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Significance of nitrogen, phosphorus, and boron foliar spray on jojoba plants

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Abstract

Background: Jojoba plants [*Simmondsia chinensis* (Link) Schneider] are appropriate to the semiarid regions; it has the ability to survive in a harsh desert environment and it is very drought-resistant and can be grown on marginal lands without replacing any existing crops. After that, Jojoba is a new oil-producing industrial crop, oil-producing cash crop, and has much of the interest in worldwide in recent years. So, processes are made to increase the seed yield of jojoba as requirements of essential fertilizer and evaluation of new clones. Two field experiments were conducted on five clones (S-BS-, S-700, 610, S-L, and S-G) aged 3 and 13 years from planting at North Sinai, Egypt on sandy soil to study the effect of foliar spray with nitrogen, phosphorus, and boron with three rates of NPB (00, NPB1 (N 1%, P 0.75%, and B 0.4%) and NPB2 (N 1.5%, P1.25% and B 0.8%)) on oil and other contents of jojoba plants.

Results: Results showed that all treatments improved the vegetative growth, yield, and seed quality. Concerning oil, weight of 100 seeds and oil percent in seeds with treatment NPB2 under clone S-700 gave the highest value for all study parameters.

Conclusions: Therefore, for improving yield and seed quality, it could be recommended with foliar spray NPB2 (N1.5%, P 1.25%, and B0.8%) under the condition of this study on jojoba plants.

Keywords: Jojoba, Oil yield, Seed quality, Nitrogen, Boron, Phosphate

Background

Jojoba (*Simmondsia chinensis* L.) is an economically important shrub for it is extensively drought-resistant and can grow in semi-arid regions of the world, high soil salinity, and low fertilize requirement and requires little water according to Tal et al. (1979), Al-Ani et al. (1972), and Rasoolzadegan et al. (1982). Yermanos (1982) showed that jojoba yield is a crop of seeds that have 40–50% oil. The proportion of fat stored in the form of wax liquid represents about 40–60% of dry weight of jojoba seeds, so it is used in lubrication to withstand the high temperature and very similar to sperm whale oil. Many factors affect the oil yield of Jojoba seeds, including genetic factors (Das et al. 2010), plant age (Jongschaap et al. 2007), geographical characteristics of soil and soil (Francis et al. 2005), and agronomic practices such as agricultural practices, such as the distances of agriculture, irrigation, pruning, and fertilization. In this direction, addition of 50 kg N and/or 50 kg P_2O_5 kg ha^{-1} for three consecutive years induced no effect appeared in vegetative growth. Osman and AboHassan (1998), Reyes et al. (1977), Feldman et al. (1984), and Yermanos (1982) found that the root length of the jojoba plants enables it to draw nutrients from much deeper soil profiles, root type (fibrous or tap root), and soil condition. Element of nitrogen is very important in agriculture subject because it led to increase the crop yield. Plants need the largest quantities from nitrogen in different stages from sowing to harvest, and plants contain higher than 1% nitrogen (Massignam et al, 2009) found that the application of nitrogen increased growth and seed yield of jojoba plants. In this respect, Benzioni et al. (1982) and Nelson and Watson (2001) evaluated the effect of increasing nitrogen rates which led to an increment of 65% higher seed yield than an unfertilized group (control plants), and increased leaf N content.

Plants need phosphorus (P) for complete of life cycle, so P is an essential macronutrient for plant growth (Holford 1997). Steen (1998), Cordell et al. (2009), and

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Ryan et al. (2001) showed that phosphorus application improved morphological plants such as length and surface area of roots. There are many studies that cleared the role of phosphorus on the initiation and growth of roots and release of carboxylate according to Bolland et al. (1999)and Shane and Lambers (2005).

While Benzioni and Ventura (1998) found that the application of different P levels in irrigation water on two clones of jojoba, 64 and 879–154, led to inhibit root development in both clones but to a higher degree for clone 879–154, but low concentration of P led to decrease in magnesium (Mg) and calcium (Ca) content in the leaves, while shoot growth or chlorophyll concentration were not affected.

