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Impact of nitrogen and potassium fertiliser application on quality of CTC teas

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Abstract

Tea flush shoots, comprised of three leaves with a bud, were collected from long-term fertiliser trial plots, in four successive plucking rounds after NK manuring, and processed into black tea. The black tea samples were analysed for thearubigins, theaflavins, caffeine, volatile flavour compounds, crude fibre content and water-soluble solids. Results indicated that overall quality of tea was impaired when either nitrogen or potassium was used at high levels. The NK ratio of 1:0.83 appeared to be optimum with respect to quality of made tea as well as for flavour index, particularly when the N dose was 300 (or) 450 kg/ha/year. Amino acid and polyphenol contents of the crop shoots were also higher due to this ratio of NK manuring. A lower polyphenol content was recorded when the plots were supplied with less (or) no nitrogen and potash fertilisers. Positive correlation coefficients were obtained between nitrate reductase (NR) activity of crop shoots and amino acid content.

Keywords: NK fertilisers; NR activity; CTC Teas; Quality parameters

1. Introduction

The south Indian contribution to the national tea production is about 24% and almost all in the form of black tea manufactured by the CTC (crush, tear and curl) process. The profitability of the operation is governed by the quantity as well as the quality of tea produced. Though many of the basic relations between quality and chemical composition of plant tissue remain unanswered, there have been several attempts to study the effect of changing manurial practices on quality parameters of made tea. Polyphenols and their oxidised derivatives (mainly theaflavins and thearubigins) are important chemical constituents, which are responsible for colour formation of tea during infusion and the unique aroma of black tea. The promoting effect of K fertilisers on polyphenols has been demonstrated by various researchers (Ruan, Wu, Ye, & Hardter, 1998; Wilson & Choudhury, 1968). Effects of nutrient elements, such as magnesium, sulphur, boron and nitrogen on quality of black tea have also been widely reported (Barbora, 1995; Dev Choudhury & Bajaj, 1988; Rahman, Sharma, & Nandi, 1978; Sharma & Sharma, 1992; Tasneem Sultana, Deka, & Barbora, 1977). It is reported that a high quantity of nitrogenous fertilisers has a deleterious effect on quality of made tea (Guseinov, 1973; Hilton, 1971; Ranganathan & Natesan, 1987); even so, there is no alternative to nitrogenous fertiliser application if commercial levels of production are to be achieved. However, data on combined effects of nitrogen and potassium on quality of made tea are scarce and the subject deserves study, since NK fertilisers are always applied together in south Indian tea gardens. The metabolic activity of applied nitrogen is expected to vary depending on the synergism/antagonism between the nutrients. In this paper, the influence of various ratios/doses of NK fertilisers on biochemical composition of flush shoots and quality parameters studied with special reference to south Indian CTC teas.

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2. Material and methods

Investigations were carried out by collecting flush shoots, consisting of three leaves and a bud, from long-term fertiliser trial plots at UPASI Tea Experimental Farm between 1999 and 2000, in clone UPASI-9. The experiment, laid out in random block design in 1994, had sixteen treatments, of which only twelve were selected for the present study with different levels of N and K fertilisers, including an untreated control (no NK fertiliser application), owing to limitations in the manufacturing facility. The source of nitrogen was urea and that of potassium was muriate of potash (MOP). Other nutrients such as P, Ca, Mg, S, Zn, Mn and B, were supplied at a uniform rate to all the treatments according to the standard recommendations of UPASI TRF (Verma & Palani, 1997). A portion of collected leaf samples was subjected to the laboratory analysis to assess free amino acids (Moore & Stein, 1948), total polyphenols (Dev Choudhury & Goswami, 1983) and NR in vivo-assay of NR activity (Sarmah, Chaudhury, & Goswami, 1987). About 2.5–3 kg of harvested leaves were manufactured under set conditions and the black teas were analysed for theaflavins (TF), thearubigins (TR) (Thanaraj & Seshadri, 1990), caffeine (Harold, Ronald, & Ronald, 1984), crude fibre content (Anonymous, 1998) and water soluble solids (Anonymous, 1999). Volatile flavour compounds (VFC) were analysed using a gas chromatograph (GC). About 2.0 g of made tea sample were analysed through the Headspace sampler of the GC (Varian model 3800) for VFC using a flame ionization detector (FID). The injector and the FID temperatures were 200 and 250 °C, respectively. A capillary column of length 15 m, with 0.32 mm internal diameter, was used. The column material was 50% phenyl-polysiloxane. The compounds were identified by comparison of the GC retention times with those of authentic chemicals (Sigma). This method is 100% reproducible. The flavour index (Obanda & Owuor, 1995) was calculated from the flavour profile, which is the ratio of the sum of VFC Group II to that of VFC Group I. The figures given in the subscript, along with N and K represent the actual quantities of fertiliser applied in kg/ha/y.

