

Biochemical and crop responses of tea (*Camellia sinensis*) to applied nitrogen

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ABSTRACT

Changes in nitrate-reductase enzyme activity in feeder roots and certain biochemical constituents of pluckable shoots in tea [*Camellia sinensis* (L.) O. Kuntze] after fertilizer application were monitored at weekly intervals in the field-grown mature bushes to determine the optimum N level and the interval between 2 applications. Nitrate-reductase activity (NRA) built linearly up to 300 kg N/ha/year, but declined at 600 kg N/ha. Nitrogen at 600 kg/ha, though balanced with potash, inhibited NRA in feeder roots and increased the nitrogenous compounds in green shoots. The NRA was at peak during third week and declined in fourth week. For sustained efficiency and productivity without any adverse effect on quality, 300 kg N/ha balanced with potash applied at a minimum of 3–4 weeks interval appeared optimum.

Key words : Tea, Nitrate-reductase activity, N, Productivity

Tea plant responds well to nitrogenous fertilizers when they are balanced with potash. Differential responses to nitrogenous fertilizers have been reported in different tea-growing regions (Jain, 1988, Sharma and Jain, 1994). Metabolic changes within the plant system and quality of made tea as influenced by different levels of nitrogen balanced with potash have not been documented for South Indian teas, although such reports are available for North-East India (Dev Chaudhury *et al.*, 1985, 1988, 1990).

An attempt was made to study the impact of different levels of N and ratios of N:K, optimum time interval between 2 applications

and to generate information on the influence of NK fertilizers on biochemical/quality constituents. Crop responses due to applied N were also monitored.

MATERIALS AND METHODS

The experiment was conducted in an estate at the Anamallais using a high-yielding clone, S/6/5 ('China' hybrid). Nitrogen levels ranging from 50 to 600 kg/ha/annum balanced with potash at 1:0.5, 1:1 were adopted as sub and main plot treatments respectively in split-plot design. Levels of NK and different forms of N were applied as recommended by Ranganathan and Natesan (1987). Out of 100% of total N input, 20% of N supplied as

ammonium sulphate (1 split applied during April), 65% as urea (4 splits, May, June, August/September, September/October) and remaining 15% of N supplied as calcium ammonium nitrate (October/November). Observations were made between 2 fertilizer (urea) applications (August to September and September to October 1994) in a long-term fertilizer experimental plots. All other agronomical operations inclusive of plucking standard, interval and plant-protection measures were followed as per the UPASI recommendations (Swaminathan *et al.*, 1990). Yield response was monitored from 1990 to 94 and expressed as made-tea/ha, based on dry-matter recovery (23%).

Feeder roots were collected from the treated plots at weekly intervals and NRA was measured (Sarmah *et al.*, 1987). Similarly, green-shoot samples were collected at random and analysed for amino acid, caffeine, catechin, chlorophyll, nitrogen and polyphenol

content using standard procedures. The results were expressed as percentage on dry-weight basis. The data were analysed statistically based on split-plot design, especially for crop and crude fibre content, while combined analysis of variance over sampling time was adopted for other parameters (Gomez and Gomez, 1984).

The tea samples were manufactured in the miniature crush, tear, curl (CTC) unit. Theaflavin (TF), thearubigin (TR), total liquor colour (TLC) and high polymerized substances (HPS) were estimated by modified Takeo and Oosawa method (1976). The method suggested in Indian Standard Specification (1973) was adopted for the estimation of total soluble solids (TSS) in made tea and crude fibre content (CFC) in green shoots. Briskness index (BI) and colour index (CI) were calculated (Ramaswamy, 1986). Tasters' score was obtained for black tea sample through organoleptic tests.

