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Effects of Different Pruning Intervals on Fresh Shoot Yield and Some Quality Properties of Tea (*Camellia sinensis* (L.) O. Kuntze) in Turkey

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Abstract: In the present study, fresh shoot yields and some quality characteristics of tea pruned one, two, three, four and five years earlier were studied in three different harvests in the year 2000. As years after pruning (pruning age) increased, heights of plucking table increased, shoot lengths shortened and percentages of banjhi shoots (i.e. dormant shoots) increased. Number of shoots increased until pruning age 3 and then decreased. Fresh shoot yields increased until the age 4 and then had a 12% decrease. Dry matter content clearly increased from pruning age 1 to 4 and then did not change much. Cellulose content was slightly low right after pruning. Polyphenol content of tea, a trait important in tea quality, almost linearly dropped from the pruning age 1 (17.6%) to 5 (11.1%). Thus, although yield losses are not tremendous at the pruning age 5, polyphenol content of the tea sharply decreased, meaning a serious loss in quality. Accordingly, present policy of pruning after four harvest years seem to be a good balance between farmers who do not want to have frequent pruning and the government who wants better quality.

Key words: Tea, *Camellia sinensis*, pruning, fresh shoot yield, polyphenol content

INTRODUCTION

Three varieties of cultivated tea *Camellia sinensis* (L.) O. Kuntze are known: var. China, var. Cambod and var. Assam. The teas grown in Turkey are hybrids of these varieties although var. China features are predominant[1]. Tea plants are generally in the form of small evergreen shrubs. Height of the plants can reach 1.5 m. Plants produce many branches and shoots developed from the lateral buds on lateral branches constitute the tea crop. Tea plants are pruned to obtain a given table form and height, to eliminate unnecessary and diseased branches and to rejuvenate the tea plants. In addition to obtain a healthier crop and better quality shoots, development of shoots is promoted by breaking the balance between aboveground and underground biomass via pruning. Hence, periodical pruning of tea plants increases the yield and quality of tea plants.

Although no harvest is made in the pruning year, yields increase in the subsequent years[2]. In a pruning study conducted in India, effect of rejuvenation pruning on tea fresh shoot yield was investigated for six years[3]. Pruning greatly affected the plant form. Besides, pruning once in every four or five years increased tea fresh shoot yield by 25-50% as the total of three harvests in a year. In another study carried out in India, Udayakumar[4] reported that yields of tea plants were 486-1287, 1061-2138, 1830-3010 and 2400-3600 kg ha^{-1} in the first, second, third and fourth years after rejuvenation pruning. Esartiya[5] also reported that the best shoot production and a good quality crop were obtained within four or five years after rejuvenating pruning of 45 year-old tea plants. A study conducted in China reports that plants pruned 50 cm above the ground had less yields in the first year after pruning[6]. But the yields increased by 15.2 and 18.9% in the second and third years, respectively. Thus, pruning increases tea yields in long term.

Pruning also improves some agronomic traits of tea plants. As the years from pruning increase, plucking table rises, shoot lengths shorten and percentage of banjhi shoots increase[7]. These are all unfavourable conditions related to yield and quality of tea crop. Hence, eliminating their unfavourable effects, pruning indirectly improves tea yield and quality.

Flavour is the most important factor determining the tea quality and is related with aroma and taste. Aroma involves volatile compounds such as terpenoids, alcohols and carbonyl compounds whereas taste involves non-volatile compounds such as polyphenols, amino acids and caffeine[8]. Polyphenol contents of tea leaves are affected by many factors including climate, tea growing techniques, nutrients in the soil, age of the leaves and

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genetic factors[9]. Choudhury *et al.*[10] reported that pruning, along with other environmental factors such as fertilizing, elevation, cultivar properties, climate and age of the shoots, affect the level of caffeine which is an important component of tea quality. Cellulose is a component of tea leaves and varies among the harvests within a year[11]. Low cellulose content is desired for high quality in black tea[1]. Pruning might affect all of these environment dependent quality traits of tea crop.

