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RESPONSE OF MATURE TEA (*CAMELLIA SINENSIS L.*) TO NITROGEN DURING DIFFERENT SEASONS

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Field experiments were conducted on mature tea bushes of Chinese Qi-Men variety at two different altitudes (1000 and 1500 m) from sea level during three consecutive years from 1998 to 2000. Different levels of nitrogen with the basal dose of phosphorus and potassium were applied to seven years old tea bushes. Mother leaf sampling was carried out during plucking season for the period of study. The mother leaves were analysed for nitrogen, phosphorus and potassium. The results revealed that the tea plucking in different months had a significant effect on the absorption of nitrogen from the soil. High uptake of nitrogen was observed during the main growing season than dormant months. It was observed that the dose of 420 kg N ha^{-1} gave the good results to overcome the critical level of NPK in the uppermost mature tea leaf in different plucking seasons.

Keywords: *Camellia sinensis L*., Qi-Men, Nitrogen uptake, Altitudes, Seasons,

1. Introduction

Tea (*camellia sinensis. L*) is normally grown as a long-term monoculture crop and fertilization plays a vital role for its economic production. Bonheure and Willson [1] reported that without fertilizer application the supply of nutrients available in the soil is exhausted leading to mineral deficiencies in the plants and severe reduction in the yield. Fertilizer is needed for vigorous growth of young tea plants. Lack or insufficient supply of nutrients, particularly nitrogen, increases dormancy and results in poor growth of shoots [2]. Nitrogen is important for plant growth and is essential constituent of the plant [3]. It is also needed to induce more vegetative growth and reduce the reproduction phase. The commercial portion of tea crop consists of leaves and is, therefore, highly responsive to application of nitrogen fertilizer. The response of nitrogen at any level is dependent on adequate availability of other nutrients. Bonheure and Willson [1] have reported the recommended NPK fertilizer mixture in the ratio of 5:1:2 with 100-200 and 100-250 kg nitrogen $ha^{-1}annum^{-1}$ in South India and Kenya, respectively. The economic limit of nitrogen varies locally. This limit came to around 200 kg $ha^{-1}annum^{-1}$ in East Africa [4] whereas, in Srilanka and South India a range between 160 and 370 kg ha^{-1} $year^{-1}$ based on expected yield holds good in the specific situation [5]. The absolute efficiency of nitrogen in increasing yield varies with age and growth of the plant, agricultural practices including standard of plucking [6]. The Japanese farmers use 600 to 1000 kg N ha^{-1} $annum^{-1}$ evidently not for the yield but for quality consideration [7]. The uptake of nitrogen was highly stimulated after heavy pruning [8]. The establishment of exact limit to plants' response to nitrogen is very difficult because of the operations of various interacting factors. The main reason for variation in nitrogen response in different tea soils may be related to mineralization and rapid conversion of nitrate by nitrification [9]. The tea flush normally contains 5% nitrogen, 1% phosphorus and 2% potash but when this level is exhausted, these major nutrients may affect the entire dynamics of crop productivity [10]. The mechanism of nitrogen uptake by the tea plant and analysis of various elements in tea leaves have been reported by numerous authors [3, 11, 13]. This method was applied to a series of field experiments and critical levels were established for nitrogen [14], phosphorus [15] and potassium [16]. The levels that established in the third leaf as N 5.0%, P 0.50% and K 3% as normal whereas deficient levels were N 3 %, P 0.35% and K as 1.60%. Tea Research Foundation of Kenya used the leaf analysis on the basis of uppermost mature leaf sampling [12]. Owuor and Wanyoko [17]

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indicated the nutrients in the uppermost mature leaf 3% N, 0.15% P and 1.20% K as deficient levels whereas above 3.5% N, 0.17% P and 1.50% K as adequate levels. Hasselo [11] concluded that the mature leaf provided a better index of the nutritional status of tea plants grown under a wide range of environmental conditions than leaves above the plucking table. Sivasubramanium *et al.* [18] claimed that the chemical analysis of the mature leaf would be a more reliable index of the needs of the tea plant for fertilizer/nutritional requirements.

