Effect of Paclobutrazol and potassium on growth of Date Palm *Phoenix dactylifera* L. seedlings

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Abstract

A field trial was lead at the Centre of Date Palm Researches, Basrah University, to investigate the effect of Paclobutrazol (PBZ) at 0, 100 and 200 mg. L^{-1} and Potassium Sulfate (K_2SO_4) at 0, 2.5 and 5 g. L^{-1} on growth characteristics of *Phoenix dactylifera* L. plants grown from seeds in a factorial experiment designed with R.C.B.D. Most growth parameters recorded were affected by the application of Paclobutrazol and/ or potassium sulfate. Results showed a significant decrease in the number of leaves, leaf length, leaf width, leaf area, and shoot height when applying PBZ. In contrast, shoot dry weight, root length, and root dry weight were increased. Whereas the application of Potassium significantly improved all the previous parameters. On the other hand, total chlorophyll content, dry matter, total soluble carbohydrates, protein content, potassium content in leaves and C/N ratio in leaves showed a significant increase in PBZ and K_2SO_4 treatments. The interaction between the two factors in this trial was found significantly effective in some growth parameters.

Keywords: Paclobutrazol, PBZ, Potassium fertilizer, K_2SO_4, Date palm seedling.

Introduction

Palm trees are of economic importance both as a source of agricultural produce and as an ornamental component in landscaping projects. Palms are globally important as socioeconomic plants (Henderson *et al.*, 1995). Based upon archaeological evidence, the date palm (*Phoenix dactylifera*) was domesticated some 6000 years ago in the Mesopotamian Region (Zohary and Hopf, 2000). Date Palm *Phoenix dactylifera* L. is a useful traditional medicinal plant belonging to the family Arecaceae; the genus *Phoenix* contains 12 species, including *P. dactylifera* which is a subtropical fruit tree widely grown in Iraq and some middle east regions (Barreveld, 1993; Copley *et al.*, 2001; Sirisena and Ajlouni , 2015). Date palm trees require relatively great amounts of macro and micronutrients to achieve good growth and reasonable economic production. Fertilization is, therefore, one of the important practices that increase date production and improve fruit quality. Properly applying of macro and micro nutrients is necessary to increase the quantitative, qualitative, and economic output of date production in palm groves (Shaaban and Mahmoud, 2012). Seeds were the means to intentionally reproduce date palms for millennia in Mesopotamia, and later in North Africa, from native wild species or through seed introductions. From these two areas, seeds were transported, in association with human migrations or invading armed forces, east to present-day Pakistan, into southern Europe, and later to South and North America, on southern Africa, and to distant Australia and New Caledonia (Johnson, 2010). Paclobutrazol, a plant growth regulator from imperial chemical industries, has been very effective for dwarfing many crops (Lever *et al.*, 1982; Menhenett and Hanks 1982). It has been documented to reduce plant growth without directly interfering with secondary metabolite biosynthetic pathways, as it inhibits gibberellin synthesis downstream in the chain of reactions leading to the production of secondary metabolites, i.e., the biosynthesis of tannins, phenolic compounds, and terpenoids inhibit GA biosynthesis and act as inhibitors of mono-oxygenases catalyzing the oxidative steps from ent-kaurene to ent-kaurenoic acid of biosynthesis path way of GA and employed magnificently to reduce the height of date palm (Rademacher, 2000; Cohen *et al.*, 2013). Potassium is necessary for basic physiological functions, such as the formation of sugars and starch, the synthesis of proteins, cell division and growth, fruit formation and could improve fruit size, flavor and color (Abbas and Fares, 2008). Moreover, Potassium is also an important nutrient for date palm growth and productivity (Al-Kharusi *et al.*, 2009). Researchers have obtained many positive and clear indications that the date palm does not differ from other plants in response to foliar spraying. All these experiments recommended using their results and conducting other operations to develop the reality of date palm cultivation globally; one of the nutrients used in feeding date palms is potassium sulfate (Shareef *et al.*, 2021). In this regard, potassium is a mobile nutrient, it is well adapted to foliar fertilization because it is rapidly translocated from the leaves to other plant parts and consequently increases yield and components (Mengel, 2002).

