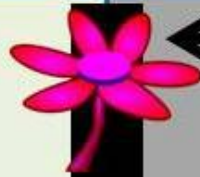


Dormancy

Definintions, physiology, Types of
dormancy in vegetables

Plant Development

Seed
Development



← Pollination

Seed
Dormancy



← Seed
Maturation

Plant
Growth



← Germination



← Plant
Maturation



PLANT BEHAVIORAL ADAPTATIONS

DORMANCY - A state of rest or inactivity.

Many plants go dormant in the winter. Fall is the time of year when plants are preparing for dormancy.

Why do trees
lose their leaves
in the fall?



What other types of
plants go dormant in the
winter?



In plant physiology, dormancy is a period of arrested plant growth.



Seed dormancy

Dormancy

- **Dormancy** is a mechanism to prevent germination during unsuitable ecological conditions, when the probability of seedling survival is low.



Dormancy

- A mature plant can turn dormant for survival against extreme temperatures.
- Environmental triggers for growth and dormancy are temperature, water, and light.
- Most dormant plants lose their leaves and form winter buds.
- Unfavorable weather conditions can be bypassed by producing dormant seeds.

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(a)

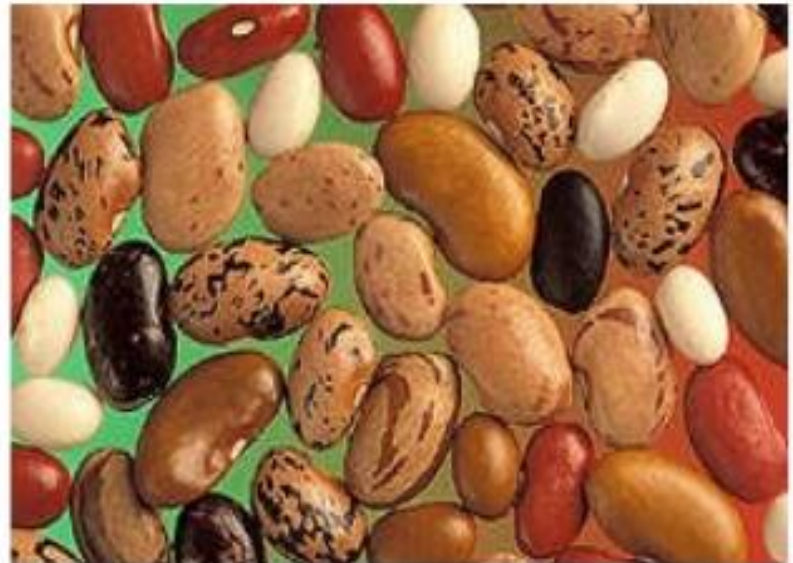


(b)

- Among the many structures which exhibit dormancy, **seeds and buds** are important. There are two types of dormancy
 - **predictive dormancy**
 - **consequential dormancy**
- Dormancy can last long nearly **1300 yrs in lotus fruit recovered from a dry lakebed in north eastern china.**

Dormancy (advantages)

- Plant avoids harsh winter conditions
- Gives the embryo time to develop
- Provides time for dispersal



- The controlling factors that impose dormancy are many ex., the strength or the susceptibility of seed coat, ability of the seed to absorb and utilize water or oxygen, presence of inhibitors and environmental factors like temperature, water, day length,

SEED GERMINATION = radicle emergence

Seeds Lacking Dormancy Moisture Warmth

Dormant Seeds need more than this:

