Pak. J. Agri. Sci., Vol. 48(2), 107-113; 2011
ISSN (Print) 0552-9034, ISSN (Online) 2076-0906
http://www.pakjas.com.pk

PHENOLOGICAL GROWTH PATTERNS AND FLORAL MALFORMATION OF MANGO (*Mangifera indica* L.) TREE UNDER SUBTROPICAL CLIMATE

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Vegetative and reproductive growth pattern of mango tree cv. Langra and development of floral malformation were investigated under subtropical conditions. Vegetative flushes emerging during April were tagged for subsequent growth until August and then studied for three consecutive growth seasons. Growth of flushes occurred in alternate month's pattern. Re-growth frequency of April and April-based flushes decreased overtime. In the next flowering season, April and June flushes produced higher percentage of panicles while malformation intensity was recorded minimum (3.0%) in same flushes as compared to younger August flushes (12.9%). During subsequent growth season after flowering, April flushes contributed only 18.2% in the production of flushes while contribution of June flushes (31.1%) followed by May flushes (28.1%) with maximum. Out of total tagged April flushes, only 38.4% flushes could switch over to panicle production while rest of the 61.6% flushes did not bloom. So, it may be concluded that gradual decline in re-flushing capacity of April and June flushes during current year not only ensure their maximum contribution in next year's flowering but also cause less floral malformation while late emerging flushes contribute less towards next year's flowering and produce more floral malformation.

Keywords: Vegetative, reproductive, malformation, flushes, panicles, cv. Langra

INTRODUCTION

Mango (*Mangifera indica* L.) is being grown across a large latitude range of tropics and subtropics under widely varied environmental and soil conditions (Chapman, 2000; Iqbal *et al.*, 2007). It is also successfully cultivated commercially under diverse agro-ecological conditions of Pakistan (Ziaf *et al.*, 2004; Amin *et al.*, 2008). Generally a healthy mango shoot completes four to five flushing episodes per year (Davenport & Nunez-Elisea, 1997), while blooming occurs on a few of them during the following year (Issarakraisila *et al.*, 1991). However, older and more mature flushes accumulate sufficient reserves of carbohydrates to attain physiological maturity required for fruit bud differentiation (Sen and Malik, 1946; Singh, 1978). Nunez-Elisea and Davenport (1995) further endorsed the possibility of mature shoots having a level of some floral stimulus sufficient enough to cause floral induction. Later findings suggested that induction of generative (floral), vegetative or mixed shoots from axillary or apical buds of mature flushes appears to be governed by the interaction of an age-dependent vegetative promoter and a temperature-dependent florigenic promoter (Davenport and Nunez-Elisea, 1997; Davenport, 2000; 2003; 2007; 2009). Under subtropical conditions, cool temperature not only triggers bud break but also favours higher ratios of florigenic promoter to vegetative promoter in developing buds resulting in induction of generative shoots (Nunez-Elisea and Davenport, 1995; Ramirez and Davenport, 2010). It is however intricate to forecast vegetative and reproductive response of mango trees. Thus, understanding and controlling of this phenomenon has been of prime interest to scientists over a century. As vegetative and reproductive growth pattern of mango is highly dependent on cultivar and growth conditions of a particular region (Davenport and Nunez-Elisea, 1997), there is still a lot to be done on modeling and growth patterns development under agro-climatic conditions of Pakistan and many aspects are still to be discovered by using different research approaches.

From mango industry perspectives, flowering and fruit setting are the most critical events which determine when and how much fruit could be produced during a season, provided favorable growth conditions are available. In addition to this, mango industry is also facing many other production and postharvest issues (Maqbool *et al.*, 2007). For example, commercial cultivars suffer from complex problems like alternate bearing, malformation, tree decline, limited shelf life of fruit and related quality issues (Fateh *et al.*, 2006; Malik *et al.*, 2006). Among production issues, malformation is known as a serious problem since long time