The addition of nutrients to plants through spray application ensures the nutrient is inputted directly into the plant and enhances plant tissue metabolism, reducing energy consumption. The foliar technique increases the potential for mixing nutrients with growth regulators, saving much effort and time (Salvagiotti*et al.,* 2008), as the power of plant leaves to absorb nutrients has resulted in the fact that the foliar application of nutrients becomes a recurrent method for supplying nutrients to plants (Swietlik and Faust, 1984).

For the importance of the date palm plant, this experiment was applied to investigate the effect of Paclobutrazol and Potassium Sulfate on the growth of *Phoenix dactylifera* L. seedlings and likewise to find mathematical relationships that serve environmental studies.

Materials and Methods

A field trial was carried out at the of Date Palm Research Center -University of Basrah during 2016/2017 to study the effect of Paclobutrazol (the commercial product from the German company Syngenta Agro AG) and Potassium Sulfate and their treatment combinations on growth characteristics of *Phoenix dactylifera* L. seedlings. One-year-old Date Palm Barhi cv. seedlings were transplanted to 25 cm plastic pots (one plant per pot) containing a 6:2:1 (v/v) mix of sand: peat moss: organic manure. Pots were kept in a greenhouse and were watered whenever they need. Three concentrations of PBZ (0, 100 and 200 mg. L^{-1}) and K_2SO_4 at 0, 2.5 and 5 g. L^{-1} were prepared as distilled water was used for control plants. Two weeks after transplanting, seedlings were sprayed with the PBZ and K_2SO_4 solutions applied until run off once a week, for a duration of eight weeks as a foliar spray. At the end of the experiment, seedlings were extracted from pots carefully using water and data was tabulated on: shoot height (cm): was measured from the soil surface until the bottom of the leaves; number of leaves, leaf length (cm), leaf width (cm), average of one leaf area (cm^2): was measured according to Dvorinic (1965); total chlorophyll content in leaves (mg. 100 g^{-1} fresh wt.): was estimated according to Goodwin (1976); dry weight of shoot (without leaves as leaves were separated from shoot): was measured by replacing in a circulatory air oven at 65 Cº for 72 hours until the weight stabilized; dry matter in leaves (%): fresh weight of leaves was recorded then leaves were dried in a circulatory air oven at 65 Cº for 72 hours until the weight stabilized then dry matter was calculated; total soluble carbohydrates content in leaves (%): was estimated according to DuBois *et al.,* (1956); protein (%) in leaves: nitrogen was estimated as described by Jackson (1958), then protein was evaluated according to the reported procedures in A.O.A.C. (1970) using the equation: Protein = N % X 6.25; K% in leaves: was estimated using flame photometer as described by (Page *et al*., 1982); C/N ratio (as C/N = total soluble carbohydrate/ nitrogen content in leaves); root length (cm); roots dry weight (g): roots were dried in a circulatory air oven at 65 Cº for 72 hours until the weight stabilized then dry matter was calculated.

The applied experimental design of this trial was a randomized complete block design (Al-Rawi and Khalaf-Alla, 2000). All data collected were analyzed using analysis of variance (ANOVA) with the GenStat Statistical Analysis System (2007). Seventh Edition (DE3). Means were compared using Least Significant Difference (LSD) ($P \leq 0.05$).

