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Sustainable Mango Production Technology for Climatic Aberration in Coastal Agroclimate of Maharashtra

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Abstract

Mango is a dominant and major fruit crop with paramount importance in economy of coastal Maharashtra. An estimated 3.8 lakh ha area under mango in the state links livelihood of farmers in this aprt of Maharashtra. Alphonso is the ruling cultivar, sharing around 95 per cent area in coastal Maharashtra. It is popular due to its excellent taste and flavour, unique sugar:acid blend and fibre-less pulp. However, present climatic fluctuations, is a concern affecting its productivity. The weather vagaries sweeping the Konkan region has disturbed the crop phenology especially the vegetative growth dynamics eventually affecting the reproductive phenophases. It is affecting the production cycle, delaying harvesting season, quality of the produce and farmers economy. Investigations on various moderation of technologies were conducted and several technologies viz. varietal selection, appropriate planting material and planting, regulation of flowering, prediction models for emergence of vegetative shoot as well as flowering, rejuvenation protocol for old and senile orchards, post harvest bagging for production of spotless fruits, precise harvesting and appropriate handling along with sustainable plant protection schedule are developed for sustainable production of quality mangoes under aberrant climate of coastal Konkan region.

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Introduction

Mango (*Mangifera indica* L.) is one of the choicest tropical fruit of the world and rightly designated as "King" of all fruits. In India, it is under cultivation for more than 4000 years and conspicuous bonds have been formed between the fruit and cultural history of the country. India dominates the world production and ranks first with major share of 43 per cent with total production of 10.8 mt from about 1.6 million ha, which is nearly 43 % of total world area under mango (Table 1) (Anonymous 2014a, 2014b). It is an important foreign-exchange-earning fruit crop of country, and is currently earning ₹ 110.5 crores and ₹ 241.99 crores from export of 60551 t of fresh fruits and 89514 t of processed products, respectively. However, the share of Indian mango in global export is 5.20 %. and Konkan region is one of the largest mango growing belts in the country occupying 182 000 ha area, which accounts for about 8 % of the total area under mango in the country with major contribution of over 35 per cent to the total export from India.. It comprises of five mango growing districts viz. Palghar, Thane, Raigad, Ratnagiri and Sindhudurg, along the West Coast of India The Konkan region is traditionally known as homeland for commercial cultivation of world famous Alphonso which is the choicest variety of mango in the world occupying more than 95 per cent area in Konkan under mango. Mango

being the major component of livelihood of this region, the multifarious improved technology for production of quality fruits under aberrant climate has been developed by DBSKKV, Dapoli.

The Climate change, its impact and mitigation

The weather vagaries sweeping the Konkan region such as unseasonal rains especially during the flowering and fruit development, delayed monsoon, prevalence of low temperature (< 17 ºC) for prolong period, sudden rise in maximum temperature during February to March etc have disturbed the crop phenology especially vegetative growth dynamics, greatly affecting the reproductive phenophrases. The deviation in various weather parameters in depicted in the figure 1 (a,b,c).

The distinct phenological changes due to climate change consists of no or shy vegetative growth immediately after harvest, low percentages of hermaphrodite flowers, severe fruit drop due to temperature variation, irregular flowering and recurrent flowering, manifestation of new pests like thrips, fruit borer, midge fly, and mealy bug, improper pollination and fruit set due to foggy weather condition at the time of flowering (Figure 2).

Mango produces 3-4 vegetative flushes during a year which vary according to variety as well as climate. The hybrid varieties are endowed with greater rate of growth (Gautam 2000). However, in most of the mono embryonic varieties only one reproductive flush is noticed which is staggered mode. Flowering mechanism in mango is influenced by environmental factors and is a complex and still poorly understood aspect. After the withdrawal of monsoon and commencement of the dry spell, winter begins to induce flowering in mango. Normally flowering occurs in three flushes in the season. However, flowering process is controlled by several factors (Anonymous 2013, Haldankar and Parulekar 2013, Tongumpai *et al.* 1991). On a full grown mango tree, about 1000 panicles appear depending on the variety, canopy spread and tree vigour. Each panicle produces 500 to 6000 flowers (in Alphonso from 1000 to 2000) (Figure 3). Under normal conditions, percentage of hermaphrodite flowers in Alphonso, Ratna, Kesar, Sindhu and Goamankur were found 13, 27, 30, 35 and 25 % respectively. Cool temperatures activate flower bud initiation, however due to prolonged low temperature (below 12 to 16 ºC), heavy flowering with long panicles are produced with remarkable reduction in the hermaphrodite flowers (4 to 6 %) (Table 2). Usually, on an average five to eight fruits (at pea grain stage) are set per panicle in Alphonso mango but only one fruit is retained from every 6 panicles. Out of the total hermaphrodite flowers in panicle, drop of 20 per cent is due to lack of floral parts, deformed or imperfect flowers and other 20 per cent is due to pest attack; remaining 40 to 50 per cent fall is due to either failure or improper pollination (Jorwehar 1976).

The above development of disturbances have affected the production cycle, has delayed harvesting season, damaged quality of the produce and inclusively farmers fetch severe economic losses. Hence, investigations on various moderation technologies were initiated under Konkan Coastal conditions such technologies include developing prediction models, improving tree health through rejuvenation so that such plant will tolerate such changes and protection of fruit for maintaining its quality (Haldankar *et al.* 2015, Shinde *et al.* 2015).

Varietal development

Alphonso is the dominant cultivar in the Konkan region

Table 1. Area, production and productivity of mango in the World, India and Konkan region.

Particular	Area (lakh ha)	Production (mt)	Productivity (t ha^{-1})
World	37	26.34	9.3
India	16	10.80	6.75
Maharashtra	3.8	0.81	4.11
Konkan	1.47	0.27	2.5

Source: Anonymous 2014a

Table 2. Effect of low temperature on various flowering parameters.

