



Effect of summer shoot tip pruning and early winter de-flushing on flowering, fruit yield and quality of litchi (*Litchi chinensis*)

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ABSTRACT

The present study was undertaken at the National Research Centre on Litchi, Muzaffarpur, Bihar for two consecutive years 2011-12 and 2012-13 in the young bearing litchi (*Litchi chinensis* Sonn.) orchard of cv. Shahi to see the effect of shoot tip pruning and de-flushing on reproductive behaviour and fruit yield in litchi. This study confirmed the treatment of shoot tip pruning in mid June evoked maximum number of panicles (41.8% during 2011, 50.5% during 2012-13), causing maximum phase change under the annual production cycle, leading to maximum flowering (860.8 and 1004.3 nos./panicle) with moderately higher fruit set (2.11 % and 4.22%) and highest fruit yield (19.4 kg/tree and 31.9 kg/tree), the pronounced effect recorded when treatment of flush removal applied during mid November, which bore maximum number of panicles (47.3% during 2011-12, 64.3% during 2012-13), maximum flowering (1110.0 nos and 898.5 nos of flowers /panicle) with moderately higher fruit set (3.17% and 4.14 %) and highest fruit yield (25.5 kg/tree and 27.9 kg/tree) in litchi during both the years. Shoot tip pruning in late summer (mid July and mid August) and flush removal in December had virtually poor crop yield since most of the de-flushed branches did not projected a flush of either type of vegetative or reproductive growth before the normal time of even panicle emergence. The study also showed that the age of the previous flush modifies with the cool-temperature-induced floral response during winter season, while older stems exhibited a higher percentage of reproductive growth by phase change in the form of panicle emergence. The operation of flush removal in mid October displayed only a higher percentage of a vegetative growth and while de-flushing in December projected no growth or if any only vegetative nature. The treatment having pruning in mid June and practice of uniform size and aged (5-8cm) flush removal in the month of November (mid) exposed to low temperature under the conditions of north Bihar leading to highest fruit yield (37.75 kg/tree) and better quality fruits (38.42 % under extra class) with minimum wastage.

Key words: De-flushing, Flushes, Fruit set, Fruit yield, Panicle emergence, Phenological changes, Quality grades, Tip pruning

The litchi (*Litchi chinensis* Sonn.) tree is an evergreen tree in nature having spectacular dark green foliage throughout the year and what is desirable is the clusters of delicious red fruits at particular juncture of time. Unlike other perennial fruit trees, litchi is very fastidious in its climatic requirement, as irregular flowering and erratic bearing resulting inconsistent poor quality fruit yields is related to variations in timing of flushing and its interactions with the environmental factors. Bihar, the premier state in litchi production in India, provides suitable soil and climatic conditions for excellent quality fruit production. Recently, the era of climate change has also influenced the trend of litchi production, which requires the needful manipulations of some regulative operations for successful fruit production. The phenological occurrence incorporate adaptations to climate including timing of flowering and

stress (desiccating) conditions. Growth occurs as periodic, ephemeral flushes of shoots emerging from apical or lateral resting buds before returning to a quiescent state. Litchi tree responds to different extent of punning and its timely operations. Apart from it, the frequently encountered limiting factor in commercial litchi fruit orchard, is erratic bearing behaviour due to non-occurrence of phase change from vegetative to reproductive stage. Though, by default pruning conducted during harvesting of fruits is not proper and is unable to bring forth enough numbers of bearing shoot for the next year in its natural phenomenon of flushing and shoot emergence, remains only vegetative throughout the year. For flowering and fruit producing generative shoots, i.e. panicles, which produce inflorescences borne on the same nodes at particular juncture of time for desired outcome (fruit production). In the ephemeral episodes of vegetative growth occurring, there may be several flushes of vegetative shoots per year, but flushes of reproductive shoots usually occur only once

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per year on individual stems, which is dependent on the interaction of so many natural and independent factors. In litchi, pruning operations impact the normal growth cycle including both vegetative and reproductive phase. Tree management strategy to increase shoot numbers (fruiting units) and induce panicle emergence leading to profuse flowering for fruit production is very important for successful litchi cultivation. Based on the handful information through references and developed concept, an attempt has been made to bring out the solution for regular bearing and high quality fruit production. Hence, the present investigation was designed to regulate the fruit production and quality through timely pruning and de-flushing treatments in the time frame of annual production cycle.

