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Plant Growth and Development of Bush Tea as Affected by Nitrogen, Phosphorus, and Potassium Nutrition

Nixwell F. Mudau
Department of Plant Production, University of Limpopo, Private Bag X 1106, Sovenga, 0726, Republic of South Africa

Puffy Soundy and Elsa S. du Toit
Department of Plant Production and Soil Science, University of Pretoria, Pretoria, 0002, Republic of South Africa

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Abstract. **Bush tea (*Athrixia phylicoides*) belongs to the Asteraceae family. It is a popular beverage used as an herbal tea and as medicine for cleansing or purifying the blood, treating boils, headaches, infested wounds, and cuts, and the solutions may also be used as a foam bath. In some parts of South Africa, people drink bush tea for aphrodisiac reasons. Bush tea was grown under varying N, P, and K levels in all four seasons to determine the seasonal nutrient requirements for improved plant growth. Three parallel trials for N, P, or K one at each season were laid out in a randomized complete block design (RCBD) with six treatments replicated eight times. Treatments consisted of 0, 100, 200, 300, 400, or 500 kg·ha^{-1} N, P, or K. Parameters recorded were plant height, number of branches and leaves, fresh and dry stem mass, fresh and dry root mass, stem girth, fresh and dry shoot mass, leaf area and percentage leaf and root tissue N, P, and K. Results of this study demonstrated that, in all trials regardless of season, N, P, or K nutrition increased bush tea fresh and dry shoot mass, plant height, number of leaves, number of branches and leaf area. Regardless of season, the optimum level of N, P and K fertilization for bush tea on growth parameters was 300 kg·ha^{-1} N or P and 200 kg·ha^{-1} for K. No significant differences in number of flowers and buds (fall and winter), stem girth, fresh and dry root mass as well as fresh and dry stem mass were obtained.**

Bush tea (*Athrixia phylicoides*) belongs to the Asteraceae family (Bremer, 1973). It is a small, pretty shrub, branched, with thin woolly stems. It also has small, dark green pointed leaves with white woolly backs and small pink daisy flowers with a bright yellow centre (Roberts, 1990). Flowers vary from pink to all shades of pink and attractive purple colour depending on soil types and geographic areas (Van Wyk and Gericke, 2000). It is a popular beverage used as herbal tea and as medicine for cleansing or purifying the blood, treating boils, headaches, infested wounds and cuts, and the solution may also be used as a foam bath. The foam bath brew can also be used as a lotion dabbed on to the boil, skin eruption or cut (Roberts, 1990). The tea infusion is also excellent for coughs and colds and as a gargle for throat infections and loss of voice. In some parts of South Africa, people drink it for aphrodisiac reasons (Mabogo, 1990).

Cultural practices have a significant influence on tea growth and productivity of herbal teas (Owour, 1989; Ruan et al., 1999; Venkatesan et al., 2004). Among such cultural practices, mineral nutrition (Hilton et al., 1973; Barauh et al., 1986; Owour et al., 1990; Owour and Odhiambo, 1994); plucking (Owour et al., 2000), and irrigation (Stephens and Carr, 1991) have been widely reported to improve tea growth and maximize productivity.

In mineral nutrition, the application of nitrogenous, potassium and phosphorus fertilizers are the main normal agronomic practices and several studies have shown improvement on growth and yield (Keen and Zidenberg-Cheer, 2000; Marschener et al., 1996; Owour and Odhiambo, 1994; Owour et al., 2000), thus resulting in increasing biomass production of tea.

The plant materials of bush tea are only harvested from the wild and the concept of domesticating wild plants is very important in order to avoid the natural population from becoming extinct from its native environment. Presently, the mineral nutrition on bush tea is not well established. Data are lacking on the response of N, P, and K on growth and productivity of bush tea. Therefore, the present paper reports the effects of N, P, and K application on growth and development of bush tea under cultivation as influenced by season.

