African Crop Science Journal, Vol. 11. No. 4, pp. 259-268, 2003
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ISSN 1021-9730/2003 $ 4.00

ROLE OF POTASSIUM AND NITROGEN ON SUGAR CONCENTRATION OF SUGAR BEET

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(Received 10 September, 2002; accepted 4 August, 2003)

ABSTRACT

Sugar is obtained from root of sugar beet (*Beta vulgaris* L.) in addition to other sources. Three important economic parameters are often considered and these are root yield, sugar concentration in root juice and total sugar yield. All the three are affected by cropping period and use of fertilisers. Existing literature suggests the use of nitrogen and potash as fertilisers. An experiment over a period of three years with different combinations of N and K fertilisers for different cropping periods was carried out with multiple replicates. The highest root yield was obtained at a combination of N= 150 kg ha $^{-1}$, K = 155 kg ha $^{-1}$ and cropping period at160 days. The maximum sugar concentration was obtained at N = 120 kg ha $^{-1}$, K = 155 kg ha $^{-1}$ and cropping period at 130 days. The highest sugar yield was from N = 150 kg ha $^{-1}$, K = 155 kg ha $^{-1}$ and cropping period at 160 days. All factors and their interactions were statistically significant for all parameters assessed.

Key Words: *Beta vulgaris* L., root yield, sugar yield, regression

RÉSUMÉ

Le sucre est extrait des racines de la betterave (*Beta vulgaris* L.) en plus d'autres sources. Trois paramètres économiques importants sont souvent considérés notamment le rendement en racines, la concentration en sucre et le rendement en sucre. Tous les trois sont affectés par la période culturale et l'utilisation des engrais. La littérature existante suggère l'utilisation de l'azote et du potassium comme engrais. Une expérience de trois ans avec différentes combinaisons d'engrais en N et K pour différentes périodes culturales était conduite avec plusieurs répétitions. Le rendement le plus élevé était obtenu avec la combinaison N=150 kg/ha, K=155 kg/ha et une période de culture de 160 jours. La concentration maximale était obtenue pour N=120 kg/ha, K =155 kg/ha et une période de culture de 130 jours. Le rendement en sucre le plus élevé correspondait au traitement N=150 kg/ha, K=155 kg/ha et une période culturale de 160 jours. Tous les facteurs et leurs interactions étaient statistiquement significatifs pour les trois paramètres considérés.

Mots Clés: *Beta vulgaris* L., rendement en racines, rendement, régression

INTRODUCTION

Sugar is obtained from canes (*Sacharis* sp.) and roots of sugar beet (*Beta vulgaris* L.). In the case of sugar beet, the three important economic parameters are root yield, sugar concentration in root juice and total sugar yield. Sugar beet root juice contains on an average 16 to 25% of sugar concentration (Singh *et al.*, 1985). Many scientists have carried out experiments on how to increase these yields (Lee and Comerford, 1970; Milford and Watson, 1971). Important factors which emerge from these experiments are (1) nitrogen (N) fertiliser, (2) potassium (K) or sodium (Na) fertiliser, (3) plant population density, and (4) cropping period, Jackson and Ulrich (1971), Christenson and Butt (2000), Herlihy (1992) and Clinton *et al.* (2000) demonstrated that (a) inadequate N limits plant growth, (b) root yield increases with N rate and, (c) excess N may reduce both sugar concentration and recoverable sucrose. Wooley and Bennett (1962), Holmes and Adams (1966), and Hull and Webb (1970) demonstrated better yield from longer growing season. Divies *et al.* (1972) concluded that Na fertiliser increases sugar beet yield more than K fertiliser and at less cost. Many farmers in European countries assume Na damages soil structure, increases soil moisture and makes it difficult to cultivate. Draycott *et al.* (1976) showed Na increases soil moisture but does not damage soil structure. Burcky and Winner (1986), and Yonts and Smith (1997) found that increasing plant population resulted in higher root yield and/or higher sucrose content. Boyd *et al.* (1970) showed that 125 kg ha^{-1} of N was enough for sugar beet grown on nearly all mineral soils. They did not consider if the amount needed was related to the length of the growing period. Draycott (1971), found more root yield with higher nitrogen. They also found decrease in sugar concentration at later growth stages. Durrant *et al.* (1974), Draycott and Durrant (1976) and Barik (2001) checked this lower sugar yield with potassium fertiliser. Herlihy (1989) observed a positive influence of K on photosynthesis, assimilate translocation and sink capacity of storage root, leading to increase in sugar content and yield.

