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Influence of Pruning Times on the Production of Tea (*Camellia sinensis* L.) in Darjeeling Hill

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Abstract – **The experiment was conducted at Experimental Farm, Darjeeling Tea Research and Development Centre, Kurseong during 2008-12 with the objectives to find out the most suitable time for pruning of tea to get higher production of Darjeeling tea cultivation. Old china tea bushes were Light pruned (LP) manually in the 3rdweek of each month i.e. September, 2008; October, 2008; November, 2008; December, 2008; January, 2009 and February, 2009. The 1stplucking on 10th Jun, 2009 while the first plucking in the tea bushes pruned during January and February, 2009 was obtained on 3rd July, 2009 with 22 days delay as compared to September, October, November and December pruning during the 1st year of 5 year pruning cycle (LP-LOS-LS-MS-LS). The highest annual mean yield of green leaf was 2980.0 kg ha^{-1} recorded in the pruning time of December and lowest 2281.6 Kg ha^{-1}in September than other pruning time. Pruning in December gave 698.2 Kg ha^{-1}(23.43 %) and 506.40 kg ha^{-1}(16.99 %) more fresh green tea leaves production per hectare as compared to September and October pruning, respectively. It was found that the tea bushes pruned on December, 2008 recorded significantly the highest number of Leaf area index (2.94 m^{-2}), root Starch (17.46 %), No of shoots (363 m^{-2}) and processed tea yield (655.6kg ha^{-1}) followed by January, 2009 pruning regarding these parameters, while the pruning on September, 2008 produced the minimum number of shoots (273 m^{-2}), leaf area index (2.15 m^{-2}), fresh green tea leaves yield (2281.8 kg ha^{-1}) and processed tea (501.99 kg ha^{-1}). A gradual decline was observed in leaf area index; active shoots, number of plucking round and green leaves production in plots pruned before December. Maximum shoot population density and leaf area index were associated with higher tea production. On the basis of these findings, it can be concluded that the pruning activities of tea during December (Light Pruned) and January (Skiffed) gave the highest production of green tea leaves under the climatic conditions of Darjeeling hill.**

Keywords – **Leaf Area Index, Pruning Times, Starch, Tea, Yield.**

I. INTRODUCTION

The tea plants and seeds brought from china around 1835 by Gordon who was a Botanist with East India Company were planted in Darjeeling district and some other parts of India. Subsequently, seeds were collected from there sources and more and more areas were planted. They were China or China hybrid types and of low yield potential. Pruning is an important agronomic practice and it has been shown to be most important operation, next to plucking, which directly determines the productivity and quality of tea plantations. Pruning helps stimulate vegetative growth and prevent reproductive growth phase. In addition, pruning leads to enhanced branching and hence it rejuvenates the tea plants resulting in a greater number of tender leaves for healthier and better quality tea plants. Cultivated tea plants are usually pruned to a height of around 1–1.5 m to make crop maintenance and harvesting ("plucking") easier and to increase yields. However, in their natural state, tea plants will grow to small trees. The Assam variety can grow into a loosely branched tree about 15 m tall. It is a lowland plant, and requires high rainfall and good drainage. The Chinese variety grows to a much smaller size, reaching a height of 3–5 m.

A lot of research has been done in an attempt to find the best time of pruning for maximum regrowth and these attempts have yielded varying results that could be attributed to complex factors prevailing during pruning time [6]. However, no work has been done on the effect of pruning time on tea regrowth and productivity. Root starch reserves play an important role in recovery of tea after pruning [15]. The results showed that the minimum 2-3 months of resting before pruning increased root reserves. The level of root reserves declined rapidly soon after pruning. The replenishment of root reserves commenced only after two months from pruning and complete replenishment of root reserves occurred about 10 months after pruning. The speed of recovery from pruning of a bush depends on plant's starch reserves in the roots [13]. The more starch reserves there are, the faster will be the recovery from the prune. Potassium deficiency, in particular, has been shown to have a very marked effect on recovery.

The ideal temperature for growth is 18 – 30°C. Growth is limited by temperatures above 32 –35°C and below 12 – 13°C. Strong winds, frequent frost, hail, and excessive rainfall are also detrimental to the production of high quality tea. Tea requires long hours of sunshine for good production. The ideal day length for vegetative growth is 11¼ hours. This means that tea can be harvested year round within 15 – 18° of the Equator. Outside this area, dormancy will occur at a rate of 30 days for every additional 3 – 5° from the Equator. Growth of tea plant is dependent on many factors i.e. inherent characteristics, soil climatic conditions, pest, diseases and crop husbandry [12]. The quality of tea is affected by cultivars, environment, cultural practices and tea processing techniques [5]. The objective of this experiment was to find out the most suitable time for pruning of tea to get higher production of Darjeeling tea cultivation.