Thick Seed Coat Scarification

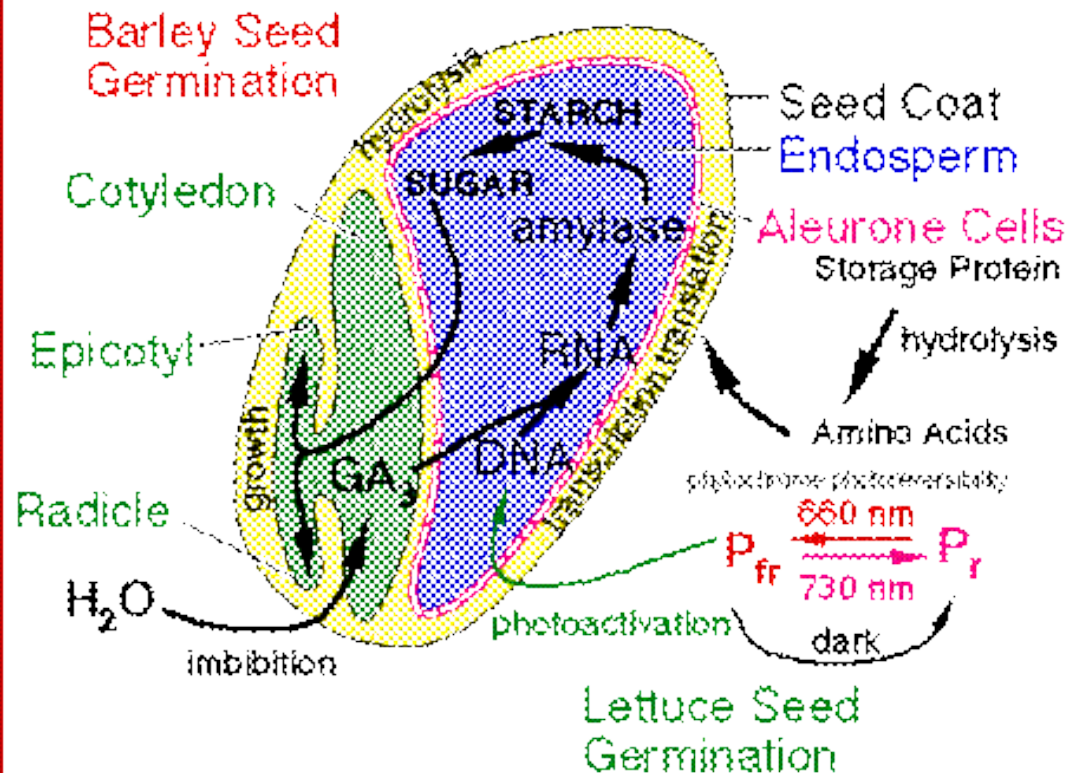
Thin Seed Coat Light or Darkness

Insufficient Development After-ripening with Fungi

Inhibitors

Abscisic Acid Vernalization

Phenolic Repeated Leaching



CAUSES OF SEED DORMANCY

1) Hard Seed Coat

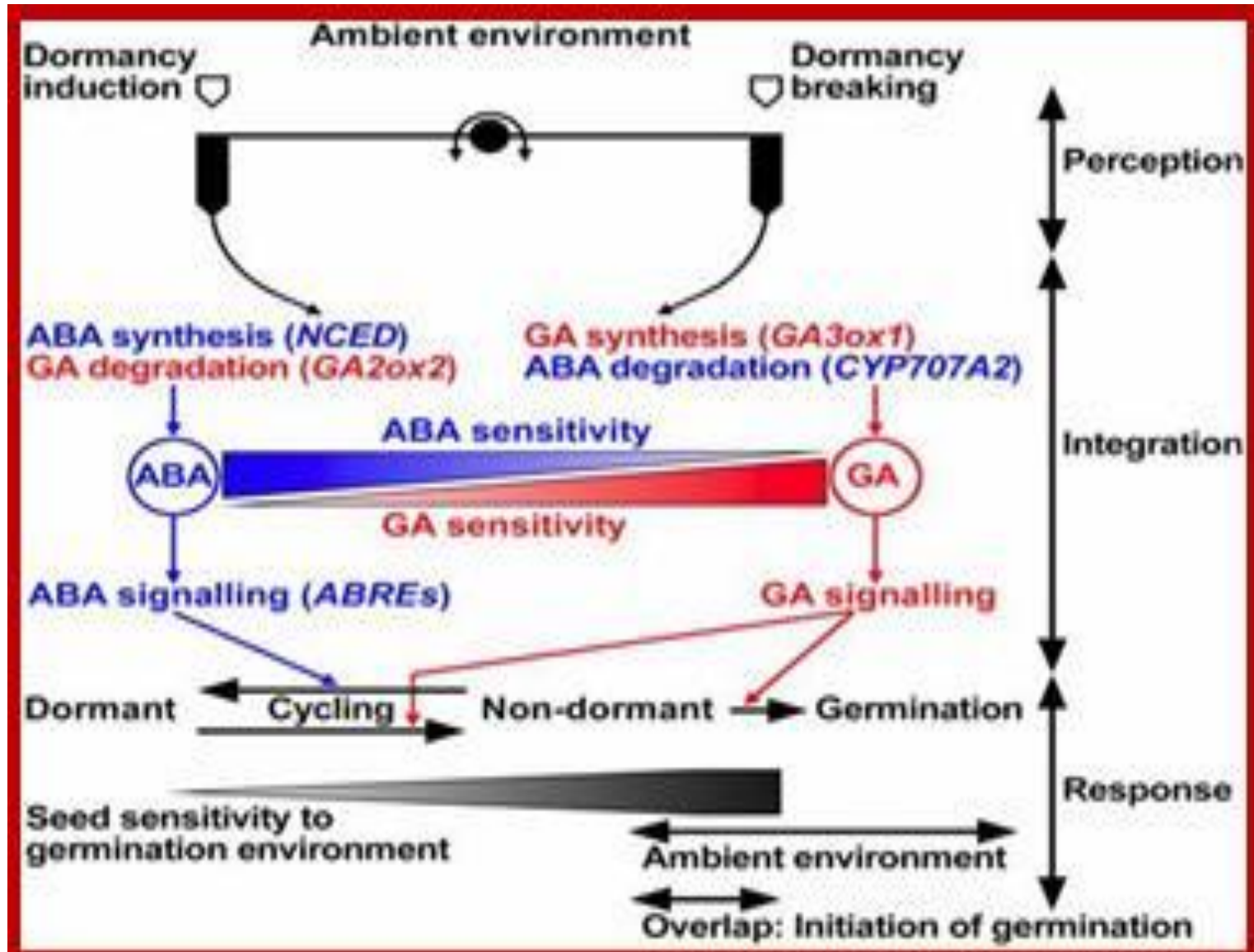
Seeds of many species possess hard seed coat. Most of these seeds belong to the family Leguminosae and Malvaceae. Such seeds remain dormant. Hard seed coat prevents germination due to following reasons:

- (a) Hard seed coat prevents the entry of water into the seed.
- (b) Hard coat obstruct exchange of gases, especially oxygen. Oxygen is necessary for respiration.
- (c) Hard seed coat causes mechanical resistance. Thus radicle does not come out

1. **Impaction and Mechanical Scarification:** Shaking the seed with abrasives or nicking the seed coat with sharp edged metals or chewing the seed coats without damaging the embryo makes the seed coat to crack open. This greatly facilitates the emergence of the embryo out of the seed coat.
2. **Chemical Scarification:** The hard seed coats can be loosened by strong acids or solvent treatments where the hard coat is rendered soft. However the duration of treatment has to be determined for every kind of seed, otherwise the treatment may cause damage to the young embryos.
3. **Natural Scarification: By fire, Fungus, Birds, Water**

- Effect of temperature-Pre Chilling/Stratification
- Immature seeds-After ripening
- Effect of light
 - 1.Photo blastic-Positive
 - 2.Photo blastic- Negative
 - 3.Non Photo blastic-Insensitive
- Chemical inhibitors

Role of GA and ABA in antagonistic manner during dormancy and breaking dormancy

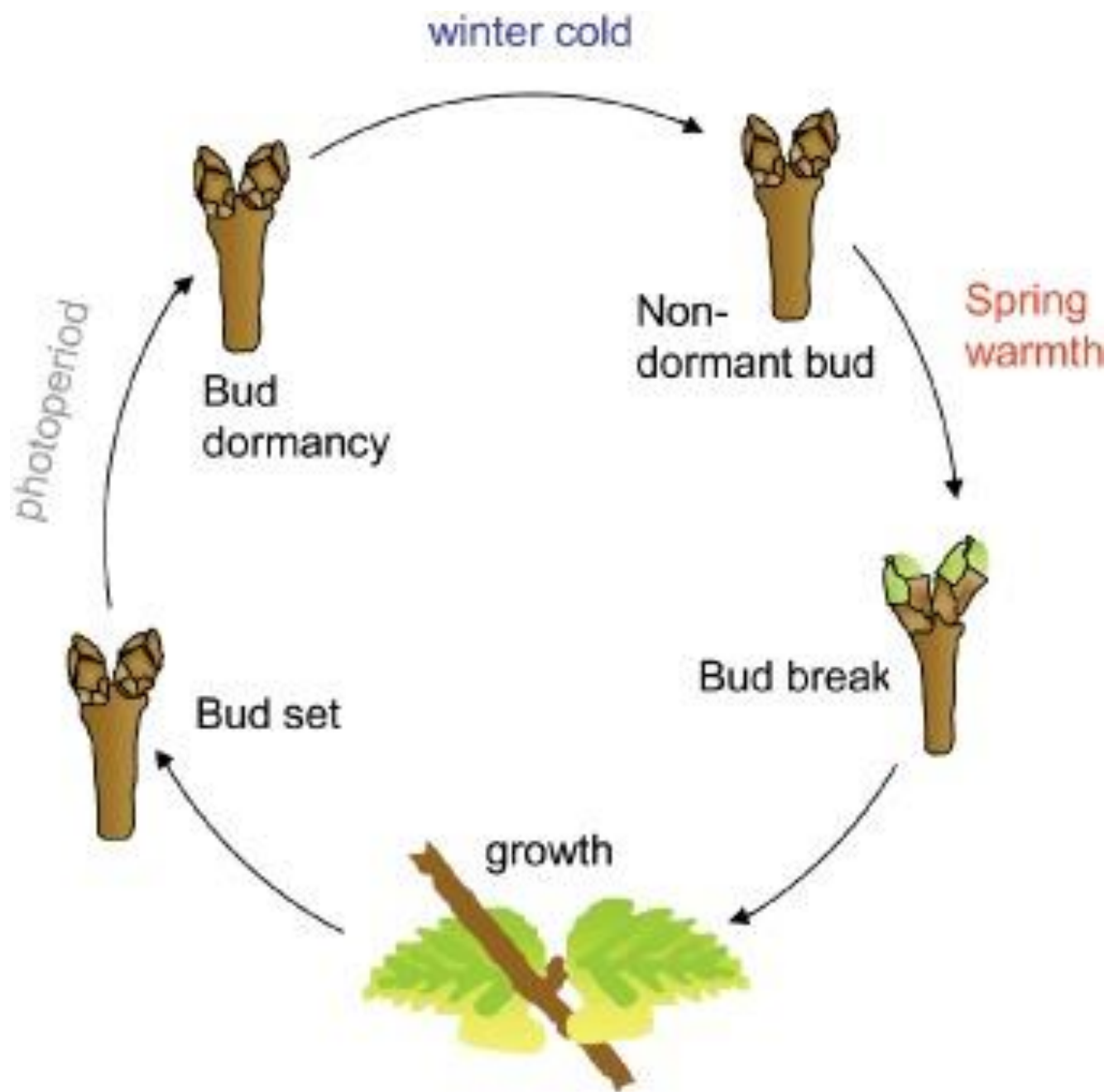


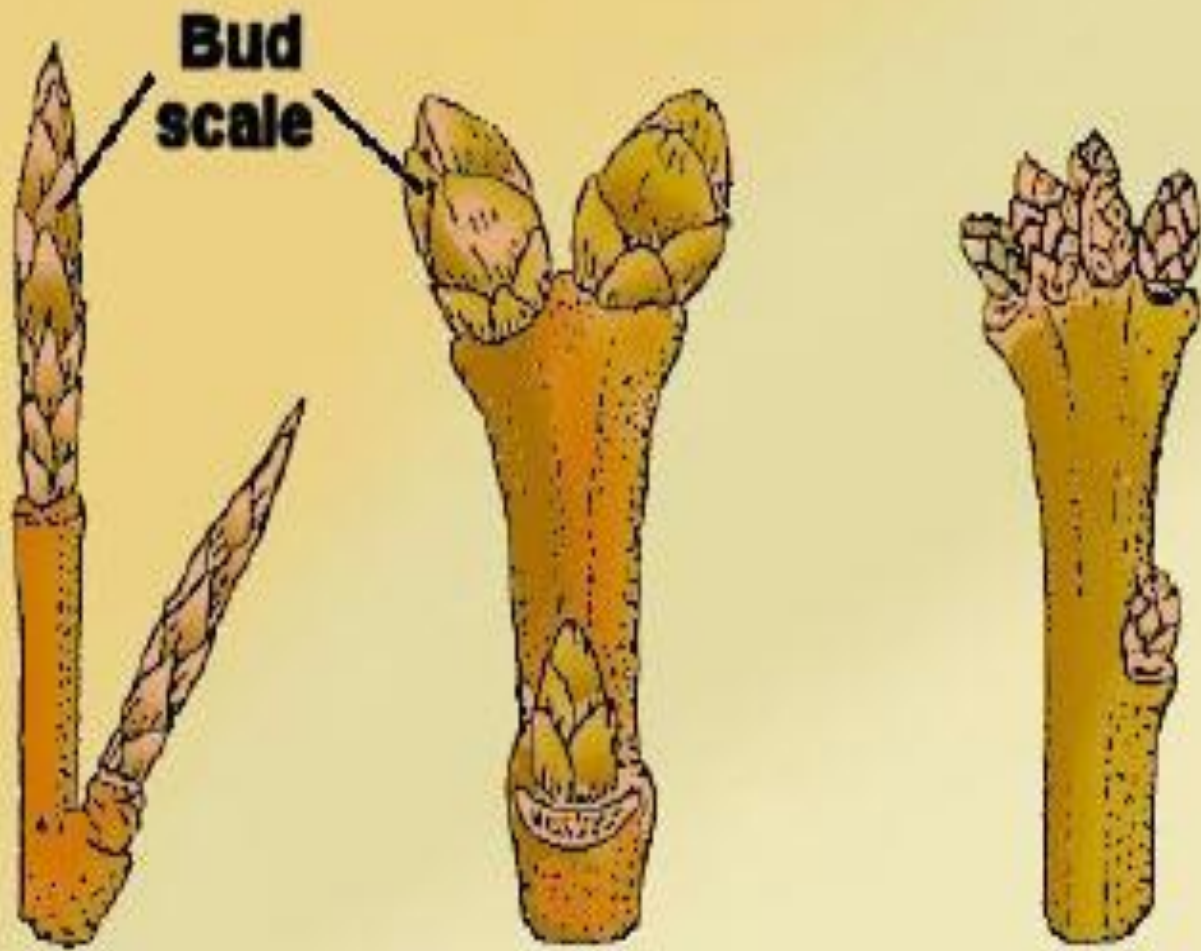
Bud dormancy



- **Bud Dormancy**

- Perennial plants like shrubs, trees have to go through different seasons in a year.
- The onset of winter is always an unfavorable season for the growth and even survival of plants become difficult because of extreme variations in the temperature, especially cold conditions.
- In order to survive against such hostile conditions the growth regions like **apical buds, axillary buds and underground structures like rhizomes, tubers, etc,** undergo a period of dormancy “suspended growth”.
- It is during this season that leaves wither. **In fact, it is not the change in the temperature that acts as the signal but it is the change in the photoperiodic conditions which triggers the falling of leaves.**
-





Dormant apical buds



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- meristematic cells found in the buds undergo **temporary suspension** of their activities. In addition to it, the meristematic regions will be armed and protected with a number of leaves called **bud scales** which are thick, waxy and covered with a dense coat of hairs. Such structures provide **thermal insulation** to the meristematic zones and prevent them from **cold injury or frost bite**.





What are the sites of perception?



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- The involvement of photoperiodic effect on bud dormancy indicates that the phytochromes have a role in imposing dormancy.
- Phytochromes are known to be present in plastid membranes and other surface membranes.
-
- It is also known that ABA is synthesized and often stored in plastids. Phytochromes by perceiving the changes in photoperiodic conditions probably induce the synthesis of ABA and also facilitate the release of ABA.
- Then ABA is translocated to the buds where it brings about temporary suspension of metabolic activities and totally inhibits mitotic activity.
- The presence of Abscissin II, which is also called '**Dormin**' has been detected from various plant structures involved in dormancy ex., dormant potato tubers, birch leaves, winter buds in clerodendron, pinus, etc.