Results and Discussion

Plant growth performances represented in Table (1) revealed that the number of leaves, leaf length, leaf width and means of leaf area were significantly reduced with the application of PBZ. While a significant increase in the same parameters took place when applying K_2SO_4 as compared to the control treatment. On the other hand, the combined treatments of PBZ and K_2SO_4 affected some of these growth characteristics significantly, as the highest values in number of leaves and those of leaf length (3.58 and 37.21 cm respectively) were recorded when spraying with 0 mg. $L^{-1}$of PBZ + K_2SO_4 at 5 g. L^{-1}. While the lowest values in same two parameters (2.04 and 21.33 cm respectively) were recorded when spraying with 200 mg. L^{-1} of PBZ + 0 g. L^{-1} of K_2SO_4. On the other hand, 0 + 0 and 0 + 5 g. L^{-1} of PBZ and K_2SO_4 scored the greatest values (0.95 cm and 43.81 cm^2) in leaf width and leaf area, respectively and the lowest values (0.56 cm and 27.67 cm^2) were found in 200 mg. L^{-1} + 0 and 200 + 5 g. L^{-1}, of PBZ and K_2SO_4 respectively. It has been suggested that the effectiveness of inhibition in shoot and leaf growth by PBZ is determined by the concentration of the chemical used, the plant species under study, and its stage of development (Lee *et al.,* 1998; Chaney, 2004). On the other hand, the increases in physical characteristics when applying Potassium Sulfate may be due to K important role in pH stabilization, osmoregulation, enzyme activation, protein synthesis, stomata movement, photosynthesis, cell extension, cell division, cell size, cell number and cell turgidity. These results are in accordance with (Mengel and Kirkby, 2001; Dialami and Mohebi, 2010). El-Sabagh (2012) and Amro *et al*., (2014) informed that translocation of photosynthetic assimilations depends on the concentration of cell potassium. Potassium is involved in controlling cell water content and photosynthetic activity. Furthermore, the beneficial influence of K might be attributed to the enhancing of many metabolic which reproduced on yield development (David *et al*., 1998).

Table l . Effect of PBZ and K_2SO_4on the morphological characteristics of leaves of Date Palm seedlings

Treatment			No. of Leaves	leaf length cm	leaf width cm	leaf area cm^2
PBZ con. Mg. L^{-1}		0	3.31	30.97	1.34	37.91
		100	3.24	23.42	1.34	30.45
		200	2.81	22.84	1.00	28.03
L.S.D.$_{(P \leq 0.05)}$			0.050	0.755	0.032	0.778
K_2SO_4 con. g. L^{-1}		0	2.76	23.17	0.94	29.91
		2.5	3.20	25.88	1.24	32.81
		5	3.40	28.18	1.50	33.69
L.S.D.$_{(P \leq 0.05)}$			0.050	0.755	0.032	0.778
PBZ con. Mg. L^{-1} X K_2SO_4 con. g. L^{-1}	0	0	3.10	25.99	0.95	31.68
		2.5	3.25	29.69	1.20	38.25
		5	3.58	37.21	1.86	43.81
	100	0	3.14	22.19	1.32	30.24
		2.5	3.22	23.82	1.35	31.54
		5	3.36	24.24	1.35	29.58
	200	0	2.04	21.33	0.56	27.80
		2.5	3.14	24.11	1.16	28.63
		5	3.26	23.08	1.29	27.67
L.S.D.$_{(P \leq 0.05)}$			0.087	1.308	0.055	1.348

It was obtained from the data in Table (2) that shoot height was significantly reduced in the high PBZ concentrations and increased when adding K_2SO_4 when compared to control plants in this study. Whereas root length and dry weights of shoots and roots were increasing significantly when applying PBZ or K_2SO_4. Results also revealed that some treatments of PBZ and K_2SO_4 used in a combination caused a significant increase in shoot height, shoot dry weight, root length and root dry weight values.

The relationship between shoot height and root length of date palm seedlings is represented in Figure 1.

Table 2. Effect of PBZ and K_2SO_4 on the physical characteristics of shoot and roots of Date Palm L. seedlings.

