Physiological Aspects of Flowering, Fruit Setting, ~~Fruit~~ Development and ~~Fruit~~ Drop, Regulation and Their Manipulation- a Systematic Review

Abstract:

Thephysiologyofflowering and fruit settinginvolvesthechangesinthecharactersofcells proliferatinginthemeristematictissuesoftheshootowingtothespecificgene actionandchangeinthephyto-hormoneslevel. Flowerformation isatransitionphaseinthelifecycleofaplant.The alteration of vegetative apex into reproductive structure results in flowering initiation.The reduction of shoot meristem starts development ofsepals,petals,stamens,carpalsinstead ofleaves.Theplant mustattainspecificstateof'ripenesstoresponse'beforeitflowers.Oncethe stageisreached,thenitcaninducetoflower. Thefloweringiscloselylinkedtothediverseenvironmentalconditionsin whicheachspecieshasevolved.Theeffectsofthelargenumberoffactorsthat influencetheproportionofbudsgivingrisetoflowershavegenerallybeen interpretedintermsofaninbuiltpropensitytofloweringandinterferencewith attainmentofthis.

Introduction~~:~~

1. PhysiologyofFlowering

Theflowerbuds'differentiationisconsidered to be the mostsignificantrevolvingpointinflowering,andthelifecycleof plant's shiftsfromvegetativetoreproductive growth.Thephenomenon of switching plant growth fromvegetativetoreproductivephase iscalled flowering.The activation of flowering genes are responsible for ~~inititiation~~initiation of flowering in plants and ispromptedbyenvironmentalfactors. Thefloweringonly ariseswhenplantsreachedat aspecificage.The process of flowering is divided into two major developmental processes which takes place in two consecutive growing seasons. The two major developmental processes ~~includes~~include the initiation and development of flower buds during the summer and fall of one season. Moreover, the flowering process itself occurring in early spring of next season. The seedling trees take~~s~~ years to reach flowering age. The non-flowering period of young seedlings is called *juvenility*. Seedlings of most fruit trees do not produce flowers~~,~~ before they reach 3-7 years of age (Visser et al., 1976). The ecological factorsresponsible for the activation ofgenes causing floweringare photoperiodic conditions, lowtemperatureandvarious otherstresses.Photoperiodicfloweringregulatedby photoperiodandvernalizationregulatedbylowtemperaturehavebeenwellstudied.

Itcanbestudiedunderthefollowingheads:

1.1 Factorsinthebudforemosttoflowering

~~1.~~ ~~:~~Threefactorswereproposedto happenduringthetransition phase frombudstofloweringi.e.induction,evocationand initiation(Metzger,1987).

- **Induction:** Theperiodwhenfloweringstimulusisproducediscalledfloralinduction.Searle(1965)explained theinductionstate asaphysiologicalconditionof tissues which is

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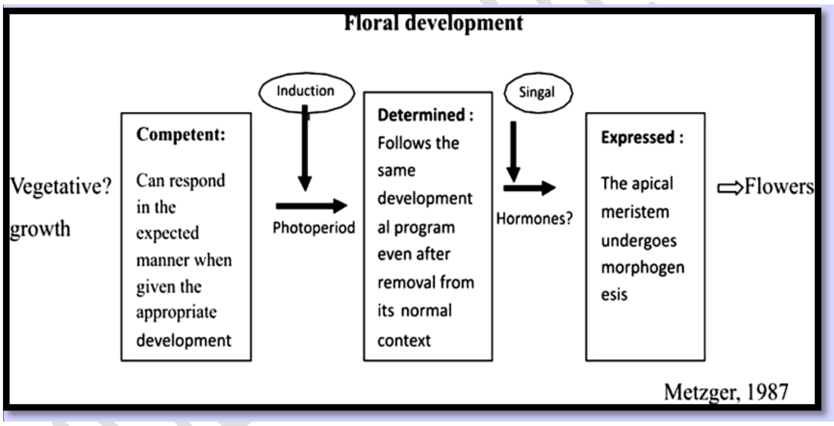
- **Evocations:** Thereception of flowering stimulus by shootapicalmeristemandispermanently devotedtoformthe primordia for flowerbudiscalledfloralevocation(Metzger,1987).After induction and prior to formation of flowering primordia in the apical meristem of photoperiodic plants, the fluctuation of protein complements has been ~~analysed.~~

~~On~~analyzed. On the other hand, the floralevocation processcontains twodevelopmentsituations:competentanddetermined.A cell orgroupofcellsissaidtobecompetentifitcanretortinthepredictable mannerwhengivento asuitabledevelopmentalsignal.

- **Initiation:** Inthisprocess,theevokedbudsdetectibleasaflower budandthusdevotedinreproductivedevelopment.The initiation process cause broadeningandflatteningofthegrowingpointwithconcomitantlyemerginglobes.

Chart 1: Role of induction and signal in floral development.



1.2 Distinctionofthegrowingpoints

~~2.~~ Th econversion of development phasesfromvegetativeto reproductive phasesare usuallymanifestedbythe intensification ofcell divisionwithinthecentralzoneoftheshootapicalmeristems.The intensification of cell division leadsto an increaseinthesizeofshootmeristemtodevelop various flower parts such as sepals,petal,stamensandcarpelsinplaceofleaves.Theprimarynoticeable changefound inthegrowingpointsofthebudis cumulativesynthesisofDNAandRNA. (Buban and Faust, 1982). Normally8-14daysareessentially requiredfrom thebeginning of histological differentiation to the appearance of lower meristem in temperate fruits.The subsequentdevelopmentoftheflowermeristemisrelativelyrapid.Theentire processofflowersanddifferentiationmaytake54-112daysdependingon thespecies.

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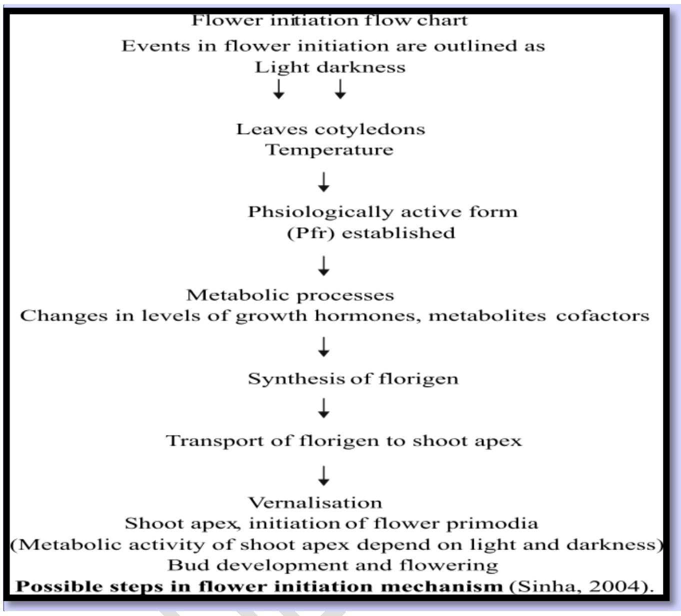
Chart 2. Steps in flower initiation mechanism.



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2. Fruit Setting

The fruit set plays a significant character in modern fruit production. A large yield of fruit can only be expected if conditions are favorable for pollinations ~~for pollination~~ and fruit set ~~are favorable~~. The fruit set involves different steps; the first step is the transfer of pollen to a receptive stigma. This transfer may be natural or artificial, followed by germination and pollen tube growth.These processes are affected by environmental factors, mineral nutrition, and the genetic makeup of the tree. Concomitantly, the mature embryo sac must develop at the base of the style. Then successful fertilization must occur followed by growth of the embryo. The successful occurring of these steps results in overall process called 'fruit set'. Fruit can set and grow to full size without fertilization, the production of fruit without pollination is termed as parthenocarpy. However, a small degree of parthenocarpy is observed in many fruit species, most widespread in pears among the temperate zone fruits. The degree of parthenocarpic fruit set in some of the pear varieties is significantlyinclined by various environmental conditions. In fruit plants, the process of fruit development and seed set is generallytaken place in a very coordinated manner resulting from pollination and subsequent double fertilization in the flower ovule.The final fruit shape is totally dependedon the number of contributive factors,kind and location of various floral organs, and how the different tissues perform functions within them. During the formation of the dry *Arabidopsis thaliana* fruit, the ovary containing two fused carpels enlarges to form a silique with localized dehiscence zones at each carpel boundary that split open to release the mature seeds. By contrast, the ovary of tomato fruits enlarges after the process of fertilization and the locule space round the emergent seeds fill with pulp to form the fleshy fruit.