Boron is considered as an essential elements for growth and development of higher plants according to Shelp (1993). Considerably many research represented that boron plays an important role in plant growth and development, cell wall strength and development, cell division, seed development, sugar transport, and hormone development; some functions of boron interrelate with those of nitrogen, phosphorus, potassium, and calcium in plant and stimulation or inhibition of specific metabolism pathways, according to Rasheed (2009) and George et al. (2012).

Materials and methods

Design and planting

Jojoba plants were cultivated at Almagharah Research and Production Station (latitude 30, 717993″ N, longitude 33, 329103 E) which follows the Desert Research Center, Agriculture Ministry, Egypt. Two field experiments were carried out in this station at 2016/2017 and 2017/2018 seasons for five clones (S-L, S-610, S-700, S-B, and S-G), to study the effect of foliar spray of nitrogen, phosphorus, and boron rates on jojoba plants aged 3 and 13 years from planting. Two experimental rows (five plants each age) were assigned for each clone in each replication. Distances between rows and plants within in rows were 2 and 4 m respectively. Plants (mixed males and female seedlings) derived from the open population, as a source of pollen, were repeated one row every six female (clone) rows. Additional border mixed seedling rows were planted around each replication and no free space was left between rows within each replication to ensure homogeneity within each replication. Before start, drip irrigation system was installed in the experimental areas and physical and chemical analyses of the experimental soil were presented in Table 1. Weed control and irrigation were done as necessary but no fertilizers were applied in the course of the study. All clones were treated at three times (October, March, and April) with three rates of NPB (00, NPB1 (N 1%, P 0.75%, and B 0.4%) and NPB2 (N 1.5%, P 1.25% and B 0.8%)).

Table 1 Physical and chemical analyses of the experimental soil (average of the two seasons)

Item	Value		Element	Value	
Physical properties			Available macro elements (mg/100 g)		
Sand%	86.00		P	0.82	L*
Silt%	10.00		K	9.94	L
Clay%	4.00		Mg	17.00	L
Texture	Sandy		Ca	24.21	L
			Na	45.17	H
Chemical properties			Available microelement ppm		
pH	7.89	H	Fe	7.40	L
E.C (dS/m)	1.60	H	Mn	6.50	L
CaCO3 (%)	1.98	L	Zn	1.13	L
O.M (%)	0.56	VL	Cu	0.42	L

VL very low, *L* low, *M* medium, *H* high, according to (Jones Jr. et. al., 1991)

Collection, prepare sample, and measurement of growth

The plants were collected at 22nd April to determine the growth, yield characters, and some chemical content. Leaf area (cm^2) was estimated from the following equation: Leaf area = 0.717 X – 0.095, which X is the product of length by width (Charles 1982). The following measurements: plant height (cm), shoot characters (number of shoot, stem diameter, number of nods/stem, length of nods), leaves characters (number of leaves, leaf width, length, leaf area, number of flowers/m, number of fruits/m, total branches, weight of seeds harvest (kg), weight of seed (gm), and weight of 100 seed (gm)).

Chemical analysis

Photosynthetic pigments: chlorophyll a, chlorophyll b, and carotenoids were determined using spectrophotometric method described by Lichtenthaler and Buschmann (2001). Oil content of seed (%) was determined. Total nitrogen content: sample of 0.2 g dry material were digested by sulfuric and perchloric acids using Micro-Kjeldahl method (Jackson 2005). Distillation was carried out with 40% NaOH, and ammonia was received in 4% boric acid solution. Protein content was determined by the Kjeldahl method for the calculation of all proteins which equal nitrogen content multiplied by 6.25, according to A.O.A.C (1990). Potassium content: weight of 0.2 g dry matter from jojoba shoot was extracted for 1 h in a boiling-tube of distilled water in a boiling water bath, the extract was filtered. Sodium and potassium content in the aqueous extracts were measured with Flame Photometer. Meanwhile, chloride was determined by titration by 0.001 N $AgNO_3$ and using potassium dichromate as indicator. Phosphorous content: phosphorous was determined calorimetrically at wave length 725 nm using chlorostannous-reduced molybdo phosphoric blue color method, in hydrochloric described system as described by A.O.A.C (1990).

Statistical analysis

The experiment was conducted as split plot design having clones in main plot and treatments in sub plot. Data were subjected to statistical analysis of variance according to Gomez et al. (1984) and L.S.D. value for comparison.