3. Results and discussion

The free amino acid and total polyphenol contents of flush shoots were estimated in four harvesting rounds immediately after manuring. The statistically analysed mean data are presented in Table 1. The amino acid content was highest in the treatment where NK fertilisers were applied at 1:0.83 ratio (at rates of N, 300 and 450 kg/ha/y). Table 1 show that, at the same level of nitrogen, when the potassium dose was increased there was a significant increase in polyphenols and free amino acid contents of flush shoots until a ratio of 1:0.83 is reached, beyond which there was a sharp decrease. A highly significant (at $P = 0.01$) and positive correlation coefficient was obtained when estimated NR activity and the amino acid content in the crop shoots were subjected to correlation analysis ($r = 0.659^{**}$, $n = 47$). The increase in amino acid contents could be because of improved nitrogen metabolism induced by nitrate reductase at the optimum NK (1:0.83) ratio (Raun, Wu, & Hardter, 1999; Raun et al., 1998). The treatments supplied with 0, 150, 300 and 450 kg of N/ha/y, without K, did not differ in their amino acid contents and recorded comparatively lower amounts of amino acids. This observation underlines the importance of the nutrient K, in tea production. This is in contrast to the observation made in other crops where amino acid accumulation was noted in K-deficient plants (Mengel & Helal, 1968). The range of polyphenols in clone UPASI-9, under south Indian conditions, was reported to be 25–35% of its dry weight. But in this study, a value as low as 21.4% was observed. This field trial was initiated in 1994 and continued until the date of sampling and hence, the continuous exposure of some treatments to either a minimum quantity of fertilisers or no fertilisers would have resulted in lower values of polyphenols. The direct increase of polyphenols with the applied potash fertilisers has already been reported by Ruan et al. (1999).

Crude fibre content (CFC) and water soluble solids of the tea obtained from the shoots harvested in four successive plucking rounds after manuring were analysed. The mean data, along with statistical data, are given in Table 2. The CFC of all the treatments was slightly higher than the normal level, since a crude fibre extractor was not used to remove the crude fibre from black teas. In general the CFC was higher when excess quantity of

Table 1
Green leaf parameters, as influenced by nitrogen and potash fertilisers

Treatment details	Amino acids (%)	Polyphenols (%)
N_0 K_0	1.17	21.4
N_0 K_{125}	1.49	23.6
N_{150} K_0	1.19	21.4
N_{150} K_{250}	1.47	24.3
N_{300} K_0	1.15	23.5
N_{300} K_{125}	1.80	25.6
N_{300} K_{250}	2.34	26.4
N_{300} K_{375}	1.82	30.1
N_{450} K_0	1.14	25.4
N_{450} K_{125}	1.57	27.2
N_{450} K_{250}	1.60	29.6
N_{450} K_{375}	1.97	31.4
SEM±	0.18	0.52
CD at $P = 0.01$	0.49	1.42
CD at $P = 0.05$	0.37	1.06

potash fertiliser was applied. The highest value was recorded in the treatment, with 300 kg of N and 375 kg of K fertilisers. The CFC was comparatively high even when fertiliser was not applied. It was reported that the presence of potassium inhibits the formation of starch (Dev Choudhury & Bajaj, 1988). The percentage of water soluble solids was in contrast to that of the crude fibre content. However, the teas were not deficient in water soluble solids and they were well above 32%, the limiting value, below which the teas become substandard according to the Prevention of Food Adulteration Act.

