of enzymes preventing cells from maturing. Furthermore, the enhanced chlorophyll level in PBZ-treated plants could be due to reduced damage from reactive oxygen and carotenoid alterations. ascorbate, and ascorbate peroxidase levels (Tesfahun, 2018). Application of PBZ has been reported to stimulate the photosynthetic pigments and rate in tomato (*Lycopersicon esculentum* Mill.) Plants (Berova and Zlatko, 2000), faba bean (*Faba vulgaris* Mill.) Cv. Gridley plants at 5 and10 ppm (Ismaeil and Abd El-All, 2011), *Camelina sativa* L. Crantz (Sumit *et al*., 2012), *Solanum trilobatum* (Nivedithadevi *et al*., 2015), and the number of chloroplasts in individual cells in herbaceous peony (*Paeonia lactiflora* Pall.) (Xia *et al*., 2018). Mepiquat chloride enhances Chl. aggregation, resulting in higher photosynthesis in the Giza 716 cultivar. The most effective concentration was 500 ppm MC.In the cotton (Xu and Taylor, 1992) and two chickpea varieties during reproductive, the promotion effect of MC was observed on photosynthetic pigments (Wasnik and Bagga, 1996). Likewise, in this study the AGR in the leaves of Giza 716 farmed up to 800 ppm considerably higher concentration of chl. a, b, carotenoids, and TPP than control in both phases of development, and the AGR in 400 ppm increased the photosynthates of faba bean leaves the most in both seasons (Table 4). In this respect, NAA at 200 or 100 ppm increased photosynthetic pigments content in faba bean (Faba vulgaris Mill.) Cv. Gridley leaves at 60 and 85 days (Ismaeil and Abd El-All, 2011) and chlorophyll levels in cotton leaves at 1% NAA solution (Parveen *et al*., 2017).TC, CP, FAA, N, P, and K increased in dry seeds of feba beans as a consequence of the biological impact on enzyme activity and the translocation from the leaves into seeds, linkage, or transformation into other plant metabolites. Application of Folic Blend of PBZ, MC, or AGR increased. The most effective treatments in increasing the chemical constituents in seeds at the harvest date were 30, 500, and 600 ppm of PBZ, MC, and AGR, respectively (Table 6). PBZ increased Carbohydrates in maturing Brassica carinata leaves (Setia *et al*.,

1995) and a small rise in *Catharanthus roseus* amino acids (Jaleel *et al*., 2006) and carrot (Gopi *et al*., 2007). The positive effect that existed with PBZ on total carbohydrates could be attributed to that increase of chlorophyll content and its reversion on improvement or enhancement of photosynthetic processes in cotton (El-Desouky *et al*., 2001) and faba bean (Sharaf El-Deen and Manaf, 2009). On the other hand, PBZ at 25 and 50 ppm significantly decreased total phenols, indoles, free amino acids (in leaves), and total soluble carbohydrates (in seeds) of (*Vicia faba* L.) cv. Giza 716 (Ibrahim et. al., 2007). In this study, the greatest level of TC, CP, FAA, N, P, and K in Giza 716 seeds was obtained for 400 ppm AGR, followed by 30 ppm PBZ, then 500 ppm MC. The increase in nitrogen, phosphorus, and potassium by the application of agritone may be the consequence of its role in ion control and may change the absorption of nutrients within plant tissues and their metabolism. In this connection, NAA increased amino acid content in *Phaseolus vulgaris* (Zaghlool *et al*., 2001) and total soluble sugars, total phenols and amino acids (in leaves), as well as total soluble carbohydrates, were significantly increased (in seeds) at 25 ppm in *Vicia faba* L. cv. Giza 716 (Ibrahim et. al., 2007). In faba bean, NAA at 200 or 100 ppm followed by PBZ at 10 or 5 ppm were more effective and significantly increased total carbohydrates, nitrogen, phosphorus, potassium, and crude protein contents in seeds (Ismaeil and Abd El-All, 2011).