Result

Growth characters

All data in Tables 2 and 3 showed that the foliar application of NPB led to increase of all growth characters as plant height (cm), number of main branches/plant, stem diameter (cm), number of nodes/stem, length of node (mm), leaf number of leaves/plant, leaf width (mm), leaf length (mm), and leaf area (cm^2). All growth characters affected by increased in NPB and especially with NPB2 under clone S-700. Data presented in Table 2 and 3 showed that the clone S-700 at aged 3 years produced the highest value of plant height (83.94 cm), number of main branches/plant 3.256, stem diameter (1.705 cm), number of nodes/stem18.45, length of node (13.77 mm), leaf number of leaves/plant115.4, leaf width (30.44 mm), leaf length (39.90 mm), and leaf area (8.797 cm^2), while at aged 13 years produced the highest value of plant height (220.8 cm), stem diameter (2.540 cm), circumference 9.809 m^2, leaf width (26.17 mm), leaf length (44.68 mm), and leaf area (8.387 cm^2).

Yield characteristics

Data in Tables 4 and 5 showed that the effect of foliar application of NPB on some clones and interaction between them those lead to increase of all yield characters studied. Effect of NPB low specially control and NPB1decrease the total number of branches7.920 and 8.310, number of leaves126.4 and 133.8, weight of seeds/plant (67.05 and 68.41 kg), weight of seed (0.68 and 0.72 g), weight 100 seeds (68.00 and 72.00 g), and oil content of the seeds 40.3 and 45.7%, respectively at aged 3 years while at 13 years gave these value. All characters affected by decrease in NPB and especially control and NPB1 under clone S-L number of stem/p5.227 and 5.485, number leaves/m 69.520 and 73.590, number of flowers/m 17.41 and 19.52, number of fruits/m 11.32 and 13.71, weight seeds/plant (5.632 and 5.746 kg), weight of seed/g 0.6596 and 0.6984, weight (100 seed 65.960 and 69.840 g), and oil content of the seeds 45.186 and 46.614%, respectively.

Chemical constituents

All data in Tables 6 and 7 showed that the foliar application of NPB led to increase of some chemical contents the leaves. All characters studied were affected by increase NPB and especially with NPB2 under clone S-700

Table 2 Effect of rates of NPB on growth characters of clones jojoba plants at 3 years

Clones treatments		Shoot characters					Leaves characters			
		Plant height (cm)	Number of main branches/plant	Stem diameter (cm)	Number of nodes/stem	Length of node (mm)	Leaf number of leaves/plant	Leaf width (mm)	Length (mm)	Leaf area (cm^2)
S-L	0	74.00	2.475	1.296	15.17	11.32	88.4	27.98	38.53	7.732
	NPB1	77.60	2.597	1.360	16.67	12.44	93.6	29.04	38.78	8.076
	NKB2	80.60	3.069	1.607	17.22	12.82	102.7	29.10	40.27	8.404
S-610	0	75.59	2.549	1.335	15.72	11.73	91.0	28.04	38.61	7.794
	NPB1	79.21	2.675	1.400	16.95	12.68	102.7	29.10	38.85	8.141
	NKB2	82.21	3.161	1.655	17.50	13.06	111.8	30.38	39.82	8.710
S-700	0	77.08	2.626	1.375	15.99	11.94	93.8	28.10	38.68	7.872
	NPB1	80.84	2.755	1.442	16.95	12.68	105.6	30.44	38.93	8.583
	NKB2	83.94	3.256	1.705	18.45	13.77	115.4	30.44	39.90	8.797
S-B	0	76.35	2.600	1.361	15.85	11.82	92.46	28.07	38.64	7.833
	NPB1	80.04	2.728	1.428	17.09	12.75	101.4	29.13	38.89	8.181
	NKB2	83.03	3.224	1.688	18.04	13.44	109.8	30.41	39.86	8.753
S-G	0	74.81	2.524	1.322	15.44	11.56	89.7	28.01	38.57	7.763
	NPB1	78.47	2.649	1.387	16.81	12.56	98.8	29.07	38.82	8.108
	NKB2	81.46	3.130	1.639	17.36	12.94	106.6	30.35	39.78	8.675
LSD C		21.16	0.921	0.0946	2.301	3.245	23.112	12.546	22.321	0.9584
LSD T		16.02	0.521	0.0556	4.871	3.124	17.345	8.438	19.435	0.6493
LSD C x T		11.23	0.3121	0.0426	4.721	2.054	12.439	6.325	17.549	0.2352