Year	Minimum temperature (>14 ºC) (days)				Bisexual flowers (%)	Fruit set (%)	Flowering flushes
	December	January	February	March			
2010-11	16	29	23	7	3-6	20-25	3-4
2011-12	18	25	23	17	6-8	22-25	4-5
2012-13	13	26	13	3	8-10	28-30	3-4
2013-14	17	13	10	5	3-14	30-32	5-6

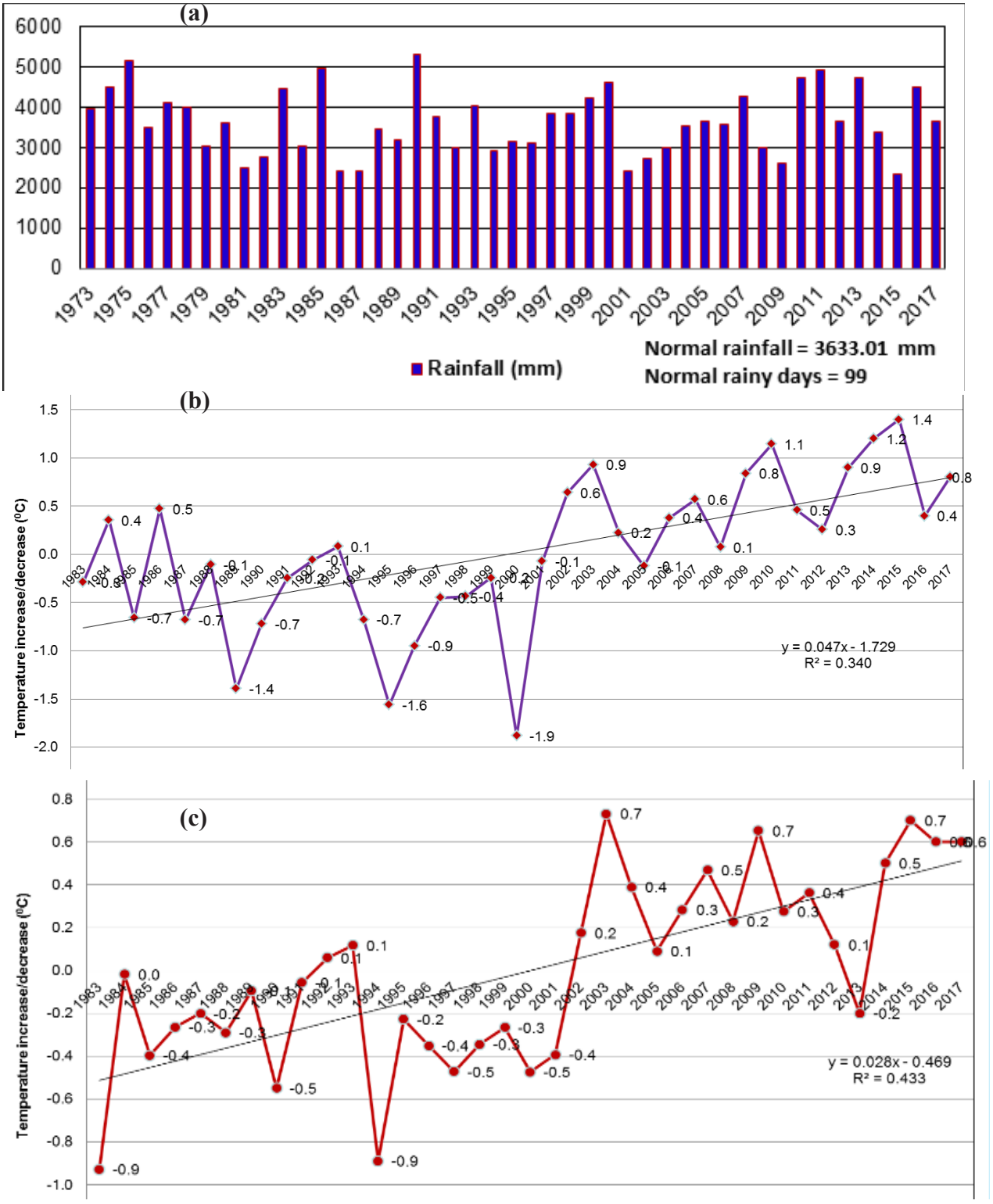
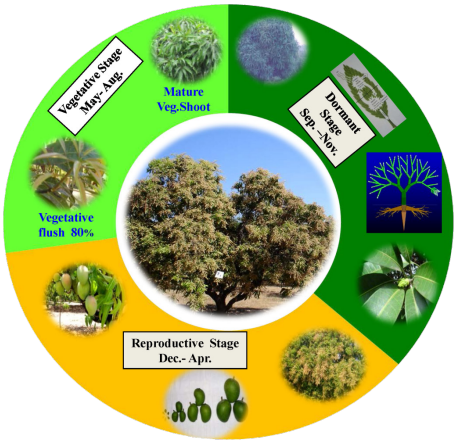
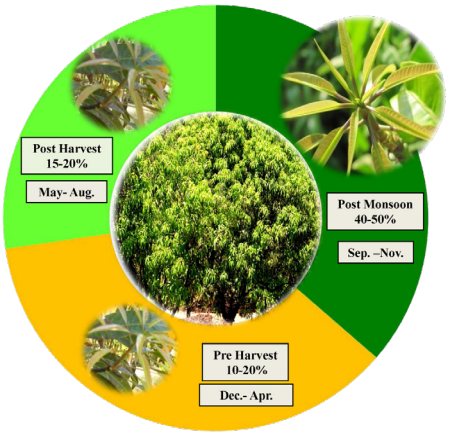


Fig. 1. Long-term trends in climate parameters in Konkan region based on data collected at Dapoli: (a) Yearly total rainfall (mm) received, (b) Yearly increase or decrease in minimum temperature, (c) Yearly increase or decrease in maximum temperature.



Desired Growth Cycle of Alphonso Mango



Current trends of vegetative Growth Flushes in Konkan

Fig. 2. Deviations in mango phenology occurring in Konkan region.

Fig. 3. Profuse Flowering in mango cv. Alphonso in konkan.

Fig. 4. Alphonso: the most popular mango cash crop in Konkan, Maharashtra, India.