5. Conclusions

In conclusion, PBZ, MC, and AGR have the potential to be used as a foliar application to improve the growth and yield of faba bean cv. "Giza 716" in the field. The use of three growth regulators compounds reduced plant height, increased total chlorophyll level, and delayed senescence leading to greater build-up and yield of biomass per plant, which in turn caused increased yield per feddan. Application of AGR at 400 ppm, followed by PBZ at 30 ppm then MC at 500 ppm. The seed yield and quality of the faba bean can be largely successful and offers an easily applied solution for ensuring sustainable agriculture worldwide in sandy soils.

List of abbreviations

- Paclobutrazol (PBZ)
- Mepiquat chloride (MC)
- Agritone (AGR) (of 0.45% α-naphthyl acetic acid, 1.2% α-naphthyl acetamide, 1.3% adjuvants and 97.05% inserts**.**
- Branches dry weight (BDW)
- Height of the plant (PH)
- Branch number (BN)
- The number of leaves (LN)
- Branches fresh weight (BFW)
- Leaves fresh weight (LFW)
- Branches dry weight (BDW)
- Leaves dry weight (LDW)
- Fourth leaf area (4-LA)
- Specific leaf weight (SLW)
- Crop growth rate (CGR)
- Leaf area index (LAI)
- Net assimilation rate (NAR)
- Relative growth rate
- Chlorophylls (Chl)
- Number of pods/plant (PN/P)
- Number of seeds/plant (SN/P)
- Weight of pods/plant (PW/P)
- Seed yields/plant (SY/P)
- Straw yields/plant; StY/P**(**
- Seed yields/fed (SY/F)
- Straw yields/fed (StY/F)
- Seed index (SI)
- Harvest index (HI)

- Total free amino acids (FAA)
- Total carbohydrate percent in seeds (CP)
- Crude protein percentage (CPP)

References

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. Egyptian Research Bulletin, 1412: 1–17.

Amin, A.A., 2003. Physiological response of wheat plant (*Triticum aestivum* L.) to foliar application of pix and atonik. J. Agric. Sci. Mansoura Univ., 28(2): 979-993.

Amin, A.A., 2007. Physiological response of two hybrids of yellow maize to foliar application of atonik and paclobutrazol. J. Agric. Sci. Mansoura Univ., 32(4): 2527-2541.

AOAC., 1988. Official methods of analysis, 21st ed. Washington, D.C., Association of Official Analytical Chemists.

Banon, S., J. Ochoa, and A. Gonzalez, 2001. Manipulation of Oleander Growth, Development and Foliage Colour by Paclobutrazol and Ethephon. Gartenbauwissenschaft, 66: 123–132.

Bayat, S. and A. Sepehri, 2012. Paclobutrazol and salicylic acid application ameliorates the negative effect of water stress on growth and yield of maize plants. J. Res. Agric. Sci., 8(2): 127–139.

Berova, M. and Z. Zlatko, 2000. Physiological Response and Yield of Paclobutrazol Treated Tomato Plants (*Lycopersicon esculentum* Mill.). Plant Growth Regul., 30: 117–123.

Berova, M., and N. Zlatev ZandStoeva, 2002. Effect of paclobutrazol on wheat seedlings under low temperature stress. Bulg. J. Plant Physiol., 28: 5-84.

Berry, P.M., J.M. Griffin, R. Sylvester-Bradley, R.K. Scott, J.H. Spink, C.J. Baker and R. Clare, 2000. Controlling plant from through husbandry to minimize lodging in wheat. Field Crops Res., 67: 59-81.

Biles, S.P. and J.T. Cothren, 2001. Flowering and yield response of cotton to application of mepiquat chloride and PGR-IV. Crop Sci., 41: 1834-1837.

Brar, Z.S., J. Singh, S.S. Mathauda, and H. Singh, 2001. Fruit retention and yield of cotton as influenced by growth regulators and nutrients. J. Res. Punjab Agric. Univ., 38: 6-9.