Table 3 Effect of rates of NPB on growth characters of clones jojoba plants at 13 years

Clones Treatments		Shoot characters			Leaves characters		
		Height	Diameter	Circumference m^2	Leaf width (mm)	Length (mm)	Leaf area (cm^2)
S-L	0	194.6	1.931	7.514	24.06	43.15	7.444
	NPB1	204.1	2.026	7.956	24.97	43.43	7.777
	NKB2	212.0	2.394	8.730	25.02	45.10	8.092
S-610	0	198.8	1.988	7.735	24.11	43.24	7.476
	NPB1	208.3	2.087	8.730	25.02	43.51	7.807
	NKB2	216.2	2.466	9.503	26.12	44.59	8.354
S- 700	0	202.7	2.048	7.973	24.16	43.32	7.505
	NPB1	212.6	2.149	8.976	26.17	43.60	8.183
	NKB2	220.8	2.540	9.809	26.17	44.68	8.387
S-B	0	200.8	2.028	7.859	24.14	43.27	7.490
	NPB1	210.5	2.128	8.619	25.05	43.55	7.823
	NKB2	218.4	2.515	9.333	26.15	44.64	8.370
S-G	0	196.8	1.969	7.625	24.08	43.19	7.460
	NPB1	206.4	2.066	8.398	25.00	43.47	7.793
	NKB2	214.2	2.441	9.061	26.10	44.55	8.337
LSD C		55.658	0.7183	1.96452	8.789	9.999	1.93304
LSD T		42.136	0.4063	1.47432	7.2566	8.767	1.13160
LSD C x T		29.539	0.2434	1.05731	5.4395	8.654	0.76561

Table 4 Effect of NPB rates on yield of clones jojoba plants at 3 years

Clones Treatments		Number of branches	No. leaves /plant	W, Seeds harvest (g)	Weight of seed gm	Weight (100 seed gm)	Oil content of the seeds %
S-L	0%	7.920	126.4	67.05	0.68	68.00	40.3
	NPB1	8.310	133.8	68.41	0.72	72.00	45.7
	NKB 2	9.820	146.8	69.84	0.84	84.00	49.4
S-610	0	8.158	130.1	71.03	0.70	70.05	41.7
	NPB1	8.559	146.8	72.49	0.74	74.17	46.7
	NKB2	10.115	159.4	74.01	0.87	86.54	51.2
S-700	0	8.402	134.4	75.21	0.70	70.12	42.7
	NPB1	8.816	151.8	76.58	0.74	74.25	48.4
	NKB2	10.418	165.2	78.18	0.87	86.62	52.3
S-B	0	8.321	132.8	73.02	0.69	69.43	41.9
	NPB1	8.730	145.2	74.53	0.74	73.51	47.1
	NKB2	10.317	157.1	76.10	0.86	85.77	51.6
S-G	0	8.078	128.2	68.04	0.69	69.36	41.1
	NPB1	8.476	141.2	69.43	0.73	73.44	46.2
	NKB2	10.016	152.4	70.89	0.86	85.68	50.3
LSD C		4.5983	37.3482	13.8658	0.38658	13.38	14.892
LSD T		4.43292	28.2435	11.004	0.00204	12.771	15.671
LSD C x T		3.19872	26.1453	10.306	0.00306	11.853	12.445

