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Jojoba (*Simmondsia chinesis* (Link) Schneider): A Potential Shrub in the Arabian Desert: IV. Effect of NPK Fertilization on Vegetable Growth and N Content of Leaves*

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Abstract. A two-years field trial was initiated on 20/9/93 to assess the effect of eight (2^3) fertilizer treatments comprising two levels (zero and 50 kg ha^{-1}) of each of the three major fertilizer elements (N, P and K) on vegetative growth of a heterogenous jojoba population established on 28/2/93. Data taken on nine morphological traits for eight consecutive seasons (Fall 1993 up to Summer 1995) revealed high significant differences among seasons for each of the studied traits. In addition, main effects of N, P and K on morphological traits were generally absent and when present (1st and 8th seasons) they were all negative, with the exception of branch length (winter 1993) that was positively increased by N application. Effect of N_1P_0 and N_0P_1 on number of branches (3 out of 8 seasons), N_1P_1 on leaf area and leaf weight (Fall 1993) and of P_0K_0 and P_1K_1 on plant height and number of branches (Summer 1995), on the other hand, were all positive and significant. Among second order interactions, effects of $N_1P_1K_1$ and $N_1P_1K_0$ on leaf area and Specific Leave Area (SLA) (1st and 3rd seasons) were the highest, but were statistically similar to those of $N_0P_0K_0$. Application of N had also significantly increased N content (fall, winter and spring) and P content (summer) of Jojoba leaves in the first year.

Introduction

Jojoba has recently attracted worldwide attention for several reasons: (a) 50% of the seed weight is liquid wax with several potential uses (Yermanos, 1982); (b) it is an extremely drought tolerant (Al-Ani *et al.,* 1972) and salinity tolerant species (Tal *et al.,*

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1979 and Rasoolzadegan *et al.,* 1982); (c) it can be grown in areas of marginal soil fertility, high atmospheric temperature and low humidity (Yermanos, 1982); and (d) it has low fertilizer and energy requirements (Yermanos, 1982). These attributes had encouraged the utilization of jojoba in sand stabilization, greenification and landscape projects and in establishing open rangelands and national parks in desert areas. Under these conditions, little, if any, fertilizers are used. This approach was mostly attributed to the general belief that jojoba does not respond to fertilizer applications. In this respect, application of 50 kg N and/or 50 kg P_2O_5 kg ha^{-1} for three consecutive years induced no obvious superiority in vegetative growth. This, according to Yermanos (1982), could be attributed to the deep and extensive root system of the jojoba that enables it to draw nutrients from much deeper soil profiles. Adams *et al.* (1977) and Reyes *et al.* (1977) indicated that the response of jojoba to fertilizer application depends on the root type (tap vs fibrous), soil temperature and season of growth. In this respect, they indicated that young plants, initiated from cuttings, having a fibrous root system, unlike young seedlings with a tap root system, did not respond to fertilizer application. According to Feldman *et al.* (1984) N, P and K contents in leaves of rooted cuttings in the spring were lower than those recorded in the summer. Root elongation in the spring and branch extension in the summer were, according to these workers, positively correlated to N, P and K contents of leaves.

Fertilizer studies conducted in the occupied land of Palestine indicated that the application of relatively higher doses of NPK under irrigated conditions had significantly induced positive growth (Benzioni and Nerd, 1985; Benzioni and Dunstone, 1986), induced flowering and increased the percentage of buds that broke dormancy (Nerd and Benzioni, 1988). In a separate study, Lovenstein (1985) indicated that about 58, 11, 22, 4 and 4 kg ha^{-1} of N, P, K, S and Mg were needed for the production of 3 t of seeds per hectare in jojoba plantations, respectively.

The present work was conducted to assess the effect of NPK split application on vegetative growth and nitrogen content of jojoba under the arid environments of Western Saudi Arabia. In addition, mineral content at various soil depths in the jojoba field was also determined.