Brown, J. and O. Lilliland, 1946. Rapid determination of K and Na in plant material and soil extracts by flame photometer. J. Am. Soc. Hortic. Sci., 48: 341–346

Burbano, C., C. Cuadrado, M. Muzquiz, and J.I. Cubero, 1995. Variation of favism-inducing factors (vicine, convicine and L-DOPA) during pod development in *Vicia faba* L. Plant Foods Hum. Nutr., 47(3):265–274.

Carpena, R., A.H. Ramon, and A. Garate, 1990. The effects of short-term deficiency of B, K, Ca, and Mg ions distribution in leaves and roots of tomato (*Lycopresicon esculentem* L.) plants. In: Van Bensichem ML (ed.) Plant Nutr. Physio. Appl., 287–290.

Cazzato, E., V. Tufarelli, E. Ceci, A.M. Stellacci, and V. Laudadio, 2012. Quality, yield and nitrogen fixation of faba bean seeds as affected by sulphur fertilization. Acta Agriculturae Scandinavica, Section B - Soil and Plant Sci., 62 (8): 732-738.

Chaieb, V., J.L. González, M. López-Mesas, M. Bouslama and M. Valiente, 2011. Polyphenols content and antioxidant capacity of thirteen faba bean (*Vicia faba* L.) genotypes cultivated in Tunisia. Food Research International, 44 (4): 970–977.

Chapman, H.D. and P.F. Pratt, 1978. Methods of analysis for soil, plant and water. Agric. Sci. Dept. Univ. of California, USA, 309 Chem., 36: 345-347.

Chen, Z.H., F.B. Wu, X.D. Wang, and G.P. Zhang, 2005. Heterosis in CMS Hybrids of Cotton for Photosynthetic and Chlorophyll Fluorescence Parameters. Euphytica, 144: 353–361.

Daniels, R.W., D.H. Scarisbrick, J.F. Chapman and A.B.N. Rawi 1982. The influence of plant growth regulators on the growth, development and yield of oilseed rape (*Brassica napus* L.). In: J. S. McLaren, ed. Chemical Manipulation of Crop Growth and Development, 153-164. Butterworths, London.

Davis, T.D., Steffens, G.L. and N. Sankhla, 1988. Triazol plant growth regulators. Hortic. Rev., 10:151-188.

De Lucas, M., J.M. Davière, M. Rodríguez-Falcón, M. Pontin, J.M. Iglesias-Pedraz, S. Lorrain, C. Fankhauser, M.A. Blázquez, E. Titarenko, and S. Prat, 2008. A molecular framework for light and gibberellin control of cell elongation. Nature, 451(7177): 480–484.

Dewi, K., R.Z. Agustina, and F. Nurmalika, 2016. Effects of blue light and paclobutrazol on seed germination, vegetative growth and yield of black rice (*Oryza Sativa* L. 'Cempo Ireng'). Biotropia, 23(2): 85–96.

Dippenar, M.C., C.R. Nolte and C. Barnard, 1990. Controlling excessive growth in cotton by multiple applications of low concentrations of mepiquat chloride. S. Afr. J. Plant Soil, 7: 50-54.

Dubois, M., K.A. Gilles, J.R. Hamilton, P.A. Robers and F. Smith, 1956. Colorimetric method for determination of sugar and related substances. Ann. of Chem., 28: 350–356.

Elkoca, E. and F. Kantar, 2006. Response of pea (*Pisum sativum* L.) to mepiquat chloride under varying application doses and stages J. Agronomy, &Crop Science, 192: 102-110

El-Desouky, S.A., Z.M. Khedr, A.L. Wanas, and H.S. Ahmed, 2001. Response of the Egyptian cotton plant to foliar spray with some macro nutrients (NPK) and the growth regulator paclobutrazol (PP_{333}). I- effects on vegetative growth, leaf anatomy and chemical components., Annals. Agric. Sci. Moshtohor, 39(4): 2087-2107.