Treatment			Shoot Height Cm	Shoot Dry weight G	Root length Cm	Root Dry weight g
PBZ con. Mg. L^{-1}		0	4.39	12.93	31.14	12.31
		100	3.57	13.28	36.01	12.24
		200	3.15	14.17	39.29	13.95
L.S.D.$_{(P \leq 0.05)}$			0.116	0.180	2.038	0.144
K_2SO_4 con. g. L^{-1}		0	3.25	13.02	34.02	12.31
		2.5	3.90	13.44	35.70	13.00
		5	3.96	13.93	36.72	13.20
L.S.D.$_{(P \leq 0.05)}$			0.116	0.180	2.038	0.144
PBZ con. Mg. L^{-1} X K_2SO_4 con. g. L^{-1}	0	0	4.15	12.20	29.59	11.88
		2.5	4.48	13.23	31.54	12.58
		5	4.53	13.36	32.29	12.47
	100	0	3.51	12.89	34.33	11.57
		2.5	3.56	12.87	37.25	12.58
		5	3.64	14.08	36.46	12.58
	200	0	2.08	13.96	38.14	13.47
		2.5	3.65	14.21	38.31	13.83
		5	3.72	14.34	41.42	14.54
L.S.D.$_{(P \leq 0.05)}$			0.202	0.312	3.530	0.249

Values are means of four replications

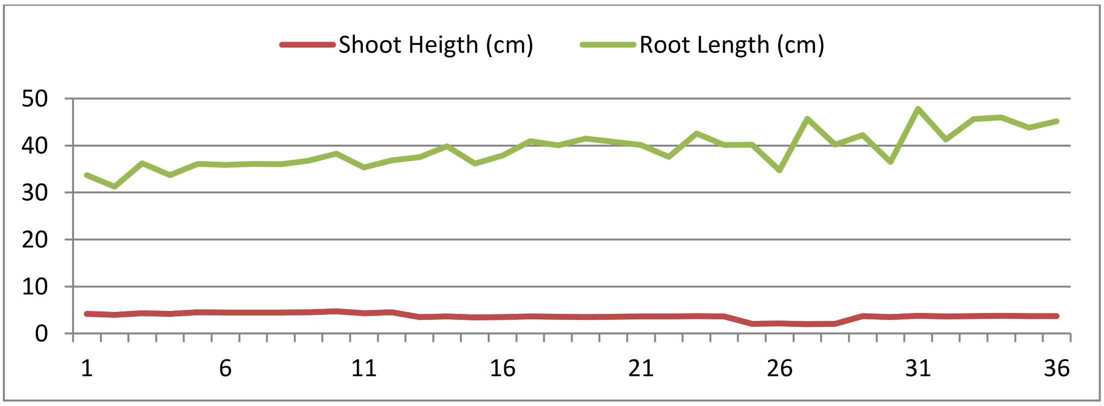

Figure 1. The relationship between shoot height and root length (cm) of date palm seedlings.

PBZ employed magnificently to reduce the height of the date palm (Cohen *et al.*, 2013). Also according to Berova and Zlatev (2000), the application of PBZ resulted in both of the reduction of plant height and the increasing of stem thickness in young plants, it contributed to an enhancement of seedling quality at planting. Likewise, PBZ reduced the plant height, number of new shoots, length of internode, and total plant weight. The percentage of new shoots, length and diameter of terminal shoots, number of leaves and leaf area were significantly reduced in mango (*Mangifera indica* L.) plant (Khader, 1991; Singh *et al.,* 2004).