Materials and Methods

The present work was conducted at the Experimental Farm of King Abdulaziz University at Hada Al-Sham, 120 km northeast of Jeddah. The soil at the experimental site is sandy clay (72% sand, 18% clay and 10% silt) having average estimates of 0.17, 0.20 and 2.61 g kg^{-1} of N, P and K, respectively, and pH 8.2 and EC of 0.96 dSm^{-1}. The meteorological data characterizing the site during the course of the experiment are shown in Table 1. A seed lot of jojoba introduced from Arizona was sown in 1989. Seeds harvested from this lot were used in establishing the NPK fertilization plots evaluated in this study. The test plot was seeded on 28/2/1993 in an area of 1.152 ha (18 rows × 4 × 160) under a drip irrigation system. On 20/9/93, the test plot was divided into four blocks, each of which, apart from marginal rows, consisted of 16 experimental rows (16 × 40 m) two of which were randomly assigned for each one of the eight (2^3) NPK combinations where two levels (0 and 50 kg ha^{-1}) for each of the three elements were tested. In conducting the trial, urea as a source of N, was splitted into ten doses, five of which were applied in the fall and five in the spring in each of the two years during which the experiment was conducted. Triple superphosphate as a source of P_2O_5 and potassium sulphate as a source of K_2O were splitted into four doses (two per season) and were applied simultaneously with urea.

TABLE 1. Absolute seasonal maximum and minimum temperature and relative humidity (R.H.) at the experimental site for the periods from 21/12/93 to 20/12/96.

Season	1993 / 94		1994 / 95		1995 / 96	
	Temp. (ºC)	R.H. (%)	Temp. (ºC)	R.H (%)	Temp. (ºC)	R.H. (%)
Winter (W)	6 - 40	22 - 98	10 - 42	17 - 100	24 - 41	42 - 97
Spring (Sp)	14 - 49	24 - 93	18 - 49	19 - 95	25 - 47	40 - 98
Summer (S)	19 - 48	21 - 100	21 - 48	22 - 95	31 - 49	43 - 100
Fall (F)	14 - 42	22 - 99	20 - 46	21 - 95	22 - 44	60 - 100

Starting 21/12/93, *i.e.* after 300 days from planting, and for eight consecutive seasons (*i.e.* until 21/9/95), ten plants were randomly tagged from each experimental plot and were used for determining plant height, branch length, number of basal branches, number of leaves $branch^{-1}$, leaf area, specific leaf area (*i.e.* leaf area per unit leaf weight) in addition to leaf, culm and total branch dry weights. Nitrogen content of the leaves in four samples (seasons) of the first year and mineral content of the soil at four depths (0-25, 25-50, 50-75 and 75-100 cm) for the last sampling date of the second year (21/9/95) were also determined.

Results

1. Overall Performance

Data taken on vegetative growth components in the course of the trial (Figs. 1A to 3C) revealed no significant differences among the eight NPK fertilizer treatments for each of the studied traits except for leaf area (Fig. 2B) in fall 1993 and spring 1994 and SLA (Fig. 2C) in spring 1994. The highest estimates, being 66.1 and 69.6 cm^2 and 45.8 cm^2 g^{-1} for the respective traits were recorded at $N_1P_1K_1$, $N_1P_1K_0$ and $N_1P_1K_0$, respectively. It is also evident from the data that each of the studied traits, with the exception of plant height (Fig. 1A) and number of branches (Fig. 1C), maintained a relatively low or negative growth during the four seasons of the first year and relatively fast growth in the first season (5th) of the second year. Following this stage, a differential seasonal response was observed among the studied traits. In this respect, leaf area (Fig. 2B) and leaf dry weight (Fig. 3A) maintained positive growth until the end of the seventh season; branch length (Fig. 1B), culm dry weight (Fig. 3B) and total dry weight (Fig. 3C) maintained positive growth during the 6th and 8th seasons whereas number of