Feng, S., C. Martinez, G. Gusmaroli, Y. Wang, J. Zhou, F. Wang, L. Chen, L. Yu, J.M. Iglesias-Pedraz, S. Kircher, E. Schäfer, X. Fu, L.M. Fan, and X.W. Deng, 2008. Coordinated regulation of *Arabidopsis thaliana* development by light and gibberellins. Nature, 451:475–479.

Fletcher, R.A., A. Gilley, T.D. Davis, and N. Sankhla, 2000. Triazoles as plant growth regulators and stress protectants. Hortic. Review, 24: 55–138.

Gausmann, H.W., H. Walter, F.R., Rittig, D.E., Escobar and R.R. Rodriguez, 1980. Effect of mepiquat chloride (Pix) on CO_2 uptake of cotton plant leaves. In: M. Abdel Rahman, ed. Proceedings of the Plant Growth Regulator Working Group, Longmont, CO, USA, 1-6.

Gopi, R., C.A. Jaleel, R. Sairam, G.M. Lakshmanan, M. Gomathinayagam, and R. Panneerselvam, 2007. Differential effects of hexaconazole and paclobutrazol on biomass, electrolyte leakage, lipid peroxidation and antioxidant potential of *Daucus carota* L. Colloids Surf. B. Biointerface, 60:180-186.

Gous, R.M., 2011. Evaluation of faba bean (*Vicia faba* cv. Fiord) as a protein source for broilers. South African J. of Animal Sci., 41 (2): 71–78.

Grossmann, K., 1992. Plant growth retardants: Their mode of action and benefit for physiological research, In: C.M. Karassan, L.C. Van Loon. And D. Vereugdenhil (ed.). Progress in plant growth regulation. Kluwer Academic Publishers, Netherlands, 788-797.

Gutam Sridhar Sridhar, R.V.K., M.B. Chetti, and S.M. Hiremath, 2009. Effect of naphthalene acetic acid and mep. chloride on physiological components of in bell pepper (*Capsicum annuum* L.). J. Agric. Res., 47(1): 53-62.

Hajihashemi, S. and A.A. Ehsanpour, 2014. Antioxidant response of Steviarebaudiana B. to polyethylene glycol and paclobutrazol treatments under *in vitro* culture. Applied Biochem. and Biotech., 172: 4038–4052.

Halmann, M., 1990. Synthetic plant growth regulators. Adv. Agron., 43: 47-105.

Ibrahim, I.S., A.B. Abdel-Razik and M. Ebeed Naglaa. 2007. Effects of some plant growth regulators on biochemical gene expression, growth and yield of faba bean. Pak. J. Biotechnol., 4 (1-2): 47-64.

Iqbal, M., M.Z. Iqbal, R.S.A. Khan, K. Hayat and M.A. Chang, 2004. Response of new cotton variety MNH-700 to mepiquat chloride under varying plant population. Pak. J. Biol. Sci., 7: 1898-1902.

Ismaeil, F.H.M. and M.M.M. Abd El-All, 2011. Effects of some growth regulators and antioxidants on growth, yield and seed chemical composition of faba bean plants. J. Plant Production, Mansoura Univ., 2 (11): 1563 –1577.

Jaleel, C.A., R. Gopi, P. Manivannan, A. Kishorekumar, B. Sankar, and R. Panneerselvam, 2006. Paclobutrazol influences on vegetative growth and floral characteristics of *Catharanthus roseus* (L.). G. Don. Indian J. Appl Pure Biol., 21:369-372.

Jungklang, J., K. Saengnil, and J. Uthaibutra, 2016. Effects of water-deficit stress and paclobutrazol on growth, relative water content, electrolyte leakage, proline content and some antioxidant changes in *Curcuma alismatifolia* Gagnep. cv.Chiang Mai Pink. Saudi J. Biologic. Sci., 24(7): 1505–1512.

Kamran, M., S. Wennan, I. Ahmad, M. Xiangping, C. Wenwen, Z. Xudong, M. Siwei, A. Khan, H. Qingfang, and L. Tiening, 2018. Application of paclobutrazol affect maize grain yield by regulating root morphological and physiological characteristics under a semi-arid region. Scientific Reports, 8, 4818: 1-15.