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II. Materials and Methods

The study was conducted at the experimental farm of the Darjeeling Tea Research & Development Centre, Kurseong which is located at Lat. 26.9^0N, $88^0$12 E, altitude 1347 m during 2001 to 2011 on old chinary tea bushes, using 5 years (LP – LOS – LS - MS – LOS) pruning cycle. The topography comprised of moderate slopes (25-30%). The top-soil is about 45 cm in depth and the sub soil is stony. The soil is an Umbric Dystrochrept, moderately permeable and moderately well drained having sandy loam, texture. The experiment was arranged in Randomized Complete Block Design with four replications and pruning time as a factor. The treatment were T1= 3rd week of September 2008, T2= 3rd week of October 2008, T3= 3rd week of November 2008, T4= 3rd week of December 2008, T5= 3rd week of January 2009 and T6 = 3rd week of February 2009. Climatic data is also recorded during the experiment period. Plants were subjected to water deficit from March to May and were without irrigation every year. The recommended dose of fertilizers i.e. N: P: K::90: 45: 90 Kg ha^{-1} through the mixture of Urea, Rock Phosphate and Muriate of potash were applied.

The root sample was collected from the each plot for measuring the percent of root starch. Dip cut ends of pencil thick roots collected at random in Iodine solution. (Iodine crystals 1 gm., potassium iodine 1 gm. in 12 ml of distilled water and shaking the container gently the diluted to 100 ml and stored in dark coloured bottle and kept away from light in the dark or Tincture iodine diluted 8 times).From each plot, leaf samples were collected for measuring Leaf Area Index (LAI). Sample size was 1 square meter. Leaf area was measured from the field using a portable area meter (Li-3000A, Li – Cor, Nebraska, USA) as described (Li - Cor Inc., 1987). Leaf area index (LAI) is the total leaf area divided by the sample surface area. The harvested leaves comprised of young shoots, (normally two or three leaves) and a terminal bud, plucked at 7 days intervals (weekly) throughout the growth period. Shoot population were recorded weekly on the five bushes within a 0.30 X0.30 m^{-2}Quadrate placed at the centre of the bush. Data were recorded from 1st plucking of 10th June, 2009 and ceased in November, 2013, when plucking points reached a peak. Shoots of harvestable size were plucked and counted. The total fresh green leaf from each plot was weighed at each harvest and converted to the made tea equivalent using a constant value of 0.22 [1]. In the Darjeeling Hills, flushing of the tea crop starts at the end of March and after a sequence of production of normal leaves in April the shoot goes dormant for a short period during May. Thereafter, harvesting of the tea crop continues until September, declines considerably towards the end of October and then ceases during November until flushing starts again at the end of March.

III. Result and Discussion

Mean maximum air temperature ranges from around 16^0C in February to 27 ^{0}C in July and minimum temperature of 3 ^{0}C was recorded in January during the study. In winter season, light intensity was moderate, sunshine hours (5.0 h day^{-1}) and relative humidity (89%) were high. Maximum precipitation was recorded during Jun to August and minimum in the month of November to February. Sunshine hours were very low (below 2.0 h d^{-1}) in rainy season. The minimum (base) air temperature for shoot extension and development varies from clone to clone in the range of 7- 15 ^{0}C. Above the base temperature, the rates of extension and development are linear up to a maximum of about 30 – 35 ^{0}C. Unlike extension growth, photosynthesis does not stop at 12 ^{0}C. In Darjeeling, photosynthesis was observed to continue during winter (higher rate than summer and rains) when minimum temperature fall below 12^0C and the tea bushes were dormant. In Darjeeling, higher rate of photosynthesis was recorded in cold and only 12.5% depression in comparison with autumn was observed [8]. Although shoot growth diminishes as the temperature falls and ceases below 12^0C but photosynthesis accompanied by slow rate of respiration continues even at lower temperature. As a result, the bush gains in weight in a cool climate without concomitant increase in shoot weight.

Plucking or harvesting of tea is the most important and costly operation of productivity of Darjeeling tea. The method of plucking affects the level of production, the quality and the health of the tea bush. Tea plants light pruned manually in the month of 3rd week of September, 2008; 3rd week of October, 2008; 3rd week of November, 2008; 3rdweek of December, 2008 observed the early plucking while in 3rd week of January, 2009 and 3rd week of February, 2009 light pruning. The first plucking was recorded on 5th Jun, 2009 while the first plucking in the tea bushes pruned during January and February, 2009 on 3rd July, 2009 with 28 days delay as compared to September, October, November and December pruning during the 1st year of 5 year pruning cycle (LP-LOS-LS-MS-LS).The effects of plucking frequency have also been studied. Plucking once a week produced more plucking points than plucking twice a week, produced smaller shoots (1L + b, 2L+b and 3L+b)), slightly more dry matter as a proportion of fresh shoots and a lower weight of pruning per unit area, but gave significant yield differences in a five-year pruning cycle.