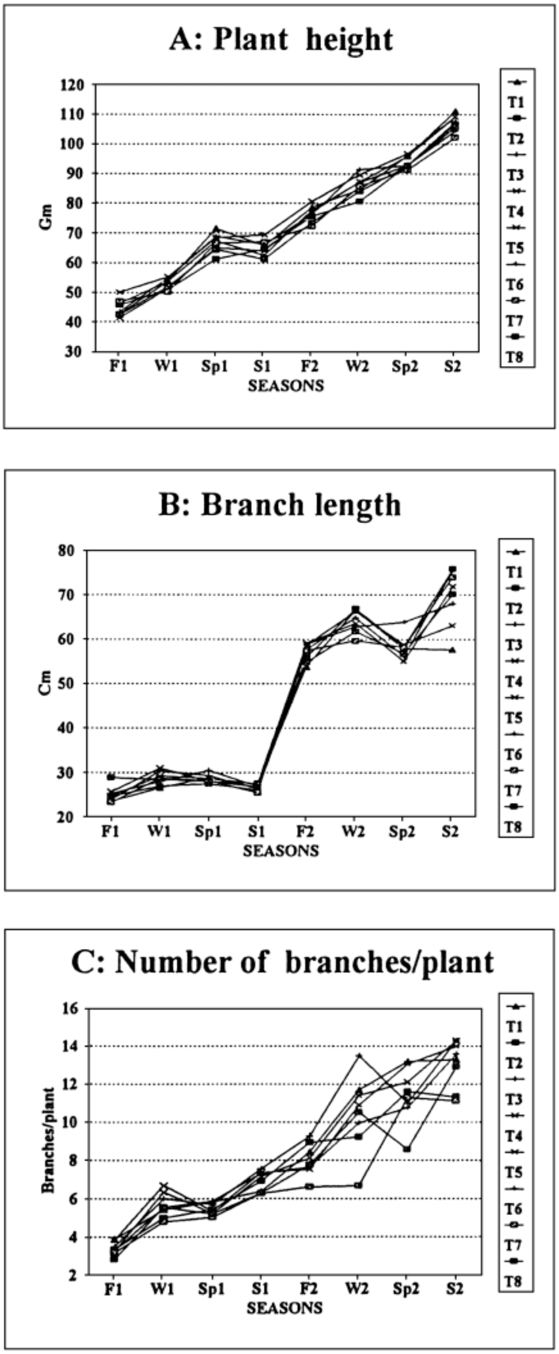

Fig. 1. Effect of NPK on plant height (A), branch length (B) and number of branches per plant (C) in eight growing seasons.

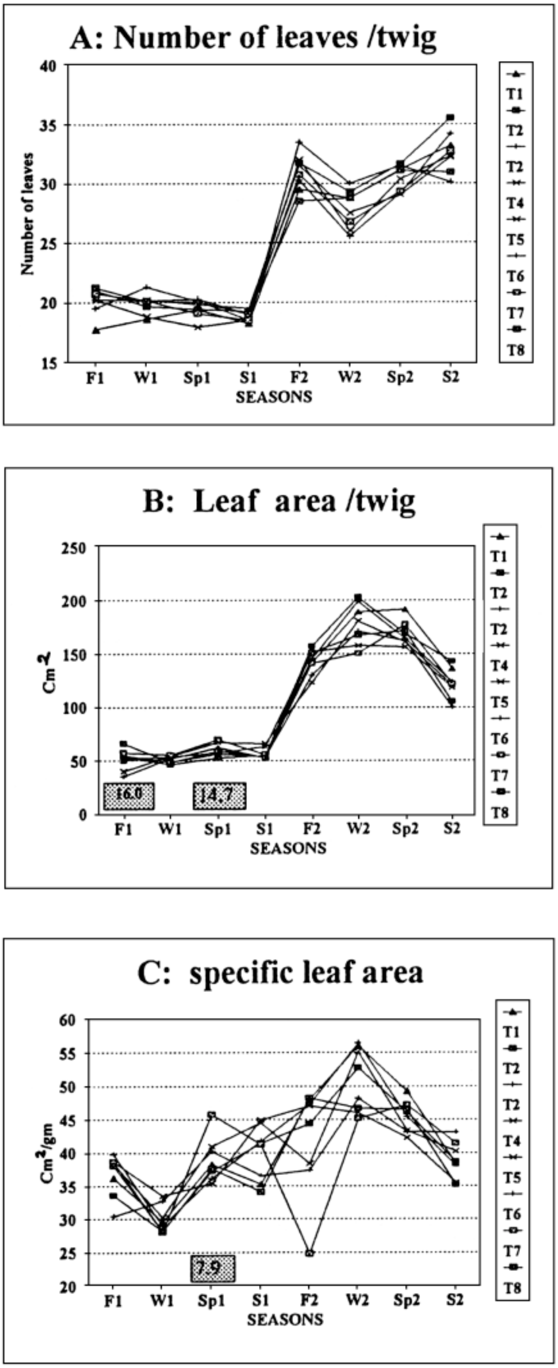

FIG. 2. Effect of NPK fertilizer on number of leaves per twig (A), total leaf area (B) and specific leaf area (C) in eight growing seasons (shaded figures refer to LSD at $p \leq 0.05$).