Caffeine content was estimated in the sample, analysed statistically, and is shown in Table 2. Evidently, at lower nitrogen levels (N_0 and N_{150}), the caffeine content increased with increase in the K fertiliser dose. It was observed that, when the N dose was stable at 300 kg/ha/y, caffeine content increased, along with increase in K fertiliser. This trend continued until the ratio 1:0.83 was reached, beyond which the increase lacks statistical significance. Also, in the absence of K, increasing N increased the caffeine content proportionately up to 300 kg/ha beyond which, the caffeine content showed a significant decrease. Similar results have been reported in various tea growing countries (Dev Choudhury & Bajaj, 1988; Owuor & Odhiambo, 1994).

Table 2
CFC, WSS and caffeine contents, as influenced by nitrogen and potash fertilisers

Treatment details	Crude fibre content (%)	Water-soluble solids (%)	Caffeine (%)
N_0 K_0	15.0	38.16	3.00
N_0 K_{125}	14.0	39.10	3.08
N_{150} K_0	14.0	39.20	3.16
N_{150} K_{250}	14.3	37.82	3.38
N_{300} K_0	14.4	38.68	3.25
N_{300} K_{125}	14.2	38.25	3.31
N_{300} K_{250}	14.8	37.80	3.56
N_{300} K_{375}	15.6	36.39	3.31
N_{450} K_0	13.9	38.79	2.87
N_{450} K_{125}	13.2	38.43	2.98
N_{450} K_{250}	14.2	38.30	3.30
N_{450} K_{375}	14.8	38.33	3.67
SEM±	0.25	0.46	0.09
CD at $P=0.01$	0.68	1.26	0.25
CD at $P=0.05$	0.51	0.94	0.18

Table 3
Theaflavins, thearubigins and flavour indices as influenced by nitrogen and potash fertilisers

Treatment details	Theaflavins (%)	Thearubigins (%)	Flavour index
N_0 K_0	0.88	8.4	1.08
N_0 K_{125}	0.96	8.9	1.56
N_{150} K_0	0.78	8.5	1.32
N_{150} K_{250}	0.94	8.9	1.72
N_{300} K_0	0.86	8.6	1.53
N_{300} K_{125}	0.89	9.3	1.72
N_{300} K_{250}	1.12	9.2	2.37
N_{300} K_{375}	0.96	9.8	1.97
N_{450} K_0	0.86	9.2	0.92
N_{450} K_{125}	0.87	9.3	0.96
N_{450} K_{250}	0.92	10.1	1.29
N_{450} K_{375}	1.08	10.6	2.02
SEM±	0.04	0.20	0.10
CD at $P=0.01$	0.11	0.55	0.27
CD at $P=0.05$	0.08	0.41	0.20

Mean theaflavin (TF) and thearubigin (TR) contents are provided in Table 3, which reveals that TF and TR were higher in the treatment N_{450}:K_{375}, followed by N_{300}:K_{250}. The increase in TF content could be because of the increased synthesis of polyphenols at the optimum NK ratio, which is the precursor of TF and TR. Because of the increase in amino acid content at the 1:0.83 ratio, the pH of the fermenting dhool might have dropped. The formation of theaflavins is favoured when the pH tends towards 5.0 by virtue of the enhanced steady state concentration of simple catechin quinones (Robertson, 1992).

An increase in flavour index (FI) was observed the higher NK levels (Table 3), due to the higher concentration of group II compounds that produce desirable aroma. But there was no significant change in group I compounds. Among group II compounds, linalool, methyl salicylate and benzaldehyde, which impart sweet aromas to tea, were the main compounds showing increased concentration. The flavour index was higher in the 1:0.83 ratio but lowest in the N_{450}:K_0 ratio (lower than the control, where no fertiliser was applied), indicating the need for a balance between N and K fertilisers. Since teas are valued for their aroma, which has a direct relationship with FI (Owuor, 1992), application of large quantities of N fertiliser without balancing with K should be avoided.

A negative impact of manuring on overall quality and biochemical parameters was observed when higher amount of nitrogen or potassium were separately applied. However, it is clear from the results that a significant improvement in quality is quite possible when a balanced NK ratio (1:0.83) is used for fertiliser application.

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