- Cytokinins are known to be synthesized in root tips but under cold conditions because of the snow fall, the root meristems are very inactive and they don't synthesize sufficient quantities of cytokinin required for the buds to be active. That is probably one of the reasons why buds remain dormant. As soon as cytokinins are provided to dormant buds, mitotic activity is initiated and buds start sprouting. Besides, cytokinins also counteract ABAs inhibitory effect of the metabolic activity level and promote growth activity.

- Another class of phytohormones, which overcomes the bud dormancy, is **Gibberellins**. Now it is certain that Gibberellin synthesis takes place in plastids. Moreover, the synthesis of GA and ABA starts from the same precursor called **mevalonate**. Under short day conditions, the pathway from mevalonate is directed towards ABA synthesis and GA synthesis is inhibited, but during **long day photoperiods it is directed towards GA synthesis and** ABA synthesis is blocked. That is the reason why gibberellins under long day conditions or not light treatment, break bud dormancy and nullify the effect of ABA present in such dormant buds.

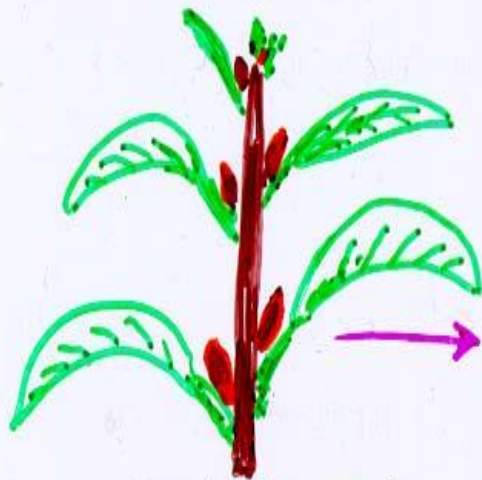
- The photoperiodic effect either in breaking the dormancy or induction of dormancy is explained on the basis of **phytochrome** involvement. When long day conditions prevail, more amount of **PfR form of phytochrome accumulates in the cells which initiates not only the synthesis of more GA and but also it facilitates the release of it from the plastids into the cytoplasm.** Once GA is released, it brings about the activation of dormant cells, and thus GA breaks bud dormancy. It is really very fascinating to understand the **three way interaction between phytochrome, photoperiod and GA/ABA synthesis in imposing bud dormancy or breaking it.**

Breaking of Bud Dormancy: Chilling

In woody perennials breaking of bud dormancy in spring is a factor determining the timing of flowering... Example apple, pear

- Bud dormancy in fall is initiated by low temperatures and short photoperiod. Fruit trees
- In spring bud dormancy is broken by environmental signals, especially chilling during the spring warming period.
 - Linear accumulation of chilling hours occurs below 7° C. 45° F.
 - Short photoperiod promotes blooming.
 - Phenology of spring woody perennial flower activation is complex and still not well understood.
 - Remember: flowers formed in late fall, early winter in woody perennials. It is bud break that determined flower activation.

Summer



Buds formed
June, July

Winter



Defoliation
Oct.

cold

warm

Spring



Flowering and
fruiting

(Temperate zone)

