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Shoot Generations in Productivity Management in Tea (*Camellia L . spp.*)

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Abstract

Tea yield, in simple terms is the weight of all shoots plucked in a unit area in unit time. Shoot generations and their weight, therefore, determine the productivity of tea. The relations between shoot generation, shoot weight and yield are *quantified* in this paper to enable to understand and appreciate the significance of plucking interval style and standard in planning tea harvesting systems.

Keywords

Shoot Generation; Plucking Points; Shoot Weight; Productivity.

Introduction

The commercial end product for which tea is grown is the growing shoots (2 to 3 leaf and a bud). Tea is basically a tree growing to a height of 20 to 30 feet but it is trained as a bush and managed at a comfortable height by periodical pruning to facilitate plucking of shoots.

Shoot Generation

As soon as a shoot is plucked, it stimulates the growth of buds from the axils of leaves below it. Immediately following tipping (the first plucking after pruning) and regular plucking, axils at two or three leaves below the point of plucking are stimulated to grow leading to multiplicity of plucking points. These buds take 40 to 110 days depending on growing conditions mainly that of temperature and water availability with unconstrained supply of nutrients to grow into a pluckable shoot.

The multiplicity quotient decreases with time from tipping as the cycle advances. Thus the plucking points increase with every plucking from tipping onwards exponentially reaching asymptomatic plateau after 10 to 12 generations. In other words, the degree of multiple stimulation decreases progressively from tipping onwards up to next prune. Normally after 18 to 24 months from the time of prune the stimulus is restricted mainly to leaf axil below the point of plucking. One could easily note that any breaking back up to 24 months since prune could adversely affect the multiplicity of plucking points (Table 1).

Multiple shoots also occur due to more than one bud growing from the same axil. The occurrence of multiple buds in leaf axils decreases in the order, mother leaf axils, fish leaf axil and scale leaf axils and also decrease with length of time from pruning. Breaking back at the time of plucking is carried to thin the shoots growing from the same axil. The shoots growing from the same axil open out and grow in different angles and fill the plucking surface eliminating hollows on the surface resulting in increased density of plucking points for future crop. They also do not cause either chocking and congestion of the surface or crowding of shoots of the type, normally imagined to occur when breaking back is not done. Nevertheless surface becomes little uneven and this should be accepted as long as it is associated with increase in crop. Some of the factors affecting the growth of shoots are summarized in Table 2.

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Table 1: Multiplicity of Plucking Points (Mc)

Equation	$Mc_n = 1 + 4\ e^{-0.30n}$: Mc_n- multiplicity coefficient at 'nth ' generation ; '1'is the lower limit of Mc; (1+4) is equal to the maximum Mc observed in primary shoots developed after the prune;0.030 is a constant that determine the rate of decline in multiplicity coefficient with age from pruning and depends on spreading behavior of clones							
Months after prune	0	2 #	6	12	24	36	48	60
Generation	0	1	3	6	12	18	24	30
Multiplicity coefficient	5.0	4.0	1,67	1.02	1.00	1.00	1.00	1.00

Tipping of primary shoots completed

Multiplicity coefficient is the number of new growing points created at the point of plucking

On an annual mean of 60 days for the growth of shoots, one generation of crop is harvested in two months

Table 2: Factors Affecting growth of shoots

Climate	Temperature is related to Elevation and rainfall of the region
Photoperiodism	Requires 11hours and 15 minutes for growth
Monsoon / heavy continuous rains	Die back of shoots
Multiple bud creation	ML>FL>SL Plucking
Turning banjis	SLbuds >> 3rd or 4th leaf buds ;Any stress (Water nutrients and climate

Sensitivity analysis of factors affecting growth rates

(1) Climate-50% ; (2) Clones / cultivars-10% : (3)Fish, mother, Scale leaf plucking-0.4%;

(4) Shoots from banjhi / flush leaves -0.0% ; (5) others 36%

Time taken to grow to a pluckable shoot t_g= 120 –(ACP*70)

Anamallais Mean ACP 0.87 tg=59 days 40 to 90 days Coonoor mean ACP=0.77 t_g= 66 days (40 to 95 days)

ACP-agro-climatic potential (Ranganathan *IJPS* ,1 (2):11-14.)