This study aimed at investigating the effect of fertiliser N and K at different cropping periods on root yield, sugar concentration and total sugar yield.

MATERIALS AND METHODS

A field experiment was conducted in Agricultural Experimental Fields of Plant Chemistry Unit, Indian Statistical Institute, Calcutta, India during 1996-1999. The land was prepared and divided into plots of 4 m x 3 m each. Soil before sowing was medium to low in organic carbon (<0.5-0.75%), medium to low in available potassium (<100-280 kg ha^{-1}) and high in available phosphorus (>25 kg ha^{-1}), with slightly acidic reaction (5.5-6.0 pH). The methods described by Jackson (1972) were used.

A 6 x 3 factorial experiment involving six nitrogen and three potassium doses were applied in a randomised complete block design (RCBD) with three replicates each year. Nitrogen, in form of urea ($CO(NH_2)_2$), was applied at 0, 30, 60, 90, 120 and 150 kg ha^{-1} . Potassium, in form of muriate of potash (K_2O), was applied at 75, 115 and 155 kg ha^{-1} . Phosphorus, in form of single super phosphate (P_2O_5), was fixed at 60 kg ha^{-1}. The treatment combinations are denoted as $N_0K_{75,}$ $N_0K_{115,}$ $N_{30}K_{75,}$ $N_{150}K_{155}$ etc.

At the time of land preparation, one half of the N along with all K and P were applied. The remaining N was applied at 35 days after sowing when first irrigation and thinning operation were done. The dates of sowing are November 22nd 1996, November 15th 1997 and December 5th 1998. Standard methods were applied for pest management, irrigation, thinning. Plant population was kept at 100,000 plants per hectare, as suggested by Robinson and Worker (1969).

Data were collected on 70, 100, 130 and 160 days after sowing. For root yield, 10 plants were uprooted from each plot randomly. Then roots were separated, weighed and converted into tonnes per hectare. The samples were analysed for sucrose by the method outlined by the A.O.A.C. (1955). Sugar yield was calculated from root yield and sucrose concentration.

Statistical analyses were done using BMDP 7.1 (2001) software and is carried out on SUN SPARKSTATION 10 at Computer and Statistical Service Centre (CSSC) of Indian Statistical Institute. Treatment means were separated using Modules 4V, 5R and 1R were used for ANOVA and Regression analysis.

RESULTS AND DISCUSSION

Tables (1a) through (1d) provide data of the three parameters at different combinations of the factors. Additional means of parameters, pooled (P) over the years,are also presented.

The highest root yield of 55.1 t ha^{-1} was obtained at N = 150 kg ha^{-1}, at 160 days of the crop. In the 1996-97 experiment, the highest root yield of

TABLE 1. Root yield (t ha^{-1}), sugar concentration (%) and sugar yield (t ha^{-1}) and for different cropping periods under N and K interactions