Materials and Methods

Experimental site and plant material. The study was carried out in Morgenzon, a commercial nursery in Louis Trichardt (23°N 50'E, 30°S17'E; alt 610m; subtropical-type climate i.e. summer rainfall and cold, dry winter). On 13 Nov. 2002, plant materials was collected from Venda (Limpopo Province) and 1500 planting materials of apical cuttings were dipped in Seradix No. 2 hormone (0.3% IBA) and established in seed trays on a mist bed. Rooted cuttings were transplanted into 1-L bags and placed in a hardening chamber for 3 months. After 3 months, planting materials were transplanted into 20-L bags. The medium was a 1 pine bark : 2 sand : 1 stryofoam bead mix (v/v), with AquaGro wetting agent (Aquatrols, Cherry Hill, N.J) at 0.2 kg·m^{-3}. The initial media test chemical analyses were determined using (Hanlon et al., 1994) procedure. The EC was 0.9 dS·m^{-1} and pH was 4.7. The pine bark contained NO_3-N of 1.2 mg·kg^{-1}, 0.1 mg·kg^{-1} P and 1.3 mg·kg^{-1} K.

Experimental design and treatments. Three (N, P and K) parallel trials were conducted under 50% shade nets with one at each season in a randomized complete block designed with six treatments replicated 8 times. Fertilizer sources used were limestone ammonium nitrate (for N trial), single super phosphate (for P trial) and potassium chloride (for K trial) applied as post plant one week after planting in the form of granules. The treatments consisted of 0, 100, 200, 300, 400, or 500 kg·ha^{-1} N, P, or K. The standard nursery management applications of 1% $MgSO_4$, ZnO, Microfel Fe (Fe = 29%), mono ammonium phosphate (Climax) [52% P_2O_3 (P = 22%) and 34% K_2O (K = 28.2%)] and urea (N = 46%) (except for N and P trial), sodium borate [$Na_2B_4O_7{\cdot}10H_2O$ (27% boron and 18% Na)] and KCL (except for K trial) were applied twice per week as foliar sprays to supplement the rest of the elements necessary for the production of good quality tea.

Data collection. At harvest, all plants per treatment per replication (fall, 30 May 2003; winter, 30 Aug. 2003; spring, 30 Nov.and summer, 28 Feb. 2004), plant height (cm), number of branches, number of leaves, flowers and flower buds (fall and winter), stem girth (mm), fresh and dry root mass (g), fresh and dry stem mass (g), leaf area (measured by a LI-3100 area meter; LI-COR, Lincoln, Neb.), fresh and dry shoot mass (g), and percentage leaf and root N, P, or K content were recorded.

Leaf and root tissue N content. Total N was determined using the Auto-analyser method (Technicon, 1972) on a Sanplus Segmented Flow Analysis System (Skalar Instruments, Netherlands).

Leaf and root tissue P and K content. P and K were analyzed using the method by Adrian (1973).

Statistical analysis. Analyses of variance were performed on data using the GLM (General linear model) procedure of SAS version 8.0 (SAS Institute Inc., 1999). Treatment sums of squares were partitioned into linear and quadratic polynomial contrasts.

Results and Discussion

***Nitrogen trial*.** Regardless of season, plant height, number of branches and leaves, leaf area, and fresh and dry shoot mass increased quadratically in response to nitrogen nutrition (Tables 1, 2, 3, and 4). Regardless of season, the optimum level of N for growth parameters was 300 kg·ha^{-1}. Most of the growth responses

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occurred between 0 and 300 kg·ha^{-1} N. Wanyoko (1983) reported that biomass production of green tea increased to an optimum at 250 kg·ha^{-1} N. Krishnapillai and Pethiyagoda (1979) reported that when different forms of nitrogenous fertilizer such as ammonium sulphate, ammonium nitrate, urea and calcium nitrate were applied at 300 kg·ha^{-1} N, biomass production of young tea (*Camellia sinensis* L.) was increased.

Regardless of season, leaf tissue N content increased quadratically to reach maximum at 300 kg·ha^{-1} N (Tables 1, 2, 3, and 4). In contrast, Wanyoko (1983) reported that the normal harvestable (*Cammellia sinensis*) tea leaves had leaf tissue N content of 3% to 3.4%.

