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Effect of partially replacing potassium by sodium on growth and yield of *Hevea brasiliensis*

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Among the fertilizer elements supplied to *Hevea brasiliensis*, potassium (K) is the one which is applied in large quantity as straight fertilizer. The widely used and cheapest K fertilizer is potassium chloride (KCl), known commercially as muriate of potash (MOP). The question of whether sodium (Na), the closely related ion can replace K is of practical significance, since the source of sodium is common salt which is much cheaper than muriate of potash. When supplied with both K and Na, majority of plants show selectivity for K and the degree of selectivity differs between species (Khanna and Balaguru 1981a and 1981 b). It has been established in crops like tomato (Besford,1978) and barley (Lehr and Wybenga, 1958) that potassium can, to certain extent be replaced by sodium in crop nutrition. Smith (1969) reported that Na could replace K in coconut when the foliar concentration of K was less than 0.5% and that of Na was less than 0.4%. Mathew *et al.* (1984) found that substitution of K_2O by Na_2O to the extent of 50% or even 75% did not reduce the yield of coconut grown in a laterite soil. George *et al.* (2000) reported that substitution of K_2O by Na_2O even to the extent of 75 % did not reduce the dry matter production and uptake of K in young rubber plants under glass house condition. George *et al.* (2006) also reported that substitution of K_2O by Na_2O up to the extent of 50 % did not influence diameter of rubber seedlings, dry matter production and uptake of nutrients under seedling nursery condition. This experiment was aimed to study the effect of substitution of various levels of K with Na on the growth, nutrient uptake and yield of mature rubber under field condition.

A field experiment was conducted in a 10 years old rubber plantation at Malankara estate, Thodupuzha. These plants had been receiving NPK as per the recommendation of Rubber Board until 1998.The experiment constituted of using different levels of K_2O and Na_2O in factorial randomized block design with 10 treatments and 3 replications maintaining 30 plants in each plot. The soil of the experimental site was laterite and the initial physico-chemical properties of the soil is given in Table 1.

Table 1. Initial physico-chemical properties of the soil

Parameters	Depth of soil	
	0-30 cm	30-60 cm
Organic carbon (%)	1.30	1.04
Av. phosphorus (mg/100g)	0.76	0.21
Av. potassium („)	7.78	4.72
Av. sodium („)	5.18	5.63
Av. calcium („)	6.10	5.35
Av. magnesium („)	1.74	1.35
pH	4.84	4.88
EC (d S/m)	0.024	0.020
CEC c mol/kg	8.53	8.85
Texture	Sandy clay	Sandy clay

Treatments were combinations of 3 levels of potassium and 3 levels of sodium and an absolute control with neither K nor Na. Different K levels tried were 100, 75 and 50 per cent of recommended level of K at the rate of 30 kg K_2O per hectare and the sodium levels tried were at the rate of 0, 7.5 and 15 kg Na_2O per hectare. In addition, a uniform dose of N and P at the rate of 30 kg ha^{-1} as per the fertilizer recommendation for mature rubber was applied every year in two split doses as urea and rock phosphate. K was applied as muriate of potash (KCl) and Na was applied as common salt (NaCl). The plants were rainfed and all cultural operations were done as per the recommendations of Rubber Board (Punnoose *et al.*, 2000).

Plant girth was recorded annually and annual girth increment since commencement of the experiment was computed. Yield recording was done monthly from each plot by measuring volume of latex and dry rubber content (DRC) estimation. The mean annual yield per tree per tapping for each plot was worked out for 8 years from 1999 to 2007. The data related to annual dry rubber content, yield, girth and girth increment were statistically analysed. Leaf samples were collected annually and analysed for N,P,K,Ca and Mg content (Karthikakutty-amma, 1989). Soil samples were collected at the commencement of the experiment and during 2001, 2003, 2005 and 2006 and analysed for organic carbon, available phosphorus, potassium, calcium, magnesium, pH EC and CEC by standard procedure (Jackson,1958). All the data were subjected to statistical analysis (Snedecor and Cochran, 1967). Effect of different levels of K and Na on girth and girth increment is given in Table 2.