N	Year	K75			K115			K155			Marginal		
		root	(%)	Sugar	root	(%)	Sugar	root	(%)	Sugar	root	(%)	Sugar
a) Cropping period of 70 days													
N0	1996	5.18	6.50	0.33	6.52	6.67	0.44	5.78	7.25	0.42	5.83	6.81	0.40
	97	4.30	6.50	0.28	5.44	7.33	0.35	5.28	7.33	0.39	5.01	7.05	0.34
	98	4.70	7.00	0.33	5.03	7.50	0.38	4.73	6.50	0.31	4.82	7.00	0.34
	P	4.73	6.67	0.31	5.66	7.17	0.39	5.26	7.03	0.37	5.22	6.95	0.36
N30	96	9.90	8.37	0.83	10.19	9.25	0.94	9.73	9.42	0.92	9.94	9.01	0.90
	97	9.00	8.42	0.76	9.05	9.33	0.85	9.31	9.42	0.87	9.12	9.06	0.83
	98	8.09	9.17	0.74	8.77	9.00	0.79	9.34	10.33	0.96	8.73	9.50	0.83
	P	9.00	8.65	0.78	9.34	9.19	0.86	9.46	9.72	0.92	9.26	9.19	0.85
N60	96	11.12	10.33	1.15	10.86	11.37	1.23	10.58	10.37	1.10	10.85	10.69	1.16
	97	11.95	10.42	1.24	12.25	11.42	1.40	11.83	10.42	1.23	12.01	10.75	1.29
	98	10.71	10.50	1.13	10.70	11.00	1.17	11.27	12.00	1.35	10.89	11.17	1.22
	P	11.26	10.42	1.17	11.27	11.26	1.27	11.23	10.93	1.23	11.25	10.87	1.22
N90	96	11.82	10.33	1.22	13.04	11.32	1.48	13.48	12.37	1.67	12.78	11.34	1.46
	97	13.54	11.08	1.50	13.05	11.92	1.55	13.77	12.42	1.71	13.45	11.81	1.59
	98	12.01	11.17	1.34	12.47	12.00	1.49	12.49	13.67	1.70	12.32	12.28	1.51
	P	12.46	10.86	1.35	12.85	11.75	1.51	13.25	12.82	1.69	12.85	11.81	1.52
N120	96	14.65	13.37	1.96	16.19	13.30	2.15	15.76	14.33	2.26	15.53	13.67	2.12
	97	14.84	13.42	1.99	16.19	13.50	2.19	15.54	14.12	2.20	15.52	13.68	2.13
	98	12.73	14.67	1.87	14.84	15.17	2.26	15.23	19.83	2.56	14.27	16.56	2.23
	P	14.07	13.82	1.94	15.74	13.99	2.20	15.51	16.09	2.34	15.11	14.63	2.16
N150	96	17.94	16.42	2.95	17.65	15.67	2.76	17.74	17.08	3.03	17.78	16.39	2.91
	97	18.35	16.42	3.01	18.74	16.08	3.01	19.54	17.08	3.34	18.88	16.53	3.12
	98	17.08	17.00	2.90	16.89	16.50	2.79	18.01	17.83	3.21	17.33	17.11	2.97
	P	17.79	16.61	2.95	17.76	16.08	2.85	18.43	17.33	3.19	17.99	16.68	3.00
b) Cropping period of 100 days													
N0	1996	8.51	8.30	0.71	8.73	8.42	0.74	9.41	8.33	0.78	8.88	8.35	0.74
	97	6.35	8.33	0.53	6.77	8.50	0.58	7.31	8.42	0.62	6.81	8.42	0.58
	98	7.63	7.33	0.56	7.33	7.67	0.56	7.76	7.33	0.57	7.57	7.44	0.56
	P	7.50	7.99	0.60	7.61	8.20	0.63	8.16	8.03	0.66	7.76	8.07	0.63
N30	96	14.09	9.83	1.39	18.58	9.72	1.81	18.68	10.4	1.95	17.12	9.99	1.72
	97	12.13	9.33	1.13	14.58	9.33	1.36	14.69	10.4	1.53	13.80	9.69	1.34
	98	15.03	9.67	1.45	16.51	10.17	1.68	17.15	11.00	1.88	16.23	10.28	1.67
	P	13.75	9.61	1.32	16.56	9.74	1.62	16.84	10.61	1.79	15.72	9.99	1.58
N60	96	21.70	11.37	2.47	21.58	11.30	2.44	22.52	12.18	2.74	21.93	11.62	2.55
	97	20.36	11.50	2.34	21.42	11.67	2.50	24.10	12.08	2.91	21.96	11.75	2.58
	98	20.99	11.50	2.41	21.15	12.00	2.53	20.93	13.67	2.86	21.02	12.39	2.60
	P	21.02	11.46	2.41	21.38	11.66	2.49	22.52	12.64	2.84	21.64	11.92	2.58
N90	96	25.48	12.30	3.13	28.78	14.17	4.08	26.86	14.08	3.78	27.04	13.52	3.66
	97	25.19	12.50	3.15	26.34	14.25	3.76	26.63	14.25	3.79	26.05	13.67	3.57
	98	26.37	13.00	3.42	27.92	13.00	3.63	28.05	15.00	4.21	27.45	13.67	3.75
	P	25.68	12.60	3.23	27.68	13.81	3.82	27.18	14.44	3.93	26.85	13.62	3.66
N120	96	29.76	15.17	4.51	31.45	16.17	5.08	32.17	16.42	5.28	31.13	15.92	4.96
	97	27.32	15.25	4.17	29.38	16.08	4.72	29.56	16.42	4.85	28.75	15.92	4.58
	98	30.52	16.00	4.88	29.59	16.17	4.78	30.37	17.83	5.41	30.16	16.67	5.02
	P	29.20	15.47	4.52	30.14	16.14	4.86	30.70	16.89	5.18	30.01	16.17	4.85
N150	96	30.65	18.25	5.60	32.39	18.42	5.97	33.39	19.33	6.45	32.14	18.67	6.01
	97	30.41	18.33	5.58	29.69	18.33	5.44	30.97	19.25	5.96	30.36	18.64	5.66
	98	33.85	17.83	6.03	34.59	19.00	6.57	33.51	19.33	6.48	33.98	18.72	6.36
	P	31.64	18.14	5.74	32.22	18.58	5.99	32.62	19.30	6.30	32.16	18.67	6.01