Photograph: Counting of shoot population during the study

Several reports have been given on optimal pruning season and variable results were obtained and it was concluded that pruning could be done at any time of the year[14]. However, in further experiments, significant yield differences were obtained due to height of pruning and time of pruning. Results from work carried out in 1971 and 1972 suggest that in Kericho, the best time of pruning is from October to February as long as the soil moisture level has not been depleted to such an extent that growth is limited[9]. Results presented on pruning times appear rather contradictory. This is mainly due to the difficulty of synchronising harvesting times, and to weather factors. Pruning in wet weather resulted in an increase in yield, demonstrating the possible benefits of timing pruning to coincide with wet weather or irrigation[10]. Irrigation helped tea recover from pruning. The effect of soil and bark temperatures and starch reserves in relation to time of pruning were determined[11]. Results on the starch reserves were not presented but pruning when the soil was warm and moisture was not limiting produced the best recovery. The results showed that the minimum 2-3 months of resting before pruning increased root reserves. The level of root reserves declined rapidly soon after pruning. The replenishment of root reserves commenced only after two months from pruning and complete replenishment of root reserves occurred about 10 months after pruning. The percentage of starch was highest in December month and lowest in September during the study(Fig. 2). Maximum starch content of 17% was reached 5 years after pruning and after pruning age of 5 years starch content decreased to 13% in Darjeeling mid elevation. Considering the starch reserve in roots, December-January is the ideal time for pruning tea bushes in North East India while in Sri Lanka and East Africa, the period immediately following dry season is considered ideal for pruning [7].

Photograph: Light Pruning (LP) of Darjeeling tea

The time required by shoots to reach the harvestable size was less in March- April. Thereafter, fast growing shoots appeared in June. Shoots harvested during the July/August peak might be either the fast growing ones, released from apical dominance in June, or the remaining slow growing shoots that were initiated before three months. This diversity in shoot growth rates continued through the rainy season until low temperature once more began to dominate shoot extension number in November and no harvesting in winter season. The pruning time of December month showed the greatest variation with all peaks of 20 to 50 mm m^{-2} $week^{-1}$ occurring during the summer (March to May) and rainy (June to July) season. In contrast, the pruning times of September and October month was lowest active shoot at that time (5 to 30 mm m^{-2} $week^{-1}$ and did not exhibit such marked peaks in shoot extension activity except during the rainy season. In the cold weather season, shoot extension rate of all pruning times were zero (no shoot growth rates from December to February).The difference of active shoots population densities between pruning times were very marked. The pruning times of September, October and February month were lower (250 to 300 shoots m^{-2})shoot numbers than December and January pruning times (300 to 380 shoots m^{-2}). The maximum shoots numbers (363 m^{-2}) was in the pruning time of December during the study (Table 2).The field observations were noticed that the density of dormant shoots is less during the periods of higher green leaf yield and high dormancy during periods of lower leaf yield. Although actively growing tea shoots on a harvested bush become dormant after producing 3-4 leaves, most of the new shoots growing after pruning, do not show a clear periodic growth at shorter intervals as observed on a tea bush in plucking.[4] also reported that shoots of pruned tea bushes produced more leaves before they become dormant. This could be attributed to less competition between shoots for nutrient and water and also the presence of growth hormones in adequate concentrations. The maximum plucking round was recorded in the pruning time of December month and minimum in September and October month of pruning times (Table 2).Leaf area index (LAI) is an important parameter in crop productivity. The LAI during the plucking stage of the tea bush is an important state variable in the recorded of the yield. Highest leaf area index was observed in the pruning month of December (2.94 m^{-2}) followed by other pruning time's month (Table 2). LAI were recorded lowest in the pruning time of September and October and highest in pruning time of December.