The pollinated flower develops to a fruit, and the fertilized ovules grow to seeds due to an intense synthesis of growth substances. They appear first in the developing endosperm of the seed primordia (ovules) and penetrate the wall of ovary (the future pericarp) as well as the other parts of the fruit primordium including the peduncle. The ~~centre~~center of organic synthesis of the fruit primordium keeps being the growing embryo and the surrounding endosperm. The intense cell division and growth of the tissues absorbs a lot of organic matter of the reserves competing with the vegetative organs, consequently, an interaction between the different parts of the organs of the tree is building up. Not only the fate of the growing fruit, its size and quality but also the physiological potential of the whole tree is influenced by relations of sources and sinks, which in turn may impair the maintenance of the fruits set.

2.1 Endogenous hormonesinfruits

The dependence of fruit initiation on seed set in flowering plants suggests that fertilization-dependent pollen and seed-derived signals are required for fruit initiation and subsequent development, f~~F~~or example, localized but unknown signals from seeds influence. Severalplant growth regulators such as Auxin, Gibberellins (GAs), and cytokininperform a vital role in growth and development of both fruits and seeds. Both pollen and developing seeds contain plant hormones, and they may serve as sources of some of these hormones. However, movement of hormones from pollen and seeds directly into fruit progenitor tissues has not, to our knowledge, been demonstrated.

Lewisetal.(1965)reported that fruitsetintheparthenocarpicnavelorangewasfoundbytobecorrelatedwithahighlevelofcitrus auxin,acompounddistinctfromindoleaceticacid.Theperiodofmaximumfruitdropcoincidedwith achangeinpatternofaccumulationofthisauxinandtheinitialdetectionofaninhibitor.Auxinsstimul

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Formatted: List Paragraph, Indent: Left: 0.25" ate~~makedly~~markedlythe productionofethyleneby roots,stems,leaves,andfruits.In f~~F~~ig the usage of2,4,5-Twasfound effectivetohastenthe growth and maturation as much as 60 days. Stimulatedby the fact that auxin application promoted ethylene formation and subsequentfloweringinpineapple plants (Burg and Burg, 1966).

The low concentration of auxin hormone in flowers and pollen grains resulting of poor pollen tube growth which leads to poor fertilization and fruit set. Application of an auxin will increase the auxin concentration in flowers which cause better growth and development of pollen tube with better fertilization and fruit set. The deficiency of boron in flower parts will excite the performance of the enzyme indole acetic acid (IAA) oxidase. This enzyme grounds the accepted break-down of auxins hormoneforemost to lower the auxin levels in floral parts.

2.2 Plant Hormones and Fertilization-Independent Fruit Formation

Despite the usual requirement for seed set, the uncoupling of fruit development from the process of fertilization and seed development to produce seedless (parthenocarpic) fruit. (Varoquaux et al., 2002).The genetic basis of seedlessness has been exploited by various field farmers and plant breeders for the production of seedless fruits and elevated endogenous levels of plant growth regulators have been observed during parthenocarpic fruit set, suggested that continues supply of phytohormones to sink from sources other than pollen and seeds may be satisfactory to induce fruit growth. Parthenocarpy can also be induced in varied agricultural species by the exogenous application of auxins, GA_s and cytokinins.

2.3 Transitional Phases -Flowering and Initiation of Fruit and Seed Development

While the physiological basis for seed and fruit initiation and growth has long been attributed to changes in plant hormone levels, the primary hormone cue and the sequence of signal transduction events leading to the coupling of fruit and seed development have remained unresolved. Recent molecular studies on fruit formation due to fertilization-independent in both tomato and Arabidopsis, have identified that the auxin signaling is one of the initialactions in the initiation of fruit cascade. Moreover, the various components of the auxin signaling pathway involved in curbing fruit initiation until the fertilization prompt (Goetz et al., 2006).

3. Regulation and Manipulation of Flowering and Fruit setting

3.1 Induction of flowering

~~1.~~

Gibberellins generally inhibit flowering with the exception of GA, and C-3 epi-GA_4, which have been shown to promote flowering in apple-trees.Morethan90~~percent~~% floweringis inducedinpineapplebyetherel orethephon@25ppmincombinationwithurea(2%)and$CaCO_3$(0.04%) after50daysofapplication. Theflowerandfruitnumbercan beincreasedbysprayingethereal@1~~ml~~mL/~~l~~Lduetogreaterethyleneformingenzymeactivityinleavesleadingto maximumnumberofflowersandfruitsinguava.Etherelhasbeentriedtoinduceflowersin“off”seasonindifferent cultivarsofmangobuttheresultsobtainedwereerratic.However,results haveindicatedthatethylenemaypromotefloweringinmangoonlywhen conditionsforbearingarenototherwiseunfavorable.In guava foliar application of NAA@

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600 ppm or 10 % urea during the full bloom results in full flower drop in summer and betterfruit setting can be obtained in winter for better returns.

3.2 Remedial measures for inadequate winter chilling

~~2.~~

At high altitudes in tropics and sub-tropical and temperate zones, temperatures may be low enough to induce dormancy, but not sufficiently low to satisfy chilling requirements. Foliation is delayed and bud break may extent over longer periods, giving problems in cross-pollination. In Brazil, a combination of 2% thiourea and 10% potassium nitrate, followed by 4% mineral oil and 0.12% DNOC has been approved in Apple. Breeding of low-chilling apple varieties has made it possible to grow apples in warm fruit-growing areas.

3.3 Control of blossom quality

~~3.~~

In pome and stone-fruits, blossom quality, as measured by fruit-set, when blossoms are pollinated by hand, varies considerably from tree to tree and from one season to next. It can be improved by cultural practices such as branch bending (Robbie and Knight, 1985). The physiology behind bending is that it restricts carbohydrate movement and auxin from the upper portion of the limb towards the roots. An accumulation of carbohydrates and slowing down of the growth beyond the bend is, therefore, assumed to be ~~favourable~~favorable to flower bud formation. High temperatures in early spring, between the completion of rest period and blossom opening, have led to reduced fruit-set and this has been shown to be at last in part due to a shortened duration of ovule viability. Supplementary pollination at blossom time or blossom thinning in a heavy crop year is likely to be beneficial.

3.4 Control of pollination

~~4.~~

In Self- incompatible fruit the pollen transfer is the present application problem. Various cultivars of apple partially self-fertile under warm weather, but in many cases the fruitset improved by the utilization of pollinators such as pollinizing varieties and honey bees. Some stone fruits viz. Cherries and plums also requires cross pollination and these should be interplanted with pollinizingvarieties.

The various techniques of breeding and selection in term of self-fertile cultivars may help to achieve acceptable pollination in cool marginal areas where the temperature duringflowering periodisdesirable for both bee activity and growth of pollen-tube (Alston and Spiegel-Roy, 1985). Until the availability of such improved breeding techniques, the establishment of appropriate pollinizing cultivars and bee-hives can be of great help to ensure satisfactory fruit-set. The increasing tendency for using crab-apples, as a pollinator alsooccupying very little space in orchards so it is worthwhile to use only a number of pollinator varieties with widespread flowering dates to ensure cross-pollination.

The decrease in the number of natural pollinators due to indiscriminate use of chemicals and worsening of ecosystem. Managed bee pollination is very limited and available bee hives during bloom hardy meet 2- 3% of the demand. All these factors have ~~lead~~led to poor fruit setting in Delicious (Gautam et al., 1990).