(Tripathi, 1954; Singh, 1955; Watt, 1891). In Pakistan, its occurrence varies from 10-15% but in certain cases its severity ranges from 60-80% both on grafted and seedling mangoes (Yousaf, 2001). All commercial cultivars of mango suffer from this complex problem which appears mainly because of its enigmatic blooming and vegetative growth behaviour (Kumar *et al.*, 1993). Mango malformation afflicts both panicles and vegetative flushes (Kumar & Beniwal, 1992). Typical characteristics of floral malformation include dark green compact panicle due to shortened primary and secondary axes and suppression in apical dominance. Malformed panicles continue to grow even after flowering season but mostly contain over-sized staminate flowers thus rarely bear any fruit (Chadha and Pal, 1993; Singh and Dhillon, 1993). In severe cases, the whole tree may be rendered fruitless (Singh and Singh, 1993). In addition to an extensive research work done on different aspects of this malady (Usha *et al.*, 1997; Singh, 2000; Ziaf *et al.*, 2004; Shah *et al.*, 2009, Troncoso *et al.*, 2010; Nafees *et al.*, 2010), *Fusarium spp*. have recently been reported to be a potential cause of mango malformation (Kvas *et al.*, 2008; Iqbal *et al.*, 2008, 2010a, 2010b; Gamliel-Atinsky *et al.*, 2010) but still a general consensus on the precise control is yet to be attained (Krishnan *et al.*, 2009). Its intensity varies greatly among different genotypes (Schlosser, 1971; Azzous *et al.*, 1978; Nath *et al.*, 1987; Ahmad *et al.*, 2002; Hafiz *et al.*, 2008) and ecological conditions (Varma *et al.*, 1971; Singh *et al.*, 1979). So, present studies were carried out to understand the nature of vegetative growth pattern of mango cv. Langra along with its relation with intensity of panicle production in the subsequent growing season under subtropical climate. In this way, if share of flushes toward healthy and malformed panicle production would be identified, then further emphasis would be made possible on their manipulation to increase production and reduce the malformation intensity of mango.

MATERIALS AND METHODS

The present research work was carried out at the Experimental Fruit Orchard square No. 9, Institute of Horticultural Sciences, University of Agriculture, Faisalabad (31°26' North, 73°06' East, Elevation 184.4m) from February 2003 to August 2005. During the study period, average temperature ranged from 19.5°C to 33.5°C (winter, 10.7-24.7°C; summer, 27.4-39.6°C) with an annual rain fall 286.9 mm and 53.6% relative humidity. Net radiation rate was recorded as 12.7 $MJ/m^2/day$.

The experiment was laid out in randomized complete block design (RCBD) with three replications. Each replication consisted of seven healthy mango trees cv. Langra with 15 years of age. This is one of the choicest cultivars but is most susceptible to malformation having >20% disease index (Kumar and Beniwal, 1987). Vegetative flushes and panicles were tagged according to method adapted by Muhammad *et al.* (1999) and Nafees *et al.* (2010). On each tree, 40 flushes were randomly selected and tagged at the time of flush emergence in April during first year of study. All newly emerged flushes from them were further tagged from May to August and considered as primary (April flushes), secondary (May flushes emerged from April flushes), tertiary (June flushes emerged from April and April-based May flushes), quaternary (July flushes based on April and April-based May and June flushes) and quinary flushes (August flushes based on April and April-based May, June and July flushes). Flushes emerged in each treatment were further studied for their vegetative behaviour during subsequent growth season. Data were collected on weekly intervals which included number of April and April-based flushes which emerged during first growing season, number of ceased and re-grown flushes from each treatment during next growing season. All the flushes tagged during the first growing season were also studied for their reproductive and floral malformation growth pattern during the subsequent growing season. Number of healthy and malformed panicles produced from previous year's ceased flushes was recorded daily. All experimental trees received uniform cultural practices for irrigation, plant protection and fertilizer application during course of investigation.

The experimental data were subjected to analysis of variance (ANOVA) using Genstat Release 8.2 (Lawes Agricultural Trust, Rothamsted Experimental Station, UK). Within the analysis of variance, the effects of different treatments and their interaction were assessed. Least significant differences (Fisher's protected LSD) were calculated following significant F test ($P \leq 0.05$). All assumptions of analysis were checked to ensure validity. Data were also presented in percent values for better interpretation of the results.