In Pakistan, tea cultivation has recently been started. The prospective tea growing areas are located between latitudes 34º 20 and 34 º 30 North and longitudes 73º 5 and 73º 20 East at altitudes 1000-2000 m from sea level with varying soil pH from 5.6 to 6.5. The annual average temperature range is 10.7 to 22.8 ºC. Harvesting of tea commence from April till to September- October. The plucking rounds are dependent on the climatic condition and lack in some months due to drought and cold in winter. The objective of the present study was to investigate the optimal level of N-fertilizer and nutritional status of tea plants grown under different agro-ecological/environmental conditions of Pakistan.

2. Materials and Methods

The field experiments were conducted at National Tea Research Institute (NTRI), Shinkiari (1000 m) and on the farmer's field at Konsh valley in village Battal (1500 m above sea level) during the years 1998, 1999 and 2000. Seven years old tea bushes of Chinese 'Qi-Men' were selected for the study. The bushes were skiffed at the height of 40 cm in early November. The physico-chemical characteristics of the experimental plots at both the locations are given in the Table 1. The study was organized under the randomized complete block design with eight treatments replicated four times. The sources for nutrient application were ammonium sulphate, di-ammonium phosphate, triple supper phosphate and potassium sulphate. Each treatment comprised 9 bushes. Six levels of N in combination with a basal dose of P and K i-e T_1=0-0-0, T_2=0-30-90, T_3=120-30-90, T_4=180-30-90, T_5=240-30-90, T_6=300-30-90, T_7=360-30-90, T_8=420-30-90 kg NPK ha^{-1}were applied in three split doses, during the year. Other agronomic practices were applied uniformly to all the treatments.

Table 1. Physico- chemical characteristics of the experimental plots. (Pre-experiment).

Properties	Unit	1000 masl			1500 masl		
		Soil depth (cm)			Soil depth (cm)		
		15	30	45	15	30	45
Sand	%	43	45	43	51	47	43
Silt	%	34	34	34	29	29	31
Clay	%	23	21	23	20	24	26
Textural class	-	Loam	Loam	Loam	Loam	Loam	Loam
Electrical Conductivity (E Ce)	dSm^{-1}	0.23	0.45	0.32	0.34	0.26	0.20
Soil pH	-	5.66	5.53	5.83	5.71	5.91	6.37
Organic matter	%	1.38	1.07	1.00	1.28	1.10	0.97
Available K	mg kg^{-1}	64	56	54	48	52	52
PO_4-P	mg kg^{-1}	8.08	7.79	4.22	13.35	10.57	5.63
NO_3-N	mg kg^{-1}	1.84	1.66	1.56	1.27	0.98	0.70
Total N	%	0.065	0.054	0.051	0.063	0.054	0.045
Zn*	mg kg^{-1}	1.8	0.94	0.58	4.6	4.8	3.4
Cu*	mg kg^{-1}	3.0	2.4	1.9	4.8	4.6	2.6
Mn*	mg kg^{-1}	4.2	2.4	1.8	-	-	-
Fe*	mg kg^{-1}	83.60	76.40	65.2	-	-	-

* Available form

The mother leaves (the leaf from the axil of which the present pluckable shoot has emerged) were collected from the bushes of the same treatment and a composite sample of 100 leaves was made. Sampling was carried out during plucking season for consecutive three years at 1000 m and 1500 m. At 1000 m the samples were collected in the months of April, May, July, August, September and October in 1998, in April, July, August, September and October in 1999 and in May, July, August and September in 2000. The available samples of mother leaves were analysed for nitrogen, phosphorus and potassium. Similarly, the mother leaf samples were collected at 1500 m during the months of April, July, August and September in 1998, May, June, July, August and October in 1999 and May, July, August and September in 2000. The meteorological data of both the altitudes are given in Tables 2 and 3. The leaves (samples) were oven dried at 105 ^{0}C. The dried samples were crushed and passed through 40 mesh sieve. The ground material was analysed for N, P and K. The nitrogen in the mother leaves was determined by Kjeldhal method followed by A.O.A.C [19] and phosphorus was determined by molybdenum blue method using acid digest [20]. The potassium was determined by atomic absorption spectrometer (Shimadzu AA 670) using 766.5 nm wavelength with an air acetylene flame [21]. Data collected so far analyzed statistically, using Duncan s'multiple range (DMR) Test [22].

3. Results and Discussion

The data on the response of major nutrients i.e. N, P and K in the upper most mature tea leaves during the plucking season of the experimental years at 1000 m and 1500 m are presented in Tables 4-7 respectively.