MATERIALS AND METHODS

A field experiment was conducted at the National Research Centre on Litchi, Muzaffarpur, Bihar for two consecutive years 2011-12 and 2012-13 in the young bearing orchard of cv. Shahi at 8.5m × 8.5m of 11 years old plantation. The experimental site is located at 25°54' to 25°23' latitude and 84°53' to 85°45' longitude. The treatments were based on pruning operations of entire outer canopy contributing branches/twigs (including harvested ones) preferably of pencil thickness in the summer months and monitoring the ephemeral episodes of concurrent flushing for the timely selective flush removal. The experiment conducted in factorial RBD with sixteen treatments replicated twice, having unit of two trees in each treatment. The treatments comprised of four numbers of pruning operation as P₀ - No pruning; P₁ - pruning at mid June; P₂ - pruning at mid July and P₃ - pruning at mid August, while treatments of de-flushing (flush removal) of newly emerged green flushes of 5cm to 10cm were comprised of as D₀ - no flush removal; D₁ - flush removal during mid October; D₂ - flush removal during mid November and D₃ - flush removal during mid December. The observations were recorded accordingly for each year on number of shoots which bore panicle (%), number of flowers per panicle, sex ratio, fruit set (%), number of fruits per panicle, fruit yield (kg/plant) and its quality attributes. The fruit yield was also categorized into different quality grades. The quantitative characteristic data have been put to statistical analysis under factorial RBD fashion.

RESULTS AND DISCUSSION

The meteorological observations (temperature and relative humidity) recorded for the study period (i.e. 2011 to 2013) clearly indicated the trend of occurrence and its yearly changing nature. The harvesting of previous litchi crop almost ended during last week of May in all the years and the treatments imposed accordingly taking care of the vegetative growth period, phase change and reproductive behaviour including fruit yield. In Bihar conditions, the low temperature and cool months are treated as December to February (minimum - 7.0°C to 14°C and maximum - 12°C

to 20°C) and humidity which also plays a great role in deciding the vegetative and reproductive growth phase with the interaction of temperature found to be varying in erratic manner due to climate change effect. Relative Humidity (%) mean values recorded for these low temperature occurring cool months varied from 87.0% to 94% at 07.00 hr and 43.0% to 64.0% at 14.00 hrs during all the three years. The prevailing situation clearly encourages vegetative phase causing reduction in fruit yield (Kumar 2015). The climatic issues indicated the need of proper treatment application and management strategies for regulating successful litchi cultivation. The vegetative and reproductive growth regulation have been observed to be significantly influenced through shoot tip pruning and de-flushing treatments by these yearly changing weather parameters (Kumar 2015).

Responses to late summer pruning

Perusal of Table 1, showed that the panicle emergence recorded under the treatments receiving shoot tip pruning during the period starting from mid June to mid August varied from 27.20% to 45.90%. The data recorded for panicle length also showed the significant variation during both the years (22.3 cm to 40.5 cm during 2012 and 22.7 cm to 36.3 cm during 2013). The number of flowers appeared per inflorescence also showed the distinct variation for tip pruning treatments (418 to 809 numbers of flowers per panicle during 2012 and 712 to 970 numbers of flowers per panicle during 2013). The fruit set was observed to be high in case of shoot tip pruning done in the month of June (mid) as 2.34% during 2012 and 6.54% during 2013 (having mean value 4.44%) found dependent on number of flowers/panicle. The individual effect of tip pruning in mid June also recorded the maximum values for fruit weight per panicle (142.0 g during 2012 and 266.8 g during 2013) but the other treatments receiving shoot tip pruning have very low fruit weight per panicle (Table 2). Generally shoot growth in litchi is not continuous (Verheij and Coronel 1991), there is a rapid period of shoot elongation and leaf expansion followed by a period of leaf maturation, before the next period of shoot growth. While, the duration and interval of growth (either vegetative or reproductive) are strongly related to environmental conditions. Each flush produced takes a short period of its elongation, leaf expansion and finally physiologically maturation to be ready for the next episode. As it is found that just after the harvesting of previous crop and pruning of physiologically mature all those stems/twigs contributing to canopy, soon stimulates initiation of bud break in apical or lateral buds, respectively. When shoots of different age group are exposed to prevailing warm temperatures (35°C day/25°C night) at the time of shoot initiation, the resulting shoot growth is purely vegetative but not synchronous. The cyclic initiation of shoots also included as extension growths on dormant stems in the treatment of pruning, during the period of warm humid summer months, is found dependent upon the age and climatic conditions mainly