Table 5 Effect of NPB rates on yield of clones jojoba plants at 13 years

Clones Treatments		Number of stem/p	No. leaves /meter	No. of flowers /meter	No. of fruits/ meter	W, Seeds/ plant (kg)	Weight of seed/gm	Weight (100 seed gm)	Oil content of the seeds %
S-L	0 %	5.227	69.520	17.41	11.32	5.632	0.6596	65.960	45.186
	NPB1	5.485	73.590	19.52	13.71	5.746	0.6984	69.840	46.614
	NKB 2	6.481	80.740	21.41	15.23	5.867	0.8148	81.480	48.348
S-610	0	5.384	71.555	17.44	11.34	5.967	0.679	67.900	46.614
	NPB1	5.649	80.740	19.56	13.74	6.089	0.7178	71.780	47.634
	NKB2	6.676	87.670	21.45	15.26	6.217	0.8439	84.390	52.224
S-700	0	5.545	73.920	17.48	11.37	6.318	0.679	67.900	48.654
	NPB1	5.819	83.490	19.60	13.76	6.433	0.7178	71.780	50.388
	NKB2	6.876	90.860	21.50	15.29	6.567	0.8439	84.390	56.406
S-B	0	5.492	73.040	17.46	11.35	6.134	0.6693	66.930	47.838
	NPB1	5.762	79.860	19.58	13.75	6.261	0.7178	71.780	49.062
	NKB2	6.809	86.405	21.47	15.28	6.392	0.8342	83.420	52.632
S-G	0	5.331	70.510	17.43	11.33	5.715	0.6693	66.930	46.002
	NPB1	5.594	77.660	19.54	13.72	5.832	0.7081	70.810	47.124
	NKB2	6.611	83.820	21.43	15.25	5.955	0.8342	83.420	51.306
LSD C		2.5723	13.2147	4.8874	3.9588	1.8471	0.3827	13.2462	8.8031
LSD T		2.4086	12.1211	4.5763	3.7068	0.9940	0.0020	12.6433	8.5843
LSD C x T		1.1867	11.0338	2.2548	1.8264	0.3029	0.0030	11.7345	7.3706

Table 6 Effect of NPB rates on leaves chemical contents of jojoba clones at 3 years

Clones Treatments		Chlorophyll 51 content			Total carbohydrates	Nitrogen%	Phosphorus%	Potassium%	Mg (%)	Fe ppm	Zn ppm	Cu ppm
		Chl.A	Chl. B	Carot.								
S-L	0%	2.03	1.520	2.89	10.10	2.512	0.23735	1.527	0.7560	1232.0	4323.0	1221.0
	NPB1	3.08	1.690	3.32	12.10	3.191	0.24644	1.969	0.8980	1453.0	4763.0	1231.0
	NKB 2	3.88	1.750	4.05	13.40	3.223	0.27876	2.042	0.9700	1654.0	5212.0	1242.0
S-610	0	2.99	1.581	3.11	10.80	2.762	0.26361	1.898	0.7920	1246.8	4340.3	1233.2
	NPB1	3.48	1.758	3.36	13.30	3.251	0.27472	2.207	0.9420	1470.4	4782.1	1243.3
	NKB2	4.52	1.821	4.94	13.60	3.343	0.29896	2.246	1.0170	1673.8	5232.8	1254.4
S-700	0	2.99	1.581	3.11	10.80	2.762	0.26361	1.898	0.7920	1246.8	4340.3	1233.2
	NPB1	3.48	1.758	3.36	13.30	3.251	0.27472	2.207	0.9420	1470.4	4782.1	1243.3
	NKB2	4.52	1.821	4.94	13.60	3.343	0.29896	2.246	1.0170	1673.8	5232.8	1254.4
S-B	0	2.89	1.613	3.12	11.30	2.723	0.27664	1.921	0.7972	1561.5	5252.9	1224.1
	NPB1	3.16	1.793	3.45	13.50	3.274	0.28684	2.115	0.9466	1485.1	4796.4	1235.2
	NKB2	4.35	1.857	4.50	13.70	3.356	0.30906	2.240	1.0228	1690.6	5248.5	1264.5
S-G	0	2.86	1.550	3.08	10.50	2.671	0.2424	1.865	0.7740	1543.0	5232.0	1212.0
	NPB1	3.13	1.724	3.42	13.20	3.212	0.27371	2.053	0.9190	1467.5	4777.3	1223.0
	NKB2	4.31	1.785	4.46	13.50	3.291	0.28684	2.175	0.9930	1670.5	5227.6	1252.0
LSD C		0.093	0.024	0.06969	5.1342	0.12256	0.011142	0.133702	0.010213	0.010213	988.323	2.481
LSD T		0.0834	0.023	0.0983	4.879	0.11035	0.010032	0.120382	0.009196	0.009196	889.862	0.2030
LSD C x T		0.003	0.004	0.1392	4.543	0.10515	0.009559	0.114709	0.008763	0.008763	847.929	0.20390