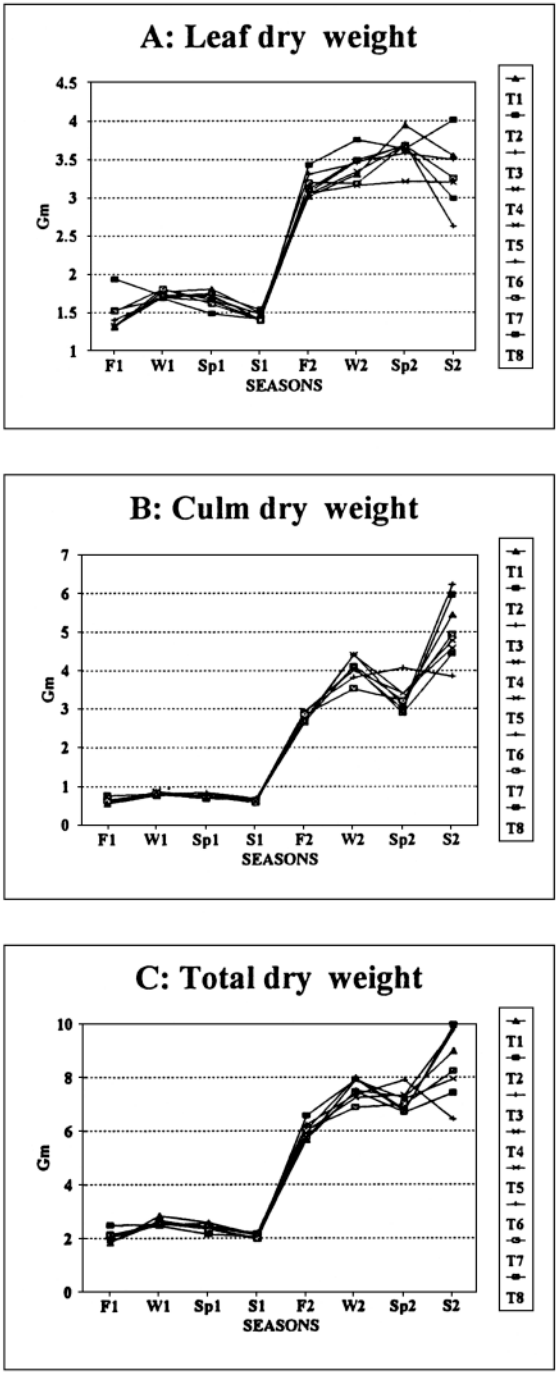

FIG. 3. Effect of NPK fertilizer on leaf dry weight (A), culm dry weight (B) and total dry weight (C) in eight growing seasons.

leaves (Fig. 2A) was reduced during the sixth season but increased again during the seventh and eighth seasons. In contrast, plant height (Fig. 1A) and number of branches (Fig. 1C), with the exception of a noticeable reduction in the 4th season, progressively increased with plant age until the end of eighth season.

2. Joint Effects of N, P and K (First Order Interactions) on Vegetative Growth

Data in Tables 2 and 3 revealed that the number of branches attained at N_1P_0 and N_0P_1 in winter 1994 and summers of 1994 and 1995 were significantly higher than those recorded at N_0P_0 and N_1P_1. Estimates of leaf area and leaf dry weight recorded at N_1P_1 in Fall 1993 were significantly higher than those attained at the other combinations, whereas those recorded at P_0K_0 and P_1K_1 for both plant height and number of branches in summer 1994 were significantly higher than those attained at P_1K_0 and P_0K_1.

TABLE 2. Summary of significance of F-values (individual seasons) for N, P and K and their interactions for nine morphological traits in jojoba.

	d.f.	Plant height	Branch length	No. of branches	No. of leaves	Leaf area	SLA	Leaf dry weight	Culm dry weight	Total dry weight
A. First Year										
N	1		*b							
P	1			*a						
N × P	1			*b, *d		**a		*a		
K	1	*a					*a			
N × K	1									
P × K	1									
N × P × K	1					*a, *c	*c			
B. Second Year										
N	1	**d				*b, **d	*b		*d	*d
P	1	**d								
N × P	1			**d						
K	1	**d								
N × K	1									
P × K	1	**d		*d						
N × P × K	1									
Error	21									

* a and ** followed by letters a to d indicate significance differences at $P \leq 0.05$ and $P \leq 0.01$, respectively in fall (a), winter (b), spring (c), and summer (d) in the respective years using LSD.