influenced by temperature and humidity. It has been found in agreement with the findings of many workers that developing vegetative shoots are rich sources of auxins and gibberellins, which may be involved in regulating the timing of subsequent shoot initiation (Davenport 1986, 1990; Menzel 1983, 1984). Light pruning in the subtropics during warm summer months results in initiation of vegetative shoots from axillary buds (Menzel 1984).

It has been hypothesized by many fruit physiologists/ research workers that a putative signal, which triggers initiation of shoot development, is separate and different from the inductive signal that determines the fate of the shoot. Removal of apical bud at the flushing stage by pinching/removal/light pruning stimulates initiation of axillary shoots in lateral bud. The shoots that emerge in response to these initiation stimuli, however, are determined by other environmental factors unrelated to initiation and which are prevalent at the time that initiation occurs, under the particular time frame of fruit production cycle. Environmental interactions between successive growth cycles are very important in perennial plants more particularly for litchi. This result get supports from the findings of many workers that summer pruning including selective removal of shoots or branches during the growing season lead to maximum flowering, fruiting and fruit yield (Davenport 1986, 1990, Flore 1994, Menzel 1983, 1984) and more specifically the time factor, tools and the approaches adopted (Davenport 1990, Menzel and Waite 2005). Although summer pruning can therefore be applied from as early as the beginning of growth season after the harvest of previous crop with different very less severity is most important, the grower's experiences (Kumar 2013, 2015).

Responses to early winter de-flushing

The data recorded for the treatment of deflushing operation practiced from mid October to mid December for number of shoots which evoked panicles, varied from 20.60% to 55.80% showing distinct phase change (Table 1). The operation of deflushing in mid November in conjunction with summer pruning in early months gave high values of panicle emergence (Fig 1). The values for number of flowers borned per panicle particularly under deflushing treatments recorded were slightly higher when compared to pruning treatments (425 to 898 numbers per panicle during 2012 and 707 to 1110 numbers per panicle during 2013). The deflushing treatment in mid November in the treatment combination with summer pruning in mid June gave high values of panicle emergence (Fig 2). The similar trend of fruit set (%) was observed that higher the number of flowers, better the fruit set. Though, the fruit set varied from 1.82% to 2.34 during 2012, while it was 3.72% to 6.4% during the year 2013. The distinct effect of pre winter

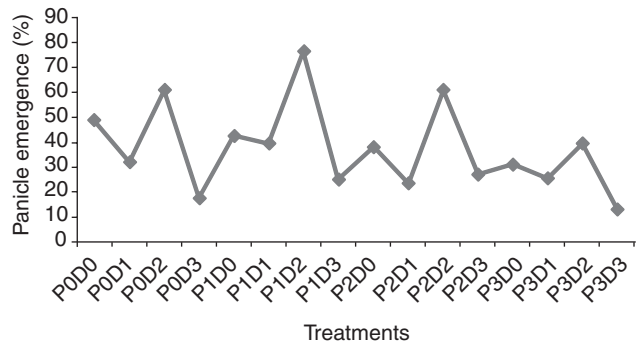


Fig 1 Number of shoots evoked panicles (%) as influenced by tip pruning and de-flushing in litchi

Table 1 Reproductive growth characters and fruit set (%) in litchi as influenced by time of pruning and de-flushing operations