RESULTS AND DISCUSSION

***Development of primary flushes during first year*:** The vegetative growth pattern is dependent upon the genetic characteristics of various cultivars in addition to climatic conditions and management practices. Significant differences were recorded among flush emergence of different months. It was observed that out of mean number of tagged primary flushes; only 7.3% flushes could restart their growth as secondary flushes while other ceased to grow (Table 1). During the month of June, 46.4% primary flushes which remained ceased in May started their growth again while 0.9% secondary flushes continued their growth. In this way, 47.4% of primary and secondary flushes flushed in June as tertiary flushes. During the month of July, total number of quaternary flushes emerging from primary, secondary and tertiary flushes was 17.4% of primary flushes. The very small number of primary and primary-based flushes could continue their growth in August and only 2.5%

of primary flushes could be observed in August with the contribution of primary and secondary, tertiary and quaternary flushes in order of 1.2%, 0.1%, 0.8% and 0.4%, respectively. These observations not only confirmed earlier findings of Khan (1960) who stated that growth flushes in 'Langra' mango trees emerging from April to August consequently produced as many as five flushes during single growing season; our findings also revealed that pattern of re-flushing and cessation of growth during different months indicated that growth generally occurs in alternate month's pattern. Each flush, after it is initiated, grows for sometimes, stops and breaks out again till growth finally ceases in August. In this way, development of each new shoot is followed by a period of dormancy (Popenoe, 1920) which helps the shoots to attain proper physiological maturity for fruit bud differentiation (Singh, 1978). This seems to be the reason for more re-flushing frequency in tertiary flushes, as very less number of flushes emerged in May as secondary flushes which consequently gave rest period to tertiary flushes.

Re-flushing and cessation pattern is given in Table 2 indicating statistically significant differences among treatments. Among re-flushed flushes, mean number of flushes produced in July and August were found to be statistically at par with each other. Cumulatively, 56.7% of total primary flushes sprouted in subsequent months during vegetative cycle of mango tree while 43.3% flushes ceased after they sprouted once in April as primary flushes. In the same way, out of total tagged primary flushes, 7.3% primary flushes sprouted in May as secondary flushes (Table 1) and 33.3% of the total secondary flushes continued their growth in June, July and August while 66.7% remained ceased and could not grow in any subsequent month. In case of tertiary flushes, their re-flushing and cessation percentage was 32.0% and 68.1%, respectively. In July, out of mean number of 146 primary-based flushes, 1.8% flushes made their contribution in giving rise to quinary flushes while 98.2% flushes did not grow further and in August sprouted flushes, all the flushes ceased their growth and could not grow further. These data revealed a definite pattern in vegetative growth of 'Langra' mango trees grown under subtropical condition indicating an increase in the frequency of ceased flushes and decrease in re-growth frequency of flushes with the passage of time (Fig.1) which is in perfect agreement with findings by Issarakraisila *et al.* (1997). Changes in climatic conditions conducive to vegetative growth seems to bring gradual changes in endogenous levels of certain hormones which are further responsible for stimulating vegetative growth.

Interestingly, percentage of re-flushed and ceased flushes out of secondary and tertiary flushes was non-significant (Fig.1) but on the other hand, mean number of secondary flushes (61.0) was much lower than tertiary flushes (398.3). In this way, less number of re-grown secondary flushes (20.3) was observed than tertiary flushes (127.3) and after that, gradual decline in percentage of re-flushed flushes was observed (Fig. 1). This indicates that among all vegetative flushes, tertiary flushes are more important for further

Table 1. Development of April flushes during subsequent months during first year

Flushes	April		May		June		July		August	
	No.	%	No.	%	No.	%	No.	%	No.	%
Primary	840[a]	100	---	---	---	---	---	---	---	---
Secondary	61.0[c]	7.3	61.0[a]	7.3	---	---	---	---	---	---
Tertiary	389.7[b]	46.4	7.7[b]	0.9	398.3[a]	47.4	---	---	---	---
Quaternary	14.7[d]	1.8	11.3[b]	1.4	120.3[b]	14.3	146	17.4	---	---
Quinary	9.7[d]	1.2	0.7[c]	0.1	7.0[c]	0.8	3.3	0.4	21	2.5
LSD ($P \leq 0.05$)	12.34		6.66		20.94					

No = Number of flushes emerged from total number of tagged April flushes

% = Percentage of flushes emerged from tagged April flushes

Any two means not sharing a letter in common differ significantly at 5% level of significance.

Table 2. Number of flushes which re-flushed or remain ceased during first year

Flushes	Re-flushed flushes	Ceased flushes
Primary	476.3[a]	363.7[a]
Secondary	20.3[c]	40.7[d]
Tertiary	127.3[b]	271.0[b]
Quaternary	2.7[d]	143.3[c]
Quinary	0.3[d]	20.7[d]
LSD ($P \leq 0.05$)	14.12	22.75

Any two means not sharing a letter in common differ significantly at 5% level of significance.

vegetative growth than secondary, quaternary and quinary flushes and thus if more emphasis is done to increase the number of tertiary flushes, ultimately more number of quaternary and quinary flushes may be produced. This would ultimately lead to good fruit set in following year as increase in flowering response has recently been strongly correlated with increasing leaf numbers (Ramirez *et al.*, 2010).