c) Cropping period of 130 days

N	Year	K75			K115			K155			Marginal		
		root	(%)	Sugar	root	(%)	Sugar	root	(%)	Sugar	root	(%)	Sugar
N0	1996	11.64	9.38	1.09	10.96	10.42	1.14	12.56	10.22	1.28	11.72	10.01	1.17
	97	9.58	9.42	0.90	10.33	10.33	1.07	9.49	10.42	0.99	9.80	10.06	0.99
	98	10.21	10.00	1.02	10.52	10.00	1.05	10.99	10.67	1.17	10.57	10.22	1.08
	P	10.48	9.60	1.00	10.60	10.25	1.09	11.01	10.44	1.15	10.70	10.10	1.08
N30	96	16.34	11.30	1.85	22.19	11.42	2.53	21.48	12.05	2.59	20.00	11.59	2.32
	97	17.45	11.42	1.99	18.36	11.33	2.08	18.66	12.00	2.24	18.16	11.58	2.10
	98	17.40	12.17	2.12	18.60	13.00	2.42	19.41	14.17	2.75	18.47	13.11	2.43
	P	17.06	11.63	1.99	19.72	11.92	2.34	19.85	12.74	2.53	18.88	12.10	2.29
N60	96	25.36	13.25	3.36	25.90	13.25	3.43	24.91	14.08	3.51	25.39	13.53	3.43
	97	25.48	13.25	3.38	25.14	13.25	3.33	27.22	14.25	3.88	25.95	13.58	3.53
	98	24.98	15.00	3.74	25.37	16.33	4.14	28.49	16.33	4.66	26.28	15.89	4.18
	P	25.27	13.83	3.49	25.47	14.28	3.63	26.87	14.89	4.02	25.87	14.33	3.71
N90	96	32.81	15.00	4.92	34.46	16.18	5.58	34.02	16.25	5.53	33.76	15.81	5.34
	97	31.83	15.08	4.80	31.67	16.17	5.12	32.59	16.25	5.29	32.03	15.83	5.07
	98	29.97	19.00	6.09	31.50	19.67	6.19	35.30	20.00	7.06	32.26	19.56	6.45
	P	31.54	16.36	5.27	32.54	17.34	5.63	33.97	17.50	5.96	32.68	17.07	5.62
N120	96	36.69	17.08	6.27	41.29	18.17	7.50	42.75	18.30	7.82	40.24	17.85	7.20
	97	40.48	17.25	6.99	39.76	18.33	7.29	41.15	18.08	7.44	40.46	17.89	7.24
	98	41.47	19.67	8.15	40.75	20.33	8.29	41.54	21.00	8.73	41.25	20.33	8.39
	P	39.55	18.00	7.14	40.60	18.94	7.69	41.81	19.13	8.00	40.65	18.69	7.61
N150	96	41.95	19.32	8.11	45.21	19.25	8.70	45.93	20.25	9.3	44.36	19.61	8.70
	97	45.11	19.25	8.68	46.52	19.25	8.96	47.30	20.00	9.46	46.31	19.50	9.03
	98	50.72	20.67	10.48	51.38	20.33	10.45	52.36	20.83	10.9	51.49	20.61	10.61
	P	45.93	19.75	9.09	47.70	19.61	9.37	48.53	20.36	9.89	47.39	19.91	9.45