	No. of shoots evoked panicles (%)			Panicle length (cm)			No. of flowers/ panicle			Fruit set (%)		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
<i>Pruning</i>												
P ₀	31.5	48.0	39.75	28.3	36.3	32.3	785.0	0970.0	827.5	1.41	3.73	2.57
P ₁	41.8	50.0	45.90	28.0	40.5	36.3	809.0	0912.5	860.8	2.34	6.54	4.44
P ₂	21.8	45.5	33.65	32.3	40.3	34.3	487.0	0747.5	617.3	2.11	4.22	3.17
P ₃	18.4	36.0	27.20	23.0	22.3	22.7	418.5	0712.5	560.5	1.82	4.27	3.05
CD (P=0.05)	8.24	5.12	6.54	4.16	3.86	1.98	96.52	102.54	133.22	0.89	1.22	1.32
<i>De-flushing</i>												
D ₀	31.0	49.0	40.0	35.5	39.0	37.3	606.5	0905.0	755.8	1.98	4.79	3.39
D ₁	22.8	37.5	30.15	31.5	34.5	33.0	569.5	0720.0	644.8	1.76	4.33	3.05
D ₂	47.3	64.3	55.80	32.0	38.3	35.2	898.5	1110.0	1004.3	2.20	4.14	3.17
D ₃	12.5	28.8	20.60	12.5	27.5	20.0	425.0	0707.5	566.3	1.74	4.69	3.22
CD (P=0.05)	7.33	6.62	10.12	6.22	4.12	2.16	089.46	146.22	156.4	1.02	NS	NS
<i>Interaction</i>												
P × D	28.4	44.9	36.65	27.9	34.8	31.4	624.9	860.6	742.8	1.92	4.48	3.20
CD (P=0.05)	6.46	5.42	6.55	4.34	3.92	2.12	92.35	136.22	148.24	0.96	NS	NS

P₀- No pruning, P₁- Tip pruning at mid June, P₂- Tip pruning at mid July, P₃- Tip pruning at mid August; D₀- No flush removal, D₁- Flush removal in mid October, D₂- Flush removal in mid November, D₃- Flush removal in mid December

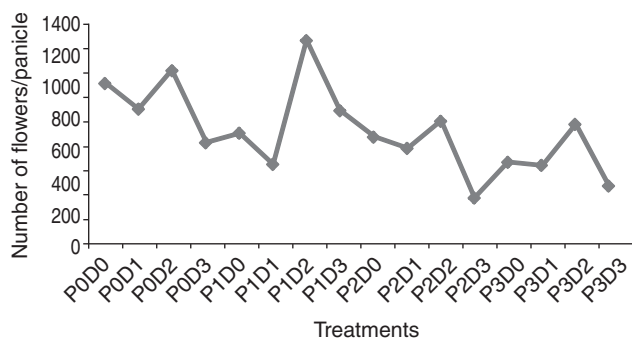


Fig 2 Number of flowers/panicle as influenced by tip pruning and de-flushing in litchi

deflushing was recorded the maximum for fruit weight per panicle (66.0 g during 2012 to 192.8 g during 2013) but the other treatments of deflushing have low values (Table 2).

The exposure of matured shoots with removed new flushes in mid November, i.e. early cool winter months resulted in initiation of maximum panicles (55.80%) developing to inflorescences. It has also been observed that deflushing had very pronounced effect on reproductive phase, when practiced during the period of November (mid) as compared to October and December months. Trees de-flushed in December had virtually very poor crop since most of the de-flushed branches tip did not project a bud or flush of growth before the normal time of even panicle emergence. Trees de-flushed in October, developed sprouts leading vegetative shoot did not transformed to panicle and resultantly very less flowering, fruit set and fruit bearing. It is clearly observed that the onset of shoot development is initiation stage regardless of the type of shoot evoked in the annual growth cycle but initiation of shoot growth in the form of panicles of resting/matured