***Growth patterns during subsequent year's flushes*:** Previous year's tagged flushes were further observed during subsequent year for their contribution in production of panicles in late winter and spring, floral malformation in late spring and vegetative flushes during late spring and summer. All these three aspects will be discussed here in the same sequence as per time-frame.

***i. Reproductive growth pattern*:** Significantly different results were observed for the production of healthy panicles out of ceased flushes from previous year. Highest mean number of healthy panicles was produced on previous year's ceased primary flushes. Maximum panicles were produced in flushes which emerged in April (primary flushes) and ceased to grow further while quinary flushes produced least panicles (Table 3). Number of healthy panicles produced on quaternary and quinary ceased flushes were statistically at par with each other. Decreasing trend in potential of panicle production with the flush age is also evident from Fig.1. Panicles produced on secondary, tertiary, and quaternary flushes were in order of 15.6%, 18.9% and 8.2%, respectively.

It was also observed that in first growing season, higher the number of ceased flushes in a specific month, more were the number of panicles in next growing season from that month

Table 3. Month-wise contribution of ceased flushes in production of healthy and malformed panicles (number) during subsequent year

Flushes	First Year	Second Year	
	Ceased flushes	Healthy Panicles	Malformed Panicles
Primary	363.7[a]	139.7[a]	11.0[b]
Secondary	40.7[d]	6.0[c]	1.0[c]
Tertiary	271.0[b]	52.3[b]	20.7[a]
Quaternary	143.3[c]	12.3[c]	19.3[a]
Quinary	20.7[d]	1.3[c]	2.7[c]
Total	839.5	210.5	55.9
LSD ($P \leq 0.05$)	22.75	20.82	4.45

Any two means not sharing a letter in common differ significantly at 5% level of significance.

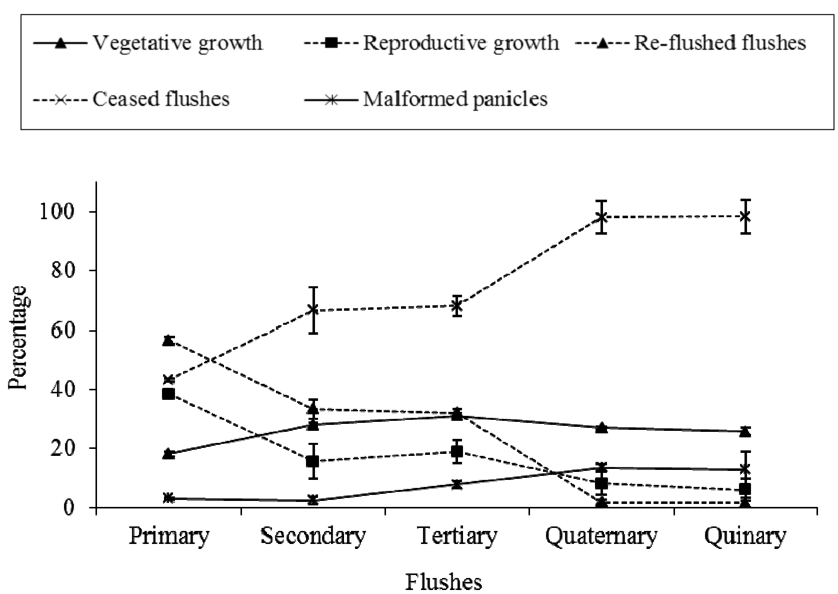

Figure1. Vegetative and reproductive growth pattern of mango cv. Langra in relation to floral malformation

(Fig.1). Moreover, higher number of panicles was produced on older branches i.e. primary flushes produced maximum panicles (38.4%) while youngest flushes produced least ones i.e. 6.0% from quinary flushes. This clearly indicates that primary flushes emerging in April had the maximum capacity to produce panicles followed by tertiary flushes under subtropical condition which was due to higher number of ceased flushes in month of April and June. Thus, delayed vegetative growth reduced the potential for new shoots to flower in the following season (Fig.1). In this way, maturity of flushes and accumulation of carbohydrate in shoot apex may be associated with the synthesis of the floral stimulus (Chacko, 1991) which increases the potential of early flushes to produce more inflorescence in mango in following season (Singh & Khan, 1940; Monselise and Goldschmidt, 1982). This is true that out of 363.7 ceased primary flushes, 139.7 primary flushes (38.4%) bloomed but important point to note is that why rest of the 224.0 flushes (61.6%) did not bloom (Table 3), as all the flushes were of the same age. This requires keener biochemical and hormonal studies to determine the factors due to which only some percentage of primary flushes bloom. Moreover, second higher contribution of tertiary flushes in production of healthy panicles revealed that if number of tertiary flushes could be increased, more number of panicles may be obtained.