3.1. Nitrogen concentration in the upper most mature tea leaf.

During the month of April 1998 and 1999 the highest quantity of nitrogen 3.37 and 2.55% was observed in mature tea leaves in T_8 and T_7 respectively. The variation in the quantity of nitrogen in other treatments is statistically non significant (Tables 4-5). The ranges of nitrogen in mature tea leaf from 1.85% in control (T_1) to 3.61% in T_2 during May 1998 and 1.975 % in T_2 and 3.28 % in T_8 are shown in Table 4 during the same month in 2000 (Table 6). No significant increase was observed in different treatments during May 1998. But, in the year 2000 significant increase of nitrogen was found when the highest dose of nitrogen (420- 30-90 kg NPK ha^{-1}) was applied.

During July 1998 the highest quantity of nitrogen (3.73%) was found in T_7 and the lowest (2.74%) in T_3. The difference in the percentage of nitrogen in different treatments exists but statistically it is non-significant (Table 4). In the same months during 1999 and 2000 the highest dose of nitrogen (T_8) gave the highest quantity of nitrogen (3.70%, 3.2%) and the lowest dose (T_2) gave the lowest quantity of nitrogen (2.325%, 1.95 %) in the mature tea leaves (Tables 5 and 6). The difference was observed highly significant in highest dose as compared to lowest. The nitrogen concentration in mature tea leaves was highest in T_8 and lowest in T_1 and T_2 during August in 1998 and 2000 (Tables 4 and 6). These tables show the significant effect of different levels of nitrogen in the mature tea leaves during the month of August. In 1999 T_7 gave the highest quantity of nitrogen (3.64%) with lowest quantity of nitrogen (2.997%) in control T_1 during August (Table 5). Though the difference exists among the different treatments but they are statistically non-significant. During September in 1998 and 1999 the highest dose of nitrogen (T_8) gave a significant increase of nitrogen (3.22%, 3.45) in mature tea leaves as compared to the control which accumulated the lowest quantity of nitrogen (2.400 % and 2.125%) in the upper most mature tea leaf (Tables 4 and 5). In the same month in 2000 the highest quantity of nitrogen was observed in T_6 i.e. 3.675% and lowest in T_1 i.e. 1.875%. But, the difference in the treatments was found statistically non significant (Table 6). Tables 4 and 6 show that in October the highest uptake of nitrogen (3.05% and 3.45 %) was in T_8 and lowest (2.10 % and 1.97 %) in T_1 during 1998 and 2000 respectively. The difference between control and higher dose of nitrogen (T_8) was highly significant in both the years. It was observed that the nitrogen uptake was highest during the main growing season of the year, which increased with the increase of nitrogen content in terms of fertilizer application to the soil.

Data regarding the response of different nitrogen levels during plucking season at 1500 m are presented in Table 7. It is clear from the Table that during May the highest concentration of nitrogen of 1.99%, 3.485 and 3.55 % was found in T_8 and lowest nitrogen concentration of 1.58%, 1.26% and 1.97% in T_1. The highest dose of nitrogen significantly increased the concentration of nitrogen in the mature tea leaf (Table 7).

Table-7 also shows the effect of nitrogen on mature tea leaf during June in 1999. Highest nitrogen concentration (3.30%) was found in mature leaf when the highest dose (T_8) of nitrogen was applied and the lowest nitrogen concentration (2.47%) was recorded in control. The uptake of nitrogen significantly increased with the application of increased level of nitrogen fertilizer to the tea bushes. During July again the highest uptake of nitrogen was observed in T_8 in the experimental years, where the highest dose of nitrogen fertilizer was applied. The concentration of nitrogen was 3.60%, 3.67% and 3.67% in 1998, 1999 and 2000 respectively .The lowest concentration of nitrogen was found in control during 1999 and 2000 but also in T_5 during 1998 (Table 7). Similarly the highest quantity of nitrogen was observed when the highest dose of nitrogenous fertilizer (T_8) was applied as compared to the lowest dose of nitrogenous fertilizer in control and T_2 during August in 1998, 1999 and 2000. The increase in the uptake of nitrogen in the highest level was observed to be highly significant. The nitrogen concentrations in uppermost mature leaf in T_8 were 3.125%, 3.300% and 3.300 in August during 1998, 1999 and 2000 respectively. The lowest concentrations of nitrogen were observed in T_1 (1.850%) in 1998, and in T_2 (2.200 % and 2.200%) in 1999 and 2000 respectively (Table 7). In October the nitrogen concentration in mature leaf was at peak in T_8 followed by T_7 and lowest in T_1 during 1999 (Table 7). The uptake of nitrogen was significantly increased in mature tea leaves with the increase level of nitrogen application in the soil.