(Figure 4), which is the world famous choicest mango variety. The fruits are medium in size with excellent flavour, proper sugar-acid blend, good keeping quality, thin skin, fibreless with saffron coloured thick consistent pulp. It is excellent table purpose variety having preference for export. It retains its peculiar flavour even after processing and hence also favoured one in processing industry. The fruits fetch premium price in the market. However, it is shy bearer, alternate bearer, coupled with occurrence of spongy tissue (Anonymous 2013) and more susceptible to present climatic vagaries in the coastal region. Hence, it is advisable to establish a mango orchard of mixed varieties in the coastal region. The crop improvement programme has contributed for development of regular bearing and spongy tissue free genotypes. The traditional varieties viz., Kesar, Pairi, Goamankur, Hybrid 10/1, Alampur Baneshan, Ratna, Mallika, Amrapalli, Benganpalli and Suvernarekha also perform well in coastal region. (Tables 3 and 4).

Planting

In coastal conditions, traditionally mango is planted at a spacing of 10m x 10m. It results in underutilization of interspace during the early stages of orchard development. Productivity of such orchards remains low due to less plant density. A high density planting at 5m x 5m spacing was beneficial for establishing high density orchards on lateritic soils as well as on lateritic rocks in Konkan region (Table 5) (Dalvi *et al.* 2010) (Figure 5). In such orchards, plantation of 10 to 15 % pollinizer trees of Kesar, Ratna or Goa mankur in Alphonso orchards is advisable.

Table 3. Comparative performance of different mango varieties for pulp in Konkan region

Variety	Fruit wt. (g)	Yield (t ha^{-1})	Pulp Wt. (g)	TSS (^{o}B)	Acidity (%)	Pulp (%)
Alphonso	260	2.82	183.06	19.5	0.30	72.50
Alampur Baneshan	450	7.60	357.86	18.0	0.17	85.50
Himayuddin	533	5.80	455.80	15.8	0.58	83.80
Hybrid 10/1	241	10.50	201.27	17.5	0.17	86.48
Kondur Goa	348	3.00	302.70	21.5	0.52	85.83
Kensington	340	4.70	292.29	13.6	0.47	84.04
Mallika	350	5.60	132.62	17.9	0.28	76.30
Ratna	300	6.80	137.96	20.0	0.24	76.97
Rumani	600	6.10	448.90	19.8	0.23	84.06
Vanaraj	256	7.60	196.88	16.8	0.29	76.90

Source: Anonymous 2014c

Table 4. Comparative performance of mango varieties for juice purpose.

Variety	Avg. fruit wt. (g)	Yield (t ha^{-1})	Juice Wt. (g)	TSS (^{0}B)	Acidity (%)
Amrapali	250	7.8	176.88	17.0	0.17
Benganpalli	400	7.1	158.10	23.0	0.23
Pairi	215	2.3	150.67	14.2	0.32
Pulihara	250	7.4	156.92	13.9	0.28
Suvarnarekha	400	12.4	208.62	21.2	0.12
Karutha Kolamban	350	6.8	85.33	16.8	0.35
SE.±	4.47	0.23	-	-	-
CD at 5 %	13.77	0.70	-	-	-

Source: Anonymous 2014d

Table 5. Flowering and yield parameters in Alphonso mango in Konkan under different planting densities

Spacing	No. of trees ha^{-1}	Flowering (%)		No. of fruits tree^{-1}		Avg. fruit yield (kg tree^{-1})		Yield (t ha^{-1})	B:C ratio
		2008	2009	2008	2009	2008	2009		
2.5 x 10 m	400	31.80	30.83	32	52	8.3	11.1	4.78	1.23
5 x 5 m	400	27.52	29.83	45	89	11.2	27.5	6.40	2.33
5 x 7.5 m	266	16.50	15.83	39	74	9.7	13.3	3.74	1.19
5 x 10 m	200	07.83	08.33	43	71	10.2	13.0	2.82	0.76
10 x10 m	100	15.80	15.00	33	48	2.0	13.3	1.12	0.22
S.E.±	-	2.21	2.57	1.1	1.4	0.32	0.79	0.19	-
CD at 5 %	-	6.72	7.60	3.4	4.1	1.3	2.5	0.67	-

Source: Dalvi *et al.* 2010

Fig. 5. High density planting of mango cv. Alphonso.

Table 6. Effect of poly bag size on various growth parameters of mango graft of cv. Alphonso and Kesar

Treatment	Length of tap root (cm)	Root spread (cm)	No. of secondary roots	Plant height (cm)	Girth at collar (cm)	No. of leaves	Plant spread (cm)
10" x 14" bag – Alphonso graft	54.00	51.40	67.40	51.15	5.91	37.21	34.35
10" x 14" bag – Kesar graft	46.00	48.40	75.00	48.10	5.69	41.39	43.03
6" x 8" bag – Alphonso graft	25.00	3.80	29.20	32.30	4.90	26.67	31.68
6" x 8" bag – Kesar graft	33.60	28.60	25.20	39.00	4.50	22.47	34.85
SE ±	5.45	5.04	3.13	1.88	0.11	1.18	1.91
CD at 5 %	16.33	15.12	9.38	5.64	0.34	3.55	5.71

Source: Haldankar *et al.* 2014

Appropriate planting material

Mango was propagated by inarch grafts in coastal region which was very expensive, slow, laborious and cumbersome (Dhakal 1979). The epicotyl (stone) grafting technique brought phenomenal change in plant propagation industry and mango orchard expansion. Around 70 per cent success achieved during June to September (Dhakal 1979), with the scion stick of 2 to 2 ½ month of age with 10 to 15 cm length on one week old rootstock with coppery red colour foliage (Rai 1982).

The size of polythene bag has recorded significant effect on length of taproot, root spread, number of secondary roots, plant height, girth at collar, number of leaves per plant and collar girth also. Bigger size polythene bag (10"×14") produced healthier grafts than the regular size (6"×8") (Table 6) (Haldankar *et al.* 2014). The drenching of humic acid at the concentration of 6 and 7 ml l^{-1} for 4 and 5 times during the period of 5-12 months showed better growth of the mango grafts (cv. Alphonso) (Korake *et al.* 2012).