No flowering but
shoot growth



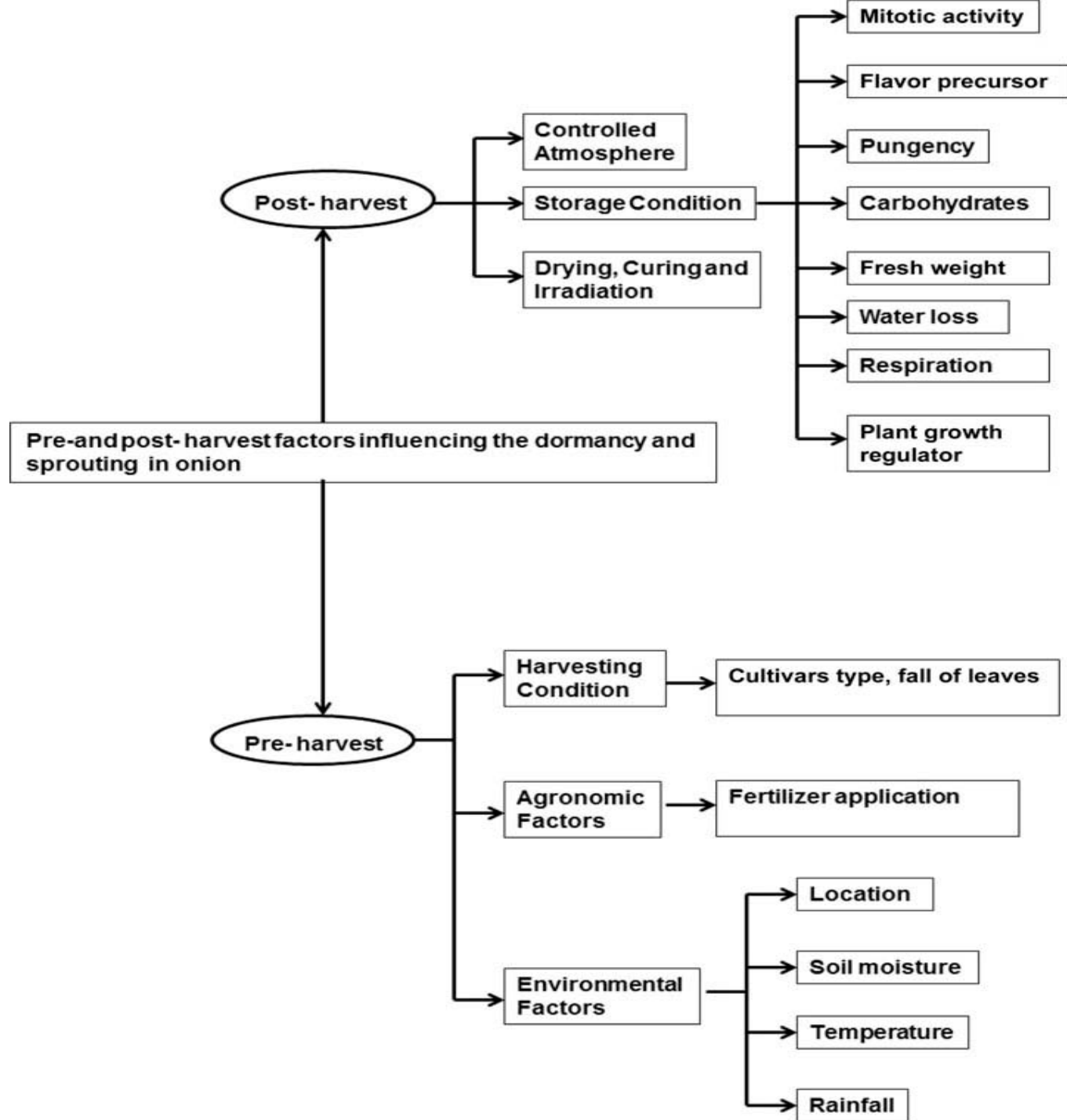
No apple, Pear
Production in
southern states

(Tropical, subtropical)

In under ground tubers, bulbs

Factors influencing storage life of onion are bulb composition, toughness of the dry scales, color, dry-matter (DM) content within a genotype, and number scales of the outer skins after curing and the depth of dormancy of the mature bulbs

- Temperature, cultivar, and seasonal change in weather conditions during the vegetation period show significant influence on dormancy, storage ability, and quality of onions.
- Biochemical and physiological parameters such as decreases in sucrose levels and increases in respiration rates, exo-hydrolase activity, and bulb-softening enzyme rates (polygalacturonase or polymethyl esterase) are responsible for ending the dormancy.