3. Main Effects of N, P and K on Vegetative Growth

Analysis of data taken in each of the eight seasons during which the trial was conducted revealed limited significant effects of N, P and K on the studied traits (Table 2). Among these, the most important were those recorded in the first and last seasons of the trial (Table 4). During these two seasons main effects of N (N_0 vs N_1) were limited to plant height (108.9 vs 105.1 cm), leaf area (130.7 vs 111.3 cm^2), culm dry weight (5.6

vs 4.1 g) and total dry weight (9.2 vs. 7.3 g); whereas those of P (P_0 vs P_1) were limited to plant height (107.6 vs 106.4), number of branches (3.6 vs 3.1) in the eighth season and to those of K (K_0 vs K_1) to plant height (46.6 vs 43.3 cm) and (107.6 vs 106.3 cm) in the respective seasons and SLA (38.3 vs 33.0 cm^2/g) in the first season (Table 3).

TABLE 3. Significant first order interactions (N × P and P × K and N × K) in jojoba NPK experiment.

	N_0	N_1	Mean		K_0	K_1	Mean		K_0	K_1	Mean
1. No. of branches (Winter 1993)				2. No. of branches (Summer 1994)				3. No. of branches (Summer 1995[a])			
	± 0.36*		± 0.26		± 0.41*		± 0.29		± 0.28**		± 0.20
P_0	5.2	6.3	5.75	P_0	6.63	7.45	7.04	N_0	12.28	13.64	12.96
P_1	5.9	5.2	5.55	P_1	7.22	6.26	6.74	N_1	13.63	12.00	12.82
	± 0.26				± 0.29				± 0.20		
Mean	5.55	5.72		Mean	6.93	6.86		Mean	12.96	12.81	
4. Leaf area (Fall 1993)				5. Leaf dry weight (Fall 1993)				6. Plant height (Summer 1995)			
	± 3.9**		± 0.27		± 0.09**		± 0.06		± 0.45**		± 0.32**
P_0	51.8	43.4	47.6	P_0	1.42	1.32	13.70	N_0	110.0	105.5	107.7
P_1	47.6	61.8	54.7	P_1	1.36	1.62	14.89	K_1	105.3	107.3	106.3
	± 2.7				± 0.06				± 0.32**		
Mean	49.7	52.6		Mean	13.87	14.73		Mean	107.6	106.4	

a) P × K (No. of branches) in summer 1995 = P × K = (13.2, 12.7, 12.5 13.2) ± 0.28* for P_0K_0, P_0K_1, P_1K_0 and P_1K_1, respectively.

* and ** significant at $P \leq 0.05$ & $P \leq 0.01$, respectively, using LSD.

4. Main Effects of N, P and K and their Interactions on N Contents of Leaves

Data in Table 5 indicated that N content in jojoba leaves was significantly increased by application of urea (N) in the fall, winter and spring and by application of triple super phosphate (P_2O_5) in the summer. Joint effects of N with P and/or K, *i.e.* first order interactions (Table 5) and second order interactions (not shown) had no significant effect on N-content of leaves.

5. Effects of N, P and K and their Interactions on Soil Mineral Contents

Data in Tables 6 and 7 indicated that nitrogen application (N_0 vs N_1) alone had adverse effects on K content of the soil (260.1 vs 196.5 mg kg^{-1}); whereas that of P (P_0 vs P_1) had positive affect on Fe (3.16 vs 3.4 mg kg^{-1}), Ca (11.7 vs 19.5 mg kg^{-1}) and Cl^{-1} (21.0 vs 46.6 meq. L^{-1}) contents. Application of K alone, on the other hand, had positively affected Fe (2.87 vs 3.69 mg kg^{-1}) contents and adversely affected Ca (16.8 vs 14.4 mg kg^{-1}) contents (Table 7). It is also evident from Table 6 that joint application of N and P had significantly ($P \leq 0.01$) affected Fe, Zn and SO_4^{--} levels in the soil; whereas that of N with K had significantly ($P \leq 0.01$) affected P, Ca, HCO_3^- and Cl^- levels. Joint effects of P and K were limited to those on Fe; whereas those of N × P × K were limited to those on Na contents (Table 6).