Tea is harvested three or four times a year in Turkey. The first harvest is in May, second in June and others follow until November if the temperature is enough. The first, second, third and fourth harvests constitute 40, 32, 20 and 8% of the total yield, respectively[1]. Percentage of banjhi shoots increases at the later harvests. Cellulose contents of fresh tea were 10.52, 11.55, 12.25 and 13.09 at the first, second, third and fourth harvests in the same year. Polyphenol levels were the highest at the second harvest (17.32%) followed by the first, third and fourth (16.88, 16.42 and 15.82%, respectively)[1]. Roberts[12] also reported that total polyphenol contents of tea leaves dropped towards the end of the growing season. Thus, tea quality considerably decreases at the later harvests.

In order to improve the quality of tea produced in Turkey and, thus, to be able to compete with imported tea, pruning of tea plants in every five years (four harvests years after the year in which pruning is conducted) is a legal obligation. Pruning interval is one of the most important factors to obtain the highest possible benefit out of pruning. Aim of present study was to evaluate the mandatory pruning policy in Turkey. In this investigation, various agronomic and quality properties of tea crop pruned one to five years earlier were studied.

MATERIALS AND METHODS

The experiment was conducted in a tea plantation established in 1965 in Sürmene district of Trabzon province. Elevation was about 100 m and the site was 1 km away from the Black sea coast. The soil of the experimental area was a sandy-clay, acidic in soil reaction (pH=4.5) and rich in organic matter (3.8%). Climatic features of the experimental area were given in Table 1.

Each plot was 15 square-meter. Tea plants were in 100x100 cm hills. Thus, there were 15 plants in each plot. Tea plants in each treatment were pruned in one of 1995, 1996, 1997, 1998 or 1999 years. These treatments were referred to pruning age and were assigned years 5 through 1, respectively. Pruning was conducted at a height of 30 cm above the ground in November of each year. Data were taken in the year 2000.

No irrigation or pesticide application was made. Two hundred kg ha^{-1} N in the form of urea was applied. Two third of the N was applied in early April and one-third in early June. Weeds in the plots were controlled by hand. Three harvests were made in each plot in May 15th, July 16th and September 18th. Harvests were conducted using "tea-scissor", which is a scissor-shaped equipment to which a collecting bag was attached. Harvested fresh leaves were weighed immediately.

Height of plucking table, shoot length, number of shoots per plant, ratio of banjhi shoots, fresh shoot yield, dry matter percentage, cellulose and polyphenol contents were determined. The last three analyses were conducted in Biochemistry Laboratories of Tea Research Institute in Rize province. Crude cellulose analyses were conducted on dried leaves using OAOC method[13]. Total polyphenol analyses were carried out on dried leaves using Lowenthal method[13].

Data were subjected to analysis of variance. Experimental design was a Randomized Complete Block design with split arrangement where pruning ages were main plots and harvests subplots. There were three replications. Comparisons among the means of harvests and pruning ages (years after pruning) were conducted using LSD test. MSTAT statistical analysis software was used for all statistical analyses[14].

Table 1: Climatic features of the experimental area in the experiment year and long term

Climatic factors	1	2	3	4	5	6	7	8	9	10	11	12	Total
Temperature (°C)													
2000	5.2	6.4	7.5	15.5	16.0	20.3	24.4	23.4	20.3	15.8	13.6	10.0	14.8
1980-1999	7.3	7.3	8.2	11.6	15.7	20.0	22.6	22.9	20.0	16.3	12.9	9.5	14.5
Precipitation (mm)													
2000	191.2	111.4	98.5	55.7	39.1	48.4	73.4	92.4	181.4	122.3	10.1	76.7	1100.6
1980-1999	85.2	65.2	58.1	58.4	53.8	53.1	37.0	47.7	78.3	113.2	99.0	84.8	834.0
Relative humidity (%)													
2000	6.4	70.1	70.1	74.0	72.6	73.9	77.8	76.3	77.3	64.8	67.9	66.2	71.7
1980-1999	7.3	68.1	72.0	74.2	78.3	75.2	74.6	73.4	74.4	72.0	69.1	66.0	72.0

RESULTS

Agronomic characteristics: Heights of plucking tables in the first, second and third harvests were 69.2, 64.4 and 68.0 cm, respectively (Table 2). As the pruning age advanced, plants became taller ($P<0.01$) and plant height increases were almost geometrical. It increased from 60.0 cm at the age 1 to 63.0 cm at the age 3 and then to 69.1 at 4 and to 82.8 at 5.