4. Enhancement and induction of fruit-set and retention

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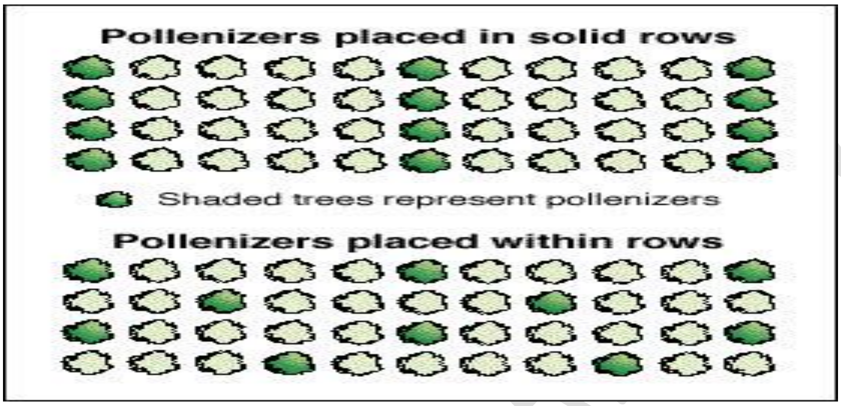
Fruit-set is frequently suboptimal in apple, pear, plum and cherry. This can often be increased by tipping growing shoots to reduce competition from these either just after flowering or at any early fruit let stage.Fruit set can be aided or induced by application plant-growth substances at flowering or after this. Mixture of GA_3 with an auxin induces fruit-set of cherries. $GA_{4\text{-}7}$ is generally more effective than GA_3 on apples (Modlibowska, 1975).

Chart 3. Control of pollination



4.1 Control of frost damage

~~6.~~

Fruit-buds become more sensitive to frost towards full-bloom partly as the result of the increase in water content. Even buds at early stages can be de-hardened by a period of warm weather.Breeding for late-flowering varieties should offer effective control (Jones, 1985). Efforts to increase frost hardiness by chemical sprays or to delay blossoming by use of plant-growth regulators have not yet been as successful to be adopted on a large scale.

4.2 Reduction in crop load

~~7.~~

The first approach to reduce number of fruits per tree is by pruning. This usually involves selective removal of thin shoots with weak fruit-buds; which will give small fruits and have less number of spurs. However, thinning fruitlets after blossoming provides a more flexible technique for adjusting actual fruit load in any particular year.

Blossom thinning by DNOC is practical when there is certainly of oversetting in the absence of thinning e.g. Golden Delicious grown in favorable climates and with minimal pruning. It is achieved by physical damage to blossoms, by preventing pollen germination and by inactivating pollen-tubes growing down the styles.Post-blossom thinning of apples is usually achieved by the use of NAA or Carbaryl (sevin). Childers (1983) suggested chemical application between 10 and 25 days after full bloom. NAA application imposes a physiological stress on the tree which causes shedding of least vigorously growing fruitlets. The growth of the remaining fruit may also be ~~checked,~~checked; their ultimate size may also be less as compared to hand-thinning.

4.3 Hybridization

~~8.~~

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Improved technique of hybridization in mango helps to develop hybrids for airingof desirable characters. Embryological studies revealed that in mango flowers the pollen tubes nurture downward the style and cause effective fertilization but the progress of zygote is impassable due to saprophytic type of incompatibility. The process of hybridization in large scale provides a resolution to the biennial bearing problem (Mukhjere et al., 1968).

4.4 Irrigation

~~9.~~

Maintenance of proper soil moisture at the time of flowering and fruit set is every important. Excessive soil moisture or water stress during these processes results in flower and fruit drop. It has been reported that the irrigation was stopped at the end of September and trees were stress for 6-weeks until beginning of rains in November-December, it set and doubled the yield of litchi while irrigation at 20% or 40% soil moisture depletion gave maximum fruit set and yield of mango (Chandel and Singh, 1992).

4.5 Nutrition

~~10.~~

Various nutrients such as Nitrogen, Phosphorus, Calcium, Magnesium, Zinc, Potassium and Boron have a specific role in maintaining the fruitful ~~behaviour~~behavior of the plants. The balance application (through soil and foliar application) and availability of these nutrients is very much essential for obtaining good fruit set and yield. Fruit retention was significantly improved by the application of $ZnSO_4$ in Kinnow (Daulta et al., 1986).

4.6 Application of Plant Growth Regulators

~~11.~~

In several fruit plants the unproductive nature can be overwhelmedwith the application of phytohormones. Some of the recent findings on ~~unfruitfullness~~unfruitfulnessare given in the following table.

Table 1. Responses of plant growth regulators

Fruit Crop	Growth regulators	Response	Reference
Apple	NAA or Carbaryl (at full bloom stage)	Decrease fruit set Increase yield	Komzik (2004)
	GA3+NAA(a~~A~~t petal fall)	Increase initiation and final set	Jackson et al.~~,~~ (1983)
	Ethephon (for thining)	Decrease fruit set Increase size of fruit	Metz (2005)
Lichi	TIBA,KNO3	Increase pollen fertility	Sanyal et al.~~,~~(1996)
	NAA,200ppm	Increase size, quality and retain bloom	Cuello et al. (~~,~~1992)
	Baoguoji (to prevent fruit drop)	Increase fruit set Increase photosynthetic rate	Liu et al.~~,~~ (2000)
Grapes	GA3	Increase fruit set	Hyatt et al. (~~,~~1994)
	CCC@ 2000 mg/L~~l~~	Increased fruit set Inhibited shoot growth	Todic (2004)
	CPPU (10 ppm) 14 days after bloom	Increase fruit retention, yield and quality	Notodimedjo (2000)
Citrus	GA3	Increase fruit retention	Turnball (~~,~~1989)

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	2,4-D@10ppm	Increase fruit retention	Daulta et al.(1986)
	Paclobutrazol@2.5g/lL	Increase fruit set	Walstenholme et al. (,1990)
	Ethephon	Increase fruit yield	Dumer and Gianfaguo (,1992)
Pear	GA3@50ppm	Increase fruit set and retention, Parthenocarpy	Yuda et al. (,1993)
	1-MCP 0.75 μ/Ll during prepollination	Increase fruit set	Franco et al., (2005)
	GA_3 10 g/ha	Increase fruit set	Decker et al., (2000)
Peach	Dormex,Paclobutrazol,KNO_3	Reduce fruit set	George and Nissan (,1993)

5. Fruit Growth and Development

Fruitisthestructurethatarisesfromanovary(orseveralovariesandinsome casesassociatedfloralparts)afterfertilizationandsupportsthedeveloping seeds.Itisanevolutionaryadaptationuniquetofloweringplantsandisdesigned toaidinthedispersalofseedsbyvariousagencies.

5.1 Stages of fruit development

Inmostspecies,fruitgrowthcanberepresentedbyasigmoidcurveoradouble sigmoidcurvewithasecondburstofgrowthduringtheripeningperiodwhile Kiwifruitfollowsatriplesigmoidgrowthcurve.Physiologicallyandbiochemically fruitdevelopmentcanbedividedintofourphases,whichalthoughcontinuous, areseparatedonthebasisofmajoractivities.

Phase-I: Itincludesovarydevelopmentintheflower,andfloweringanthesis, adecisiontoabortorproceedwithfurtherdevelopment(i.e.rupture ofantherstoreleasematurepollen).

Phase-II: Thisphaseinvolvesaperiodofmostrapidcell divisions.

Phase-III: Itistheperiodofmostrapidgrowthwhencelldivisionsmoreor lesscease,andgrowthisalmostexclusivelybycellenlargement.In thisphase,foodreservesareaccumulatedandmostfruitsattaintheir finalshapeandsizebeforetheonsetofripening.

Phase-IV: Ripening phase.

Insome fruits, such as avocado, cell division may continue well in to phase-III.