d) Cropping period of 160 days

N0	1996	14.01	11.10	1.55	12.44	11.93	1.49	14.52	11.13	1.61	13.66	11.39	1.55
	97	14.54	11.08	1.61	14.52	11.25	1.64	16.41	11.17	1.83	15.16	11.17	1.69
	98	12.53	11.50	1.44	13.19	11.50	1.52	14.12	11.00	1.55	13.28	11.33	1.50
	P	13.69	11.23	1.53	13.38	11.56	1.55	15.02	11.10	1.66	14.03	11.30	1.58
N30	96	23.21	11.50	2.67	26.22	11.67	3.06	25.63	12.83	2.95	25.02	12.00	2.89
	97	22.51	11.50	2.59	25.63	12.08	3.10	28.34	12.92	3.66	25.49	12.17	3.12
	98	23.55	12.67	2.98	21.44	14.00	3.00	20.74	15.33	3.18	21.91	14.00	3.05
	P	23.09	11.89	2.75	24.43	12.58	3.05	24.90	13.69	3.26	24.14	12.72	3.02
N60	96	32.17	13.18	4.24	32.43	13.17	4.27	33.21	14.17	4.71	32.60	13.51	4.41
	97	31.23	13.42	4.19	30.83	13.25	4.09	32.42	14.25	4.62	31.49	13.64	4.30
	98	31.37	15.17	4.76	29.93	16.50	4.94	31.77	16.83	5.35	31.02	16.17	5.02
	P	31.59	13.92	4.40	31.06	14.31	4.43	32.47	15.08	4.89	31.71	14.44	4.57
N90	96	36.50	16.15	5.89	39.69	17.50	6.95	40.08	17.10	6.85	38.76	16.92	6.56
	97	36.37	16.50	6.00	41.59	17.50	7.28	41.69	17.42	7.26	39.88	17.14	6.85
	98	35.75	19.33	6.91	38.31	19.67	7.53	37.78	19.83	7.49	37.28	19.61	7.31
	P	36.21	17.33	6.27	39.86	18.22	7.25	39.85	18.12	7.20	38.64	17.89	6.91
N120	96	41.86	18.97	7.94	48.34	19.22	9.29	52.02	20.30	10.56	47.41	19.50	9.26
	97	47.95	18.17	8.71	50.41	19.33	9.74	49.78	20.33	10.12	49.38	19.28	9.52
	98	46.54	19.83	9.23	44.39	20.67	9.17	44.46	20.83	9.26	45.13	20.44	9.22
	P	45.45	18.99	8.63	47.71	19.74	9.40	48.75	20.49	9.98	47.31	19.74	9.34
N150	96	55.57	20.25	11.25	58.23	21.25	12.37	59.75	21.50	12.9	57.85	21.00	12.16
	97	50.65	20.33	10.30	51.57	20.42	10.53	52.48	21.50	11.3	51.57	20.75	10.70
	98	55.44	20.33	11.27	55.44	20.67	11.45	56.70	20.83	11.8	55.86	20.61	11.51
	P	53.89	20.30	10.94	55.08	20.78	11.45	56.31	21.28	11.98	55.09	20.79	11.46

No - N150 = kg N ha^{-1}; K75 - K155 = kg K ha^{-1}

59.75 t ha^{-1} was obtained from the combinations N150 and K155 kg ha^{-1} at 160 days of the crop; the second highest yield of 58.23 t ha^{-1} was given by the N150 and K115 kg ha^{-1} treatment at the same growth stage. In 1997-98, the maximum root yield was 52.48 t ha^{-1}, while 1998 - 99, the maximum yield was 56.70 t ha^{-1} given by the N150 and K155 kg ha^{-1} combination at 160 days crop growth stage. There were significant differences between the treatments mean of root yield in each harvesting stage for nitrogen.

In terms of potassium, root yield shows the highest yield of 36.21 t ha^{-1} (Table 2d) was obtained from K155 kg ha^{-1} treatment at 160 days of the crop. This was closely followed (35.26 t ha^{-1}) by K115 kg ha^{-1} at the same growth stage. Table 3(a) to 3(d) shows sugar concentration for nitrogen in different years and stages. The maximum mean sugar concentration was 20.79 % given by N150 kg ha^{-1} at 160 days of the crop. However, the highest sugar concentration (21.5 %) was observed in both 1996-97 and 19997-98 with, N150 and K 155 kg ha^{-1} combination at 160 days of the crop. Yearwise sugar concentrations showed significant ($P<0.05$) differences between the different levels of nitrogen.

Tables 2(a), to 2(c) show that all factors, namely, year, cropping period, nitrogen, potassium and their interactions were significant ($P<0.05$) for the three parameters, root yield (t ha^{-1}), sugar concentration (%) and sugar yield (t ha^{-1}). This leads to the following conclusions: (1) environmental factors affect yield. This is indicated through the importance of year and its interactions with the other three factors. (2) N, K and cropping period are important contributors, and this is indicated through their main effects. This corroborates with earlier findings (Barik, 2001). (3) The significance of two and three level interactions of N, K and cropping period indicate that their effects are not additive. This can be interpreted in multiple ways, e.g. same linear relationship between root yield and cropping period will not hold for different amounts of nitrogen or potassium or their combinations. If one tries to form a response curve for any parameter based on the three attributes, it will not be a hyper-plane.