stems is the first event that occur after induction of low temperature, which later produce inflorescence bearing flowers (Menzel and Waite 2005). It commences with the first event involved in the cell division and cell elongation of dormant cells specially in leaf primordia (vegetative shoot), axillary meristems (generative shoots) or both (mixed shoots), followed soon thereafter by cell divisions in the apical meristem. Shoot initiation has been found stimulated by pruning and deflushing along with the effect of environmental factors (causing shift from warm to cold to warm temperatures). There are references clearly mentioning that at the initial stage of initiation of bud giving rise to shoots, its type (vegetative, generative and mixed) of shoots are not decided, as this characteristic is strongly influenced by climatic factors more particularly by low temperature (Davenport 1986, 1990; Flore 1994; Menzel 1983, 1984; Menzel and Waite 2005). If it is instead maintained in cool conditions (21.0°C day/9.0°C night), it produces generative shoots. If selective tip pruning is done in summer months (before actual vegetative growth periods), initiation of bud break may take very less as evidenced by many workers (Davenport 1990, Davenport and Nuñez-Elisea 1997). Vegetative or generative shoots are, thus, evoked according to shoot maturity and environmental conditions present at the time of initiation (Batten and McConchie 1995; Nuñez-Elisea and Davenport 1991a, Nuñez-Elisea *et al.* 1991, 1996, Southwick and Davenport 1986, 1987). Stems do not retain their floral inductive potential when removed from the cool environment. If transferred from cool to warm temperatures before initiation of bud break, then the new shoot growth is vegetative instead of reproductive and vice versa (Davenport 1990, Nuñez-Elisea *et al.* 1996). This point was further reinforced by observations that vegetative (V) or

Table 2 Fruit bearing and fruit yield in litchi as influenced by time of pruning and de-flushing operations

	No. of fruits/panicle			Fruit weight (g)/panicle			Fruit yield (kg/tree)			Fruit yield (tonnes/ha)		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
<i>Pruning</i>												
P ₀	5.5	10.5	08.0	108.8	188.8	148.8	14.2	29.4	21.8	2.07	4.23	3.15
P ₁	6.0	12.8	09.4	142.0	266.8	204.4	19.4	31.9	25.7	2.79	4.59	3.69
P ₂	5.5	09.0	07.3	119.8	170.5	145.2	13.0	12.8	12.9	1.87	1.84	1.86
P ₃	3.3	06.8	05.1	085.3	144.0	114.7	10.0	10.6	10.3	1.44	1.52	1.48
CD (P=0.05)	0.45	2.24	1.56	11.34	16.19	13.30	4.32	5.54	5.12	0.68	0.32	0.46
<i>De-flushing</i>												
D ₀	5.5	09.5	07.5	111.0	166.8	138.9	14.1	21.9	18.0	2.02	3.15	2.59
D ₁	3.5	09.3	06.4	086.0	184.5	135.3	10.8	21.7	16.3	1.58	3.12	2.35
D ₂	8.3	12.5	10.4	192.8	256.5	224.7	25.5	27.9	26.7	3.66	4.01	3.84
D ₃	3.0	07.8	05.4	066.0	162.3	114.2	06.3	13.2	19.8	0.90	1.91	1.41
CD (P=0.05)	1.92	3.02	2.86	24.22	21.44	19.24	6.96	6.66	5.98	0.92	0.61	0.78
<i>Interaction</i>												
P × D	5.1	7.8	06.5	113.9	192.5	153.2	14.2	21.2	17.7	2.04	3.04	2.54
CD (P=0.05)	0.96	2.44	1.22	14.66	19.26	16.22	5.84	5.72	5.42	0.78	0.46	0.62

P₀- No pruning, P₁- Tip pruning at mid June, P₂- Tip pruning at mid July, P₃- Tip pruning at mid August; D₀- No flush removal, D₁- Flush removal in mid October, D₂- Flush removal in mid November, D₃- Flush removal in mid December

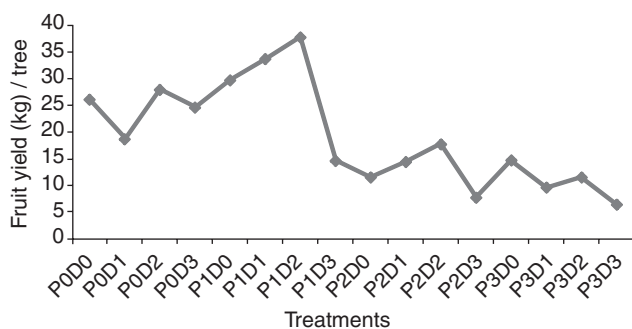


Fig 3 Fruit yield (kg)/tree as influenced by tip pruning and de-flushing in litchi

generative (G) shoot types can be reversed in litchi during shoot morphogenesis. Transition shoots ($V>G$) were evoked when early bud development (Batten and McConchie 1995, Nuñez-Elisea *et al.* 1996).