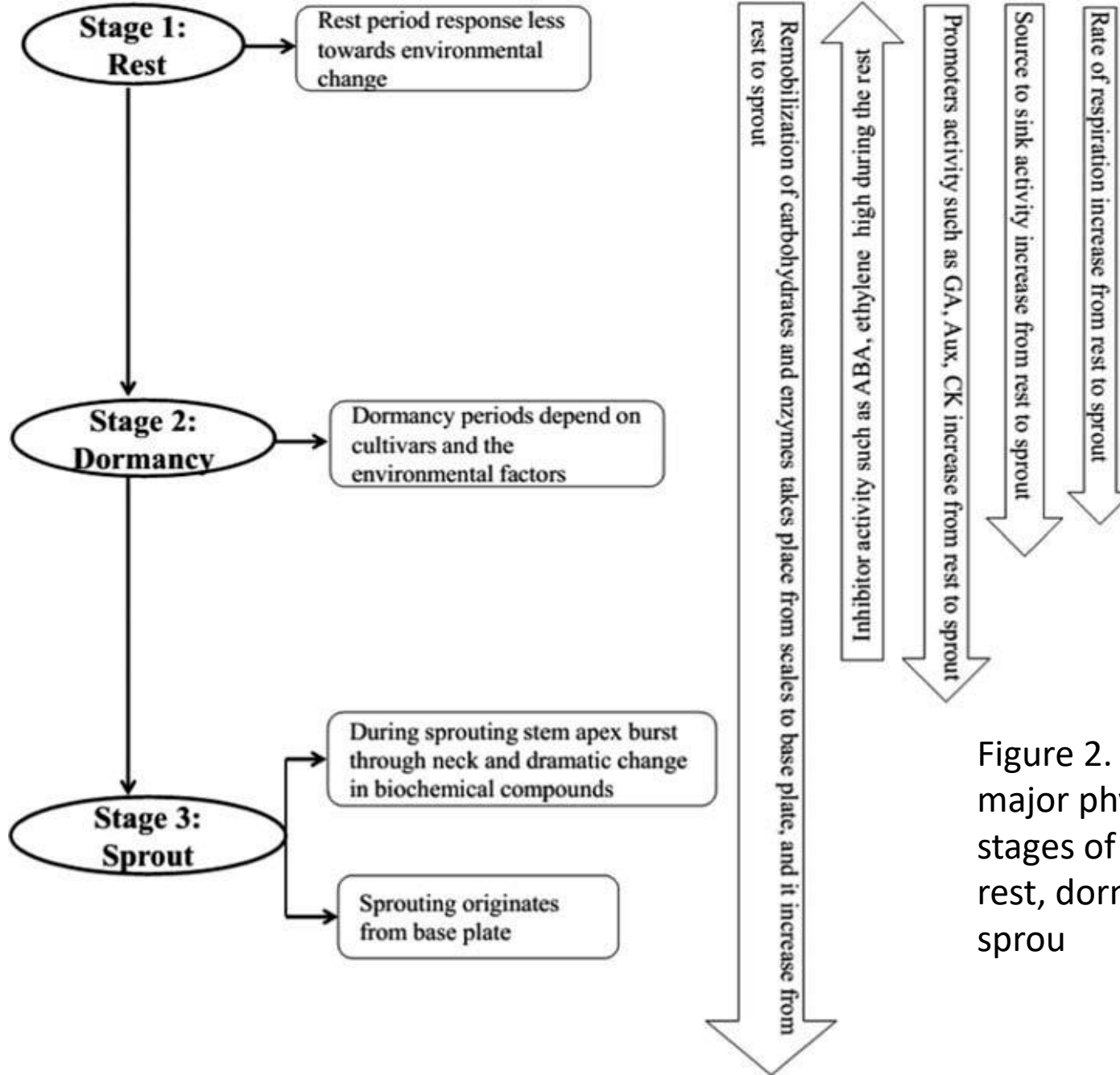


Figure 2. Three major physiological stages of onions: rest, dormancy, and sprout

Abbreviations: GA= Gibberellin acid, AuX: Auxin, CK: Cytokinin, ABA: Abscisic acid

Figure 3. Annual life cycle of onion with respect to the change in plant growth regulators.

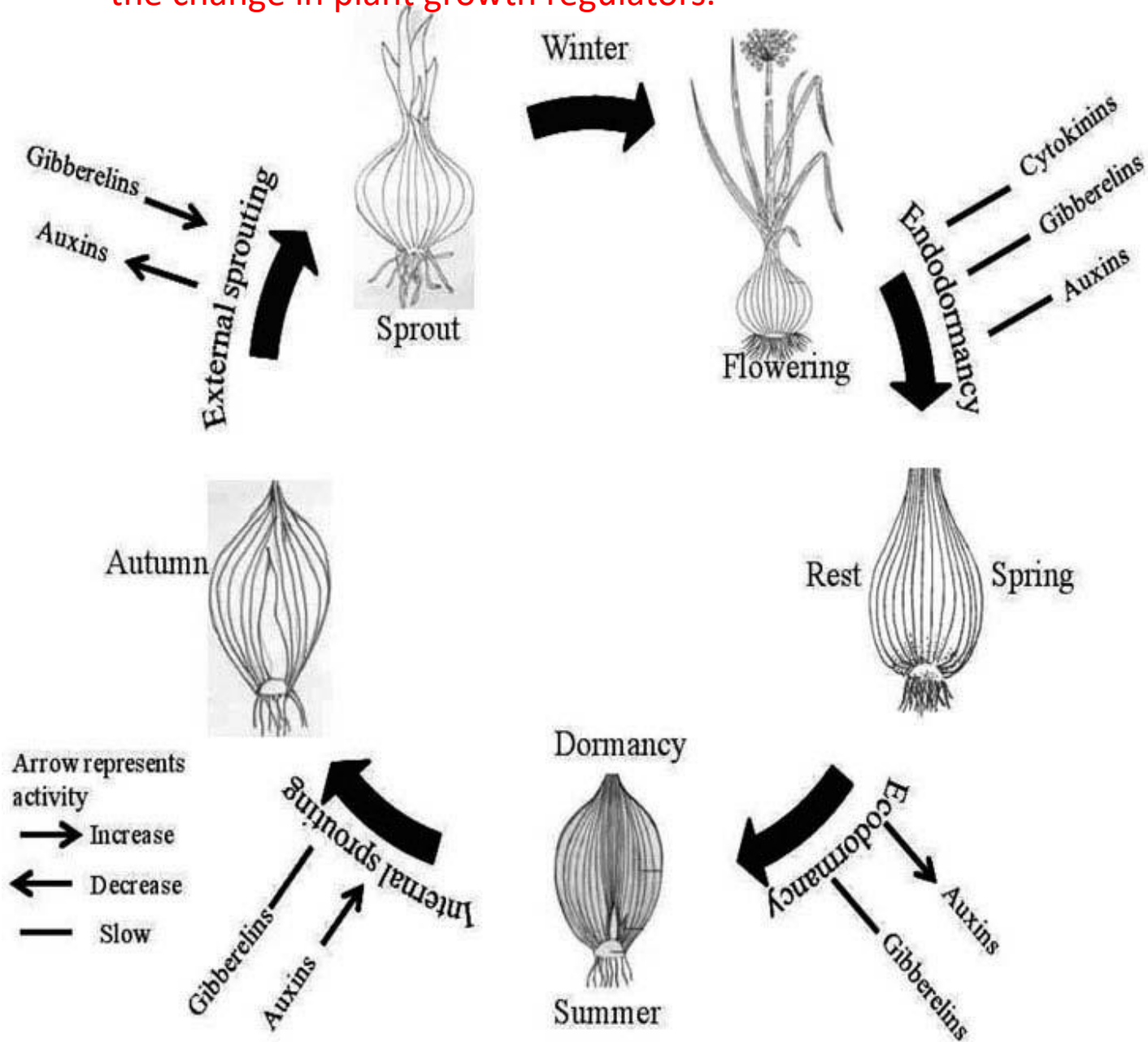


Table 1. Overview for the change in plant growth regulator with respect to onion stages.