Fruitcrop	Periodofcelldivision
RibesandRubus	Celldivisionceasesatanthesis
Cherry	Ceasesabout2weeksafteranthesis
Plum	4weeks
Apple	4-5weeks
Pear	7-9weeks

Sometimesduringcelldivisionperiod,cellenlargementbeginsandproceeds

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atarapidrate.Atblossomtime,intercellularairspacesareabsentorverysmall. Concurrentwithcellenlargement,airspacesincreasetoamaximum,and thenremain constantfortheremainderoftheseason.Earlyinthecellenlargementphase, vacuolesforminthecellsandincreaseinsizeasthecellenlarges,ultimately occupyingmostofthespaceinthe~~centre~~center.Thecombinedgrowthresultingfromcelldivision,cellenlargementandair spaceformationresultsinageneralsigmoidal(S-shaped)curve.Somefruitssuch asstonefruits-current,pistachioandseededgrapehaveadoublesigmoidal growthcurve.Thefirstslowgrowthperiodofstonefruitscoincideswiththe periodofpithardeningduring~~whichlignifications~~lignificationofendocarp(stone)proceeds rapidlywhilemesocarp(flesh)andseed(kernel)growthissuppressed.Nearthe endofpithardening,fleshcellsenlargerapidlyuntilthefruitisfirmripe,after whichgrowthslowsandstops.

FruitDevelopmentStages

1. Celldivision:

- Predominatesafterbloom.
- Smallerfruitedcropsgenerallyhaveashorterperiodofcelldivision.
- Extendedinsomebyblossomthinning.
- 2millioncellsinfleshofappleatanthesisrequire21doublingsofcell number.
- 40millioncellsatharvestrequireonly4.5doublings.
- Mostpost-anthesiscelldivisionsoccurinfirstfewweeksafterbloom, butaslong as100days.

2. Pithardening(stonefruitsonly): Lignification~~s~~ofendocarp.

3. Cellenlargement:

- Predominateslaterinfruitdevelopment(andafterpithardeninginstone fruit).
- Beginssoonafterpollination,continuesthroughcelldivisionstage,then at diminishingrateuntilharvest.

4. Fruitmaturation: Finalweeks(days)offruitdevelopment.

Chart 4. Relationship between relative volume and days for full bloom

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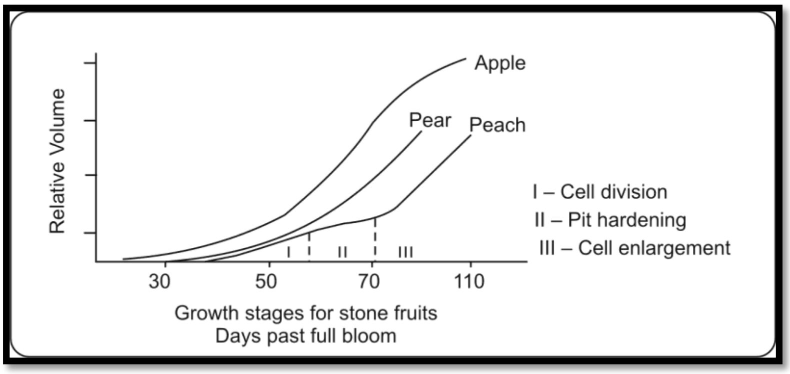

(Jackson,1975)

KeyGrowthStages

Dormant: Fruitbudsrelativelyinactive. Thisistheoverwinteringstage~~,~~(applies toallfruits).
Silvertip: Appliesonlytoapple.Fruitbudscalesseparatedattip,showing lightgraytissue.
Swollenbud: Equivalenttosilvertipstageinapple.Fruitbudsswollen, scalesseparatedtoexposeareasoflightercoloredtissue(appliestoallfruits exceptapple).
Greentip: Appliesonlytoapple.Fruitbudsbrokenattip,showingabout 1/16inch(1-2mm)green.
Budburst: Equivalenttogreentipstageinapple.Fruitbudsbrokenattip, showingtipsofblossombuds(appliestopear,sweetandtartcherry,plumand prune).
Half-inchgreen~~:~~(centimetergreen):Appliesonlytoappleandpeach.In apple,whenabout1/2inch(1cm)ofleaftissueisprojectingfromthefruitbuds. Inpeach,whentheleafbudoccurringbetweenapairoffruitbudshasproduced about1cmofnewgrowth.
Tightcluster: Appliesonlytoapple.Blossombudsmostlyexposed,tightly grouped,stemsshort.
Greencluster: Appliesonlytopear,plumandprune.Blossombudsgreen, mostlyseparatedinthecluster,stemslengthened.
Pink: Appliesonlytoappleandpeach.Forapple,allblossombudsincluster pink,stemsfullyextended.Forpeach,whentheblossombudshowsapinktip.
Whitebud: Appliestopear,sweetandtartcherry,plumandprune.Blossom budswhite,separatedintheclusterandstemslengthened.
Bloom: Blossombudsopen(appliestoallfruits).
Petalfall: Afterabout75percentofthepetalshavefallen(appliestoall fruits).
Fruitset: Astagerangingfromabout4(cherry)to10(peach)daysafter bloomwhentheblossomsthathaveorhavenotsetfruit,initially,areclearly evident(appliestoallfruits).

6. FactorsAffectingFruitGrowthandDevelopment

~~1.~~

6.1 Effectofhormones

~~2.~~ Auxin,GAsandcytokininsareinvolvedintheearly stagesoffruitgrowth,especiallyinPhase-IandPhase-II,althoughtheir exactrolesandinterrelationsamongthemareunclear.InPhase-I,sources ofhormones~~is~~arematerialtissues,butinPhase-IIandIII,whichcoincideswith embryo growth and maturation, respectively, the source ofhormones is debatable.Thehormonescouldbesynthesized*insitu*ortranslocatedfrom

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***Roleofauxins*:**Theinfluencesofseedonfruitgrowthwereshownby Nitsch(1950)instrawberry.Itisanaggregatefruit.Afruitformedfrom severalsinglecarpelsinaflower.Eachcarpelhasasingleseedandproduces anachene(ajointstructureofseedandthesurroundingovarywall).Achenes areborneonthereceptacle,whichformthefleshyfruit.Nitsch (1950)removed varyingnumbersofdevelopingachenesfromyoungfruitofstrawberriesand showedastrongcorrelationbetweenthenumberofacheneleftandthefruit growtharoundthem.Similarpositivecorrelationsbetweenthenumberof seedsandfruitgrowthhavebeenshownforotherfruits(e.g.grapes,blackberry, appleetc.).

Inadditiontoauxin;CKsandGAsalsoplayaroleinthegrowthofthe youngfruit.Cytokininlevelsspeciallyzeatinandzeatinribosidearehighat earlieststageofseveralfruitsandcorrelatedwithperiodofmaximumcell division.Inkiwifruit,theconcentrationoftotalcytokininswashighatthe earliesttimeafteranthesis,droppedtolowlevelslater(Lewis*etal.*,1996).

6.2 Fruitsizeandshape

Theshapeandsizedependonthenumberofcell divisionsanddirectionalityofgrowthofdaughtercellinvarioussectorsof fruitinphaseIIandIII.Thegrowthofbananarequirescellgrowthmostly inalongitudinaldirectionandgrowthofpearfruitwouldberequiredaltered patterns ofcelldivisionandgrowthindifferentsectorsofthefruits.

~~3.~~

6.3 Leafratio

Leafratioplaysanimportantroleinfruitgrowthand development.Itvariesfromcroptocrope.g.30-40leavesareconsidered optimumforapple.

~~4.~~

6.4 Photoassimilates

DuringtherapidgrowthinPhaseIIandIII,fruitsact asstrongsinkandimportmassiveamountofphotoassimilatesfrom photosynthesizingorgan.Suchtranslocationoccursinthephloemtissueand the translocated materials are mostly sucrose, although in some species oligosaccharides(raffinose)orhexitols(mannitol,sorbitol)maybethe predominantsugar/sugaralcohol.Hormoneshavebeenimplicatedin regulatingthepartitioningofphotoassimilatesbetweencompetingsink.In manystudies,ABAhasbeensuggestedasthehormonethatfacilitates unloadingofthephotoassimilatesatthesinksite,butevidenceisequivocal.