K is an activator of many important enzymes, such as protein synthesis, sugar transport, N and C metabolism and photosynthesis. Furthermore, K is very important for cell growth which is vital for the function and development of plants (Hepler *et al.,* 2001; Marschner, 2012; Oosterhuis *et al.,* 2014). About the growth-promoting mechanism of K, it is generally granted that K stimulates and controls ATPase in the plasma membrane to generate acid stimulation, then triggers cell wall loosening and hydrolase stimulation whih promots cell growth. K has strong mobility in plants and plays an important role in regulating cell osmotic pressure and balancing the cations and anions in the cytoplasm (Kaiser, 1982; Oosterhuis *et al.*, 2014; Hu *et al.,* 2016). Through these processes, K is involved in regulating stomatal opening, cell elongation, and other important physiological processes. Also adequate K supply can promote N metabolism and enhance the synthesis of amino acids and proteins (Ruan *et al.,* 1998; Ruiz and Romero, 2002). Also, PBZ influences the isoprenoid pathway and changes the status of phytohormones by inhibiting gibberellin synthesis, decreasing ethylene production, and enhancing cytokinin and ABA contents (Kamountsis and Sereli 1999). PBZ has been testified to inhibit GA biosynthesis in plants by inhibiting kaurene oxidase, a Cyt P-450 oxidase, thus blocking the oxidation of kaurene to kaurenoic acid (Dalziel and Lawrence, 1984). Browning *et al.*,(1992) investigated the effect of PBZ on the translocation of endogenous IAA (indol- 3-acetic acid) as they found that PBZ caused a slower movement of IAA in shoot tips. In this study, the results obtained indicated that PBZ or K_2SO_4 applications led to a significant increase ($p \leq 0.05$) in chlorophyll content, dry matter percentage, percentage of carbohydrates, protein content, potassium content and C/N ratio in leaf tissue, compared to the control plants values (Table 3). Regarding the treatment combinations, results showed that spraying with 200 mg. L^{-1} of PBZ + K_2SO_4 at 5 g. L^{-1} scored the highest values in chlorophyll content (10.94 mg. g^{-1}

fresh wt.), dry matter in leaves (5.14 %), carbohydrates content (53.58 %), protein content (9.00 %) and C/N ratio (37.22). Whereas, the highest value of potassium content (0.74 %) was found when spraying with 200 mg. L^{-1} of PBZ + K_2SO_4 at 2.5 g. L^{-1}.

Table 3. Effect of PBZ and K_2SO_4on the chemical analysis in leaves of Date Palm seedlings

Treatment			Total chlorophyll mg .100 g^{-1} fresh wt.	Dry matter (%)	Carbohydrates (%)	Protein (%)	Potassium (%)	C/N ratio
PBZ con. Mg. L^{-1}		0	9.00	3.35	31.61	7.63	0.53	25.92
		100	10.48	3.72	37.85	8.56	0.57	27.66
		200	10.65	4.24	47.68	8.88	0.67	33.58
L.S.D.$_{(P \leq 0.05)}$			0.261	0.429	2.194	0.125	0.040	1.677
K_2SO_4 con. g. L^{-1}		0	9.74	3.60	36.23	8.06	0.53	27.89
		2.5	10.10	3.59	38.92	8.29	0.63	29.23
		5	10.29	4.11	41.99	8.70	0.62	30.04
L.S.D.$_{(P \leq 0.05)}$			0.261	0.429	2.194	0.125	0.040	1.677
PBZ con. Mg. L^{-1} X K_2SO_4 con. g. L^{-1}	0	0	8.45	3.28	28.25	7.19	0.47	24.57
		2.5	9.19	3.31	32.35	7.38	0.56	27.41
		5	9.35	3.45	34.23	8.31	0.57	25.79
	100	0	10.33	3.67	37.21	8.25	0.50	28.19
		2.5	10.54	3.74	38.17	8.63	0.59	27.65
		5	10.57	3.75	38.18	8.79	0.62	27.13
	200	0	10.44	3.84	43.22	8.75	0.61	30.90
		2.5	10.58	3.73	46.24	8.88	0.74	32.63
		5	10.94	5.14	53.58	9.00	0.66	37.22
L.S.D.$_{(P \leq 0.05)}$			0.452	0.743	3.799	0.216	0.070	2.905

The relationship between Protein content (%) and C/N ratio of date palm seedlings is represented in Figure 2.