Table 2. Effect of different levels of K and Na on girth of rubber

	Treatments (kg/ha)		Girth (cm)	Girth increment
	K_2O	Na_2O	2007	(cm) 1999-2007
T1	30.0	0	74.02	15.14
T2	30.0	7.5	72.43	14.55
T3	30.0	15.0	71.14	14.98
T4	22.5	0	74.66	15.87
T5	22.5	7.5	76.44	17.64
T6	22.5	15.0	71.10	13.88
T7	15.0	0	75.10	14.47
T8	15.0	7.5	78.07	16.27
T9	15.0	15.0	72.60	14.57
T10	0	0	68.40	12.46
SE			2.58	1.87
CD (P = 0.05)			NS	NS

The treatments differ only numerically in their influence on the girth and girth increment. Maximum girth increment (17.64 cm) was recorded in plants receiving T_5 (22.5 kg K_2O + 7.5 kg Na_2O) followed by T_8 (15 kg K_2O + 7.5 kg Na_2O). Though there was 42 % increase in girth increment in T_5 as compared to T_{10}, the difference is not statistically significant. Similar observation on girthing of rubber seedlings was reported by George *et al.* (2006). Punnoose and Mathew (1990) also reported that response to K application in girthing of rubber is variable and depends on soil available K status.

The data on dry rubber content as influenced by various combinations of K and Na are presented in Table 3. The data shows that the proportion of K or Na applied to the soil for 8 years does not affect the dry rubber content of latex.

The data on yield of rubber as influenced by various combinations of K and Na are presented in Table 4. The yield was significantly influenced by the treatments only after 6 years. All the treatments recorded higher yield compared to the control plots which received neither K nor Na from 1999 and significant difference was noted during 2005, 2006 and 2007. However, during 2005, the effect was statistically significant only in the case of T_6 (22.5 kg K_2O + 15 kg Na_2O). During 2006, the performance of the plants in treatment receiving full dose of K_2O, 75% K_2O + 25% Na_2O and 50% K_2O + 25% Na_2O being comparable. Maximum yield (69.8 g/tree/tap) was in T_8 (50% K_2O + 25% Na_2O) followed by T_5 and T_1 and the differences between T_8, T_5 and T_1 were not significant while in 2007, the effect of treatments was statistically significant for T_1, T_2, T_3, T_5 and T_8 over control. Maximum yield was in T_8 (50% K_2O+ 25% Na_2O) followed by T_5 and T_1 and the difference between T_8 T_5 and T_1 was not significant. The fact that addition of 25 per cent Na_2O to 50 and 75 per cent K_2O did not reduce the yield is of high practical significance since the cost of NaCl (common salt) is cheaper as compared to KCl (muriate of potash). From this it is believed that sodium may partially substitute the role of K in plants and hence maintains the same level of yield at this rate of substitution. When KCl is substituted by NaCl, only K is substituted without affecting the supply of chlorine to any significant extent. Since in the present experiment, both Na and K are supplied as chlorides it is not possible to partition the effect of Cl from that of K or Na. However, it can be confirmed that the present recommendation of K_2O can be substituted by Na_2O to the extent of 25%. Mathew *et al.* (1984) has reported that replacement of K at the rate of 50% or even 75% by Na_2O for 9 years did not reduce the yield of coconut.

Leaf samples were collected and analysed every

Table 3. Effect of different levels of K and Na on DRC of latex

	Treatments (kg/ha)		Dry rubber content (%)								
	K_2O	Na_2O	1999	2000	2001	2002	2003	2004	2005	2006	2007
T1	30.0	0	40.1	40.1	36.8	36.8	37.3	37.3	37.7	37.0	37.3
T2	30.0	7.5	38.2	40.1	36.7	37.6	37.3	35.1	36.4	37.4	37.6
T3	30.0	15.0	37.4	37.7	36.6	37.3	37.8	36.4	37.0	37.5	37.8
T4	22.5	0	39.4	38.6	35.5	38.1	37.2	36.3	36.3	37.7	37.2
T5	22.5	7.5	40.0	39.7	36.7	37.1	38.1	36.4	38.1	38.0	37.8
T6	22.5	15.0	39.3	39.8	35.7	38.5	37.4	36.1	37.0	38.3	38.4
T7	15.0	0	38.8	39.2	36.1	39.0	36.0	35.5	36.9	36.8	36.0
T8	15.0	7.5	38.8	40.1	35.5	37.2	36.1	36.7	38.0	38.6	37.1
T9	15.0	15.0	39.4	39.7	36.1	37.5	37.9	35.1	36.8	37.3	37.0
T10	0	0	39.4	38.0	34.2	39.0	35.7	34.2	38.2	37.4	35.7
CD (P = 0.05)			NS	NS	NS	NS	NS	NS	NS	NS	NS