~~5.~~

7. Fruit development in some important fruits

7.1 Mango

Thefloweringperiodinmangoisusuallyoftwotothreeweeks.Itisachievedby

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lowtemperature,whereashightemperatureshortensit.Itbearsmainlytwotypes offlowers–maleandperfect,thoughneutralflowersarealsofoundoccasionally. Thepercentageofperfectflowersvariesandisinfluencedbytheenvironmentin whichthesearegrown.Duringtheperiodofpanicledevelopment,lowtemperature increasesproportionofmaleflowers.Thefruitsetisdirectlyrelatedtoproportion ofperfectflowersinitiallybutfinalretentionappearstobegeneticcharacteristic ofthecultivare.g.theinitialfruitsetinLangraisveryhigh,butultimatelyretention perpanicleisbetterinDasheharíwhichhasarelativelylowerproportionofperfect flower(MajumderandSharma,1996).Thefruitgrowthfollowedasigmoidpattern andingeneral,growthisrapidbetween30to90daysafterfruitset.Thefruit volumeisinitiallymorethanthatoffruitweightandthedifferenceoffruit volumeandweightisnarrowupto70daysafterfruitset.Afterwards,thefruit weightwasgreaterthanthatofthevolume.Withtheadvancementofmaturity,the numberoflenticelsdecreases.Themangoseedalsofollowsasigmoidgrowth. Therapidincreaseinlengthanddiameterofseedwasrecordedupto60days afterfruitset(DuttaandDhua,2004).

7.2 Citrus

Citrusspeciesusuallyproducealargenumberofflowersovertheyear.Thefloral loaddependsonthecultivar,treeageandenvironmentalconditions(Monselise, 1986).Ithasbeenreported,forexample,thatsweetoranges(*Citrus sinensis*)may develop250,000flowerspertreeinabloomseasonalthoughonlyasmallamount oftheseflowers(usuallylessthan1%)becomesmaturefruit.Thus,floweringrepresents agreatinputforcitrustreesandtosomeextentevenawasteofresources.For someauthors,however,thisreproductivepatternmaybelinkedtoasurvival strategy.Underunfavorableenvironmentalconditions,suchaslatefrostordrought orexcessiverainetc.mostofthecitrusspeciesproducepoorfruitsetandhigh fruitdropresultsinpooryield.

7.3 Grapes

Pollination,fertilizationandseeddevelopmentresultsinberryset.However,some cultivarssetbyparthenocarpy.Inseedlesscultivars,fertilizationoccursbutthe embryosubsequentlyabortswhichistermedasstenospermocarpy.Thegrapeberry growthfollowsadoublesigmoidgrowth.Berry growthanddevelopmentinPusaUrvashiobservedadoublesigmoidgrowth patternlikethoseintypicalseedlessgrapegenotypes;however,thetotalduration wasremarkablyshortincludinglagphase.Vineswere trunkgirdledatfruit setstagealone orincombinationwiththreeconcentrationsofGA$_3$(20,30and40ppm)onceand twiceafteraweekoffirstapplicationtoimproveberryquality.Thedifferent combinationsofgirdlingandGA$_3$showedthattrunkgirdlingatfruitsetpriorto applicationof40ppmGA$_3$atfullbloomhastenedtheberryripeningby5days. Berryqualityimprovedwithoutaffectingtheyieldi.e.byloosening thebunchwith uniform,largeandelongatedberrieshavingbetterTSS/acidityratio.

7.4 Apple

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Duetolackofcultivarssuitableforcrosspollinationfruitsetofapplemaybe affected.Weatherconditionsduringbloomingseason,suchastemperaturerainfall andhumiditymayalsoproduceanunsatisfactoryfruitset.Frostatbloomtime canpreventpollinationbykillingthestyle.Highrelativehumidity(>50%)in March,delayfloweringwithoutaffectingfruitsetandyield.Verylowtemperature (<4.5°C)reducedfruitsetbyinterferingpollengerminationandbeeactivity. Sprayofaminoethoxyvinylglycine(AVG200ppm)appliedaloneorwithGA+ BA(50ppm)inhibitsendogenousethyleneproductionandincreasefruitsetin treatedflowers(Greene,1980).Thereisacontinuedenlargementofreceptacleduringthedevelopmentof fruit.Arapidphaseofcelldivisionoccursinfirstfewweeksafterpollination, whichceaseabruptly30-40daysafterfullbloominCox'sOrangePippin.The subsequentfruitgrowthoccursmainlyduetocellexpansion.Thefruitgrowth patternfollowsasmoothsigmoidcurve(Mitra,1991).PrebloomapplicationsofGA$_3$at10ppm+BA at5 ppm+NAAat5ppmgavethebestqualityfruits(intermsoffirmness,total solublesolidsandtotalsugars),andthemostefficientinmarginalapple growingareasofHimachalPradesh.

*50percentGA4+7+50percent6-benzyladenine(BA):*Promalinstimulates growthofapicalportionofapplefruit,increasedlength/diameterratio.

*5percentGA4+7+95percentBA:*Accel,apostbloomthinnerthat sometimesincreasesfruitgrowth(size)ofapple.

Gibberellicacid(GA$_3$): ProGibbdelaysmaturityandincreasesfruit size,solublesolidsandfirmnessofcherryfruit.

***CPPUandBA*:**Croploadreductionwithcommercialthinnersisusedto increasefruitsize.Although,totalyieldisreduced,theremainingfruitsare ofhighervaluebecauseoftheirincreasedsize.Bezyladenine(BA)isused tothinapplesanditincreasesfruitsize(MoranandSouthwick,2000)by stimulatingadditionalcelldivisionswithinthefruit(Wismer*etal;*1995). CPPU[N(2-chloro-4-pyridyl); N-phenylurea] at 10 ppm and BA (Benzyladenine)at50ppmresultedinsignificantincrease(>50%)infruit sizeofRoyalGalacv.ofapplewhenappliedtwoweeksafterfullbloomdue tosimulationoffruitcortexcelldivisionBA promotes celldivisionintissuespossiblybyincreasingzeatinribozidelevelsinthe fruits.Bothcytokininsincreasedfruitsizewithout affectingfruitshapeandseednumber,andwithnoreductioninthereturn bloomoryieldofthefollowingyear.

***Promalin*:**Promalin(GA+BA)sprayedat50percentfullkingbloomand repeatedatfullbloominsingleandsplitdosestoStarkingDeliciousapple increasedtheTSS,totalsugars,solubleproteinsandanthocyaninanddecreased acidity.Inareasexposedtowarmweatherduringfloweringanddevelopment promalintreatmentsimprovedthequantitativeaswellasqualitativeparameters.

7.5 PearandStoneFruits

Cross-pollinationisrequiredinmostofthecommercialcultivarsofJapanesepear (*Pyruspyrifolia*Nakai),tosetfruitsbecausetheyexhibitgametophyticself-incompatibility.Toimprovefruitsetandproduceacceptablecommercialfruit sizeandperfectlyroundshape,artificialpollinationusingcompatiblepollenis commonpracticeinthepredominantJapanesepear.Generally,fruitsetisnotaproblemincommercial pearcultivars.FruitsofPatharnakhpeartake150daystomatureandphysiological developmentinvolvesmeasuringchangesinsize,specificgravity(SG),skin~~colour~~color,

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pigment,TSS,phenoliccontents,andfruitfirmness.Fruitgrowthshows3phases, active,veryactiveandveryslow,asmeasuredbysize(lengthanddiameter)and weight.Fruitfirmnessdecreasesduringthefinal50daystoharvest.TSSshowsa continuousincreaseduringdevelopment(from7.80to13.53%);thisincreaseis mostrapidbetween15and30days,andagainbetween75and90days.Reducing andtotalsugarsbothincreasecontinuouslyuntilharvestandtheincreasesare rapidduring120to150days.(MannandSingh,1990).

7.6 Plum

All*prunus*speciesfollowthedoublesigmoidgrowthcurve.Duringthesubsequent developmentofthefruittheouterwalloftheovarygivesrisetothreedistinct layersofthepit.Twohypodermallayersintheovaryproducetheskinofthe fruit,whichconsistofcuticle,theepidermisandafewlayersofcollenchymatous cells.Thefleshcontainsmostofthevascularbundleofthefruit,whichare embeddedinthelignifiedtissueofthepit.Thefreshfruitweightandsizeincreases ~~throughout~~througho utthegrowingseason,whilethesugarcontentincreasesgraduallyand rapidlyduringripening.Drymattercontentincreasesgradually,beingsharperat ripening.Theorganicacidincreasesinitiallybutdecreasesduringfruitdevelopment (JosanandChohan,1982).