TABLE 4. Main effects of N, P and K on nine morphological traits in jojoba during the first and last seasons of a 2-year field experiment.

	Plant height (cm)		Branch length (cm)		No. of branches		No. of leaves		Leaf area (cm^2)		SLA (cm^2 / g)		Leaf dry weight (g)		Culm dry weight (g)		Total dry weight (g)	
Season	1	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8	1	8
N_0	44.1	108.9	24.6	74.8	3.4	13.0	19.8	33.8	49.7	130.7**	34.9	39.3	1.39	3.6	0.59	5.6*	1.98	9.2*
N_1	45.8	105.1	25.5	71.3	3.3	12.8	20.4	31.7	52.6	111.3	36.4	38.8	21.47	3.1	0.64	4.1	2.11	7.3
P_0	45.6	107.6**	24.05	73.2	3.6*	13.0	19.6	32.8	47.6	124.2	34.7	39.5	1.37	3.4	0.58	5.0	1.95	8.4
P_1	44.3	106.4	25.6	72.9	3.1	12.8	20.6	32.5	54.8	117.8	36.6	38.7	1.49	3.2	0.65	4.8	2.14	8.0
K_0	46.6*	107.7**	24.5	74.6	3.5	12.8	19.7	33.2	53.6	124.9	38.3*	38.9	1.38	3.5	0.60	5.3	1.99	8.8
K_1	43.3	106.3	25.6	71.4	3.2	12.9	20.5	32.1	48.7	117.0	33.0	39.3	1.47	3.2	0.62	4.4	2.10	7.6
S.E.±	0.89	0.32	0.87	1.58	0.17	2.0	0.48	0.86	2.7	44.	1.59	2.85	0.06	0.21	0.03	0.42	0.08	0.59

* and ** indicate significant differences between the two levels of N, P and/or K at $P \leq 0.05$ and $P \leq 0.01$, respectively during the first (1) or eighth (8) season, using LSD.

TABLE 5. Main effects of N, P and K and their interactions on N content of jojoba leaves.

	N_0	N_1	Mean		K_0	K_1	Mean		K_0	K_1	Mean
Fall 1993											
	± 0.04		± 0.02		± 0.04				± 0.04		± 0.032
P_0	1.0	1.17	1.085	N_0	1.02	0.97		P_0	1.11	1.06	1.085
P_1	0.99	1.24	1.115	N_1	1.22	1.199		P_1	1.13	1.10	1.115
	± 0.032*				± 0.032				± 0.032		
Mean	0.995	1.205		Mean	1.12	1.08		Mean	1.12	1.08	
Winter 1994											
	± 0.08		± 0.069		± 0.08				± 0.08		± 0.069
P_0	1.83	2.27	2.050	N_0	1.67	1.96		P_0	1.95	2.16	2.050
P_1	1.80	2.01	1.905	N_1	2.06	2.22		P_1	1.78	2.03	1.905
	± 0.069*				± 0.069				± 0.069		
Mean	1.815	2.14		Mean	1.865	2.090		Mean	1.860	2.095	
Spring 1994											
	± 0.22		± 0.156		± 0.22				± 0.22		± 0.156
P_0	2.67	3.07	2.870	N_0	2.72	2.21		P_0	2.95	2.80	2.875
P_1	2.26	3.05	2.655	N_1	3.06	3.06		P_1	2.83	2.47	2.650
	± 0.156*				± 0.156				± 0.156		
Mean	2.465	3.12		Mean	2.890	2.635		Mean	2.890	2.635	
Summer 1994											
	± 0.11		± 0.082**		± 0.11				± 0.11		± 0.082
P_0	1.77	1.91	1.840	N_0	2.02	1.87		P_0	1.93	1.75	1.840
P_1	2.03	2.16	2.095	N_1	1.95	2.12		P_1	2.03	2.16	2.095
	± 0.082				± 0.082				± 0.082		
Mean	1.90	2.035		Mean	1.985	1.995		Mean	1.98	1.955	

** significant at $P \leq 0.01$, using LSD.
a, b, c = def of N, P, or K = 1 and that of their 1st order interactions in each season = 1.

TABLE 6. Summary of significance of F-values for N, P and K and their interactions for major soil cations and anions in jojoba experimental plot.