Table 4. Effect of different combinations of K and Na on yield of rubber

	Treatments (kg/ha)		Yield (g/tree/tap)								
	K_2O	Na_2O	1999	2000	2001	2002	2003	2004	2005	2006	2007
T1	30.0	0	34.1	43.4	64.3	52.8	68.2	62.3	57.7	68.0	60.0
T2	30.0	7.5	36.0	36.1	55.9	45.8	56.3	57.6	56.7	62.8	55.6
T3	30.0	15.0	27.1	28.2	52.5	45.3	52.6	50.5	58.2	52.2	56.3
T4	22.5	0	32.2	36.8	53.4	48.0	58.8	59.5	48.0	57.3	54.1
T5	22.5	7.5	33.2	35.3	59.5	52.9	66.6	62.5	54.0	68.5	60.8
T6	22.5	15.0	34.8	39.2	57.6	54.5	73.6	62.9	63.4	63.1	55.0
T7	15.0	0	34.6	35.0	52.2	45.5	59.9	57.6	46.2	56.8	51.9
T8	15.0	7.5	30.7	39.6	54.8	54.2	74.8	67.4	55.8	69.8	69.7
T9	15.0	15.0	40.4	37.3	60.2	53.0	57.2	54.7	59.8	57.9	52.3
T10	0	0	30.4	32.4	52.3	48.7	51.8	49.5	44.3	51.3	42.7
CD (P = 0.05)			NS	NS	NS	NS	NS	NS	16.1	14.5	12.3

year from 1999 to 2006 which revealed that the N, P, Ca, Mg and Na content did not vary significantly by the treatments while the uptake of K differed significantly. The data on N, P, Ca and Mg content of leaf collected during 2006 is given in Table 5. The data indicated that substitution of various levels of K by Na did not affect the N, P, Ca and Mg content of leaf. Hence it can be confirmed that the substitution of KCl by NaCl did not affect the uptake of N, P, Ca and Mg from the soil. This is in confirmity with the findings of Prema *et al.* (1987) for coconut and George *et al.* (2006) for rubber seedlings.

Table 5. Effect of different combinations of K and Na on leaf nutrient status

	Treatments (kg/ha)		Leaf nutrient content (%)			
	K_2O	Na_2O	N	P	Ca	Mg
T1	30.0	0	2.96	0.23	0.91	0.27
T2	30.0	7.5	3.10	0.23	0.98	0.26
T3	30.0	15.0	3.17	0.21	0.96	0.22
T4	22.5	0	2.99	0.22	1.06	0.26
T5	22.5	7.5	2.96	0.21	0.86	0.26
T6	22.5	15.0	2.98	0.20	0.88	0.24
T7	15.0	0	3.12	0.22	1.18	0.28
T8	15.0	7.5	3.04	0.22	0.92	0.26
T9	15.0	15.0	3.25	0.23	1.05	0.28
T10	0	0	2.85	0.22	1.00	0.27
SE			0.08	0.01	0.09	0.02
CD (P = 0.05)			NS	NS	NS	NS

The data on leaf K content of mature rubber as influenced by various combinations of K and Na for 8 years is given in Table 6. Significant difference in leaf K status was obtained only during 2002, 2003 and 2006. All the treatments recorded higher K content compared to the control plots which received neither K nor Na. During 2002, treatments T_1, T_3 and T_5 retained significantly higher leaf K status while during 2003, treatments T_1, T_3, T_5 and T_6 retained significantly higher leaf K status over control. This is in conformity with the findings of Prema *et al.* (1987) and George *et al.* (2006). However the data on leaf samples collected during 2006 indicated that the treatments T_1, T_4, T_5 and T_9 retained significantly higher K content as compared to T_{10}. However no significant difference was noted between them. Among K alone treatments, a gradation in leaf K status was obtained with levels of K application. In the case of treatment T_9 (15 kg K_2O +15 kg Na_2O) in the presence of high level of Na, the absorption of K by soil would have been affected marginally.