Photograph: Experimental field

The tea is manufactured using tender shoots having few leaves with an apical bud. Shoots with one leaf, and shoots with more than three leaves are also included in the harvest. The highest green leaf production (2980.0 Kg ha^{-1}) was recorded in the pruning time of December followed by pruning of January, November and February with production of 2800.00, 2747.50 and 2544.00 Kg ha^{-1}, respectively (Table 2). The annual average yield of processed tea was recorded 582.00 kg ha^{-1} and varied with times of pruning. Highest mean annual yield of processed tea was 655.60 Kg ha^{-1} recorded in the pruning time of December month and minimum (501.99 kg ha^{-1}) in September (Fig. 1). The yield of processed tea from the pruning time of September and October were lower than other times of pruning months. There were differences between pruning times in the distribution of seasonal yield. Highest yield in all pruning times were recorded in rainy season. The variation in yield for different pruning times is due to the variation in date of first plucking, number of plucking point's m^{-2} and shoot growth, as these are the yield determinants of tea bush [2]. The timing, amount and location of their deposits should be investigated as a possible indicator to predict vigour and yield [3]. Pruning should be done when the root reserves are high. Pruning and or tipping have been shown to check root growth and development. Carbohydrate reserves are enhanced by cultural practices.

IV. Conclusion

From this study it was observed that pruning of tea under the climatic conditions of Darjeeling hill should be carried out in the dormant period. Mid November to December month for Deep/Light pruning and January month for Skiffing are the most suitable times for the pruning of tea plantations to get high productivity. The study was suggested that the pruning should be done when the root starch will be high.

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Author's Profile

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was born on 08.12.1965.Passed M. Sc. (Ag) in Agricultural Chemistry in 1989 from Meerut University, Meerut, Uttar Pradesh. Joined as Assistant Teacher in 1989.Obtained B. Ed. (Ag) in 1992 from Regional College of Education Centre, Ajmer, Rajasthan (NCERT).Joined as Jr. Sc. Asstt. (Farm Management) in October, 1992 at Tea Board of India, Darjeeling Tea Research and Development Centre (DTRDC), Kurseong, Darjeeling, West Bengal.Now, working on plant physiology as a Scientific Officer at DTRDC since 2009. I have published more than 25 scientific papers in National and International reputed journals, and attended more than 10 National and International Conferences, and trained 25 Small Tea Growers of Darjeeling tea Industry, and contributed one technical bulletin of young tea management of Darjeeling tea, and contributed one Book Chapter on Tea Research for Darjeeling Tea Industry. I am also Life time member of Journal of Crop and Weed.

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Table 1. Weather observations recorded at the meteorological observatory of the Darjeeling Tea Research & Development Centre (Lat $26^0$55' N, long $88^0$12' E, altitude 1347m).

Months	Mean Max Tem (^{0}C)	Mean Min Tem (^{0}C)	R. H. (%)	Sunshine duration (hrs.)	Total rainfall (mm)	Pan Evaporation (mm)
January	12.9	3.6	88.6	5.0	5.0	4.9
February	15.6	6.6	88.0	4.3	9.0	4.9
March	17.5	11.3	90.0	4.8	30	5.2
April	19.6	12.5	89.0	4.9	67	6.3
May	21.0	14.6	90.0	2.7	257	4.8
June	23.7	17.3	95.6	1.2	958	3.3
July	24.8	18.1	96.3	0.4	1240	3.3
August	23.4	18.4	95.5	1.0	985	3.0
September	22.0	17.3	93.5	1.7	532	3.3
October	21.1	15.0	90.3	2.6	105	3.7
November	18.7	12.0	88.3	4.0	0	4.1
December	15.4	9.8	89.0	4.5	0	4.5

Table 2: Effect of different pruning time on Leaf area index, Shoot population, Number of plucking round and green leaf production of Darjeeling tea (Average mean of 5 years pruning cycle).

Pruning Times	Leaf area index (m^{-2})	Shoots population (m^{-2})	Plucking round (Per year)	Green leaf yield (Kg ha^{-1})
September (3rd week)	2.15	273	23	2281.8
October (3rd week)	2.35	295	24	2473.6
November (3rd week)	2.69	331	26	2747.5
December (3rd week)	2.94	363	28	2980.0
January (3rd week)	2.75	342	26	2800.0
February (3rd week)	2.64	260	26	2544.0
CD at 5 %	0.32	36.74	NS	196.31