Regulation of flowering

In mango the gibberellins are positively associated with alternate bearing. Paclobutrazol motivate flowering process by preventing shoot elongation and also causes rapid development of reproductive buds by interfering gibberellin metabolism which otherwise promotes vegetative growth. It is a broad spectrum synthetic plant growth retardant which modifies anatomy and physiology of mango. It changes the levels of endogenous hormones in xylem sap as well as leaves, increases phloem tissue, ABA, cytokinins L.T.R and DHIR and total phenols whereas IAA and GA decreases. It helps in maturation

of shoots and induction of regular flowering under favourable conditions. In Alphonso, soil application of paclobutrazol is recommended in second fortnight of July to first fortnight of August, to prevent further extension of vegetative growth under Konkan climatic conditions. Paclobutrazol also induces early flowering by about 2 weeks in the season (Haldankar and Parulekar 2013).

Prediction models for vegetative shoots and flowering

A climatological regression model to predict emergence of vegetative flush during September to November in Alphonso mango is developed with high R^2 value (0.94**) indicating its utility to undertake suitable control measures under the climatic aberrations during the period so as to obtain proper flowering (Equation 1). So that necessary measures can be taken for protection as well as its suppression (Anonymous 2015a). The flowering emergence can be successfully predicted one week before during December to January by using Equation 2 having $R^2 = 0.79$** (Anonymous 2015b).

In these equations-

T_{max}: Maximum temperature

T_{min}: Minimum temperature

RH_2: Relative humidity at 2:00 PM

R: Rainfall

BSS: Bright Sunshine hours

Rd: Rainy days

Rejuvenation

Healthy plants resist better to climatic vagaries. In traditional wide density (10m X 10m) orchards, plants grow tall and become physiologically weak. Due to unattainable height of plant and limited penetration of sunlight inside the canopy the photosynthetic ability of plant is not exploited to its full potential; which further affects the carbohydrate accumulation in plant which is prerequisite for the flower induction. Such old and weak orchards are more susceptible to weather fluctuations and produce very low yield. Rejuvenation makes such orchards economically viable. The rejuvenation technology includes suitable pruning, adequate nutrient management along with appropriate canopy management and plant protection measures. The rejuvenated plants are more vigorous, bear healthy canopy and produce more yields with better quality. It has been observed that the rate of photosynthesis, hermaphrodite flower percentage. Average fruit weight as well as yield was better in rejuvenated plants in comparison with non rejuvenated plants (Table 7 and figure 6) (Anonymous 2016).

Preharvest bagging

The climatic aberrations such as sudden rise in temperature and humidity, abnormal rains especially during fruit development are often experienced, which not only damage the external appearance of the fruit by developing the spots and bruishes but also aggregate the incidence of mealy bug as well as spongy tissue disorder.

$$\text{Vegetative flush Emergence (3 week before)} = 49.47 + 0.44\ T_{max} - 0.18\ RH_2 - O - 0.03\ R - 1.61\ E \quad \text{...Eq. 1}$$

$$\text{Flower Emergence} = -91.91 + 10.79\ T_{max} + 6.05\ T_{min} - 0.34\ RH_2 - C + 0.86\ RH - O - 5.04\ BSS - 3.48\ R - 12.62\ Rd \quad \text{...Eq. 2}$$

Table 7. Vegetative, flowering and yield parameters of rejuvenated plants and non rejuvenated plants of mango cv. Alphonso

Treatment	Avg. Leaf Area (cm^2)	Rate of photosynthesis (µmol CO_2 sec^{-1})	Rate of respiration (µmol $CO_2 sec^{-1}$)	hermaphrodite flowers (%)	No. of fruits	Average fruit weight (g)	yield per hectare (t)
Rejuvenated plants	99.26	9.46	1.69	132.94	132.94	255.93	3.38
Non-Rejuvenated plants	85.79	5.81	3.09	113.84	113.84	223.50	2.54
SE	2.46	0.33	0.18	7.27	7.27	5.71	0.17
CD at 5 %	7.58	1.04	0.55	22.43	22.43	17.62	0.55

Source: Anonymous 2016

Fig. 6. Growth of mango cv. Alphonso after rejuvenation.

Fig. 7. Nutan mango harvester for harvesting mature fruits with stalk developed by DBSKKV, Dapoli.

Table 8. Effect of different type of bags on physico-chemical properties of mango fruits.

Treatments	Fruit retention (%)	Weight of fruit (g)	Shelf life (days)	Mealy bugs (%)	Spongy tissue (%)
Newspaper bag	71.25±0	264.07±10	17.50±2	0	0
Brown paper bag	71.67±0.72	254.07±8.48	16.50±0	4.17±0	0
Scurting bag	71.67±1.90	243.53±6.48	(15±0	1.67±0	1.72±0.48
Plastic bag with perforations	65±0.72	225.78±15.38	13.50±0	0	6.17±1
Butter paper bag	68.75±1.44	245.65±25.88	14.50±0	0	0.67±0
Muslin cloth bag	68.58±2.62	239.24±4.14	15.5±0	2.84±0	0.84±0
Polythene coated Brownpaper bag	67.92±2.16	251.37±11.95	16±0	3.33±0	2.39±0.96
No Bagging	66.25±0.72	232.46±4.88)	15±1	9.63±2.24	9±0
Range	65.00-71.67	225.78-264.07	13.50-17.50	00-9.63	00-9.00
Mean	68.88	244.57	15.43	2.7	2.59
SE ±	0.86	4.98	0.43	0.46	0.27
CD at 5%	2.61	15.09	1.3	1.39	0.82

Source: Haldankar *et al.* 2015

The affected fruits earn less market prices causing severe economic loss to the farmers. The preharvest bagging of fruits at 30 days after fruit set modified the fruit retention, shelf life after ripening as well as produced spotless clean fruits without spongy tissue. It was also observed that the bagged fruits recorded significantly higher fruit weight as compared to control (Haldankar *et al.* 2015).