Khan, M.S.H., T. Wagatsuma, A. Akhter, and K. Tawaraya, 2009. Sterol biosynthesis inhibition by paclobutrazol induces greater aluminum (Al) sensitivity in Al-tolerant rice. Amer. J. Plant Physiol., 4: 89–99.

Kerby, K.A., D.R. Buxton, and K. Matsuda, 1980. Carbon source sink relationship within narrow-row cotton canopies. Crop Sci., 20: 208-213.

Kerby, T.A., 1985. Cotton response to mepiquat chloride. Agron. J. 77: 515-518.

Khafaga, H.S., A.H. Raeefa, M.M. Hala, and S.A. Alaa, 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. 4th Conference on Recent Technologies in Agriculture, 236.

Kim, J., R.L. Wilson, J.B. Case, and B.M. Binder, 2012. A comparative study of ethylene growth response kinetics in eudicots and monocots reveals a role for gibberellin in growth inhibition and recovery. Plant Physiol., 160: 1567-1580.

Kondhare, K.R., P. Hedden, P.S. Kettlewell, A.D. Farrell, and J.M. Monaghan, 2014. Use of the hormone-biosynthesis inhibitors fluridone and paclobutrazol to determine the effects of altered abscisic acid and gibberellin levels on pre-maturity amylase formation in wheat grains. J. of Cereal Sci., 60: 210–216.

Kuai, J., S. Yingying, Z. Min, Z. Peipei, Z. Qingsong, W. Jiangsheng, and Z. Guangsheng, 2016. The effect of nitrogen application and planting density on the radiation use efficiency and the stem lignin metabolism in rapeseed (*Brassica napus* L.). F. Crop. Res., 199: 89–98.

Kumar, A., N.P. Nidhi, and S.K. Sinha, 2015. Nutritional and antinutritional attributes of faba bean (*Vicia faba* L.) germplasms growing in Bihar, India. Physiol. Mol. Biol. Plants, 21(1):159 –162.

Kumar, K.A.K., B.C. Patil, and M.B. Chetti, 2005. Effect of plant growth regulators on physiological components of yield in hybrid cotton. Indian J. Plant Physiol., 10: 187-190.

Kumar, K.A.K., V. Ravi, B.C. Patil, and M.B. Chetti, 2006. Influence of plant growth regulators on morphophysiological traits and yield attributes in hybrid Bt. cotton (DHH-11). Ann. Bio., 22: 53-58.

Lichtenthaler, H.K. and A.R. Wellburn, 1983. Determination of total carotenoids and chlorophylls a and b of leaf extracts in different solvents. Biochemical Society Transactions, 11: 591–592.

Nachi, N. and J. Le Guen, 1996. Dry matter accumulation and seed yield in faba bean (*Vicia faba* L) genotypes. Agronomie, EDP Sci., 16(1): 47–59.

Nepomuceno, A.L., D.M. Oosterhuis and A. Steger, 1997. Duration of Activity of the Plant Growth Regulators PGR-IV and Mepiquat Chloride. Special Report, 183:136-139. Agricultural Experiment Station, Division of Agriculture, University of Arkansas, Fayetteville, AR.

Nivedithadevi, D., R. Somasundaram, and R. Pannerselvam, 2015. Effect of abscisic acid, paclobutrazol and salicylic acid on the growth and pigment variation in *solanum trilobatum* (L). Inter. J. Drug Developments Researcher, 4: 236–246.

Orabi, S.A., S.R. Salman, and M.A.F. Shalaby, 2010. Increasing resistance to oxidative damage in cucumber (*Cucumis sativus* L.) plants by exogenous application of salicylic acid and paclobutrazol. World J. Agric. Sci., 6(3): 252–259.