Table 1. Changes in biochemical and chemical constituents of tea after fertilizer application

Treatment	NRA (nmol/ g fresh weight)	Total AA (%) dry weight)	Caffeine (% dry weight)	Total chlorophyll (mg/g fresh weight)	Leaf N (% dry weight)	Catechins (% dry weight)	Poly- phenols (% dry weight)
<i>N : K ratio</i>							
1:0.5	108.5	2.77	4.21	1.29	3.36	19.8	31.6
1:1.0	110.8	2.91	4.28	1.32	3.42	21.1	31.0
CD (P = 0.05)	4.4	0.15	0.11	0.10	0.05	0.66	0.91
<i>N level</i>							
50	106.5	2.40	3.79	1.04	3.22	19.2	29.0
100	110.1	2.57	4.09	1.18	3.38	20.1	31.6
200	116.3	2.92	4.29	1.32	3.49	20.9	32.7
300	109.9	3.03	4.41	1.44	3.48	21.5	33.3
600	104.8	3.26	4.66	1.56	3.38	20.4	30.0
CD (P = 0.05)	7.0	0.24	0.18	0.16	0.08	1.04	1.45
<i>Weeks after fertilizer application</i>							
1	92.3	2.67	3.78	1.20	3.17	18.4	28.3
2	113.0	2.07	4.09	1.41	3.38	19.5	32.0
3	126.5	3.57	4.73	1.30	3.60	21.4	34.0
4	106.2	3.03	4.39	1.33	3.42	22.5	31.0
CD (P = 0.05)	6.3	0.21	0.16	0.14	0.08	0.94	1.29

NRA, Nitrate-reductase activity; AA, amino acid content

Table 2. Quality constituents of made tea due to applied N (mean of 2 observations)

N : K ratio	N (kg/ha /annum)	TF (%)	TR (%)	HPS (%)	TSS (%)	Caff. (%)	BI	CI	Tasters' score
1:0.5	50	0.91	8.3	8.2	37.1	3.2	22	5.2	25
	100	1.08	8.7	7.1	37.3	3.7	23	6.8	26
	200	1.18	9.0	7.8	38.7	4.7	21	7.0	30
	300	1.12	7.9	8.2	38.1	4.8	19	7.0	27
	600	0.96	8.2	7.7	37.1	4.7	18	6.0	25
1:1	50	0.91	8.9	8.2	36.8	4.4	17	5.3	26
	100	1.00	9.2	8.4	38.0	3.5	22	5.7	25
	200	1.03	9.2	9.2	39.2	3.0	26	5.6	25
	300	1.09	8.6	8.3	40.5	3.5	24	6.5	29
	600	1.00	8.2	7.9	37.4	3.9	22	6.2	26

TF, Theaflavin; TR, thearubigin; HPS, high polymerised substances; TSS, total soluble solids; Caff, caffeine; BI, briskness index; CI, colour index

RESULTS AND DISCUSSION

The NR activity in feeder roots was maximum during the third week after fertilizer application (Table 1). Linear response of NR activity to substrate (urea) was found up to 300 kg N/ha/year which reached the peak during third week of application and at 600 kg N/ha, the NR activity was lower. Changing pattern of NR activity in the feeder roots of tea was used as an indicator of yield, interval between 2 fertilizer applications and also for predicting N status of the plant (Wickremasinghe *et al.*, 1980).

Amino acid content in tea shoot showed significant increase with N levels. Amino acid content was maximum during third week of application (Table 1) and at 600 kg N level amino acid content increased significantly irrespective of the sampling time and level of applied N. It has been observed that N in plant is translocated and stored in the form of amino acid which is the precursor for protein synthesis (Wanyoko, 1990). Amino acids undergo transformation to produce volatile flavour compounds during manufacture of black tea (Roberts and Sanderson, 1966). Potassium also plays a vital role in the metabolism of amino acid and protein by activating the enzyme system of N assimilation and kinetics

(Evans and Sorger, 1966). Nitrogen at higher level, even when balanced with potash may disturb the metabolic activity of the plant through excess N.

The caffeine level in green shoot showed a tendency to increase with the increase N level (Table 1). The results confirm the findings of Dev Choudhury *et al.* (1985) with different levels of N. The caffeine content in the shoot reached the peak during third and fourth week after fertilizer application, indicating the maximum assimilation and utilization from the applied N for subsequent metabolic functions.

There was no clear trend in chlorophyll content for applied N (Table 1). However, at 600 kg N the chlorophyll content was higher and significant than other levels tested. This could be due to assimilation of excess N in the shoot. High chlorophyll content in leaves affects the quality adversely, though it contributes to black appearance (Dev Choudhury and Bajaj, 1980).