The plucking points increase at a faster rate to start with; but get slowed down, stagnant or reduced due to (1) age from pruning and (2)breaking back and cleaning up operations undertaken to gain shoot weight and plucking average and (3) to contain the creep of bushes and maintain the muttom (plucking surface) at the cost of overall productivity. The group of estates with highest productivity in India or probably in the whole world is not doing any breaking back. All other groups are doing breaking back to a varying degree with their rankings going down with increase in the degree of breaking back carried out by them.

Generalized concepts are therefore deve1oped for yield in relation to rate of formation of plucking points and shoot weight. The yield obtained at nthgeneration from / tipping could be expressed by any one of the equations given in Table 3.

In the equations 'n' represents the number of vertical generations which is equal to the required period for computing yield in days divided by the days taken for a bud to sprout and grow to a pluckable shoot of given standard and style of plucking. It varies and is dependent on growing conditions but the annual mean varies between 60 and 70 days with increase in altitude. As such 5 to 6 generations could be plucked from one growing point. It may be noted that the equations consists of three parts; (1) represented by the coefficient 'a' - the increase in number of plucking pointsgeneration after generation, (2) represented by the coefficient 'b' - giving correction for fall in compound rate of production of plucking points and (3) represented by the coefficient 'c' - average weight of shoots which show declining trend from tipping onwards as the plucking points increase.

The number of plucking points in different years of pruning cycle in two different clones,one Assam and one China planted at 10000 bushes / ha is shown in Table 4 below along with corresponding shoot weight and yield.

Table 3: Generalized concepts for yield in relation to rate of formation of plucking points and shoot weight

(1) $Y_n = (X_t(1+a)^n (1+b)^n)(W_t(1+c)^n)$ or

(2) $Y_n = (X_t e^{an+bn})(W_t e^{cn})$

$\mathbf{Y_n}$– the yield at nth generation; 'X_t'the number of plucking points at tipping; '**a'** Coefficient of multiplication of shoots; '**b**'Coefficient of reduction in multiplication of shoots due to breaking back and competition for distribution of nutrients to increasing number of growing shoots;'$\mathbf{W_t}$' Weight of shoots at tipping time; '**c'** Coefficient, of reduction in weight of shoots consequent to increase in number of plucking points. The cumulative yield "y" for "n" generations are given by:

(1) $Y = X_t\ [(a^{n+1}-1) / (a-1)]\ \ [(b^{n+1}-1) / (b-1)(n+1)]\ \ W_t(c^{n+1}-1) / (c-1)(n+1)$

(2) $Y = \{X_t[e^{a(n+1)}-1 / (e^a-1)]\ \ [(e^{-b(n+1)}-1) / (e^b-1)(n+1)]\}\ [W_t(e^{-c(n+1)}-1) / (e^c-1)(n+1)$

Table 4: Plucking points, shoot weight and yield of Clones

Clone	B/5/63					ATK				
Particulars	A	B	C	D	E	A	B	C	D	E
Plucking points/bush	10	80	290	300	286	10	240	520	600	566
Weight of shoot, g	4.0	2.1	0.89	0.87	0.83	2.0	0.65	0.48	0.44	0.44
No of generations/annum	-	5.5	7.0	7.0	7.0	-	5.5	7.0	7.0	7.0
Yield made tea kg/ha	-	2100	3900	4000	3900	-	1800	3800	4100	3800

A-at tipping: B-first year mean: C-second year mean: D-third year mean: E-fourth year mean

From the above Table 4, one could note that the shoot weight falls rapidly from tipping time up to 18 to 24 months after prune. Thereafter it remains more or less same indicating the importance of generating plucking points from the time of tipping up to 24 months to get the productivity in the pruned and second year of the cycle by exploiting the advantage in shoot weight. From third year onwards the productivity is determined by the plucking points already established taking the advantage of the high multiplicity factor of growing points in the first and second year of the cycle.

The plucking points after the prune are zero and increases to 500 to 900 per $m^2$and more. Between these limits rate of increase in plucking points is given by the equation.