7.7 Strawberry

Maximumfruitsinstrawberrydevelopfromtertiaryflowerthanfromprimary andsecondaryflowers. Plantgrowth,developmentandcompositionof fruitsareaffectedbygeneticfactors.However,environmentalfactorssuchas wateravailability,dayandnighttemperatureanddaylightintensityalsoinfluence thefruitproduction.Theeffectsoftemperatureaswellasitsinteractionwith otherenvironmentalfactors,likephotoperiodoftenvarywithcultivarsandspecies. Theinfluencesofday/nighttemperature combinationonplantgrowthandfruitqualitywasstudiedbyShiowetal.(2000) incv.EarliglowandKentofstrawberry.Theoptimumday/nighttemperaturefor fruitswasfoundtobe18/12°C.

7.8 Loquat

Loquattreesflowerprofuselyincompressedpanicles,andalthoughfruitset percentageisverylow,fruitsizeiscommonlyverysmall.Infruitcrops,fruitsize isinverselyrelatedwithnumberoffruitsproducedpertree.Increaseinaverage fruitsizecanbeobtainedbythinningthefruitmanuallyorchemicallyorby applyingsyntheticauxinsattheonsetofcellenlargement(Agustietal.,2005).

8. Regulation and manipulation of Fruit development

8.1 ~~1.~~ Climatic factors

~~:-~~Climatic factors like late spring frosts, precipitation, rainy days and low noon temperatures produce most negative effects on percentage fruit set and yield. ~~Unfavourable~~Unfavorable meteorological conditions during flowering produce low yields and the greatest reduction in yield has been found to be due to late spring frosts

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(Grabowsky and Zielenkiewicz, 2000).

8.2 ~~2.~~Chemicals:

Dormex spray resulted in earlier flowering by 2-5 days in apricots and in plums by 4-8 days. Application of 1% ~~per cent~~ and 2% ~~per cent~~ hydrogen cyanamide (Dormex, 49%) gave better flower and vegetative bud break ratio, fruit set and fruit development in dormant trees of Papaz plum and Tokaloglu and Karacabey apricot cultivars. The highest bud break and fruit set ratios were 87.67 and 85.33% ~~per cent~~ in Papaz plum treated with 2 per cent hydrogen cyanamide, respectively. Promalin applications also caused better flower and vegetative bud break, fruit set and effect fruit yield. Chemically treated trees could be harvested 2-9 days earlier than control trees. Spraying with PCPA (4-CPA) at 30 x 10^{-6} M at the stage of 75 per cent flower fall increased the fruit set and hence effect fruit development. Application of mixture of 30x10^{-6} M PCPA + 2000 x 10-6 M borax + 2000 x 10-6 M potassium dihydrogen phosphate also produced good effect on fruit size and quality (Wu *et al;* 1993).Dipping of berries of grapes in GA @40 ppm when berry size is 4mm and again after a week alongwith girdling of vine resulted in improve size of berry in grapes.

8.3 ~~3.~~ Water stress

~~:~~ Growth of shoots, flowers and fruits in deciduous trees appears at different times and therefore the timing of regulated deficit irrigation can influence its effects. The stage II of fruit growth has been identified, as an appropriate period at which fruit growth is minimal and therefore not affected by drought, while shoot growth can be reduced in stone fruits. In early cultivars, this period is very short, the main shoot growth occurs after harvest, and thus may be ideal time for droughting (Johnson and Handley, 2000). It was reported that, water deficit during fruit growth reduced average fruit weight, with a negative correlation between fruit size and integrated ~~mid day~~mid-day stem water potential. In contrast, drought after harvest did not affect flowering, fruit set, fruit growth or yield, in the short term, but drought may reduce productivity, in the long term, as a consequence of the cumulative effects of water deficit on tree growth.Regular irrigation during critical period i.e. end March to ~~e~~End April in early cv. Partap, ~~Flroda~~Florida Prince and end April to ~~mid May~~mid-May in late cv. under subtropical condition resulted in higher fruit weight and quality in peaches.

8.4 ~~4.~~ Nutrients

The tree performance (branch elongation, flowering and fruit setting intensities) and fruit size has been found to be increased by titanium sprays in combinations with other commercial compounds containing Ca^{2+} and Mg^{2+}. This improvement due to calcium absorption as a consequence of the beneficial effect of titanium is on the absorption, translocation and assimilation processes (Alcaraz *et al;* 2003).

9. Fruit Drop/Abscission

The most important components of fruit drop are: the rootstock, the combination of ~~pollinizer~~pollinizer varieties, the conditions depending of nutrition, the extent and timing of

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the administration of fertilizers, the moments of water stress and the timing of agro-technical interventions. Further adversities may appear as flushes of heat and drought, the rainy spring weather during the blooming period as well as the excessive hot, cool or windy weather impairing pollination, moreover, the appearance of diseases and pests all influence the fate of flowers of growing and become ripe fruits. As generally maintained, dry springs are causing severe fruit drop. In ~~analysing~~analyzing the endogenous and environmental causes of drop of the generative organs (flowers and fruits), the model of leaf abscission has been used, as a study of the excised, well defined abscission zone (AZ) seemed to be an adequate approach to the question. Comparing the effects active in the abscission of fruit with those of the excised leaf stem differences are observed as well as analogies between the anatomy and the accumulation of ethylene in the respective abscission tissues.

Fruit set percentage and severity of fruit drop vary considerably among the major fruit crops. Fruit set may be as high as 90% for blueberries, 10- 20% for apples and peaches to a low of 1% for sweet oranges. Moreover, blueberries have a small percentage of fruit drop after the initial fruit set period, while apples, peaches and citrus have a pronounced and sometimes extensive June drop. The severity of post-bloom drop is a function of cultivar, environment, and cultural practices. Nevertheless, some degree of fruit drop is not only desirable, but necessary. For example, a mature navel orange tree may produce 100,000 flowers. If even 10% of these produced mature fruit, yields would average about 125 boxes/tree. Abscission(fromtheLatin*ab*meaningawayand*scindere*meaningtocut)is thesheddingofabodypart.Ittakesplaceprimarilyatpredestinedsitesthat arecommonlylocatedatthebaseofanorgansuchasaleaf,flower,fruitorseed.Trees shedmanypartsbesidesleaves,includingfruit,flowers,budscales,trichomes, abscissiontwigs,andbark.

Fruit drop may be divided into 3 major periods for citrus.

9.1 Post bloom Drop

Post-bloom drop occurs during and within a few weeks of bloom, involving the abscission of flowers and small fruit. Post-bloom fruit drop accounts for an 80-90% reduction in the total flower number. The causes of post-bloom drop include inadequate pollination, water or temperature stress, inadequate nitrogen levels, and natural abscission probably regulated by hormone imbalances in the fruit.

9.2 June drop

June drop is a common occurrence for many fruit crops. As the name implies, June drop occurs in June for many temperate crops, like apples and peaches. Fruit size generally ranges from 1 to 3 cm in diameter during this time. June drop is most severe and troublesome to growers in arid climates where temperatures routinely reach 40°C. Although manycauses have been proposed for June drop including water stress, hormone imbalances and competition among fruitlets but high temperature stress appears to be the most important cause.

9.3 Pre-harvest drop

It is the most serious fruit drop which resulted in the higher economic loss to the grower and it is very difficult to control. It occurs after the fruit have reached legal maturity but prior to harvest. The problem is most severe for 'Temples', 'Pineapple' oranges, and

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'Murcotts', but also is a problem for navel 'Minneolas' and grapefruit when held on the tree late into the season Pre-harvest drop used in this sense is not caused by a specific organism or environmental factor but is simply due to natural aging and abscission.

10. Changes during fruit drop/abscission

Duringabscissionchangesoccuratmorphological,anatomicalandbiochemical levels.