Precise harvesting and appropriate handling

Mango is a climacteric fruit. Harvesting the mature fruit at correct maturity is of immense importance for quality ripening as well as to get sufficient time for marketing of fruit after harvesting.

It was also reported that conductive heat arising from soil and lateritic rock at maturity was the most important cause of melody. During April-May, surface temperature rises upto 55.8^{0}C due to solar radiation. It aggravates spongy tissue development during ripening due to malfunctioning of enzymes responsible for ripening (Katrodia and Rane 1989). The incidence of spongy tissue in ripe fruits in mulched plots (25.33%) and sod cultured plots (24.42%) was significantly lower than the clean cultivated plot (41.50%) (Burondkar *et*

al. 1994). It was also observed that intensity of spongy tissue increased with advancement of fruit maturity and delay in harvesting (Katrodia and Rane 1989). At complete physiological maturity (tree ripe fruit) per cent in incidence as well as severity of spongy tissue was higher. At 75-80 per cent maturity incidence as well severity of spongy tissue was found less.

Harvesting should be done preferably in morning before 10.00 a.m. or late in the evening after 4.00 p.m. so that they will not expose to sun rays after harvesting. Proper care should be taken to keep the stalk intact. A device known as 'Nutan Mango Harvester' is developed which is easy to operate, light in weight and harvested the fruits with stalk (Haldankar and Parulekar 2013, Powar and Joshi 1994) (Figure 7).

Grading in mango is usually followed on the basis of weight. The average fruit weight of Alphonso ranges between 200 to 350 g (Haldankar and Parulekar 2013). The different grades and their respective weight are given in Table 13. Grading according to the specific gravity helps to separate out fruits of same maturity stage (Naik 1985).

The postharvest treatments viz., hot water dip, fungicidal dips, pre cooling, waxing, increase the shelf life of mango fruits. Mango fruits are pre cooled at 13-15^0 C temperature before storage (13-14^0 C with 85 per cent RH) (Naik 1985) (Figure 8). The post- harvest treatment of harvested matured green Alphonso fruits by dipping in 500 ppm carbendazim for 5 minutes reduces the post-harvest decay.

Aggravation of Physiological disorders

Spongy tissue is a ripening disorder first which is apparent only after cutting of fruits (Cheema and Dani 1934). Identification of healthy and diseased fruits from their external appearance at unripe as well as ripe stages is difficult. The affected pulp is differentiated from healthy one by its pale yellow colour, soft or spongy nature with or without air pockets, accompanied by acidic taste (Figure 9). At later stage, it becomes blackish, having foul odour. The main feature of this malady is a slight desiccation in the centre or affected part surrounded by a soft portion or normal ripe pulp (Chhatpar *et al.* 1968). It is visible between peel and stone of the fruit with maximum incidence towards the beak, followed by middle part and very less at the stalk end.

The conductive heat arising from soil and lateritic rock at maturity was the most important cause of the melody. During April-May, surface temperature rises upto 55.8^o C due to solar radiation. It aggravates spongy tissue development during ripening due to malfunctioning of enzymes responsible for ripening (Katrodia and Rane 1989). The incidence of spongy tissue in mulched plot (25.33 %) and in sod cultured plot (24.42 %) was significantly lower than the clean cultivated plot (41.50 %) (Burondkar *et al.* 1994).

Harvesting of fruits at 85 per cent maturity either early in the morning or late in the evening, avoiding fruit exposure to direct sun after harvest, mulching, application of sulphate of potash (K_2SO_4) @ 2 kg per plant instead of muriate of potash, transport of fruits during night hours, pre harvest bagging of fruits with news paper bag are reported effective for control of spongy tissue (Haldankar *et al.* 2015) (Figure 10).

In recent years, it has observed that intermittent panicles emerge from the base of previous panicles. The emergence of these new panicles leads to severe fruit drop and weathering of main panicle. Fruit drop is observed after 45 to 60 days of (emergence of first

Table 9. Post harvest distribution of Alphonso mango fruits in different weight grades.

Weight group	% of Fruits
< 250g	21.6
250-299g	52.0
300-349g	20.2
> 350g	6.2

Source: Naik 1985

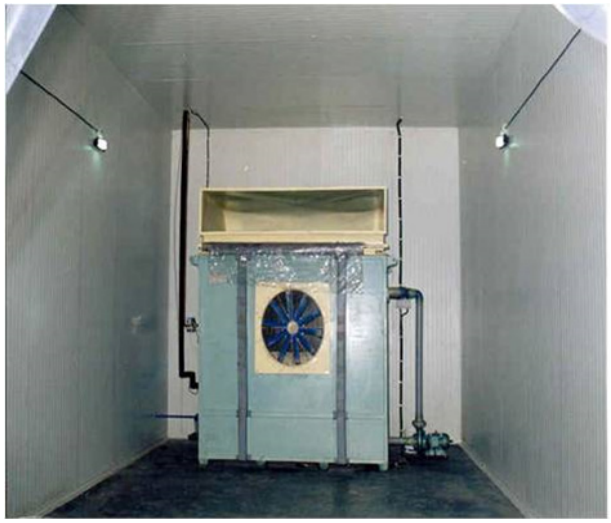


Fig. 8. Pre-cooling facility for Alphonso mango established by government

Fig. 9. Symptoms of spongy tissue disorder in mango Cv. Alphonso.

Fig. 10. View of pre-harvest fruit bagging in Alphonso with newspaper bag – technique recommended by DBSKKV, Dapoli.

Fig. 11. Incidence of Mango hoppers (nymphs and adults) on new panicles of mango.

Fig. 12. Adults of Mango Fruit Fly.

Fig. 13. Symptoms of anthracnose on mango leaves.

Fig. 14. Symptoms of anthracnose on mango fruits.