Shoots are the harvested portions of tea crop. Shoot lengths varied significantly both by harvests and pruning age ($P<0.01$, Table 2). Shoots of the first harvests (14.8 cm) were clearly taller than the second (12.4 cm) and third (11.9 cm) harvests. Shoots of plants at pruning age 1 or 2 were somewhat similar for shoot length (17.1 and 16.8 cm, respectively). However, shoot lengths shortened in the plants of age 3, 4 and 5 (12.2, 10.2 and 8.8 cm, respectively).

Numbers of shoots per plant were significantly different at different harvests within a year and were 261.2, 275.9 and 284.7 as the average of five pruning ages for the first, second and third harvests, respectively (Table 2). As the average of harvests, shoot number increased from the age 1 (260.4) to the age 3 (288.0) and then again decreased toward the age 5 (268.7).

Banjhi shoots refers to shoots that do not form a terminal bud but only carries lateral fresh leaves. Number of banjhi shoots dramatically increased toward the third harvest (14.3, 25.5 and 32.5% for the first, second and third harvests, respectively; Table 2). Ratio of banjhi shoots were quite low for pruning ages 1 (4.0, 10.7 and 13.7%) and 2 (7.7, 15.3 and 19.3%) at all harvests. At the pruning age 3, the first harvest still did not have much banjhi shoots (10.7%) but the second and third harvests had very high banjhi shoot percentages (27.3 and 35.3%, respectively). Banjhi shoot percentage reached a plateau at the pruning age 4 (average 35.1%) and did not change much thereafter (37.3% at the age 5).

Fresh shoot yields linearly decreased at the later harvests within a year. As the average of the five pruning ages, yields were 8.05, 7.24 and 6.62 t ha^{-1} in first, second and third harvests, respectively (Table 2). Pruning age significantly affected ($P<0.01$) fresh shoot yields. Fresh shoot yields increased from the age 1 (6.21 t ha^{-1}) to 4 (8.27 t ha^{-1}) and then decreased at the age 5 (7.58 t ha^{-1}) (Fig. 1). This pattern was evident within all three harvests.

Quality characteristics: Dry matter content of harvested tea crop was high in the first harvest (30.2%; Table 2). The second and third harvests were similar (25.2 and 24.9%, respectively). There was a clear increase in dry matter content as the pruning age increased from 1 (24.0%) to 4 (28.5%) and then dry matter percentage did not change much at the pruning age 5 (28.7%)

Cellulose content was low at the first harvest no matter what the pruning age was. The second and third harvests had similar but high cellulose contents (17.1 and 17.7%, respectively) compared to the first harvest (13.4%). There was a slight increase in cellulose content as the years after pruning increased although this difference was not statistically significant.

Polyphenol content of tea was slightly higher in the second harvest compared to the first (14.5 and 15.2%, respectively) and dramatically decreased (13.2%) in the third harvest (Table 2, Fig. 1). Polyphenol content of tea almost linearly dropped from the first year after pruning (17.6%) to the fifth (11.1%).

DISCUSSION

Improvement of quality of tea grown in Turkey is a government policy and pruning of tea after four harvest years is mandatory. In order to evaluate the benefits of this policy we compared the yield and quality of tea plants during the five years following the pruning, excluding the year in which pruning was conducted where no harvest was made. As the years after pruning increased, plucking table rose especially after the pruning age 4 and made the harvest very difficult as explained by Barua[7]. Shoots were clearly longer at the first harvest than the second and third. This is possibly due to higher temperature in the second and third harvest periods (Table 1). Similarly, Balasuriya[15] reported that increasing mean air temperature lowered number of shoots per area but increased the mean dry weight of tea shoots. Shoot lengths shortened after the pruning age 2 just as Barua[7] reported. Number of shoots per plant decreased after the fourth harvest year. Percentage of banjhi shoots which lower the quality of tea crop were very high (especially at the second and third harvests) at the pruning ages 4 and 5. This effect was previously reported by Barua[7] and thus, become evident for tea grown in Turkey. Although four harvests are possible for tea crop in some years in Turkey, in the experimental years only three harvests were possible. Fresh shoot yields almost linearly decreased at the later harvests. The first, second and third harvests constituted about 37, 33 and 30% of the total crop within the year. The yield percentage of the third harvest in experimental year was quite high compared to 20% reported by Oksuz[1] because of the unusually high amount of precipitation during August-September period of the year 2000 (Fig. 1). The highest yields were obtained at the pruning age 4 and then a decrease of 12% occurred at the age 5 (Fig. 1). Increasing yields until the ages 4 and