Regardless of season, root tissue nitrogen content increased quadratically to reaching maximum at 400 kg·ha^{-1} N during fall and summer (Tables 1 and 4) and at 500 kg·ha^{-1} N during winter and spring (Table 2 and 3). Anandacoomaraswamy et al. (2002) reported that 375 kg·ha^{-1} N increased assimilates of N partitioned towards the shoots at the expense of roots in young clonal tea. No significant differences in stem girth, fresh and dry root mass, number of flowers and flower buds as well as fresh and dry stem mass were recorded.

Phosphorus trial. Results in Tables 5, 6, 7, and 8 showed that regardless of season, P increased in a quadratic fashion plant height, number of leaves, branches, fresh and dry shoot mass and leaf area. Regardless of season, the optimum level on growth parameters was 300 kg·ha^{-1} P. However, most of the growth responses occurred between 0 and 300 kg·ha^{-1} P throughout the seasons (Tables 5, 6, 7, and 8). Ruan et al. (1999) reported that P nutrition applied as single super phosphate at 225 kg·ha^{-1} P increased biomass production of green tea.

Leaf tissue P was increased quadratically to reaching maximum at 300 kg·ha^{-1} P (Tables 5, 6, 7, and 8). Wanyoko (1983) also reported that the normal harvestable tea leaves had leaf tissue P content of 0.5% to 0.8%. Percentage root tissue P were also increased quadratically to reach an optimum at 300 kg·ha^{-1} P, regardless of season (Tables 5, 6, 7, and 8). No significant differences in number of flower and buds (winter and fall), stem girth, fresh and dry root mass as well as fresh and dry stem mass were recorded.

Potassium trial. Results in Tables 9, 10, 11, and 12 showed that the plant height (cm), number of branches, number of leaves (winter and spring), leaf area, as well as fresh and dry shoot mass was increased quadratically in response to potassium. The maximum level was 200 kg·ha^{-1} K throughout the seasons (Table 9, 10, 11, and 12). Most of the growth responses occurred between 0 and 200 kg·ha^{-1} K. Ruan et al. (1998) reported that biomass production considerably increased following

Table 1. Response of growth characteristics of bush tea to N nutrition during fall.

Applied N (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of flower buds	No. of leaves	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue N (%)	Root tissue N (%)
Control	77	36	32	411	32	17	818	1.7	0.5
100	86	113	38	598	39	22	935	2.1	0.6
200	88	102	39	688	50	29	1084	2.6	1.4
300	96	104	37	926	56	32	1479	3.2	2.0
400	95	121	35	702	55	33	1197	3.1	2.3
500	88	117	32	762	53	32	935	2.8	2.2
Response	Q**	Q**	NS	Q**	Q**	Q**	Q**	Q**	Q**

NS,*,**Nonsignificant or significant linear (L) or quadratic (Q) effects at $P = 0.05$ or 0.01.

Table 2. Response of growth characteristics of bush tea to N nutrition during winter.

Applied N (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of flower buds	No. of leaves	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue N (%)	Root tissue N (%)
Control	25	3	23	124	20	12	260	1.4	1.0
100	49	7	29	192	26	18	431	2.4	1.9
200	55	6	25	235	35	20	465	3.1	2.6
300	61	6	20	346	48	23	1107	3.8	3.4
400	73	7	17	310	49	22	575	3.7	3.4
500	70	7	19	317	49	22	550	3.6	3.5
Response	Q**	Q**	NS	Q**	Q**	Q**	Q**	Q**	Q**

NS,*,**Nonsignificant or significant linear (L) or quadratic (Q) effects at $P = 0.05$ or 0.01.

Table 3. Response of growth characteristics of bush tea to N nutrition during spring.

Applied N (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of leaves	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue N (%)	Root tissue N (%)
Control	63	17	841	37	16	425	1.6	1.2
100	109	36	947	69	23	896	3.2	1.8
200	114	40	1115	76	30	927	3.5	2.2
300	118	54	1479	78	37	965	3.8	2.6
400	114	28	1088	76	37	813	3.7	2.7
500	103	18	1076	74	37	553	3.6	2.7
Response	Q**	Q**	Q**	Q**	Q**	Q**	Q**	Q**

NS,*,**Nonsignificant or significant linear (L) or quadratic (Q) effects at $P = 0.05$ or 0.01.