Fruit yield and quality

Perusal of Table 2, showed fruit yield per tree that was recorded maximum (19.40 kg/tree during 2012 and 31.9 kg/tree during 2013) in case of tip pruning done in the month of June compared to the pruning treatments done during different summer months. The practice of deflushing treatment showed the consistent values for fruit yield and its quality attributes, as fruit yield was recorded maximum (25.50 kg/tree during 2012 and 27.9 kg/tree during 2013). The treatment combination comprising of shoot tip pruning in the month of mid June and early winter de-flushing done in the month of mid November (P_1D_2) recorded the maximum fruit yield (37.75 kg/tree) and this interaction effect was found to be significant (Table 2, 4), clearly depicted through Fig 3. Fruit yield showed low values for the treatment having no pruning and/or deflusing done during mid October and also doing late, i.e. during mid December (P_0D_3). Effect of various treatments were found to be varied significantly for fruit length, fruit diameter and fruit weight (g). Total soluble solids (TSS) percentage was found to be highest in the fruits borned on the inflorescences in the treatment combination of tip pruning done in the month of June, while early winter de-flushing done in the month of mid November (P_0D_3). Pruning and flush removal resulted in better health and fruiting performance in respect of maximum numbers of emerged shoots and fruit retention per panicle based on initial fruit set per panicle.

Under the quality characteristics, it has been found that maximum fruit weight (24.12g) was recorded under the treatment combination of tip pruning in mid June and de-flushing done in the month of mid November (P_1D_2) might have contributed positively for fruit yield, which was followed by the treatment combination (P_0D_2) having no pruning and de-flushing done in the month of mid November (23.98g). The obtained fruit yield (kg/tree) was categorized into different quality grades, clearly indicated that the treatments recorded high fruit yield have also showed high values of fruit yield under quality grades (Table 5). The treatment (P_1D_2) having shoot tip pruning in

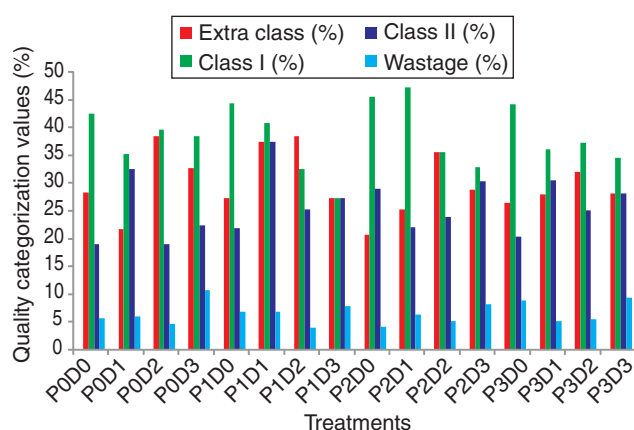


Fig 4 Fruit quality categorization value (%) under different quality grades as influenced by tip pruning and de-flushing in litchi

mid June and de-flushing in mid November also recorded the high quantum of fruits under Extra class category, i.e. exportable quality (38.52%) as depicted in Fig 4. The treatment (P_1D_2) recorded high value for fruit yield under extra class quality grades and the lowest wastage, under quality categorization study, suggesting the need of timely pruning and vegetative flush removal for enhanced quality fruit production (Table 3) and this finding also gets supported by many workers in case of perennial fruit crops (Singh 2007, Rai *et al.* 2001). Growth responses and quality fruit yield increased due to pruning and de-flushing may be attributed to altered hormonal conditions, storage of better hormonal-nutritional translocation in more numbers of de-flushed shoot tips and response of cool temperature induction. There were significant interactions between pruning treatment and operation of de-flushing treatment ($P \times D$). In discussion on competition between vegetative and reproductive growth observations, that fruits are dominant sinks and that new shoots (panicles) in the form of inflorescences, quickly becomes net contributors are sometimes used to relegate the potential for fruit growth to affect fruit yield and quality (Hieke *et al.* 2002). The results have practical implications for litchi tree management to enhance proper shoot growth and its maturity by minimising the vegetative re-flushing and enhance panicle emergence (reproductive growth), which will minimize the negative effect on fruit yield and quality (Galan-Sauco and Menini 1989, Kumar 2013).