Table 7 Effect of NPB rates on leaves chemical contents of jojoba clones at 13 years

Clones Treatments		Chlorophyll 51 content			Total carbohydrates	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Mg (%)	Fe ppm	Zn ppm	Cu ppm
		Chl.A	Chl. B	Carot.								
S-L	0 %	2.0320	1.5215	2.8929	10.110	2.5145	0.2376	1.5285	0.7568	1233.2	4327.3	1222.2
	NPB1	3.0831	1.6917	3.3233	12.112	3.1942	0.2467	1.9710	0.8989	1454.5	4767.8	1232.2
	NKB 2	3.8839	1.7518	4.0541	13.413	3.2262	0.2790	2.0440	0.9710	1655.7	5217.2	1243.2
S-610	0	2.9930	1.5826	3.1131	10.811	2.7648	0.2639	1.8999	0.7928	1248.0	4344.6	1234.4
	NPB1	3.4835	1.7598	3.3634	13.313	3.2543	0.2750	2.2092	0.9429	1471.9	4786.9	1244.5
	NKB2	4.5245	1.8228	4.9449	13.614	3.3463	0.2993	2.2482	1.0180	1675.5	5238.0	1255.7
S-700	0	2.9930	1.5826	3.1131	10.811	2.7648	0.2639	1.8999	0.7928	1248.0	4344.6	1234.4
	NPB1	3.4835	1.7598	3.3634	13.313	3.2543	0.2750	2.2092	0.9429	1471.9	4786.9	1244.5
	NKB2	4.5245	1.8228	4.9449	13.614	3.3463	0.2993	2.2482	1.0180	1675.5	5238.0	1255.7
S-B	0	2.8929	1.6146	3.1231	11.311	2.7257	0.2769	1.9229	0.7980	1563.1	5258.2	1225.3
	NPB1	3.1632	1.7948	3.4535	13.514	3.2773	0.2871	2.1171	0.9475	1486.6	4801.2	1236.4
	NKB2	4.3544	1.8589	4.5045	13.714	3.3594	0.3094	2.2422	1.0238	1692.3	5253.7	1265.8
S-G	0	2.8629	1.5516	3.0831	10.511	2.6737	0.2426	1.8669	0.7748	1544.5	5237.2	1213.2
	NPB1	3.1331	1.7257	3.4234	13.213	3.2152	0.2740	2.0551	0.9199	1469.0	4782.1	1224.2
	NKB2	4.3143	1.7868	4.4645	13.514	3.2943	0.2871	2.1772	0.9940	1672.2	5232.8	1253.3
LSD C		0.0931	0.0240	0.0698	1.1393	0.1227	0.0112	0.1338	0.0102	0.0102	989.3113	2.4835
LSD T		0.0835	0.0230	0.0984	1.8839	0.1105	0.0100	0.1205	0.0092	0.0092	890.7519	0.2032
LSD C x T		0.0030	0.0040	0.1393	1.5475	0.1053	0.0096	0.1148	0.0088	0.0088	848.769	0.2041

that gave highest value as chlorophyll content (chl. A 4.52 and 4.5245, Chl. B 1.821and 1.8228, and carotene 4.94 and 4.9449), total carbohydrates13.60 and 13.614, nitrogen 3.343 and 3.3463%, phosphorus 0.29896 and 0.2993%, potassium 2.246 and 2.2482%, Fe 1673.8 and 1675.5 ppm, Zn 5232.8 and 5238.0 ppm, Cu 1254.4 and 1255.7 ppm, and Mg 1.0170 and 1.0180 ppm.

Discussion

Effect of clones

A number of key genes are responsible for the enzymes that make wax synthesis in jojoba. The relationship between genetic variance and total phenotypic variance is then in broad sense, heritability, Ravetta and Palzkill (1993). Clones jojoba have significant effect on yield of seeds jojoba (Yermanos and Holmes 1973), where variability in clones was reflected in the high yields achieved from year to year. Results demonstrated that clones jojoba exhibited a strong positive relationship between branching frequency and flower bud production. Mount of branching (number of tips) along the stem segment and the number of nodes. Clones with more branching showed an increase in nodes. It was concluded that an increase in branching frequency (number of branch tips/ number of nodes) would likely increase node production (everything else remaining constant) and if the ratio of flower buds to nodes remain constant, then the number of flower buds would be increased (Ravetta and Palzkill 1993).