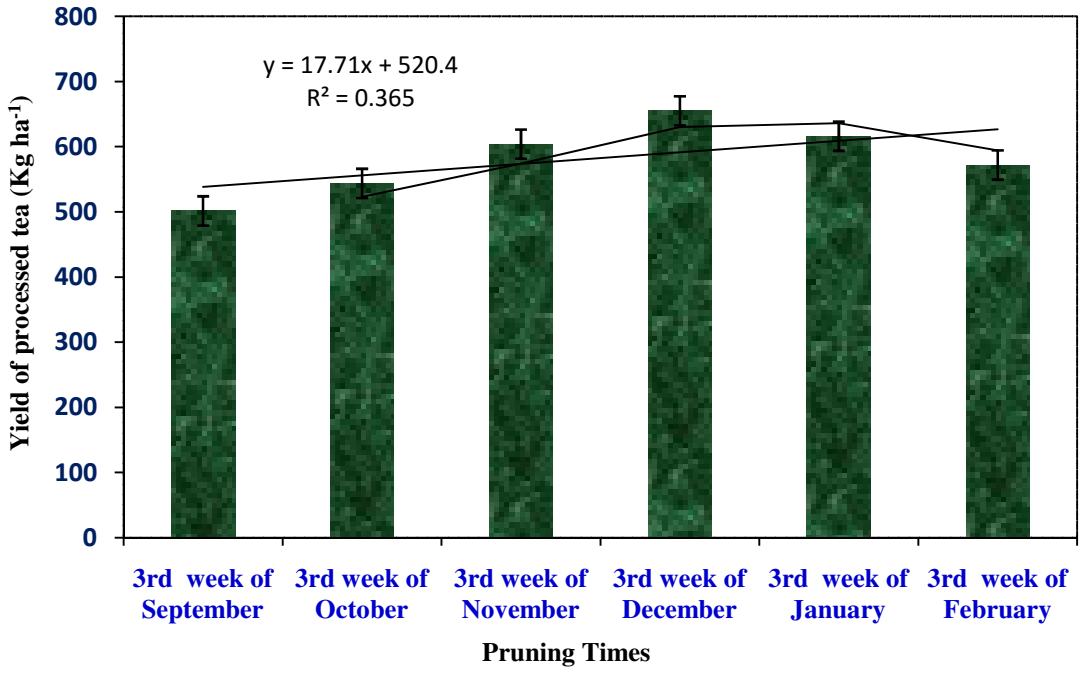

Fig.1. Effect of different pruning time on production of Darjeeling tea. Vertical bars indicate standard error of means. (Average mean of 5 years pruning cycle)

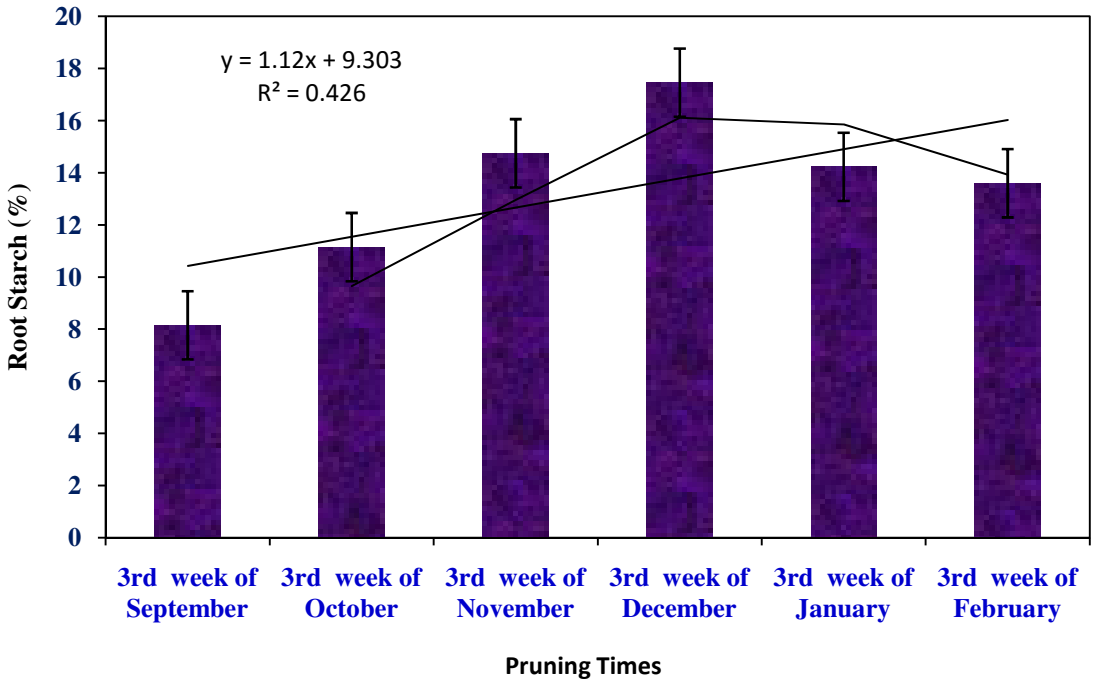

Fig 2. Changes of root starch (%) during the pruning months (time) at the Experimental farm of DTRDC, Kurseong. Vertical bar indicate standared error of means.