Table 10. Important pests of mango, their infecting stages and appropriate control measures

Common Name of the pest	Description	Control Measures
Mango hopper Three species of *Adeocerus* in coastal Konkan region were recorded of which, *A. clypeus* was more serious (figure 10).	The nymphs and adult suck the cell sap from the tender parts including vegetative flush, inflorescence and even small tender fruits. Severe infestation during flowering period resulted into weathering of flowers. The adults and nymphs secrete honey dew on which black sooty moulds developed giving blackish appearance to fruits as well as whole tree. It also hinders the photosynthetic activity of the plant which results in flower and fruit drops.	For control of mango hoppers as well as other pests damaging inflorescence, a schedule package is developed (Table 11).
Fruit fly *Bactrocera dorsalis, B. zonata, B. caryeae* infest *B. carrecta* mango occure in Coastal Maharashtra (Figure 11)	The fruit fly population was observed throughout the year. An increase in population was observed from April (131.75 flies/trap) and reached to its peak (1847flies/trap) in the month of June which further declined from July (1175.50 flies/trap) to November (58.75 flies/trap). The fruit fly population was positively correlated with rainfall.	A fruit fly trap using methyl eugenol as attracted was developed by DBSKKV, Dapoli which proved to be effective for control of fruit fly. Hot water dip treatment is a standard protocol to export the mango fruits to European countries and USA. The hot water dip treatment of 47^0C temperature for 50 minutes is effective and the safest treatment for fruit fly management.
Mango shoot borer *Clumetia transversa*	It is a major pest of tender vegetative shoot as well as panicles. The larvae feed inside by making tunnel resulted in weathering of infested shoots or panicles. The intensity of pest was observed more in young orchards leads damaging new vegetative flush which affects the growth rate of plant. The major outbreak was noticed in month of July-August and peak activity in December-January.	The parasitoid, *Megaselia chlumetiae* Disney species was first time reported from Vengurla, Dist. Sindhudurg.The pesticides monocrotophos 0.04 per cent and Quinalphos 0.5 per cent was observed effective.
Mango blossom midge *Eurosomyia indica*	The outbreak was noticed on vegetative flush in June-July. However, the severe incidence was observed during December–June on inflorescences which causes fruit drop.	The pest can be effectively controlled with application of 0.04 per cent monocrotophos.
Mealy bugs *Ferrisia vigrata* and *Perissopheumon* sp.	Sporadically infesting mango crop in month of April-May	Imidacloprid 0.009 per cent, polytrine 0.5 per cent and spinosad 0.18 per cent found to be comparatively more effective in managing the mealy bug.
Thrips *Rhipiphorothrips cryentatus, Thrips flavus* and *Thrips hawaiiensis*	It was observed in July-August. Nymphs and adults suck the cell sap by scrapping the epidermis. Severe leaf fall was noticed leaving only sticks behind. *Thrips flavus* and *Thrips hawaiiensis* was observed feeding severely on mango fruits which result in fruit drop. Infested fruits become scaby and brown leads to severe economic loss.	The pest can be effectively control with 0.1% carbaryl and 0.04% monocrotophos. These species can be effectively control with application of Spinosad 45 EC @ 2.5 ml and Thiamethoxam 25 WDG @ 2 g 10 l^{-1} of water.

Source: Wagle and Sen 1934, Morde 2003, Mulik 2004, Godase and Bhole 2002, Kharat *et al*. 1990, Anonynous 2011, Burondkar *et al*. 2014, Anonymous 2015, Patil 1986, Nadekar 2011, Khochare and Godase 1988.

Table 11. Mango blossom protection schedule.

Time of spray	Recommended Insecticides	Quantity	Remark
First spray at vegetative flush after monsoon	Cypermethrin 25 % OR Fenvelrate 20 % OR Deltamethrin 2.8 % OR Profenophos 40 % + Cypermethrin 4 % OR Chlorpyriphos 50 % + Cypermethrin 5 %	3 ml 5 ml 9 ml 15 ml 10 ml	Mix Carbendazim (50% WP) at 0.1% or Thiophenate methyl (70% WP) at 0.1% or Propineb (70% WP) at 0.2% conc.
Second spray at bud burst stage	Quinalphos 25 % OR Carbaryl 50 % OR Profenophos 50 %	20 ml 20 gm 10 ml	Mix Sulphur (80% WP) at 0.2% or Carbendazim (50% WP) at 0.1% conc.
Third spray 15 days after 2nd spray	Imidachloprid 17.8 % OR Clothianidin 50 % (WDG)	3 ml 1.2 gm	At the time of 3rd, 4th and 5th spray add Hexaconazole (5% EC) at 0.05% or Sulphur (80% WP) at 0.2% or carbendazim (50% WP) at 0.1% conc.
Fourth spray 15 days after 3rd spray	Thiamethoxam 25 % (WDGG) OR Triazophos 40 %	1.0 gm 10 ml	
Fifth spray 15 days after 4th spray	Phenthoate 50 % OR Diamethoate 30 % OR Deltamethrin 1 % + Triazophos 35 % OR Lambda Cyhalothrin 5 %	20 ml 10 gm 10 ml 6 ml	
Sixth spray 15 days after 5th spray if necessary	Insecticide recommended for 5th spray but not used for the 5th spray	-	Give need based spray

Source: Anonymous 2011

panicle. The fruits of peanut size are most probe to fruit drop (63 %) followed by marble (29 %) and egg stage (8 %). The farmer has to bear huge economical loss due to dropping of such early produce. The commercial variety like Alphonso, Neelam, Yermal Goa, Karanjio and Sannakulu are more prone to this physiological disorder. Whereas, the varieties, Ratna, Kesar, Sindhu, Pairi and Goa Mankur reported better tolerance to recurrent flowering. Foliar application of gibberellin at 50 to 150 ppm, after fruits set on initial panicles found effective in suppressing recurrent flowering (Burondkar *et al.* 2000, Shinde *et al.* 2001).