$PP_n=PP_{max}–PP_{max}\, e^{-an}$ 1

Where (1)PP_{n-}Plucking points at ‘n’ months after pruning; (2) PP_{max-}maximum plucking points per unit area dependent on morphological and genetic aspects of cultivars when other factors are not limiting (3) ‘a’ constant determining the nature of the of increase of plucking points as discussed earlier.

The weight of shoot on the contrary decreases with the time from pruning for reasons already discussed. Between the two limits of the maximum weight of shoot at tipping and tapered weight after 24 months after the prune, the rate of decrease in weight is defined by exponential equation and it is given below.

$W_n = b+c\, e^{an}$ 2

Where W_n is the weight of shoot in ‘g’ at n^{th} month after the prune ‘b’ +‘c’ is the maximum weight at tipping or at ‘o’ month and ‘b’ denotes the tapered weight at infinity. “n “ is the number of months from the prune. ‘a’ is the constant determining the rate of decrease in weight of shoot.

The results of studies on the rate of increase in plucking points and the decline in shoot weight made on two Clones of wide differences in their morphological characters are given in Table 5 and 6 respectively.

Yield of Tea: The importance of plucking points, weight of shoots (genetic factors) and generations of harvest are brought out in the above discussions. The implications of these studies on productivity management are further indicated.

Table 5: Increase in Plucking Points

Clone	B/5/63							ATK-1						
Characters	Assam type, broad leaved orthotropic							China type, small leaved, plagiotropic						
Equation	$PP_n = 500\text{-}500e^{-0.02n}$ (PP_{max}=500; a=0.02)							$PP_n = 700\text{-}700e^{-0.06n}$ (PP_{max}=700; a=0.06)						
Details	Plucking points per m^2													
	Time after prune—in months							Time after prune—in months						
	0	1	12	24	36	48	60+	0	1	12	24	36	48	60+
As per equation	0	10	107	190	257	309	350	0	40	359	534	619	661	680
Observed	0	10	80	290	300	286	Pruned	0	10	240	520	600	566	Pruned

Table 6: Decrease in weight of shoots

Clone / Equation / Details	B/5/63 $Wn= 0.8 + 3.2\, e^{-0.09n}$						Weight of one shoot ‘g’	ATK-1 $Wn= 0.44 + 1.56\, e^{-0.11n}$						
	Time after prune—in months							Time after prune—in months						
	0	1	12	24	36	48	60+	0	1	12	24	36	48	60+
As per equation	4.0	3.72	1.89	1.17	0.93	0.84	0.80	2.0	1.84	0.86	0.55	0.47	0.45	0.44
Observed	4.00		2.10	0.89	0.87	0.83	P	-	2.00	0.65	0.48	0.44	0.44	P

W_n= weight of shoot at ‘n^{th}’month after prune; P= Pruned

Yield Equation in tea: The simplest way of expressing the yield in practical terms is given below.

$Y = S_n \times S_w \times OT$ ....(1)

Where, Y= yield; S_n=number of shoots -harvested; S_w=mean weight of shoots and OT=out turn (commercial tea to green leaf ratio)

$S_n = P_n \times G_v$ . . . . (2)

Where, P_n = plucking points and G_v = vertical generations taken from the same plucking points. The shoots plucked are also equal to:

S_n = SPR X PR .... (3)

Where, SPR = shoots plucked per round and PR = plucking rounds.

All plucking points are not harvested in a plucking round. Establishment of plucking rounds create shoots of different ages called horizontal generations and only pluckable shoots which have attained certain predetermined and required shoot age for a given standard and style of plucking are plucked every time. The number of horizontal generations occurring on the bush at any given time is equal to growth rate in days required for a bud to sprout and grow into a pluckable shoot divided by the interval between two plucking (plucking interval). About half of the generations are visible above the surface. The shoots plucked in a given unit time is given by;

$S_n = SPR \times G_H \times G_V$.........(4)

Where, S_n= the number of shoots plucked; SPR= SPR = shoots plucked per round: $G_{H=}$horizontal generations :

G_V= vertical generations: G_H is also numerically equal to the number of plucking rounds needed to complete the harvest of one vertical generation crop.

Generations and Productivity

The horizontal generations are increased by decreasing the plucking interval and the vertical generations are increased by hard and fine plucking. The plucking points are increased by preventing the decline of the multiplicity coefficient by ' zero ' or 'minimum' breaking back and good crop husbandry and manuring practices.