Effect of nitrogen

Data in all tables in results attributed to the increase in growth parameter to increase of nitrogen level because nitrogen helped for the synthesis many substances that necessary to formation chlorophyll as amino acids, amines, proteins, nucleic acids, nucleotides, purines, pyrimidines, coenzymes, and hexoseamines that is a part of the chlorophyll molecule, according to Kumar (2003) and Kumar (2007). Zhao et al. (2005) showed the increase in nitrogen rates led to increments in leaf area, carbon dioxide exchange rates, increase leaf protein, and activities of several enzymes as ribulose bisphosphate carboxylase. Photosynthetic CO_2 assimilation is greatly increased at high leaf N levels and the increase in carbon exchange rate has generally been a linear function of leaf N concentration, according to Ghoneim (2005) and Mauromicale et al., (2000). Nitrogen led to increased vegetable growth and thus led to an increase in the number of leaves and branches as well as an increase in the number of flowers, which leads to increase the yield of seeds (Gendy et al. 2013).

Effect of phosphorus

Phosphorus is one the most essential elements for plant growth after nitrogen. However, the availability of this nutrient for plants is limited by different chemical reactions especially in arid and semi-arid soils. The lack of phosphorus results in decreases in magnesium and calcium content in the leaves, but there was no effect on shoot growth or chlorophyll concentration (Hänsch and Mendel 2009). Franco-Vizcaíno and Khattak (1990) found phosphorus is low in clones of jojoba with comprised clone S-700.

Phosphorus plays a significant role in several physiological and biochemical plant activities like photosynthesis, transformation of sugar to starch, and transporting of the genetic traits. Mahdi et al., (2010) reported that one of the advantages of feeding the plants with phosphorus is to create deeper and more abundant roots. Phosphorus causes early ripening in pants, decreasing grain moisture, improving crop quality, and is the most sensitive nutrient to soil pH (Mehrvarz et al. 2008).

Effect of boron

Boron plays a key role in a diverse range of plant functions including cell wall formation and stability, maintenance of structural and functional integrity of biological membranes, movement of sugar or energy into growing parts of plants, and pollination and seed set (O'Neill et al. 2004). Ganie et al. (2013) observed that boron fertilization regardless of application increases fruit yield and quality of temperate fruits. The essential role of B in nature still needs to be understood; the evidence given by scientists showed that it is essential for plant growth and important in cell division. The plants grown in B deficient or B toxic soils is poor quality compared with that of plants grown in B-sufficient soils; this reveal the effectiveness of B in the biological regulation which involves enzyme and hormone system. There is an increase in sterility with boron foliar through studying of some vegetative and reproductive growth characters (Al-Amery et al. 2011). Spraying B led to increase the concentration of N, P, K, and Na in the leaves, while it had no significant effect on N and P in leaf concentration.

Conclusion

Jojoba is an emerging crop that is well suited to cultivate in arid regions including Egypt. It requires careful management of fertilizer and varieties to obtain maximum yields. So for improving yield and seed quality, it could be recommended with foliar spray NPB2 (N1.5%, P 1.25%, and B0.8%) under the condition of this study on jojoba plants.

Abbreviations

B: Boron; C: Carotene; Ch A: Chlorophyll a; Ch B: Chlorophyll b; Cu : Copper; Fe : Ferric; Mg : Magnesium; N: Nitrogen; NPB: Nitrogen phosphorus boron; P : Phosphorus; Zn: Zinc

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Availability of data and materials

All the data obtained during the study are presented in this manuscript. Any further enquiries for additional information are available upon request from the corresponding author.

Authors' contributions

EAK, MHA, and GAA conceived and designed the study. EAK, MHA, and GAA performed the experiments. EAK and GAA analyzed the data. EAK and MHA wrote the first draft, revised, and edited it. All authors read and approved the final manuscript.

Ethics approval and consent to participate

Ethical approval had been granted approval by the Ethics Committee of Theodor Bilharz Research Institute (TBRI).

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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