Appropriate Plant Protection

The climatic aberrations have changed the phenophases in mango which necessitates cautions for plant protection. Warm and humid climate of the coastal region of Konkan, Maharashtra is very much congenial for the development of pest and diseases in mango. Unless the plant protection cover is appropriate, the mango cultivation cannot be economical. More than 37 pests are reported on mango in this region. Among them, Mango hopper, shoot borer, fruit fly, midge fly, mango thrips, mealy bugs, stem borer are best known. The important pests of mango, their infecting stages and appropriate control measures are given in Table 10. The appropriate plant protection schedule is also suggested (Table 11)

Diseases

The information of major diseases occurring on mango, their symptoms and control measures are presented in Table 12 and figure 12 and 13. High rainfall, warm and humid climate, untimely rains etc are responsible for development of various diseases in mango orchards. Among the various diseases observed in mango orchards in coastal climatic conditions, powdery mildew, anthracnose, pink disease, die back and bacterial spot are the major one of the symptoms of various diseases observed on leaves, panicles as well as fruits. Continuous rainfall, very high humidity during rainy season when coupled with insufficient penetration of sunlight especially in old and dense orchards intensifies the disease incidence causing considerable economic

Table 12. Major diseases of mango in Konkan region and their control measures

Disease	Symptoms	Control measures
Anthracnose	The black necrotic areas appear on the shoots, leaves and fruits. The affected shoots show dieback symptoms and developing fruits drop down.	1. Removal of affected branches and destruction by burning. 2. Field sanitation 3. Spray Bordeaux mixture (1%) or Carbendazim (0.1%) or Difolatan (0.2%) or Copper Oxychoride (0.25%) or 0.1% Hexaconazole or 0.2% Chlorothalonil or carbendazim + mancozeb (0.1%) 4. (During rainy season, to avoid wash out of sprayed fungicide, 1 ml of sticker should be added in every liter solution)
Blossom blight	The typical symptoms of the disease are the production of blackish brown specks on the peduncle and flowers. Small black spots appear on the open flower, which gradually enlarge and coalesce to cause the death of flower either directly or indirectly by drying up of flower stalks. Under favourable condition the whole flower stalk is infected it and set no fruits. The infected flowers and small fruits fall down.	1. Two sprays of Bordeaux mixture (1%) or Carbendazim (0.1%) or Difolatan (0.2%) or Copper Oxychoride (0.25%) at 15 days interval.
Dieback	Discolouration and darkening of the bark at some distance from the tip. Young leaves and twigs start with ring. The leaves turn brown and margins roll.	1. Collect and destroy dried branches to minimize inoculums of *Botridiplodi theobromae* and spray with 1 % Bordeaux, mixture or 0.25% Copper Oxychloride or 0.1 % carbendazim once before rains. 2-3 sprays at 10-15 days interval should be given.
Post harvest rots	In the initial stage, the epicarp darkens around the base of the pedicel with irregular margin. The infected fruit become watery and air bubble oozed out from the stalk end. Later the affected area is enlarged to form brownish patch which extend rapidly and turned the whole fruit brownish within 2 to 3 days. Frequently, the epicarp shows cracks from which a light tan or brown watery fluid oozes out from the damaged area.	1. Maintain field sanitation 2. Before harvesting of fruits, 2 sprays of fungicide (any one) Carbendazim (0.1%), Captan (0.2%) at 10 days interval. (In fruit, residue level of fungicides should be kept at minimum) 3. Harvest fruits with stalk (Use Nutan Mango harvester) 4. After harvesting, dip fruits in Carbendazim (0.1%) 5. Dipping of fruits in 0.05% Potassium Metabisulphite in hot water (50^0c) for 10 minutes or fruit dip treatment in hot water (52^0c) for 10 minutes.
Powdery mildew	The grayish white powdery mass appears on the flowers and fruitlets. The panicles get dried and turn black with total failure of the crop.	1. Spray fungicides viz Hexaconazole (0.05%) or Tridemorph (0.05%) or Carbendazim (0.1%) or 0.2% Wettable sulphur or Propiconazole (0.1%).
Black sooty mold on fruits	Affected fruits show yellowing of base with development of irregular greyish spots which coalesce into dark brown or black lesions.	1. Black fruits affected by sooty mould be washed with 0.05% bleaching powder solution, followed by dipping in Carbendazim (0.1%) for 5 minutes.

Source: Anonymous 2013; Haldankar and Parulekar 2013

loss to the growers. The casual organism, symptoms and control measures for various diseases in mango are described in Table 12.

Conclusions

Mango thrives well in coastal climatic conditions and it is a source of livelihood of large coastal population of Maharashtra. Alphonso is a leading cultivar occupying more than 90 per cent area under the crop. The recent climate vagaries like prolonged rainfall, extended low temperature, sudden increase in day temperature have been recorded altering the normal phenology of crop which has disturbed not only the production cycle but also deteriorate the quality of the production. The technologies viz. varietal selection, appropriate planting material and planting, regulation of flowering, prediction models for emergence of vegetative shoot as well as flowering, rejuvenation protocol for old and senile orchards, post harvest bagging for production of spotless fruits, precise harvesting and appropriate handling along with sustainable plant protection schedule are certainly helpful for sustainable production of quality mango under the climatic aberrations in coastal Maharashtra.

References

Anonymous 2011. Report of Research Review Committee meeting of plant protection. Recommendation passed in Joint Agresco, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.

Anonymous 2013. Mango production technology. Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli.

Anonymous 2014a. Report of Research Review Committee meeting of plant protection. Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli.

Anonymous 2014b. Database. National Horticulture Board, Govt. of India.

Anonymous 2014c. Recommendation of pulp type of mango varieties under Konkan conditions of Maharashtra. Recommendation passed in Joint Agresco, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.

Anonymous. 2014d. Recommendation of juicy mango varieties under Konkan conditions of Maharashtra. Recommendation passed in Joint Agresco, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.

Anonymous 2015a. Weather based prediction model for vegetative flush in Alphonso mango. Recommendation passed in Joint Agresco (www.dbskkv.org).

Anonymous 2015b. Weather based model of flowering prediction in Alphonso mango for south Konkan region. Recommendation passed in Joint Agresco (www.dbskkv.org).

Anonymous 2015c. Project standardization of hot water dip treatment for fruit fly. Report. APEDA, New Delhi.