Table 4. Response of growth characteristics of bush tea to N nutrition during summer.

Applied N (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of leaves	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue N (%)	Root tissue N (%)
Control	73	23	844	47	21	658	1.6	1.3
100	122	37	949	79	28	1431	1.9	1.6
200	119	40	1115	86	35	1389	2.5	1.8
300	110	54	1089	88	42	1772	2.6	1.9
400	114	28	1479	86	42	1651	1.6	2.1
500	103	18	1137	84	42	1443	1.6	2
Response	Q**	Q**	Q**	Q**	Q**	Q**	Q**	Q**

NS,*,**Nonsignificant or significant linear (L) or quadratic (Q) effects at $P = 0.05$ or 0.01.

Table 5. Response of growth characteristics of bush tea to P nutrition during fall.

Applied P (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of leaves	No. of flower buds	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue P (%)	Root tissue P (%)
Control	50	22	219	20	27	18	349	0.1	0.1
100	89	40	353	22	34	26	751	0.2	0.2
200	79	45	357	23	45	34	789	0.3	0.3
300	89	46	439	19	51	41	1014	0.5	0.4
400	83	32	345	20	50	41	733	0.4	0.4
500	81	29	318	17	51	38	705	0.3	0.3
Response	Q**	Q**	Q**	NS	Q**	Q**	Q**	Q**	Q**

NS,*,**Nonsignificant or significant linear (L) or quadratic (Q) effects at P = 0.05 or 0.01.

Table 6. Response of growth characteristics of bush tea to P nutrition during winter.

Applied P (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of leaves	No. of flower buds	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue P (%)	Root tissue P (%)
Control	27	5	61	15	11	8	142	0.4	0.4
100	36	11	177	16	14	11	312	0.6	0.6
200	50	10	259	16	19	12	342	0.7	0.7
300	40	15	260	18	26	16	463	0.7	0.8
400	38	13	257	18	25	16	409	0.7	0.7
500	37	13	216	17	25	16	371	0.7	0.7
Response	Q**	Q**	Q**	NS	Q**	Q**	Q**	Q**	Q**

NS,*,**Nonsignificant or significant linear (L) or quadratic (Q) effects at P = 0.05 or 0.01.

Table 7. Response of growth characteristics of bush tea to P nutrition during spring.

Applied P (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of leaves	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue P (%)	Root tissue P (%)
Control	73	7	294	29	17	355	0.2	0.2
100	96	15	311	41	21	521	0.3	0.3
200	97	12	413	44	22	631	0.4	0.4
300	104	20	444	48	25	729	0.6	0.5
400	95	17	355	48	22	577	0.5	0.5
500	82	16	301	47	22	400.0	0.5	0.5
Response	Q**	Q**	Q**	Q**	Q**	Q**	Q**	Q**

NS,*,**Nonsignificant or significant linear (L) or quadratic (Q) effects at P = 0.05 or 0.01.

Table 8. Response of growth characteristics of bush tea to P nutrition during summer.

Applied P (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of leaves	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue P (%)	Root tissue P (%)
Control	85	9	423	44	25	356	0.2	0.2
100	127	14	1186	56	29	548	0.3	0.5
200	143	16	1304	59	30	577	0.4	0.5
300	142	22	1372	63	33	717	0.4	0.6
400	128	19	1362	63	31	717	0.4	0.6
500	154	19	1302	62	30	401	0.4	0.5
Response	Q**	Q**	Q**	Q**	Q**	Q**	Q**	Q**

NS,*,**Nonsignificant or significant linear (L) or quadratic (Q) effects at P = 0.05 or 0.01.

the potassium application reaching the maximum at 800 mg·kg^{-1} K_2O. Percentage leaf and root tissue K was quadratically increased at an optimum level of 200 kg·ha^{-1} K (Tables 9, 10, 11, and 12).