The chemical properties of soil samples collected during 1999, 2001, 2003, 2005 and 2006 were studied. Among the soil chemical properties affecting nutrient availability, only available K status of the soil was found to differ significantly by the treatments and the data on

Table 6. Effect of different levels of K and Na on leaf K content

	Treatments (kg/ha)		Leaf K status(%)							
	K_2O	Na_2O	1999	2000	2001	2002	2003	2004	2005	2006
T1	30.0	0	1.35	1.29	1.08	1.34	1.45	1.14	1.28	1.55
T2	30.0	7.5	1.66	1.08	1.16	1.11	1.08	0.90	1.29	1.38
T3	30.0	15.0	1.42	1.33	0.82	1.38	1.57	0.91	1.13	1.44
T4	22.5	0	1.32	0.86	1.08	1.15	1.10	1.02	1.17	1.34
T5	22.5	7.5	1.63	0.92	0.95	1.26	1.39	0.96	1.16	1.47
T6	22.5	15.0	1.53	0.99	1.06	1.23	1.45	1.07	1.09	1.33
T7	15.0	0	1.42	1.13	0.98	1.12	1.28	1.01	1.07	1.24
T8	15.0	7.5	1.35	0.93	0.92	1.23	1.24	0.90	1.08	1.22
T9	15.0	15.0	1.25	1.07	0.84	1.04	1.24	0.89	1.20	1.41
T10	0	0	1.42	1.31	0.99	0.96	1.11	0.89	1.17	1.13
CD (P = 0.05)			NS	NS	NS	0.29*	0.27*	NS	NS	0.27*

Table 7. Effect of different levels of K and Na on soil av. K status

	Treatments (kg/ha)		Soil av. K status(mg/100g soil)				
	K_2O	Na_2O	1999	2001	2003	2005	2006
T1	30.0	0	8.38	7.80	8.33	7.52	6.77
T2	30.0	7.5	8.13	9.28	7.50	8.95	5.27
T3	30.0	15.0	7.50	12.17	11.83	7.03	5.63
T4	22.5	0	5.88	5.58	6.42	5.50	5.27
T5	22.5	7.5	7.00	7.17	6.58	5.65	4.37
T6	22.5	15.0	8.25	8.86	9.08	8.06	5.77
T7	15.0	0	7.88	5.15	7.75	5.09	4.37
T8	15.0	7.5	7.38	7.65	8.08	6.26	4.57
T9	15.0	15.0	8.13	7.44	7.67	5.72	4.37
T10	0	0	7.50	4.72	5.08	4.34	3.00
G.Mean			7.60	7.78	7.83	6.45	4.74
SE			0.36	0.92	1.29	0.66	0.46
CD (P=0.05)			NS	2.73	3.84	1.98	1.37

Table 8. Change in Na status in soil and leaf as influenced by different levels of K and Na

	Treatments(kg/ha)		Av.Na status (mg/100g soil)		Na status(%) in leaf	
	K_2O	Na_2O	1999	2006	1999	2006
T1	30.0	0	5.67	5.07	0.011	0.009
T2	30.0	7.5	4.63	5.97	0.010	0.011
T3	30.0	15.0	5.58	6.13	0.010	0.011
T4	22.5	0	5.38	4.43	0.010	0.010
T5	22.5	7.5	5.79	6.17	0.012	0.011
T6	22.5	15.0	5.29	6.10	0.013	0.009
T7	15.0	0	4.79	4.90	0.012	0.011
T8	15.0	7.5	5.38	5.23	0.010	0.008
T9	15.0	15.0	4.42	6.23	0.011	0.010
T10	0	0	4.70	4.90	0.012	0.009
CD (P=0.05)			NS	NS	NS	NS

change in available K status as influenced by various combinations of K and Na is given in Table 7. Significant difference in av. K status was obtained during 2001, 2003, 2005 and 2006. All the treatments retained higher amount of K in soil than absolute control (no K, no Na). Among K alone treatments, a numerical gradation in av. K status was noted throughout the period. During 2001, 2003 and 2005, for 30 and 22.5 kg level of K application, addition of 15 kg Na improved av. K status. In 2006 all the treatments gave significantly higher av. K status over control and T_1 (30 kg K_2O) maintained higher K availability than all other treatments. This is in conformity with the findings of George *et al.* (2006).