Fertilizer	d	P	K	Cu	Fe	Mg	Zn	Ca	Na	HCO_3^-	Cl^-	SO_4^-
N	1		*									
P	1				**			**			**	
N × P	1				**		**					**

TABLE 6. Contd.

Fertilizer	d	P	K	Cu	Fe	Mg	Zn	Ca	Na	HCO_3^-	Cl^-	SO_4^-
K	1				**			**				
NK	1	**						**		**	**	
PK	1				**							
NPK	1								**			
Error	21	1.37	5742	0.114	0.567	1.071	0.010	56.031	306.638	0.128	461.936	29.595

* and ** indicate significant differences at $P \leq 0.05$ and $P \leq 0.01$, respectively, using LSD.

TABLE 7. Main effects of N, P and K on soil mineral contents of jojoba field averaged over four soil depths.

	P	K	Cu	Fe	Mg	Zn	Ca	Na	HCO_3^-	Cl^-	SO_4^{--}
	(mg kg^{-1})							(meq L^{-1})			
N_0	4.10	260.1*	1.09	3.22	2.49	0.26	14.8	35.5	1.9	29.4	21.6
N_1	4.33	196.5	1.03	3.34	2.87	0.24	16.4	43.8	1.8	38.2	19.8
P_0	4.67	230.4	1.14	3.16	2.33	0.24	11.7	33.6	2.0	21.0	20.9
P_1	4.64	196.5	1.22	3.40**	3.03	0.26	19.5**	45.8	1.7	46.6**	20.5
K_0	4.96	221.7	1.07	2.87	2.11	0.25	16.8**	43.1	1.7	40.1	21.5
K_1	4.36	234.9	1.29	3.69**	3.24	0.25	14.4	36.2	2.0	27.4	19.8
S.E ±	0.293	18.9	0.08	0.19	0.26	0.02	1.9	4.4	0.09	5.4	1.4

* and ** indicate significant differences at $P \leq 0.05$ and $P \leq 0.01$, respectively, using LSD.

6. Effect of Soil Depth on Mineral Contents of the Soil

Data in Table 8 indicated that levels of P, Fe, Mg, Zn and HCO_3^- in the soil were significantly affected by soil depth. Estimates at the top layer (0-25), being 5.81, 3.96, 5.65 and 0.385 mg kg^{-1} for cations P, Fe, Mg and Zn respectively and 2.86 meq. L^{-1} for anion HCO_3^- were significantly higher than those recorded at the deeper layers (Table 8).

Discussion

Nitrogen alone or in combination with other elements is a key factor in achieving optimum plant growth. Efficient use of NPK fertilizers is, however, dependent on several factors including time of application (Abdel-Aziz *et al.* 1986 and Badreshia and Patel, 1987); source and rate of application (Grove *et al.* 1980; Njoku and Odurukwe, 1987 and Lucas, 1986 and Soelaeman *et al.* 1987); genetic background (Nerd and Benzioni, 1988) and climate-related variables (Hane, 1981 and Osman and Al-Solaimani, 1996).

Lack of response to N, P and K application, as observed in this study, was attributed to the extensive tap root system that enabled the jojoba shrub to draw these nutrients from deeper soil profiles (Yermanos, 1982). Differences among seasons, as observed in this study, were mostly attributed to differences in plant age (shallow vs deep root system) and soil temperature as reported by Adams *et al.* (1977) and Reyes *et al.* (1977). Adverse effects of N, P and K on plant height and of N on leaf area, culm weight and total dry weight and of P on number of branches in the hot summer (8th season, Table 2) may partially be attributed to these factors. Other factors such as the nature of the sandy loam soil of the experimental site and climate-related variables (Hane, 1981 and Osman and Al-Solaimani, 1996) such as seasonal variations in air temperature and relative humidity (Table 1) characterizing the experimental site might have contributed to the adverse effects associated with N, P and K applications. Apparently relatively younger plants unlike other plants (*e.g.* 4th vs 8th season) with less nutrients demands might have tolerated the harsh summer conditions in the first year and consequently their vegetative growth was not adversely affected.

TABLE 8. Effect of soil depth on major soil anions and cations in jojoba experimental plot.