***ii. Intensity of floral malformation*:** Significantly different results were observed for the production of malformed panicles out of ceased flushes of the previous year. Intensity of floral malformation on previous year's ceased flushes is given in Table 3. Minimum malformation intensity was observed in ceased primary flushes while maximum intensity was found in quinary ceased flushes. Number of malformed panicles produced from tertiary and quaternary flushes were found to be statistically at par with each other. These findings reveal that florla malformation intensity was higher on flushes, emerged late (Fig. 1) which may be related with the prevalent ambient temperature at that time (Majumdar and Sinha, 1972). Moreover, dominant malformin-like substance(s) and disturbed metabolism due to hormonal imbalance (Singh, 2000) in previous year's late flushes contributing to higher intensity of floral malformation (Muhammad *et al.*, 1999; Jose *et al.*, 2000) may be a good reason.

***iii. Vegetative growth pattern*:** Some of the flushes tagged during the previous year bloomed next year while other flushes either retained their vegetative characters or remained quiescent even in next growing season. Statistically significant differences were found among treatments for the production of vegetative flushes in different months. Contribution of previous year's tagged flushes in re-growth of vegetative flushes is presented in Table 4. It was observed that primary flushes contributed their minimum share in production of flushes (18.2%). The reason for this was their maximum share (38.4%) in the production of panicles (Fig. 1) also leaving lower probability of vegetative growth from shoots carrying fruits shoots (Issarakraisila *et al.*, 1991). Contribution of flushes in panicle production was different from their vegetative growth in subsequent growing season. There was a continuous fall in percentage of panicle production from tagged primary and subsequent flushes of other months i.e. primary flushes produced maximum panicles (38.4%) and quinary flushes produced least (6.0%). While, in case of vegetative growth, primary flushes could not produce much number of flushes (18.2%) due to production of maximum panicles, but contribution of tertiary flushes (31.1%) followed by secondary flushes (28.1%) was found maximum in vegetative growth during next growing season and again a decline was observed for quaternary and quinary flushes. Overall, it may be concluded that as flush grows older, its capacity to produce reproductive panicles increases and vegetative flushes decreases.

CONCLUSION

Alternate flushing pattern was observed in vegetative growth of mango cv. Langra with gradual decrease in re-flushing frequency of primary and subsequent flushes during the same year. Mature flushes play their major role in production of healthy panicles with minimum share in production of vegetative growth and malformed panicles while younger flushes significantly contribute towards

Table 4. Percent contribution of ceased flushes in further vegetative growth during subsequent year

Flushes	April	May	June	July	August
Primary	21.3^{b}	21.0^{c}	15.0^{c}	13.3^{c}	20.3^{b}
Secondary	31.3^{a}	25.7^{bc}	31.0^{a}	22.7^{b}	29.7^{a}
Tertiary	30.7^{a}	34.3^{a}	29.7^{ab}	32.7^{a}	28.3^{a}
Quaternary	23.3^{b}	28.0^{ab}	29.7^{ab}	29.3^{a}	24.7^{ab}
Quinary	26.0^{ab}	22.7b^{c}	24.3^{b}	27.3^{ab}	28.3^{a}
LSD ($P \leq 0.05$)	*6.01*	*6.75*	*6.52*	*6.55*	*5.72*

Any two means not sharing a letter in common differ significantly at 5% level of significance.

production of vegetative growth during preceding year. Contribution of only some percentage of primary flushes in blooming rather than whole still needs further investigation which may involve biochemical and hormonal assays of these flushes.

ACKNOWLEDGEMENTS

We would like to acknowledge Prof. M. Ibrahim Chaudhary (Late), Institute of Horticultural Sciences, University of Agriculture, Faisalabad for his unfathomable guidance during the project and Prof. Shahzad Maqsood Ahmad Basra, Department of Crop Physiology, University of Agriculture, Faisalabad for providing meteorological data.

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