The data on change in sodium status in soil and leaf as influenced by the application of different combinations of K and Na are given in Table 8. The available Na status in soil ranged from 4.43 to 6.23 mg/ 100 g of soil and the application of Na to soil at various rates produced no increase in the level of available Na in soil. The foliar concentration of Na was comparatively lower than K and the leaf Na values ranged from 0.008 to 0.011 per cent and was not affected by Na application in different rates which may be due to lower mobility of Na than K in plants (Balaguru and Khanna, 1982). No gradation in leaf Na content was noted with levels of Na applied. Similar observation was reported by Prema *et al.* (1987) and George *et al.* (2006).

The other chemical properties of soil samples collected during 2006 are given in Table 9. The data

Table 9. Effect of different levels of K and Na on chemical properties

	Treatments (kg/ha)		Soil nutrient status (mg/100g soil)			
	K_2O	Na_2O	%C	Av. P	Av. Ca	Av. Mg
T1	30.0	0	1.46	0.96	4.98	1.26
T2	30.0	7.5	1.16	0.47	5.69	1.21
T3	30.0	15.0	1.24	0.37	5.03	1.27
T4	22.5	0	1.42	0.91	4.68	1.38
T5	22.5	7.5	1.34	0.35	4.66	1.21
T6.	22.5	15.0	1.25	0.80	5.88	1.64
T7	15.0	0	1.19	0.93	6.86	1.59
T8	15.0	7.5	1.37	0.33	2.79	0.90
T9	15.0	15.0	1.28	0.32	4.17	1.20
T10	0	0	1.32	0.54	6.83	1.70
SE			0.09	0.25	1.27	0.28
CD (P=0.05)			NS	NS	NS	NS

Table 10. Effect of different combinations of K and Na on soil properties

	Treatments(kg/ha)		pH		EC (dS/m)		CEC (cmol(+)kg-1)	
	K_2O	Na_2O	1999	2007	1999	2007	1999	2007
T1	30.0	0	4.8	4.5	0.02	0.02	8.5	8.9
T2	30.0	7.5	5.0	4.5	0.02	0.03	7.8	9.0
T3	30.0	15.0	4.8	4.5	0.03	0.03	8.9	8.5
T4	22.5	0	4.8	4.4	0.03	0.02	8.0	8.2
T5	22.5	7.5	4.8	4.6	0.03	0.03	8.9	10.0
T6	22.5	15.0	5.1	4.5	0.03	0.02	7.8	9.1
T7	15.0	0	4.7	4.6	0.02	0.02	8.2	8.3
T8	15.0	7.5	4.9	4.5	0.03	0.03	9.4	10.2
T9	15.0	15.0	4.8	4.5	0.03	0.03	9.0	9.3
T10	0	0	4.9	4.6	0.02	0.02	8.8	9.2
CD (P = 0.05)			NS	NS	NS	NS	NS	NS

indicated that substitution of various levels of K by Na did not affect the organic carbon content, av. P, av. Ca or Mg of the soil. Similar observation was reported by George *et al.* (2006) in rubber seedling nursery. Hence it can be concluded that the amount of NaCl applied as common salt did not affect availability of other nutrients from the soil.

Data on pH, EC and CEC of soil by the continued application of Na for 8 years is given in Table 10. The pH, EC and CEC of the soil also were not affected by the treatments suggesting that in highly acidic laterite soils receiving good rainfall, application of NaCl as common salt to mature rubber at the rate of 15 kg Na_2O/ha/year for a period of 8 years does not hamper the pH , EC and CEC of the soil. Similar observation on pH and EC were reported by Mathew *et al.* (1984) and George *et al.* (2006).

The study revealed no significant difference in yield of rubber by substitution of KCl by NaCl up to 25 per cent. However, treatments receiving 100 % recommended dose of K_2O, 75 % K_2O + 25% Na_2O and 50% K_2O + 25% Na_2O appeared superior to other treatments in getting higher yield. There was no significant difference between treatments in girthing and the nutrient uptake by the plants except K. Plants receiving higher amount of K, retained higher amount of this element and numerical gradation in leaf K was noted with levels of application. The available K content in the soil increased with increased application of K to the soil while the availability of other nutrients remained the same. Also application of NaCl as common salt at this rate for 8 years to the laterite rubber growing soils receiving fairly good rainfall did not alter the pH and EC of the soil.

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