Soil depth (cm)	P	K	Cu	Fe	Mg	Zn	Ca	Na	HCO_3^-	Cl^-	SO_4^{--}
	($mg\ kg^{-1}$)								($meq\ L^{-1}$)		
0 - 25	5.81	253.1	1.36	3.96	5.65	0.385	7.16	43.0	2.86	31.6	20.3
25 - 50	4.17	230.4	1.24	2.86	1.83	0.210	7.37	37.3	1.62	30.5	22.0
50 - 75	4.61	190.6	1.01	3.21	1.51	0.198	7.17	43.5	1.41	45.6	18.2
75 - 100	4.03	239.0	1.11	3.09	1.73	0.202	7.22	34.9	1.49	27.4	22.3
Mean	4.66	228.3	1.18	3.28	2.68	0.249	7.23	39.7	1.84	33.8	20.7
S.E. ±	0.41*	26.8	0.12	0.27*	0.37**	0.03**	0.09	6.2	0.13**	7.6	2.0

*and ** indicate significant differences at $P \leq 0.05$ and $P \leq 0.01$, respectively, using LSD.

Positive effects of N and P application on N content of the leaves and possibly of P and K (not estimated) coupled with differential accumulation of various elements at different depths and under the NPK treated plots might have enabled the plant, through osmotic regulation (Benzioni *et al.,* 1996 and Al-Rhamani *et al.,* 1997) to survive the harsh conditions of the summer in an arid environment as that of Western Saudi Arabia. Under such conditions (Table 1) negative growth under fertilized plots (Table 3) might be anticipated. Apparently, amounts of N, P and K applied in the course of the trial, being 50 kg of each per year, were higher than the actual needs of the jojoba plant as indicated by Lovenstein (1985). This might have also contributed to the negative growth and/or the lack of response.

In conclusion, it appears that many interrelated factors, including the heterogeneous nature of the jojoba population (Nerd and Benzioni, 1988) might have contributed to the lack of positive continuous response to NPK applications. Evaluation of colonal populations under relatively semi-controlled conditions in future study might give a better understanding of the response of jojoba to NPK fertilizer applications.

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الهوهوبا : الشجيرة الواعدة في الصحراء العربية ٤- أثر التسميد بالنيتروجين والفوسفور والبوتاسيوم على النمو الخضري ومحتوى الأوراق من النيتروجين*

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المستخلص . بدأ هذا البحث في ٢٠/ ٩/ ١٩٩٣م لدراسة أثر التسميد (ثمانية معاملات : ٢[٣]) بالأزوت (N) والفوسفور (P) والبوتاسيوم (K) بمعدل مستويين (صفر و ٥٠ كجم/ هـ) لكل عنصر على النمو الخضري ومحتوى الأوراق من الأزوت لشجيرة الهوهوبا . أوضحت البيانات التي دونت لتسعة صفات مورفولوجية خلال ثمانية فصول متتالية (خريف ١٩٩٣ وحتى صيف ١٩٩٥) فروقات معنوية عالية بين المواسم . أما الآثار الرئيسية للنيتروجين والفوسفور والبوتاسيوم فلم تكن معنوية إلا في حالات قليلة (الفصلين الأول والثامن) حيث كان معظمها سلبيًا عدا طول الفرع خلال شتاء ١٩٩٣ والذي زاد مع إضافة الأزوت . أما الآثار المشتركة لإضافة عنصرين معًا مثل : N_0P_1 و N_1P_0 فقد أثرت معنويًا وإيجابيًا على عدد الأفرع (٣ من ٨ مواسم) كذلك أثرت إضافة N_1P_1 إيجابيًا على مساحة الأوراق ووزنها خلال خريف ١٩٩٣م . كذلك أثر المستويان P_0K_0 و P_1K_1 على طول النبات وعدد الأفرع خلال صيف ١٩٩٥م . أما التفاعلات بين العناصر الثلاث مثل : $N_1P_1K_1$ و $N_1P_1K_0$ فقد أدت إلى معدلات عالية من مساحة الأوراق وكثافتها النوعية (الموسمين الأول والثالث) إلا أنها لم تتفوق معنويًا على ماسجل عند المعاملة $N_0P_0K_0$ (معاملة القياس) . كذلك أدت إضافة النيتروجين إلى زيادة محتوى الأوراق من النيتروجين خلال الخريف والشتاء والربيع ومحتواها من الفوسفور خلال الصيف من العام الأول .

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