10.1 MorphologicalandAnatomicalChanges

I. Formationofabscissionzoneatthejunctionofabscisingorgans(flower, fruit)andtheparentplantbody.

II. Swellingorconstrictionofabscissionzonesw.r.totherpartsofpedicle.

III. Abscissionzoneis1-2rowsorup to15ormorecelltierthickness.

IV. Cellsareparenchymatous,devoidofligninandsuberin,denseprotoplasm, morestarch,smallintercellularspacesandhighlybranchedplasmodesmata.

V. Steleusuallydividesintoseparatebundlesbeforeitentersthezone.

VI. Dissolutionofmiddlelamellaresultinginlooseningofcells.

VII. Weakening and breaking of vascular connections between leaves, fruits, flowersandtheparentplant.

VIII. Developmentofperidermtoprotecttheexposedsurfaceandcellsbecome suberised.

IX. Formation of tylosses (bladder like protrusions from xylem parenchyma cells) whichblockxylemvessels.

10.2 Biochemicalchanges

I. Enhancedproductionofhydrolyticenzymes-cellulase,pecticenzymes,lignase whichcausedissolutionofmiddlelamellaandprimarywallsofthecellsin abscissionzone.

II. Polygalacturonaseleadingtobreakdownofmiddlelamella.

III. Capectateinmiddlelamellaishydrolysedtopecticacidandpectate.

IV. Cellexpansionbycellulaseinabscissionzone.

V. Hydrolysisofligninbylignases.

VI. Auxindestructionbyincreasedperoxidaseactivity.

VII. ActivesynthesisofproteinsandRNAinabscissionzone.

Besidestheabovechanges,manyotherprocessestakeplacetopreparethe plantforthisevent.Forinstance,thevascularelementsthatservicetheorganare occludedandtheexposedfracturesurfacesareprotectedfromwaterlossand invasionbypathogens.

11. Abscissionzones

Abscissionzonesoccuratthebaseoffruit pedicleandatthebaseofleaflets. Fruitsareshedthrough anumberofbiologicalactionswhichweakencellwallsandinitiatecellstearing awayfromoneanother. Abscissionzonecellstendtobesmaller,moredenselypacked,withnointer cellularspaces,lesslignin,andhaveremainedinacelldivisionphaselongerthan surroundingcells.Additionalcelldivisionsinthiszonepreparethesecellsfor laterabscissionprocesses.Inmostabscission zones,thereisasinglefaultlinewhichdevelopsandisaccentuatedbyadditional walldegradations.Cellsadjacenttofaultlinecellswillhaveweakenedwallsalso,allowinganyfractu restopropagatealongseveralpathsforshortdistances.

11.1 Wallweakening

Theabscissionprocessbeginswithgrowthregulatorsignals initiatingcellularchanges.Abscissionzonecellssecretepectinaseandcellulase (walldegradationenzymes).Theseenzymesdegradethestrengthofthemiddle lamellaandprimarywallbetweencells.Themiddlelamella,thegluewhichholds cells together, begins to dissolve in the abscission zone.At the same time, surroundingprimarywallsbegintoswellfromchangesinchemicalcomponents.

11.2 Wallchanges

Ascellwallinterconnectionsareweakened,waterpressure withinthinwalledcells(turgorpressureinparenchyma)causesthesecellsto expand.Ascellsexpand,theygenerateshearforcesbypushingandpullingon surroundingweakenedwalls.Mechanically,fracturelinesbegintodevelopbetween cellwalls.Ascellwallspullapartfromoneanother,thisopenwound isbeingclosedbydepositionofblockingmaterialsandprotectivecompounds.A strongprotectiveboundaryzoneispreparedtodefendremainingtreetissuesfrom theenvironmentandpests.Tyloses,suberin,ligninandotherprotectiveboundary settingmaterialsaredevelopedanddepositedonthetreesideoftheabscission zone.

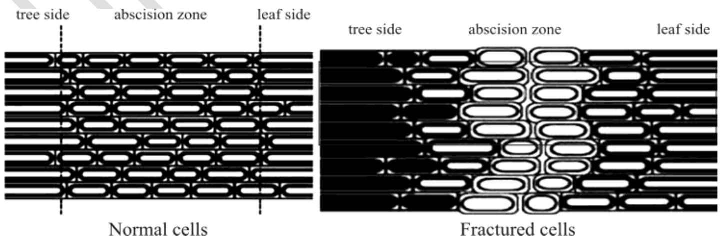

Fig. 1: Twodimensionaldiagramshowingcellsinaleafbaseabscissionzonewith afracturelinebetweencells.Treeprotectionzone,walldegradationareas, andcellexpansionzonealldisruptingcell-to-cellconnectionsareclearly shown.

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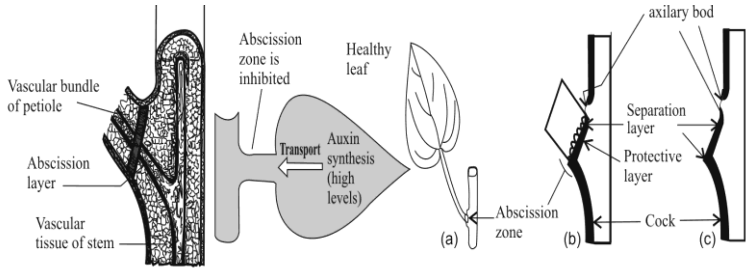

(www.answers.com/topic/abscission).

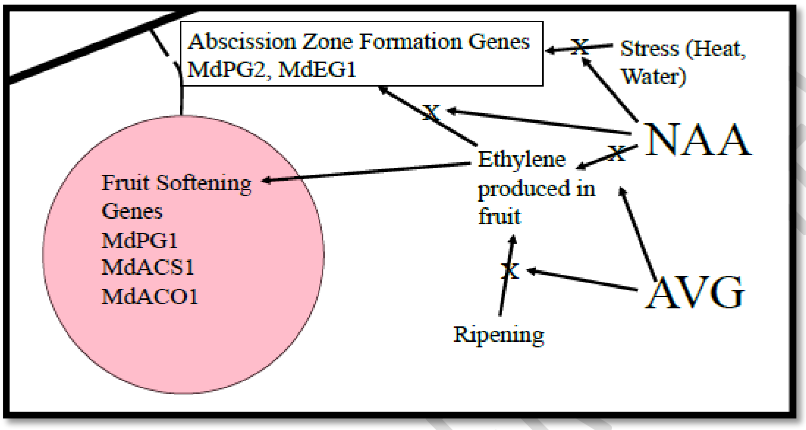

Fig.2: Proposed Model of Abscission (Rongcai Yuan, 2008).

12. Regulation of Fruit drop

Auxinisaprimarygrowthregulatorproducedinthefruit andslowlytransported towardsthestembasethroughlivingcells.Aslongasauxiniseffectivelybeing transportedacrosstheabscissionzone,abscissionzonecellsremainunreactive. Asauxinproductionbeginstodecreaseinfallandauxintransportratesbeginto declineduetolessauxinavailability,damagetolivingcellstransportingauxin,and/oracceleratingin fectionoflivingtissuesbypests,cellwallchangesare initiated.Cellwallchangesincreasinglyinhibitauxintransportandaccelerate ethyleneproduction.Smallamountsofethylenehastenabscissionzone development.Abscisicacidisresponsible(inpart)fordormancyonsetin theleafstimulatesethyleneproductionandinhibitsauxintransport.Duringabscissionendogenous auxinandcytokinincontentdecreasessharplywhileABAandethyleneincrease.

12.1 Regulationoftiming

Thetimefromthedifferentiationoftheabscissionzone toorgansheddingcanrangefromdays(orevenhours)tomanymonths.Itiswelldocumentedthatthe main abscissionacceleratingagentisethylenewhiletheplanthormoneindoleacetic acid(IAA)delaystheprocess.Ithasbeenproposedthatbyalteringthebalance betweenthesetwonaturallyoccurringstimulithetimingofabscissioncanbe accuratelycontrolledinplants.Theoriginoftheelevatedethylenethatprecedes organsheddingemanatesfromtissuesdistaltotheAZsuchasthediseasedor

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senescingleafblade,orripeningfruitinclimactericspecies.Althoughapplication ofethylenehasbeenshowntopromoteabscission,floralorgansof*Arabidopsis mutants*suchas*etr1*,thatareblindorinsensitivetothegas,areshedalbeitat alaterstageofdevelopmentthanwildtypeindicatingthatitisnotanabsolute requirementforsheddingtobeinitiated(Patterson,2001).