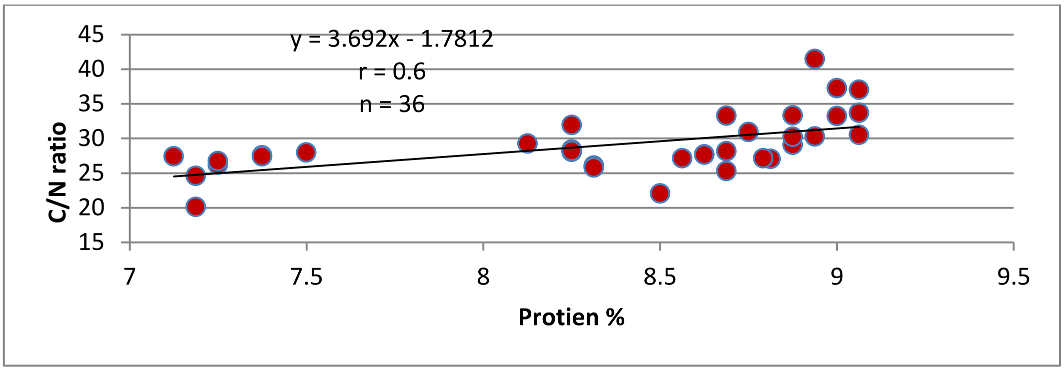

Figure 2. The relationship between Protein content (%) and C/N ratio of date palm seedlings.

An increased in photosynthetic rate in *Catharanthus* roseus (Abdul Jaleel *et al*., 2007) and potato (Tsegaw*et al*., 2005) exposed to PBZ has been reported previously. This was attributed to this higher chlorophyll content of the leaf tissue. Davis *et al*., (1986, 1988) reported that PBZ application resulted in various physiological changes that are generally associated with optimized yield in various plants as the most prominent changes include: repression of senescence with enhanced concentrations of photosynthetic pigments in plant tissues, alteration of hormonal balance, improvement in mineral absorption and carbohydrate synthesis.Wang and Steffens (1987) informed that PBZ was also shown to shift assimilate partitioning from leaves to roots, increasing carbohydrates in all parts of seedlings, rising chlorophyll and protein content and mineral element concentrations in leaf tissue, intensifying root respiration and reducing water use.

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تأثير الباكلوبوترازول والبوتاسيوم في نمو بادرات نخلة التمر *Phoenix dactylifera* L.

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الخلاصة

تم إجراء هذه الدراسة في مركز أبحاث النخيل / جامعة البصرة ، لبحث تأثير البكلوبيترازول Paclobutrazol (PBZ) بالتراكيز 0 و 100 و 200 ملغم. لتر$^{-1}$ وكبريتات البوتاسيوم (K_2SO_4) بالتراكيز 0 و 2.5 و 5 غم. لتر$^{-1}$ على بعض خصائص نباتات النخيل *Phoenix dactylifera* L. النامية من البذور في تجربة عاملية مصممة باستخدام تصميم القطاعات العشوائية الكاملة R.C.B.D.. تأثرت معظم صفات النمو التي تم تسجيلها عند الرش باستعمال الباكلوبيوترزول Paclobutrazol وكبريتات البوتاسيوم. أظهرت النتائج انخفاضا معنويا في عدد الأوراق وطول الورقة وعرض الورقة ومساحة الورقة وارتفاع النبات عند استعمال PBZ ، من ناحية ثانية، حدثت زيادة معنوية في الوزن الجاف للساق وطول الجذر والوزن الجاف للجذر. في حين أدت إضافة البوتاسيوم إلى زيادة معنوية في جميع الصفات السابقة. من ناحية أخرى ، أظهر محتوى الكلوروفيل الكلي والمادة الجافة والكربوهيدرات الذائبة الكلية ومحتوى البروتين ومحتوى البوتاسيوم في الأوراق ونسبة الكاربوهيدرات الى النتروجين C/N في الأوراق زيادة معنوية في معاملات PBZ و K_2SO_4. وجد أن التداخل بين العاملين في هذه التجربة فعال بشكل معنوي في بعض صفات النمو.

الكلمات المفتاحية: Paclobutrazol، PBZ ، سماد البوتاسيوم ، K_2SO_4 ، بادرات نخلة التمر