An increase in shoot N was related to a corresponding increase in N dose which substantiates the earlier findings (Dev Choudhury *et al.*, 1990). Linear increase in N content of shoots reached the peak during third and fourth week of fertilizer application (Table 1).

Significant differences in catechins, a

Table 3. CFC in tea shoots due to NK application

N level	N : K ratio		Mean (level)
	1:0.5	1:1	
50	14.3	15.2	14.8
100	14.4	15.3	14.9
200	14.7	15.4	15.0
300	14.8	15.6	15.2
600	15.9	16.7	16.3
Mean (ratio)	14.8	15.6	
CD (P = 0.05)			
Ratio (R)		0.45	
Level (L)		0.71	
R x L		1.00	

predominant group of phenolics, were observed between N:K ratio, N levels and between the sampling time (Table 1). However, there was a significant decline in catechin content when the N level raised from 300 kg to 600 kg/ha. Similar observation was reported by Dev Choudhury *et al.* (1990) for Assam tea. However, there is a reduction in total polyphenol content due to high nitrogen (Table 1). Hilton *et al.* (1973) reported gradual fall in the concentrations of different fractions of catechins when fertilizer N was raised from 40 to 240 kg/ha. A significant increase in polyphenol and catechin content during third and fourth week of fertilizer application was reported, indicating the synthesis of more catechins during this period. Catechins are converted into theaflavins and thearubigins that are required for liquor characteristics of black tea (Owuor *et al.*, 1986).

Theaflavin, TR, TSS and caffeine level determine the liquor characteristics of black tea (Hazarika *et al.*, 1984). The changes in the levels of these quality parameters due to applied N balanced with K are given in Table 2.

There is an increasing trend in colour index up to 300 kg of applied N, irrespective of the ratios of N and K. However, 600 kg N

reduced the value of colour index. Although, clear trend was not observed between briskness index (BI) and applied N, less value of BI was observed at high N. Tasters' score also substantiates this observation. There is an improvement in TSS up to 300 kg which declined at 600 kg N. High level of N balanced with K increased the crude fibre content in green shoots significantly (Table 3). Wanyoko (1990) reported that the quality of made tea was markedly depressed by increasing N rates.

The effect of different levels of N and N:K ratio on yield of tea is presented in Table 4. Five years data on crop indicated that N @ 300 kg/ha/year appeared optimum for yield level ranging from 4,000 to 5,000 kg made tea/ha/year. Application of 600 kg N/ha declined the yield significantly. No significant difference in yield level could be noticed between 1:0.5 and 1:1 ratio of N:K.

The results showed that repeated split application at 3-4-week intervals lead to efficient absorption and assimilation of applied N as enunciated by NR activity in feeder roots and biochemical constituents of green shoots. Thus, NR activity in feeder roots can be used as an index in determining the optimum in-

Table 4. Crop productivity in response to NK application (yield kg made tea/ha, mean of 1990 to 1994)

N level	N ratio		Mean (level)
	1:0.5	1:1	
50	4,287	4,361	4,325
100	4,435	4,691	4,563
200	4,900	4,673	4,786
300	5,091	5,100	5,096
600	4,697	4,890	4,794
Mean (ratio)	4,682	4,743	
CD (P = 0.05)			
Ratio (R)			62.6
Level (L)			76.6
R x L			83.9

terval between 2 fertilizer applications. In case of low-yielding fields, where the N level is also correspondingly low, longer interval may be useful. Increase in nitrogenous constituents like amino acids, chlorophyll, caffeine, catechins and crude fibre in green shoots at 600 kg N may contribute for the adverse effect on the quality of tea which has reflected in the liquor characteristics of made-tea. Observations made during the last 5 years have indicated that highest yield was obtained in 300 kg N/ha/year balanced with potash for yield levels ranging from 4,000 to 5,000 kg made tea/ha. There was a decline in productivity where the N levels was increased from 300 to 600 kg N/ha/year. There was no significant difference between 1:0.5 and 1:1 N:K ratios. However, this aspect needs investigation to understand the long-term effect.

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