12.2 Regulationofcellseparation

Abscissionleadstoaseriesofeventsthat resultincellseparationatthepointoforgandetachment.Ultrastructuralanalysis indicatesthatthisisprimarilyaconsequenceofthedissolutionofthemiddle lamellaandthatimmediatelypriortosheddingitisonlythelignifiedtissuesof thevasculartracethatretainanattachmenttotheparentplant.Theseconnections arethoughttobefinallyseveredbythehydraulicexpansionoftheisodiametric AZcellsoncethe constraints imposed by the matrix have been loosened. Anumberofmechanismshavebeensuggestedthatbringaboutwallbreakdown butmostimportantisbyanenzymaticprocess(SextonandRoberts,1982).

12.3 Protection of fractured part

Once cell separation has taken place and the subtending organ has been shed, the scar remaining provides an ideal site for invasion by bacteria and fungi. But the remaining cells divide and suberize to protect the wound. The broken xylem vessels become blocked with gums or tylosses and the phloem sieve plates are callused over to prevent pathogen entry.

13. Manipulation of fruit drop

Toolittleabscissionofyoungfruitsresultinproductionoflargenumberof unmarketablefruitswhereastoomuchabscissionresultsinuneconomicalyields. Hencemanipulationofabscissionundercertainconditionsisdesirable.Thereare differenttechniquesthroughwhichabscissioncanbemanipulated.Broadlythey canbecategorizedasfollows:

~~1.~~I. **Understandingphysiologicalbasisofabscission:**Byunderstandingthe physiologyofabscission,flowerandfruitdropcanbemanipulatedaccordingly.
~~2.~~II. **Genetics of abscission:**Breeding of varieties with different abscission characteristicsforexampleraspberrycultivars.Therearetwo~~tyes~~typesofcultivars viz.handpickingonesthatdonotdropripeberriesbyshakingthebushand mechanicalpickingtypes,wherefruitseasilydetach.
~~3.~~III. **rDNAtechnology:**Useof~~antisence~~antisenseRNAtechnologyforACCsynthaseto blocktheethylenesynthesisandhenceslowingabscission.Itisalsousedforwall degradingenzymescellulaseandpolygalactourasae(PG).
~~4.~~IV. **Accelerationofabscission:**Byincreasingethyleneproductione.g.spraying ethephon,wounding.
~~5.~~V. **Inhibitionofabscission:**Reducingethyleneproductionorinterferingwith ethyleneactione.g.useofantagonistslikeAVG, AOA,silverthiosulphate,DACP.
VI. **Preventionofabscission:**Useofauxinsandcytokinins.
~~6.~~

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13.1 Fruit drop in some fruit crops

- **Citrus**

The most pronounced stages of fruit drop are;~~,~~ (i) immediately after fruitset at ~~marble stage~~marble stage which lasts for a month after full bloom, referred as post-set drop;~~,~~ (ii) the second wave of intense fruit drop occurs at the onset of hot summer weather during May-June, known as June drop;~~,~~ and (iii) preharvest drop or premature drop occurring during ripening period, which lasts from August to December-January. Higher summer temperature, excess or deficiency of soil moisture, lack of nutrients like zinc, phosphorus and potash and attack of fungal diseases like anthracnose, styler-end rot and stem-end rot are some of the primary factors responsible for fruit drop. Spray of 2,4-D @ 5 g + Bavistin 50 WP @ 500 g (or Propiconazole 25 EC @ 500 ml) in 500 ~~litres~~liters of water/acre in ~~Mid April~~Mid-April, August and first week of Sept. along with sprays of Bavistin 50 WP @ 500 g (or Propiconazole 25 EC @ 500 mL~~l~~) in 500 ~~litres~~liters of water in End July and end Sept. If there are broad leaf crops grown nearby, then use GA @ 20 ppm instead of 2-4 D.

- **Mango**

In mango, there is a heavy drop of hermaphrodite flowers and young fruits amounting to 99% or more. In general, in mango 0.1% or less hermaphrodite flowers develop fruits to maturity. The maximum drop of fruits in 'Langra' and 'Dashehari' takes place in the first three weeks of April and differs significantly from the drops in the following weeks. Fruit drop is to some extent associated with the variety, as the variety 'Langra' is more prone to fruit drop than 'Dashehari'. The embryo in the initial stages of its developmentmay yet be another cause of drop. This occurs invariably, if the flowers are self-pollinated. 2,4-Dproduced better results at concentrations below 20ppm, because at higher concentrations fruitand seed development is retarded. Spray of 2,4-D @ 20 ppm in end April in Dashehri and in first week of May in Langra produced better results.

- **Apples**

All apple varieties show some fruit drop as they progress through the ripening period but some varieties begin to drop large numbers of fruits early in the ripening period before they develop sufficient red color to meet market requirements. McIntosh is particularly prone to pre-harvest fruit drop. In some ~~years~~years' losses can exceed 50% of the crop and frequently pre-harvest drop results in severe economic losses.Application of NAA, diaminozide (alar) and Aminoethoxyvinylglycine (AVG) proved better results in controlling pre-harvest fruit drops.

- **Stone fruits**

Various peach and apricot cultivars showed early and more uniform maturation and improved fruit ~~colour~~color following sprays of 2, 4, 5- TP, SADH or CEPA, but these effects were often accompanied by un-desirable responses such as softening, cessation of growth, or abscission. Other substances, such as chlormequat, ABA and calcium nitrate

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delayed fruit maturation and increased firmness, whilst phenoxy auxins decreased fruit drop of peach and almond. The use of such compounds, together or in succession, offers possibilities for the practical control of stone fruit maturation. On the almond cv. 'Ne Plus Ultra' good control of pre-harvest drop was obtained with both 2, 4, 5-TP and 2, 4, 5-T when applied about five ~~5~~weeks before harvest - the stage when the abscission layer markedly began to develop. Earlier or later sprays were less effective, the latter sometimes increasing the rate of abscission.

Conclusion

Flowerbuddevelopmentinvolvesthetransformationofthe vegetativeapex to areproductivestructure. Threeeventsoccurduringthetransitionofbudstoflowering, i.e.induction, evocationandinitiation. Firstvisiblesignofdifferentiationiswhentheflatapicalmeristembecomes domed,thenthecentralmeristemispartitionedandthepithmeristemdevelops. Flowers and pollen grains with low auxin levels have poor pollen tube growth, leading to poor fertilization and fruit set. Application of an auxin dominant will increase auxin levels in flowers resulting in better pollen tube development and growth, with better fertilization and fruit set. Correction of Boron deficiency levels will inhibit IAA oxidase and prevent the break-down of auxins present in floral parts

Mostfruitsfollowsinglesigmoid,somedoublewhilesomeotherstriple sigmoid(Kiwi)growthcurve. Celldivision,cellenlargementandmaturationareimportantstepsoffruit growthanddevelopment. Variousinternalfactorslikehormones,cellsize,cellnumber,seeds, photoassimilatesetc.andexternalfactorsincludingtemperature,light, chemicals,culturalpracticesetc.influencefruitgrowthanddevelopment. Growthregulatorsplayanimportantroleindevelopmentoffruits. Various physico-chemical changes like increase in size, weight, volume, changein~~colour~~color,TSS,acidity,reducingsugarsetc.occurduringfruitgrowth anddevelopment.

Fruit drop or abscissionisahighlycoordinatedprocessthatleadstosheddingoffruitsinplants.Variousmorphological,anatomicalandbiochemicalchanges takeplaceduringthisprocess.Duringabscissionthereisdegradationofmiddle lamellaofcellsandformationofabscissionzones,andenzymessuchasEGsand PGsarethoughttoplayimportantroleintheseevents.Thereisprotectionof fracturedsurfacesthroughexpressionofPRrelatedproteins.Althoughmany ~~hypothesis~~hypotheseshavebeenputforthtoexplaintheprocessofabscissionbutthe molecularmechanismsremainstillunclear.

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