Pal, S., J.S. Zhao, A. Khan, N.S. Yadav, A. Batushansky, S. Barak, B. Rewald, A. Fait, N. Lazarovitch, and S. Rachmilevitch, 2016. Paclobutrazol Induces Tolerance in Tomato to Deficit Irrigation through Diversified Effects on Plant Morphology, Physiology and Metabolism. Scientific Reports 6, 39321: 1-13.

Pan, S., F. Rasul, W. Li, H. Tian, Z. Mo, M. Duan, and X. Tang, 2013. Roles of plant growth regulators on yield, grain qualities and antioxidant enzyme activities in super hybrid rice (*Oryza sativa* L.). Rice, 6: 9.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: CiênciasAgrárias, 38(2): 561-570.

Patil, S.B., 1994. Effect of population levels and growth retardants on growth, yield and yield attributes and quality of soybean. M.Sc. (Agri.) Thesis, Univ. Agril. Sci., Dharwad

Peyvast, G., 2002. Vegetable Production. Agricultural Science Press. 384.

Plummer, D.T., 1978. An introduction to practical biochemistry, 2nd ed. London: McGraw-Hill Book Company (U.K.) Ltd., p. 368.

Pothiraj, P., N.T. Jaganathan, R. Vankitaswamy, M. Premsekhar, and Purushothaman, 1995. Effect of growth regulators in cotton MCV9. Madras Agric., J., 82: 283-284.

Potter, I., and S. Fry, 1993. Xyloglucan endotransglycosylase activity in pea internodes. Plant Physiol., 103: 235-241.

Radford, P.J., 1967. Growth analysis formulae their use and abuse. Crop Sci., 7: 171–175.

Reddy, V.R., A. Trent, and B. Acock, 1992. Mepiquat chloride and irrigation versus cotton growth and development: Agron. J., 84: 930-933.

Reddy, V.R., H.F. Hodges and D.N. Baker, 1990. Temperature and mepiquat chloride effects on cotton canopy architecture. Agron. J., 82: 190-195.

Sankar, B., K. Karthishwaran, and R. Somasundaram, 2013. Leaf anatomy changes in peanut plants in relation to drought stress with or without paclobutrazol and abscisic acid. J. Phytol., 5: 25–29.

Sawan, Z.M., A.E. Basyony, W.L. McCuistion and A.A. El-Farra, 1993. Effect of plant population densities and application of growth retardants on cottonseed yield and quality. J. Am. Oil Chem. Soc., 70: 313-317.

Sawan, Z.M., R.A. Sakr, and O.A. Momtaz, 1998. Effect of 1-naphthalene acetic acid concentrations and the number of applications on the yield components, yield and fibre properties of Egyptian cotton (*Gossypium barbadense* L.). Aust. J. Agric. Res., 49: 955-960.

Setia, R.C., G. Bhathal, and N. Setia, 1995. Influence of paclobutrazol on growth and yield of *Brassica carinata*. Plant Growth Regul., 16: 121-127.

Sharaf El-Deen, H.A.M. and H.H. Manaf, 2009. Effect of some plant growth regulators on shedding physiology, antioxidant enzymes, growth and yield of faba bean. J. Biol. Chem. Environ. Sci., 4(3): 21-46.

Sharma, S.K. and H.S. Dungarwal, 2004. Effect of growth regulators, sulphur fertilization and crop geometry on cotton productivity and returns. J. Cotton Res. Dev., 18: 52-56.

Singh, H., S.C. Chandra and R.S. Jolly, 1987. Effect of growth regulators in relation to time of sown and yield of soybean cultivars. Ann. Biol., 3: 36-43.

Snedecor, G.W. and W.G. Cochran, 1990. Statistical methods, 8th ed. Ames: Iowa State University Press, 609.

Sperry, C.E. and W.R. Chaney, 1999. Tree growth regulator effect on phototropism–its implication for utility forestry. J. Arboriculture, 25: 43-47.

Still, J.R., and W.G. Pill, 2003. Germination, emergence and seedlings growth of tomato and impatients in response to seed treatment with paclobutrazol. Hortic. Sci., 38:1201-1204.