Tables 3(a) - 3(c) show a linear relationship between the parameters and cropping period for different nitrogen and potassium combinations. The fitted lines estimated the observation quite accurately; the minimal R^2 values being 0.869, 0.533 and 0.920. Detailed studies of these tables lead us to conclude that the pattern of effects on sugar concentration is different from the other two. Furthermore, the following patterns are apparent in the absence of nitrogen, as potassium dosage is increase, *root yield and sugar yield per cropping period* decreases for some range and then start increasing, while *sugar concentration per cropping period* decreases. For sugar concentration, the pattern is similar up to $N = 120$ kg ha^{-1}, then it decreases. These patterns are presented in Figures 1 - 3. The absolute value of ratio of intercept and days gives us the minimum cropping period. If we take the minimum of these absolute values over the three parameters, we obtain an estimate of when not to harvest for a specific fertiliser combination. For example at $N = 150$ and $K = 155$ kg ha^{-1}, harvesting should not be done before 25 days.

CONCLUSION

It would benefit the farmers best if we can find the optimum mix of fertilisers, conditional or unconditional. The next best option would be to tell them when to harvest for a given combination of fertilisers. Unfortunately, neither our experiment nor existing literature, tells us these. Our experiments indicate that fertilisers interact amongst themselves and some optimum mix is likely to exist. We have also determined, to some extent, when not to harvest. We have also determined that other factors, besides fertilisers and cropping period, play statistically important roles. Further insight studies and experimentation is required to reach the desired goal.

ACKNOWLEDGEMENTS

This project was funded by project No. 9833, of the Plant Chemistry Unit, Indian Statistical Institute. Prof (Mrs). S. Chanda, Head of Plant Chemistry Unit, provided suggestion and advice.

TABLE 2. ANOVA for different parameters

Sources	Sum of squares	DF	Mean squares	F	Level of significance
a) ANOVA for root yield (t ha^{-1})					
Y: Year	42.85494	2	21.42747	40.74	0.0000
N	60621.40654	5	12124.28131	23052.74	0.0000
K	276.87012	2	138.43506	263.22	0.0000
D: Days	48510.18528	3	16170.06176	30745.26	0.0000
YN	214.44847	10	21.44485	40.77	0.0000
YK	57.40379	4	14.35095	27.29	0.0000
YD	228.11355	6	38.01893	72.29	0.0000
NK	57.52179	10	5.75218	10.94	0.0000
ND	9732.72008	15	648.84801	1233.70	0.0000
KD	40.52604	6	6.75434	12.84	0.0000
YNK	94.33200	20	4.71660	8.97	0.0000
YND	429.44644	30	14.31488	27.22	0.0000
YKD	69.57697	12	5.79808	11.02	0.0000
NKD	76.66817	30	2.55561	4.86	0.0000
YNKD	164.09881	60	2.73498	5.20	0.0000
ERROR	227.20465	432	0.52594		
b) ANOVA for sugar concentration (%)					
Y: Year	150.99992	2	75.49996	767.53	0.0000
N	7658.78602	5	1531.75720	15571.69	0.0000
K	113.08207	2	56.54103	574.79	0.0000
D: Days	2091.75454	3	697.25151	7088.19	0.0000
YN	70.16504	10	7.01650	71.33	0.0000
YK	2.47594	4	0.61899	6.29	0.0000
YD	59.67120	6	9.94520	101.10	0.0000
NK	24.26969	10	2.42697	24.67	0.0000
ND	116.13599	15	7.74240	78.71	0.0000
KD	1.06627	6	0.17771	1.81	0.0000
YNK	11.74147	20	0.58707	5.97	0.0000
YND	47.62941	30	1.58765	16.14	0.0000
YKD	3.89341	12	0.32445	3.30	0.0000
NKD	20.10031	30	0.67001	6.81	0.0000
YNKD	20.08696	60	0.33478	3.40	0.0000
ERROR	42.49500	432	0.09837		
c) ANOVA for sugar yield (t ha^{-1})					
Y: Year	13.40808	2	6.70404	333.48	0.0000
N	3348.27368	5	669.65474	33310.52	0.0000
K	27.64260	2	13.82130	687.51	0.0000
D: Days	1991.42750	3	663.80917	33019.75	0.0000
YN	8.41943	10	0.84194	41.88	0.0000
YK	1.41134	4	0.35283	17.55	0.0000
YD	16.24872	6	2.70812	134.71	0.0000
NK	7.53667	10	0.75367	37.49	0.0000
ND	658.04600	15	43.86973	2182.20	0.0000
KD	4.30601	6	0.71767	35.70	0.0000
YNK	3.97385	20	0.19869	9.88	0.0000
YND	22.59745	30	0.75325	37.47	0.0000
YKD	2.47264	12	0.20605	10.25	0.0000
NKD	3.00915	30	0.10031	4.99	0.0000
YNKD	5.95206	60	0.09920	4.93	0.0000
ERROR	8.68467	432	0.02010		