Table 2: Effect of pruning age on various agronomical and quality properties of the tea crop harvested three times

Years after pruning (pruning age)	Fresh shoot yield (t/ha)	Height of plucking table (cm)	Shoot length (cm)	Number of shoots per plant	Banjhi shoot (%)	Dry matter (%)	Cellulose content (%)	Polyphenol content (%)
Harvest 1								
1	7.01a	60.0d	18.0ab	241.7cde	4.0h	27.1a-d	14.4bc	17.2bc
2	8.05ab	62.3cd	18.7a	245.0cde	7.7gh	30.0ab	13.2c	14.9de
3	7.50abc	66.0bcd	15.0a-d	267.3de	10.7fgh	31.4a	12.8c	14.9de
4	8.82a	67.7bc	12.3c-f	276.7f	24.3cd	31.1a	12.9c	12.4fgh
5	8.85a	90.0a	10.0ef	275.3f	24.7cd	31.5a	13.4c	12.9fg
Mean	8.05a	69.2a	14.8a	261.2b	14.3b	30.2a	13.4b	14.5a
Harvest 2								
1	6.00cd	59.3c	15.3abc	259.0ef	10.7fgh	22.9de	16.7ab	19.2a
2	6.92bcd	59.4c	18.0ab	270.3de	15.3ef	23.1cde	16.2ab	18.6ab
3	7.17a-d	60.0c	10.3def	286.7bcd	27.3c	25.2cde	17.4a	13.9ef
4	8.46ab	67.2bc	10.0ef	293.0abc	36.0b	26.9a-d	17.6a	13.8ef
5	7.64abc	76.0a	8.3f	270.7de	38.3b	27.7abc	17.7a	10.7hi
Mean	7.24ab	64.4b	12.4b	275.9ab	25.5ab	25.2b	17.1a	15.2a
Harvest 3								
1	5.61d	60.7d	18.0ab	280.7bcd	13.7efg	22.0e	16.1ab	16.5cd
2	6.74bcd	61.3cd	13.7b-e	300.0ab	19.3de	22.7de	17.5a	14.9de
3	6.97bcd	63.1cd	11.3c-f	310.0a	35.3b	25.4b-e	17.7a	13.4efg
4	7.55abc	72.3b	8.3f	274.0cde	45.0a	27.4a-d	18.4a	11.7gh
5	6.24cd	82.3a	8.0f	260.0ef	49.0a	27.0a-d	18.6a	9.7i
Mean	6.62b	68.0ab	11.9b	284.9a	32.5a	24.9b	17.7a	13.2b
Average								
1	6.21c	60.0c	17.1a	260.4d	9.4d	24.0c	15.7	17.6a
2	7.24b	61.0c	16.8a	271.8bc	14.1c	25.3bc	15.7	16.1ab
3	7.21b	63.0c	12.2b	288.0a	24.4b	27.3ab	16.0	14.1bc
4	8.27a	69.1b	10.2b	281.2ab	35.1a	28.5a	16.3	12.6c
5	7.58ab	82.8a	8.8b	268.7cd	37.3a	28.7a	16.6	11.1c
LSD_{Age}	0.89**	3.42**	3.35**	10.42**	3.66**	2.42**	NS	3.13**
$LSD_{Harvest}$	0.87**	4.66**	1.55**	12.71**	8.04**	2.00**	1.45**	1.18**
LSD_{AxH}	1.50**	5.93**	4.29**	20.06**	6.33**	4.39**	2.36**	1.93*

*,** Means with the same letter(s) are not statistically different at 5 and 1% level of probability. NS, Non-significant

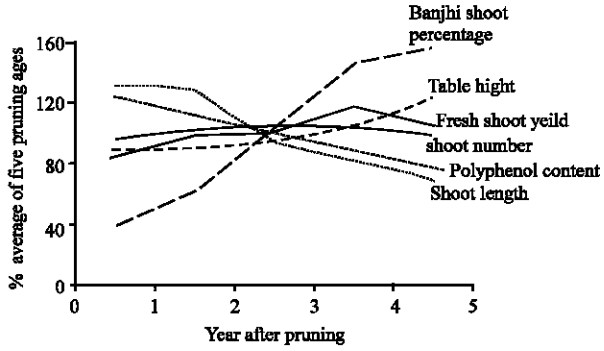

Fig. 1: Effect of pruning age on various agronomical and quality properties of the tea crop

5 have also been reported by investigators from other countries[3-5]. This finding implies that effect of pruning on yield of tea in Turkey is no different from that observed in other countries.