In shear / machine harvesting with about 30 days plucking interval there will be two generations of shoots, out of which one will not be visible. Hence muttom shearing / machine harvesting will harvest only one generation of crop on the surface ensuring uniform standard of leaf once the system is stabilized.

Above discussions lay emphasis on the interactions of the following factors- (1)increasing the number of plucking points (2) increasing the number of vertical generations and (3) increasing the shoot weight-in determining the ultimate quantum of harvest.

Plucking Points

Regular plucking increases the rate of increase of plucking points as every point plucked stimulates more than one bud to sprout and grow, and establishes a rhythm of growth enabling to put the harvesting schedule on a scientific basis.

The plucking points are increased by increasing the intensity of plucking; plucking all pluckable shoots and soft banjhis. Fly plucking, co1lecting only a fraction of pluckable shoots, delays the formation of new plucking points to the extent of shoots left on the bush and reduces the number of vertical generation from those shoots.

Generation of multiple shoots from the same axil and shoots from two or more axils below the point of plucking decreases with length of time from pruning. Early tipping and plucking at shorter intervals for a period of 6 to 9 months from tipping help to increase plucking points and thereby helps to get higher yields in the pruned year and also in subsequent years.

Nitrogen increases the number of plucking points. Starting application of fertilizers early at 2 to 3 leaf stage after the pruning helps to increase the plucking points by the tipping time. Deficiency of any one nutrient reduces the number of p1ucking points.

Breaking back and frequent surface cleaning in the name of muttom maintenance reduces the number of plucking points. These are the practices recommended when there was no nutrient support to growing points which turn banjhi or reduce the size of leaves. The modern nutrient management systems ensure support to all growing points and as such these practices are to be avoided.

Vertical Generation

Regular removal of banji above the plucking surface as an integral part of plucking enhances the number of vertical generations on these shoots by stimulating bud break which otherwise take much longer time.

Plucking all the manufacturable shoots which will otherwise become coarse by the next plucking will result in increase of mean number of vertical generations that could be harvested from all the plucking points plucked at the correct time.

Finer the plucking and harder the plucking increase the number of vertical generations. For example, two leaves and a bud plucking over fish leaf takes about 40 days, three leaves and a bud over fish leaf takes about 49 days and three leaves and a bud over mother leaf take 63 days and they produce respectively 8.6, 7.4, and 5.8 generations per year.

Climatic conditions particularly, day 1ength, moisture and temperature influence the number of vertical generations produced through their effect on growth of shoots.

Weight of Shoots

The shoot weight is increased by reducing congestion or choking on the surface by breaking back. This result in loss of plucking points, the loss being proportional to the severity of breaking back and the loss is much more than the gain in shoot weight. Moreover, as pointed earlier, nothing much is gained on shoot weight manipulation from the end of second year onwards in the pruning cycle.

Both coarse (standard) and light (style) plucking increase the weight of shoots; but both reduce the number of vertical generations which has an adverse effect on productivity.

Potassium increases the weight of shoots. Deficiency of any one nutrient particularly zinc decreases the weight and size of shoots as the immediate reaction.

The shoot weight decreases with length of time from the prune with increase in number of plucking points. Along with adequate nutrient support, optimum shoot weight could be maintained by regulating age of shoots plucked by rigid control over standard and style of plucking, and plucking interval. Some prefer to use day degrees to indicate shoot age while others prefer to adopt varying plucking intervals depending on growing conditions. None the less, the end objective is the same i.e. to pluck shoot at optimum physiological age.

Conclusion

At any given situation (jat and the length of time from prune) the shoot weight could be manipulated only within a narrow range as there is an upper limit for the weight of shoots. All the three factors (plucking points, generation and shoot weight) interact within a narrow range compensating the benefits accrued from one with damage done by others and vice versa. For a breakthrough a bold decision to markedly alter the policies so as to manipulate only those factors which have no upper limit beyond the interacting levels and which have marked and significant overall influence is necessary. These factors are number of plucking points and vertical generations. *A* system of 'minimum' or 'zero' breaking back with a standard and style of plucking, be it hand plucking shearing or machine harvesting, suited to the type of manufacture and dictated by the climatic conditions will give desired results.

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