The recent findings advocates timely pruning of litchi to facilitate healthy growth and the operation of flush removal for higher reproductive growth leading to better yield, finds agreement with the findings of Rai *et al.* (2001) in Bihar condition. Zhang *et al.* (1999) have also described the methods for pruning at top more similar to open centre window like to increase penetration of sunlight inside the canopy for better quality fruit yield. Selective pruning followed by de-flushing helped in timely fostering of strong and healthy shoots giving healthy inflorescence, which lead to higher quality fruit production. This particular treatment might have improved the storage of inherent

Table 3 Physico-chemical characteristics of fruits in litchi as influenced by time of pruning and de-flushing operations

	Fruit length (cm)			Fruit width (cm)			Fruit weight (g)			Total soluble solids (⁰ Brix)		
	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean	2011-12	2012-13	Mean
<i>Pruning</i>												
P ₀	3.12	3.23	3.18	2.95	3.03	3.10	22.05	23.43	22.74	20.78	20.63	20.71
P ₁	3.23	3.29	3.26	2.98	3.08	3.17	22.68	23.60	23.14	20.83	20.72	20.78
P ₂	3.23	3.26	3.25	2.98	3.06	3.16	22.91	23.88	23.39	20.30	21.19	20.76
P ₃	3.13	3.24	3.19	3.04	3.06	3.13	23.01	23.39	23.20	20.56	21.06	20.81
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.21	0.19	0.21			
<i>De-flushing</i>												
D ₀	3.15	3.21	3.18	2.89	3.04	3.09	21.44	23.27	22.36	20.55	20.86	20.71
D ₁	3.16	3.26	3.21	2.97	3.02	3.12	22.22	23.31	22.77	20.96	20.87	20.92
D ₂	3.25	3.31	3.28	3.04	3.10	3.20	23.95	24.15	24.05	20.62	21.29	20.96
D ₃	3.14	3.25	3.20	3.04	3.07	3.14	23.05	23.56	23.31	20.34	20.57	20.46
CD (P=0.05)	NS	NS	NS	NS	NS	NS						
<i>Interaction</i>												
P × D	3.17	3.25	3.21	2.98	3.05	3.13	22.66	23.57	23.12	20.61	20.90	20.76
CD (P=0.05)	NS	NS	NS	NS	NS	NS	0.44	0.23	0.39			

P₀- No pruning, P₁- Tip pruning at mid June, P₂- Tip pruning at mid July, P₃- Tip pruning at mid August; D₀- No flush removal, D₁- Flush removal in mid October, D₂- Flush removal in mid November, D₃- Flush removal in mid December

Table 4 Important reproductive characteristics and fruit yield (kg/tree) as influenced by interaction effect of time of pruning and de-flushing operations

Treatment	No. of shoots evoked panicles (%)	No. of flowers/ panicle	Fruit set (%)	Fruit weight/ panicle (g)	Fruit weight (g)	Fruit yield (kg/ tree)
P ₀ D ₀	48.5	1040	2.42	131.0	20.34	21.16
P ₀ D ₁	32.0	0880	2.11	177.0	21.46	18.48
P ₀ D ₂	61.0	1120	2.82	239.0	23.98	26.48
P ₀ D ₃	17.5	0670	2.99	133.0	22.44	09.36
P ₁ D ₀	42.5	0730	2.74	169.0	21.76	14.66
P ₁ D ₁	39.5	0535	3.50	199.0	22.82	18.66
P ₁ D ₂	76.5	1308	3.88	292.5	24.12	37.75
P ₁ D ₃	25.0	0870	3.55	157.0	22.96	12.81
P ₂ D ₀	38.0	0705	4.43	148.0	21.84	24.14
P ₂ D ₁	23.5	0635	4.10	128.0	21.46	15.86
P ₂ D ₂	46.0	0804	4.56	221.0	23.96	19.66
P ₂ D ₃	27.0	0325	4.00	083.0	23.46	12.16
P ₃ D ₀	31.0	0548	3.96	107.5	21.82	11.32
P ₃ D ₁	25.5	0529	2.52	077.0	23.14	19.63
P ₃ D ₂	39.5	0785	2.54	191.0	23.76	18.74
P ₃ D ₃	13.0	0400	3.18	083.0	23.34	10.68
CD (P=0.05)	6.55	148.24	NS	16.22	0.39	5.42