Pruning in the present study also affected the composition of tea leaves. Dry matter content of fresh leaves increased gradually until the pruning age 4. Cellulose contents of the leaves were very high at the second and third harvests. High cellulose contents toward the end of the growing period were previously reported for teas in Turkey[11]. However, pruning had only little improved, i.e. lowered, the cellulose contents of the leaves. Polyphenol contents, one of the most significant quality traits of tea[8], gradually declined until the pruning age 5 (Fig. 1). This decline was quite sharp after the age 4. Polyphenol contents of the first and second harvests were similar but that of third harvest was rather low. Previously reported low polyphenol contents at later harvests[12] were thus also observed in Turkish teas.

In conclusion, tea yields started to decrease after four harvest years following the pruning. Plucking table rose rapidly and inferior quality banjhi shoot percentage increased as the pruning delayed. Although yield losses are not tremendous at the fifth year after pruning, polyphenol content of the tea sharply decreased at the fifth harvest year, meaning a serious loss in quality. Farmers demand longer pruning intervals in order to get less years without crop, i.e. pruning year, which is one year in five in the present system. Nevertheless, government's policy of mandatory pruning after four harvest years seem to be appropriate as a balance between farmers who want more production and the government who wants better quality tea in order to compete with imported tea consumed in Turkey.

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REFERENCES

1. Oksuz, M., 1987. Determination of yield and made tea quality characteristics of tea clones in Turkey (In Turkish). Published by General Directorate of Tea Establishments Publication No. 8.
2. Malenga, N.E.A., 1997. Long term effect of downpruning mature Indian hybrid tea on yield. Quarterly Newsletter-Tea Research Foundation of Central Africa, 116: 18-21.
3. Hudson, J.B., 1992. Pruning. UPASI Scientific Conference, Coonoor, India. 14 Sep. 1992. Bulletin United Planters Association of Southern India, 45: 29-42.
4. Udayakumar, S., 1998. Rejuvenation pruning and consolidation in Alagaswar estate. Bulletin of UPASI Tea Scientific Department, 51: 26-30.
5. Esartiya, M.V., 1976. The effect of different pruning methods on shoot formation and development in tea. Subtropicheskie Kul'tury, 5/6: 100-102.
6. Anonymous, 1983. Pruning techniques of tea plants. China Tea Research Institute Guangdong Academy of Agricultural Sciences, No. 1, pp: 33-36.
7. Barua, D.N., 1989. Pruning. In Science and Practice in Tea Culture. (Ed. D.N. Barua). Tea Research Association, Calcutta, India.
8. Hara, Y.L., R.L. Wickremasing and T. Yamanishi, 1995. Flavour of Tea. Food Rev. Inter., 11: 475-525.
9. Hilton, P.J. and R. Jones-Palmer, 1973. Relationship between the flavanol composition of fresh tea shoots and the theaflavin content of manufactured tea. J. Sci. Food Agric., 24: 813-818.
10. Choudhury, M.N.D., F. Rahman, B.C. Barbora and M.N. Dev-Choudhury, 1991. Caffeine content in teas of North East India-A Review. Two and A Bud, 38: 3-8.
11. Kacar, B., 1991. Determination of crude cellulose content. In Tea Analysis. General Directorate of Tea Establishments Publication No. 14 (In Turkish).
12. Roberts, E.A.H., 1962. Assesment of quality in teas by chemical analysis. Two and A Bud, 9:3:3-8.
13. OAOC., 1970. Official Methods of Analysis of the Association of Official Analytical Chemists. Ed. W. Horwitz, 11th Ed. 15.046 (7.056). Washington, D.C.
14. Freed, R. and S.P. Eisensmith, 1986. MSTAT-Statistical Software for Agronomists. Agronomy Abstract.
15. Balasuriya, J., 1999. Shoot population density and shoot weight of clonal tea (*Camellia sinensis*) at different altitudes in Sri Lanka. Eur. J. Agron., 11: 123-130.