Ruan et al. (1998) reported that K nutrition increased leaf and root tissue K content by 3.5% to 4.1% K in green tea in China. In Kenyan green tea, Wanyoko (1983) reported that the normal harvestable tea leaves had leaf tissue K content of 1.5% to 1.8%. No significant differences in number of flowers buds (fall and winter), number of leaves (fall and summer), stem girth, fresh and dry root mass as well as fresh and dry stem mass were recorded.

In conclusion, the results of this study demonstrated that regardless of season N, P and K nutrition increased bush tea fresh and dry shoot mass, plant height and number of branches. The optimum level of bush tea for improved growth on growth parameters was 300 kg·ha^{-1} for N or P and 200 kg·ha^{-1} for K regardless of season. In all trials, regardless of season, no significant differences in stem girth, fresh stem and root mass and dry and stem mass were obtained.

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Table 9. Response of growth characteristics of bush tea to K nutrition tea during fall.

Applied K (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of flower buds	No. of leaves	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue K (%)	Root tissue K (%)
Control	39	17	17	229	17	13	464	2.3	0.1
100	60	46	17	226	21	17	1138	3.6	0.2
200	61	48	19	229	24	18	1589	4.4	0.3
300	53	38	18	215	24	17	1479	4.7	0.4
400	53	35	20	252	23	17	1550	4.8	0.4
500	49	28	19	218	22	16	1398	4.8	0.3
Response	Q**	Q**	NS	NS	Q**	Q**	Q**	Q**	Q**

^{NS,*,**}Nonsignificant or significant linear (L) or quadratic (Q) effects at $P = 0.05$ or 0.01.

Table 10. Response of growth characteristics of bush tea to K nutrition during winter.

Applied K (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of flower buds	No. of leaves	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue K (%)	Root tissue K (%)
Control	44	7	13	87	12	9	121	2.3	0.4
100	60	15	14	95	15	11	212	2.8	0.6
200	117	17	14	210	16	13	366	3.3	0.7
300	73	16	14	187	17	14	328	3.7	0.7
400	57	14	14	122	18	13	255	3.8	0.7
500	40	13	14	116	17	13	215	3.7	0.7
Response	Q**	Q**	NS	Q**	Q**	Q**	Q**	Q**	Q**

^{NS,*,**}Nonsignificant or significant linear (L) or quadratic (Q) effects at $P = 0.05$ or 0.01.

Table 11. Response of growth characteristics of bush tea to K nutrition during spring.

Applied K (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of leaves	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue K (%)	Root tissue K (%)
Control	70	8	363	27	12	233	1.7	0.2
100	100	18	613	50	24	287	2.3	0.3
200	102	22	712	52	30	348	2.4	0.4
300	99	13	427	50	20	310	2.5	0.5
400	79	13	609	49	19	256	2.3	0.5
500	73	13	651	46	17	233	2.2	0.5
Response	Q**	Q**	Q**	Q**	Q**	Q**	Q**	Q**

^{NS,*,**}Nonsignificant or significant linear (L) or quadratic (Q) effects at $P = 0.05$ or 0.01.

Table 12. Response of growth characteristics of bush tea to K nutrition during summer.

Applied K (kg·ha^{-1})	Plant ht (cm)	No. of branches	No. of leaves	Fresh shoot mass (g)	Dry shoot mass (g)	Leaf area (cm^2)	Leaf tissue K (%)	Root tissue K (%)
Control	77	9	233	41	16	369	0.8	0.2
100	101	19	289	64	29	673	1.6	0.3
200	106	23	294	66	35	712	2.2	0.4
300	104	15	291	64	34	500	1.3	0.4
400	100	12	257	63	24	645	1.2	0.4
500	95	13	256	60	21	651	0.7	0.4
Response	Q**	Q**	NS	Q**	Q**	Q**	Q**	Q**

^{NS,*,**}Nonsignificant or significant linear (L) or quadratic (Q) effects at $P = 0.05$ or 0.01.

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