P₀- No pruning, P₁- Tip pruning at mid June, P₂- Tip pruning at mid July, P₃- Tip pruning at mid August; D₀- No flush removal, D₁- Flush removal in mid October, D₂- Flush removal in mid November, D₃- Flush removal in mid December

nutrient status of shoot (C:N ratio) due to timely selective pruning and later receiving the de-flushing operation facilitated the projection of more reproductive growth of shoots (Zhang *et al.* 1999). The high fruit retention per panicle and maximum fruit yield gets support from the reports that high fruit retention in litchi can be ensured by timely treatments of plants for strong and healthy shoot production which increased flowering phase and sex ratio, and finally the fruit setting rate (Rai *et al.* 2001). Pruning

Table 5 Fruit yield and quality characterization under different quality grades and extent of wastage in litchi as influenced by time of pruning and de-flushing operations

Treatment	Fruit yield (kg)/tree	Extra class (%)	Class-1 (%)	Class-1 (%)	Wastage (%)
<i>Pruning</i>					
P ₀	21.8	30.30	29.79	23.17	6.71
P ₁	25.7	32.63	38.85	27.95	6.35
P ₂	12.9	27.58	36.28	26.35	5.94
P ₃	10.3	28.66	40.33	26.02	7.16
<i>De-flushing</i>					
D ₀	18.0	25.71	33.08	22.51	6.04
D ₁	16.3	28.10	32.81	30.65	4.73
D ₂	26.7	36.14	36.20	23.65	9.02
D ₃	19.8	29.22	30.86	27.07	6.54
<i>Interaction</i>					
P × D	17.1	29.79	33.24	25.87	6.54

P₀- No pruning, P₁- Tip pruning at mid June, P₂- Tip pruning at mid July, P₃- Tip pruning at mid August; D₀- No flush removal, D₁- Flush removal in mid October, D₂- Flush removal in mid November, D₃- Flush removal in mid December

usually result in second vegetative flush occurring but its time and interaction of environmental factors clearly decide the vegetative and fruiting terminals. It is essential that there should be minimum times (1 or 2) of flushing of vegetative growth immediately after harvest following the synchronising pruning cuts (Davenport 2006) and operation of flush removal for fostering reproductive growth leading to inflorescences.

The trees receiving treatments having shoot tip pruning in summer months and following the practice of early winter period flush removal showed distinct variation at significant level for phase change, reproductive growth and quality fruit yield under the prevailing condition of climate change in litchi growing areas of Bihar state. The above study was carried out for the first time in litchi cv. Shahi for the shoot tip pruning and flush removal for enhancement of fruit yield and quality. The predictable extent of phase change from vegetative to reproductive and its cycle (involving flushing, shoot growth, panicle emergence flowering, fruit yield and quality) still needs further investigation which may involve biochemical and hormonal assays of these growth pattern and flushes. This would also help in decision making for cultural operations to be carried out during the critical phenological stages for harvesting higher yields with better quality. Armed with the basic information provided here, growers can manage flowering and fruiting to occur at any desired week of the year. Local environmental conditions (in Bihar) may alter the expected responses, but scrutiny of all of the factors should bring consistent success with timely treatments. The treatments receiving mid June pruning and operation of de-flushing in mid November in Bihar produced maximum flowering, fruit set, fruit yield with best quality fruits provided suitable climatic conditions for litchi production system, i.e. warm humid summer for full vegetative growth followed by dry cool winter for induction of flowering following fruit set and fruit growth with slowly rising temperature conditions for proper fruit growth and quality fruit yield.

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