N = nitrogen, K = potassium

TABLE 3a. Linear regression of root yield (t ha^{-1}) on cropping period at different (N and K) combinations

Nitrogen (kg ha^{-1})		Potassium (kg ha^{-1})		
		75	115	155
a) Linear regression of root yield (t ha^{-1})				
0	Intercept	-2.337	-0.710	-2.444
	Slope	0.099	0.087	0.107
	R^2	0.9325	0.9091	0.9171
30	Intercept	-1.752	-1.058	-1.155
	Slope	0.152	0.161	0.164
	R^2	0.9546	0.8866	0.8685
60	Intercept	-2.723	-2.035	-2.829
	Slope	0.217	0.212	0.227
	R^2	0.9643	0.9434	0.9298
90	Intercept	-3.179	-4.693	-4.636
	Slope	0.259	0.286	0.289
	R^2	0.9247	0.9318	0.9384
120	Intercept	-7.893	-7.231	-8.293
	Slope	0.348	0.355	0.369
	R^2	0.9376	0.9612	0.9527
150	Intercept	-9.676	-10.659	-10.688
	Slope	0.409	0.425	0.432
	R^2	0.9569	0.9555	0.9598
b) Linear regression of sugar concentration (%)				
0	Intercept	3.008	3.451	3.542
	Slope	0.051	0.051	0.049
	R^2	0.953	0.935	0.897
30	Intercept	5.947	6.126	6.308
	Slope	0.039	0.041	0.047
	R^2	0.832	0.745	0.754
60	Intercept	7.464	8.369	7.747
	Slope	0.043	0.039	0.049
	R^2	0.767	0.533	0.694
90	Intercept	5.409	6.474	8.453
	Slope	0.077	0.077	0.063
	R^2	0.788	0.818	0.741
120	Intercept	9.652	9.515	10.861
	Slope	0.060	0.067	0.061
	R^2	0.844	0.865	0.803
150	Intercept	13.836	12.971	14.629
	Slope	0.042	0.050	0.043
	R^2	0.878	0.875	0.898
c) Linear regression of sugar yield (t ha^{-1})				
0	Intercept	-0.69711	-0.59952	-0.71404
	Slope	0.01357	0.01314	0.01456
	R^2	0.956	0.941	0.941
30	Intercept	-0.81270	-0.83311	-0.85859
	Slope	0.02191	0.02436	0.0259
	R^2	0.956	0.956	0.920
60	Intercept	-1.25844	-1.11985	-1.42055
	Slope	0.03590	0.03540	0.04060
	R^2	0.974	0.937	0.933
90	Intercept	-2.40011	-2.74759	-2.41841
	Slope	0.05590	0.06350	0.06190
	R^2	0.940	0.975	0.943
120	Intercept	-3.13845	-3.32496	-3.49159
	Slope	0.07560	0.08140	0.08580
	R^2	0.949	0.979	0.971
150	Intercept	-3.29126	-3.76404	-3.64252
	Slope	0.09110	0.09720	0.09980
	R^2	0.954	0.958	0.966

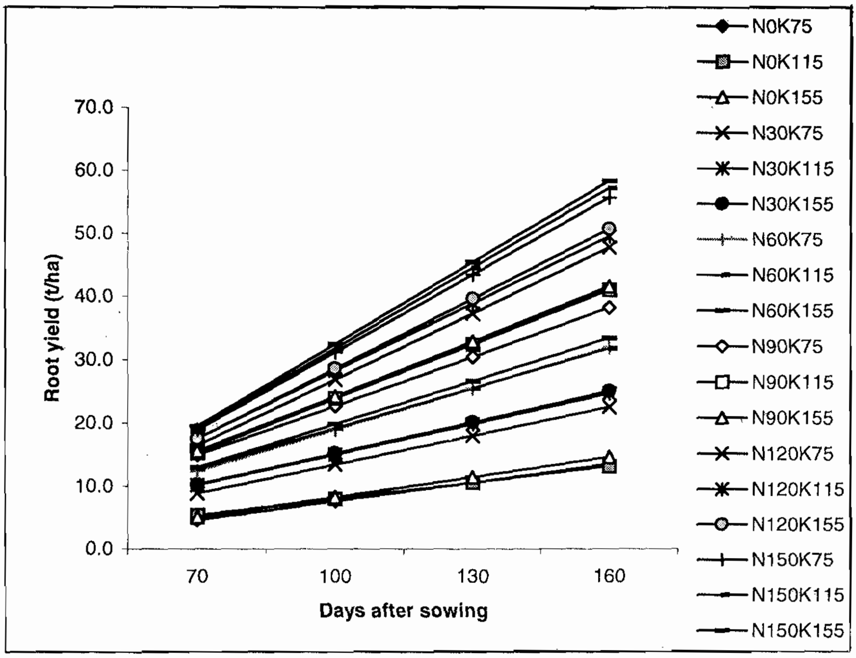

Figure 1. Best fitted linear estimate of root yield (t ha^{-1}) for different N & K combinations at different days.