It is evident from all the results that the uptake of nitrogen was highest during the main growing season than dormant months at both the altitudes. It was also observed that the plucking in different months had a significant effect on the absorption of nitrogen from the soil at both the altitudes .The altitudinal effect had no difference in the absorption of nitrogen content form the soil. Tea plants assimilated nitrogen either as ammonia (NH_3^+) or as nitrate (NO_3^-) ions. Ammonia ions thus formed from ammonium sulphate applied to the soil are partly oxidized to nitrate by soil microbes. Nitrate, after assimilation by plants gets transformed to nitrite by the enzyme nitrate reductase, which is subsequently reduced to ammonia by another enzyme nitrite reductase. Ammonia thus liberated or absorbed directly from soil assimilated in the roots of the plants to form amino acids, amides and finally protein. The uptake of nitrate is influenced by availability of oxygen, temperature and level of soil moisture [23]. The application of highest dose of nitrogenous fertilizer (NPK @ 420-30-90 kg ha^{-1}) can be used to overcome the critical level of nitrogen in the upper most mature tea leaf (mother leaf) as established by the Tea Research Foundation (TRF), Kenya for different countries [12]. The application of maximum nitrogenous fertilizer applied so far is not harmful as the concentration in the mature tea leaf was obtained in adequate as indicated by Owuor and Wanyoko [17]. However, excessive application of nitrogen and its subsequent uptake by leaves leads to poor yield, even to risk for human health and environment. Hardter and Krauss [24] reported high nitrate contents, particularly in vegetables, are found detrimental to human health.

3.2. Phosphorus and potassium concentrations in the upper most mature leaf:

Phosphorus and potassium contents were used in constant level in addition to the varying level of nitrogen at both the altitudes. Tea soils are fairly rich in phosphorus [25]. Phosphorus is strongly fixed in acid soils as insoluble aluminum phosphate, iron phosphate or calcium phosphate and thus unavailable to the plant till a point is reached when repeated application of phosphate make the soil well saturated with phosphate. Tea plant is able to utilize phosphorus compounds efficiently by surface contracts and micorrhizal association [26]. The quantity of phosphorus removed in the crop are comparatively much lesser than that of nitrogen and potassium. It was observed in the present study that the P and K concentrations in the uppermost mature leaf were at par to the adequate level of nutrients in the mature leaf as indicated by Owuor and Wanyoko [17]. Almost similar effect of phosphatic fertilizer had been observed by Saha and Bisen [26] who obtained the high percentage of phosphorus content in the flush and third leaf, where the dose of phosphate was 45 kg ha^{-1} followed by the dose of 30 kg ha^{-1}.

Response of potash is dependent on a number of factors viz. soil temperature during main growing season, severity and type of pruning to which tea is exposed, rainfall and soil moisture. Since the availability of soil potash is greatly reduced under unfavourable moisture conditions, therefore, presence of optimum moisture is an important factor for uptake of potash [5]. In the present study the potassium concentration in the uppermost mature leaf (mother leaf) were observed as more than the critical level at both the altitudes as indicated by Owuor and Wanyoko [17] except during the month of August at 1500 m. This may be due to the soil and climatic conditions as indicated by Hajra [27].

4. Conclusions

The commercial portion of tea crop consists of tender leaves and is, therefore, highly responsive to application of nitrogen fertilizer. The plucking rounds are dependent on the climatic conditions and are, therefore, lacking in some months due to drought in summer and cold in winter. The critical levels of different nutrients in the uppermost mature leaf (mother leaf) of tea shoots have been established and used satisfactorily in different tea growing countries. In the present study different levels of nitrogen in addition to the basal dose of P and K were used. It was observed that the uptake of nitrogen was at peak during the main growing season of tea plucking at both the altitudes. To overcome the critical level of NPK i.e. 3.0% N, 0.35% P and 1.60% K in the uppermost mature leaf the highest dose of nitrogen (NPK @ 420-30-90 kg ha^{-1} $annum^{-1}$) can be used in the different plucking seasons under local edaphic conditions of Pakistan.

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