Sturat, B.L., V.R. Isbell, C.W. Wendt, and J.R. Abernathy, 1984. Modification of cotton water relations and growth with mepiquate chloride. Agron. J., 76: 651-655.

Sumit, K., S. Ghatty, J. Satyanarayana, A. Guha, B.S.K. Chaitanya, and A.R. Reddy, 2012. Paclobutrazol treatment as a potential strategy for higher seed and oil yield in field-grown *camelina sativa* L. Crantz. BMC Research Notes, 5, 137.

Syahputra, B.S.A., U.R. Sinniah, M.R. Ismail, and M.K. Swamy, 2016. Optimization of paclobutrazol concentration and application time for increased lodging resistance and yield in field-grown rice. Philippine Agric. Sci., 99: 221–228.

Syahputra, B.A.S., U.R. Sinniah, S.O. Syed Rastan, and M.R. Ismail, 2013. Changes in gibberellic acid (GA) content in 3 *Oryza sativa* due to paclobutrazol treatment. J. Food Pharmaceutical Sci., 1: 14–17.

Tesfahun, W., 2018. A review on: Response of crops to paclobutrazol Application. Tesfahun, Cogent Food and Agriculture, 4: 1525169.

Tesfahun, W. and A. Menzir, 2018. Effect of rates and time of paclobutrazol application on growth, lodging, yield and yield components of Tef [*Eragrostis tef* (Zucc.) Trotter] in Ada district, East Shewa, Ethiopia. J. of Biology, Agriculture and Healthcare, 8(3): 104–117.

Turkhede, A.B., S.T. Wankhade, R.N. Katkar, and B.A. Sakhare, 2003. Effect of detopping and foliar sprays of plant growth hormones and nutrients on growth and yield of rainfed cotton. J. Cotton Res. Dev., 17: 150-152

Vivekanadan, A.S., H.P.M. Gunasena, and T. Sivanayagam, 1972. Statistical evaluation of the accuracy of three techniques used in the estimation of leaf area of crop plants. Indian J. Agril. Sci., 42: 857–860.

Wang, S.Y. and M. Faust, 1986. Effect of growth retardants on root formation and polyamine content in apple seedlings. J. Am. Soc. Hortic. Sci., 111:912-917.

Wasnik, K.G. and A.K. Bagga, 1996. Effect of mepiquat chloride on growth and yield of Chickpea (*Cicer arietinum* L). Indian J. Plant Physiol., 1 (4): 239-242.

Watson, D.J., 1958. The dependence of net assimilation rate on leaf area index. Annals of Botany, 22 (85): 37–54.

Xu, X. and H.M. Taylor, 1982. Increase in drought resistance of cotton seedlings treated with mepiquat chloride. Agron. J., 84: 69-74.

Xia, X., Y. Tang, M. Wei and D. Zhao, 2018. Effect of Paclobutrazol Application on Plant Photosynthetic Performance and Leaf Greenness of Herbaceous Peony. Horticulturae, 4, 5: 1-12.

Yang, T., P. Davies, and J. Reid, 1996. Genetic dissection of the relative roles of auxin and gibberellin in the regulation of stem elongation in intact light-grown peas. Plant Physiol., 110: 1029–1034.

Yokota, T., N. Nakamura, N. Takahashi, M. Nonaka, H. Sekimoto, H. Oshio and S. Takatsuto, 1991. Inconsistency between growth and endogenous levels of gibberellins, brassinosteroids, and sterols in *Pisum sativum* treated with uniconazole antipodes. In: N. Takahashi, B. O. Phinney, and J. MacMillan, eds. Gibberellins, 339-349. Springer-Verlag, New York.

Zaghlool, Sanaa, A.M., S.I. Ibrahim and H.A.M. Sharaf El-deen, 2001. The effect of naphthaline acetic acid (NAA), salicylic acid (SA) and their combinations on growth, fruit setting, yield and some correlated components in dry bean (*Phaseolus vulgaris* L.). Annals Agric. Sci., Ain Shams Univ., Cairo, 46 (2): 451 – 463.