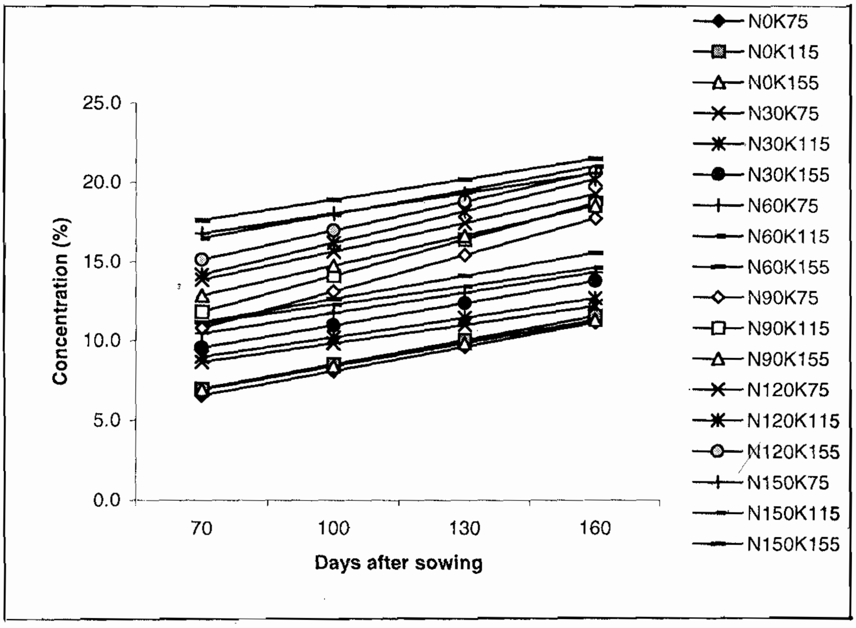

Figure 2. Best fitted linear estimate of sugar concentration for different N & K combinations at different days.

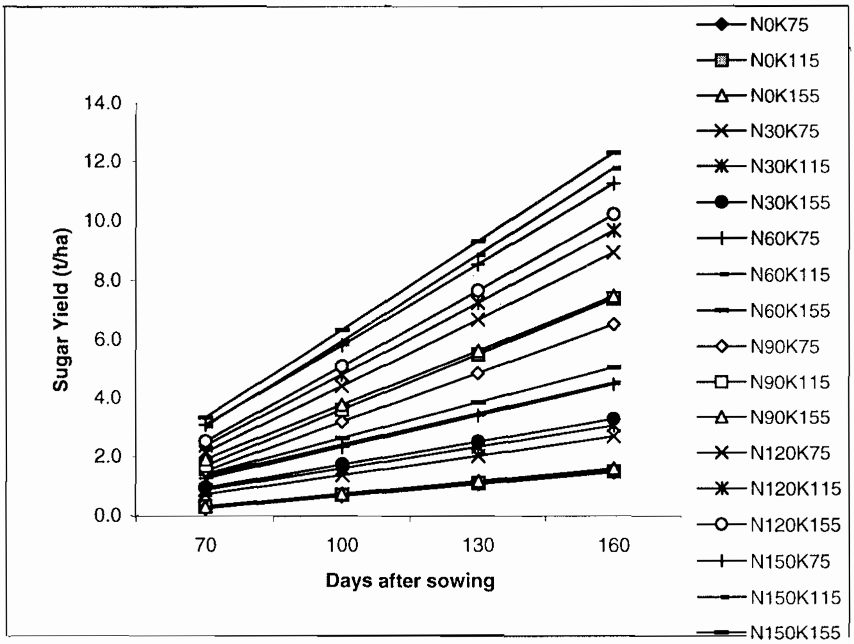

Figure 3. Best fitted linear estimate of sugar yield (t ha^{-1}) for different N & K combinations at different days.

Mr. D. Roy, Systems Analyst, CSSC, Indian Statistical Institute helped in formulation and statistical analyses. The author is also thanks to the gardeners of the experimental fields of the Unit.

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