Anonymous 2016. Rejuvenation recommendation. Recommendation passed in Joint Agresco, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (www.dbskkv.org).

Burondkar M. M., Godase S. K., Joshi M. S., Khandekar R. G. and Haldankar P. M. 2014. Effect of Vapour Heat Treatment (VHT) and Hot Water Treatment on occurrence of Spongy tissue, Fruit fly and Stem end rot in Alphonso mango fruits. In proceedings of National seminar on global opportunities in Agriculture entrepreneurship/ Business, GOEAB. Pune.

Burondkar M. M., Gunjate R. T. and Govekar M. A. 1994. Effects of Mulching and Mulch Regulated Soil and Atmospheric Temperature on Occurrence of Spongy Tissue in Alphonso Mango. J. Maharashtra Agri. Uni. 19: 408-409.

Burondkar M. M., Rajput J. C., Waghmare G. M., Jamadagni B. M. and Chavan S. A. 2000. Recurrent flowering: A new physiological disorder in Alphonso mango. Proc. Sixth Intl. Mango Symp. Acta Hort. 669 - 673.

Cheema G. S. and Dani P. G. 1934. Report on the Export of Mangoes to Europe in 1932 and 1933. Deptt. of Agric., Bombay, Bull No. 170: 1-31.

Chhatpar H. S., Modi V. V. and Vasavada P. C. 1968. Bacterial production of spongy tissue in mango. M. S. Univ. Baroda. 12 and 18.

Dalvi N. V., Salvi B. R., Chavan S. A. and Kandalkar M. P. 2010. High Density planting in mango cv. Alphonso. J. Hort. Sci. 5: 117-119.

Dhakal D. 1979. Studies on stone grafting in Mango. M. Sc. (Agri.) thesis submitted to Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.

Gautam J. N. 2000. Variability studies in mango (*Mangifera indica* L.) for growth, flowering, yield and quality. Ph.D. (Agri.) thesis submitted to Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.

Godase S. K. and Bhole S. R. 2002. Efficacy of Imidacloprid 200 SL against hopper complex of mango (*Mangifera indica* L.) Pestology 26: 29-31.

Haldankar P. M. and Parulekar Y. R. 2013. Mango Fruit Production in India (ed. W. S. Dhillon.), Narendra Publishing House, New Delhi. pp 382-402.

Haldankar P. M., Parulekar Y. R., Awala K., Kad M. S., Shinde S. M. and Lawande K. E. 2015. Studies on influence of bagging of fruits at marble stage on quality of mango Cv. Alphonso. J. Plant Studies 2: 12-20.

Haldankar P. M., Parulekar Y. R., Kulkarni M. M. and Lawande K. E. 2014. Effect of size of polybag on survival and growth of mango grafts. J. Plant Studies. 3: 91-95.

Jorwehar D. P. 1976. Studies on pollination, fruit set and fruit

drop in Alphonso mango (*Mangifera indica* L.). Thesis submitted to Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.

Katrodia J. S. and Rane D. A. 1989. The pattern of distribution of spongy tissue in the effected Alphonso fruits at different locations. Acta. Hort. 231: 873-77.

Kharat S. B., Godase S. K., and Khochare N. N. 1990. Strategy to combat present pest situation on mango in Konkan region. In proceedings of Seminar on strategies for increasing mango production. Konkan Krishi Vidyapeeth, Dapoli, pp 143-153.

Khochare N. N. and Godse S. K. 1988b. Chemical control of mango leaf thrips (*Rhipiphoro thrips* sp). Fruit Research works. Research Report pp. 299-300.

Korake G. N., Haldavnekar P. C., Haldankar P. M., Mali P. C. and Burondkar M. M. 2012. Effect of Humic Acid on physiological growth of mango (*Mangifera indica* L.) nursery grafts var. Alphonso under costal ecosystem. J. Indian Soc. Costal Agril. Res. 30: 19-23.

Morde S. S. 2003. Studies on fruit fly complex of the Konkan region. M.Sc. (Agri.) Thesis submitted to Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli (India).

Mulik D. 2004. Studies on species composition of fruit flies in south Konkan. M.Sc. (Agri.) Thesis submitted to Dr. B. S. Konkan Krishi Vidyapeeth, Dapoli (India).

Nadekar S. K. 2011. Biology and chemical control of *Ferrisia virgata* infesting mango. M.Sc. (Agri.) Thesis submitted to Dr. B.S. Konkan Krishi Vidyapeeth, Dapoli (India).

Naik S. R. 1985. Studies on physicochemical changes in Alphonso and Ratna mango (*Magnifera indica* L.) fruits during growth, development and storage. M.Sc. (Agri.) thesis Dr Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli (M.S.).

Patil P. D.1986. Chemical control of mango leaf-thrips. Fruit Research workshop. Research report. pp. 334-336.

Powar A. G. and Joshi G. D. 1994. Studies on designing and developing a new improved mango harvester and judging its efficacy. Maharashtra J. Hort. 8: 89-95.

Rai G. D. 1982. Studies on effect of potting mixtures on survival and growth of mango (*Mangifera indica* L.) stone grafts. M. Sc. (Agri.) thesis submitted to Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli.

Shinde A. K., Burondkar M. M., Waghmare G. M. and Wagh R. G. 2001. Control of recurring flowering in mango by GA3. Indian J. of plant physiology. 6: 100-102.

Shinde S. M., Haldankar P. M., Parulekar Y. R., Haldavnekar P. M., Bhave S. G., Godase S. N. and Lawande K. E. 2015. Effect of preharvest bagging with different types of bags on physico-chemical properties of mango cv. Kesar. Green Farming. 6: 809-812.

Tongumpai P., Jutamanee K., Sethapakdi R. and Subhadrapandhu S. 1991. Variations in levels of gibberellin like substances during vegetative growth and flowering of mango cv. Khiew Sawoey. Acta Hort. 291: 105-107.

Wagle P. V. and Sen S. K. 1934. The mango hoppers and their control in the Konkan region, Bombay Presidency. Agric. Liv. St. India 4: 186-188.