Onion stage	Regulator/ Inhibitor	Phenomenon	Reference
Stored onion	GA	Cold treatment increased GA in the bulb as compared with non-cold-treated bulb.	(101)
Early stage of storage to dormancy	GA	Negligible GA activity in the early stage and decreased as the dormancy period progressed.	(26)
Early stage to sprout	CCC	GA synthesis could be controlled by growth retardant CCC, but it did not inhibit sprouting of onions. Sprouting stimulation of dormant onion bulbs effected by GA3 treatment, but the effect was extremely small.	(103)
Dormant stage	GA	ABA induced earlier senescence, reduced bulb dimensions, and prolonged the dormant period.	(102)
Dormant stage	ABA	Ethylene production of onion is much higher at the end of dormancy than in the beginning.	(27)
Dormant stage	Ethylene	Low concentration of endogenous ethylene involved in the regulation of dormancy.	(58)
Dormant stage	Endogenous ethylene	Gaseous ethylene treatment before curing beneficial with respect to continuous ethylene treatment.	(59)
Stored onion	Ethylene	Ethylene and 1-MCP treatment before curing delayed sprouting as compared with the treatment after curing (6 weeks of curing).	(67)
Stored onion	Ethylene and 1-MCP	MH maintained the dormancy, reduced gibberellins, auxin, and cytokinins, and had no effect on an inhibitor.	(68)
Dormant stage	MH	MH had a positive effect on sprouting and rooting, but led to growth irregularities as compared with other chemicals.	(74)
Stored onion	MH		(2)
Stored onion	Auxin	Auxin activity found in the early stage of sprouting and persisted during the sprouting.	(26)
Stored onion	GA	GA activity started increasing after sprouting and high in sprout growth.	(104)
Stored onion	Auxin	Auxin altered the cell wall permeability of the resting shoot and resulted in ease translocation of food reserves from source to sink of the bulb.	(46)

meq/grammes as compared with other chemicals.

Stored onion	MH		(2)
Stored onion	Auxin	Auxin activity found in the early stage of sprouting and persisted during the sprouting.	(26)
Stored onion	GA	GA activity started increasing after sprouting and high in sprout growth.	(104)
Stored onion	Auxin	Auxin altered the cell wall permeability of the resting shoot and resulted in ease translocation of food reserves from source to sink of the bulb.	(46)
Stored onion	Cytokinin	Cytokinin treatments decreased ABA content and resulted in dormancy breakage with stimulation of sprouting.	(4)
Stored onion	ABA	High concentration of ABA delayed the sprouting and low ABA concentration was associated with the onset of sprouting.	(104)
Stored onion	1-MCP	1-Methylcyclopropene (1-MCP) has antagonist role, and it binds to the ethylene binding proteins, thereby blocking ethylene effects.	(105)
Stored onion	Ethylene	Ethylene with cold treatment hastened sprouting and increased the elongation and growth of the inner bud.	(29)
Stored onion	Ethylene	Excessive accumulation of ethylene took place in the presence of cytokinin synthesis, and excessive cytokinin promoted root formation.	(34)
Cold-stored onion	Ethylene	The continuous application of ethylene retarded sprout growth during cold storage.	(66)

Note. GA = gibberellin acid; CCC = (2-chloroethyl)trimethylammonium chloride; ABA = abscisic acid; 1- MCP = 1-methylcyclopropene; MH = maleic hydrazide.

In under ground tubers, bulbs

- Harvested tubers remain dormant (i.e. incapable of developing an internal shoot bud or external shoot bud/sprout) for 30 to 150 d depending on date of harvest, species, and growing and storage environmental conditions (Passam, 1982; Orkwor and Ekanayake, 1998).
- Thus, only one crop cycle is possible per year, restricting supply (Olayide et al., 1972) and the rate of progress of crop improvement. Breaking or shortening dormancy in yam is a priority for yam breeders (Asiedu et al., 1998) but the control of dormancy is not well understood (Passam, 1982; Suttle, 1996).

- Dormant yam tubers, uniquely and in contrast to potatoes (*Solanum tuberosum*), do not have any internal or external apical shoot buds or sprouts. Instead, dormant yam tubers (as observed after harvest/during storage) have a layer of meristematic cells below the surface of the tuber (Onwueme, 1973; Mathurin and Degras, 1978; Wickham et al., 1981). Onwueme (1973) and Wickham et al. (1981) have shown in *D. rotundata* and *D. alata* that at the resumption of active growth, shoot apical bud formation begins in this meristematic cell layer, long before any external shoot bud/sprout is visible on the tuber surface.

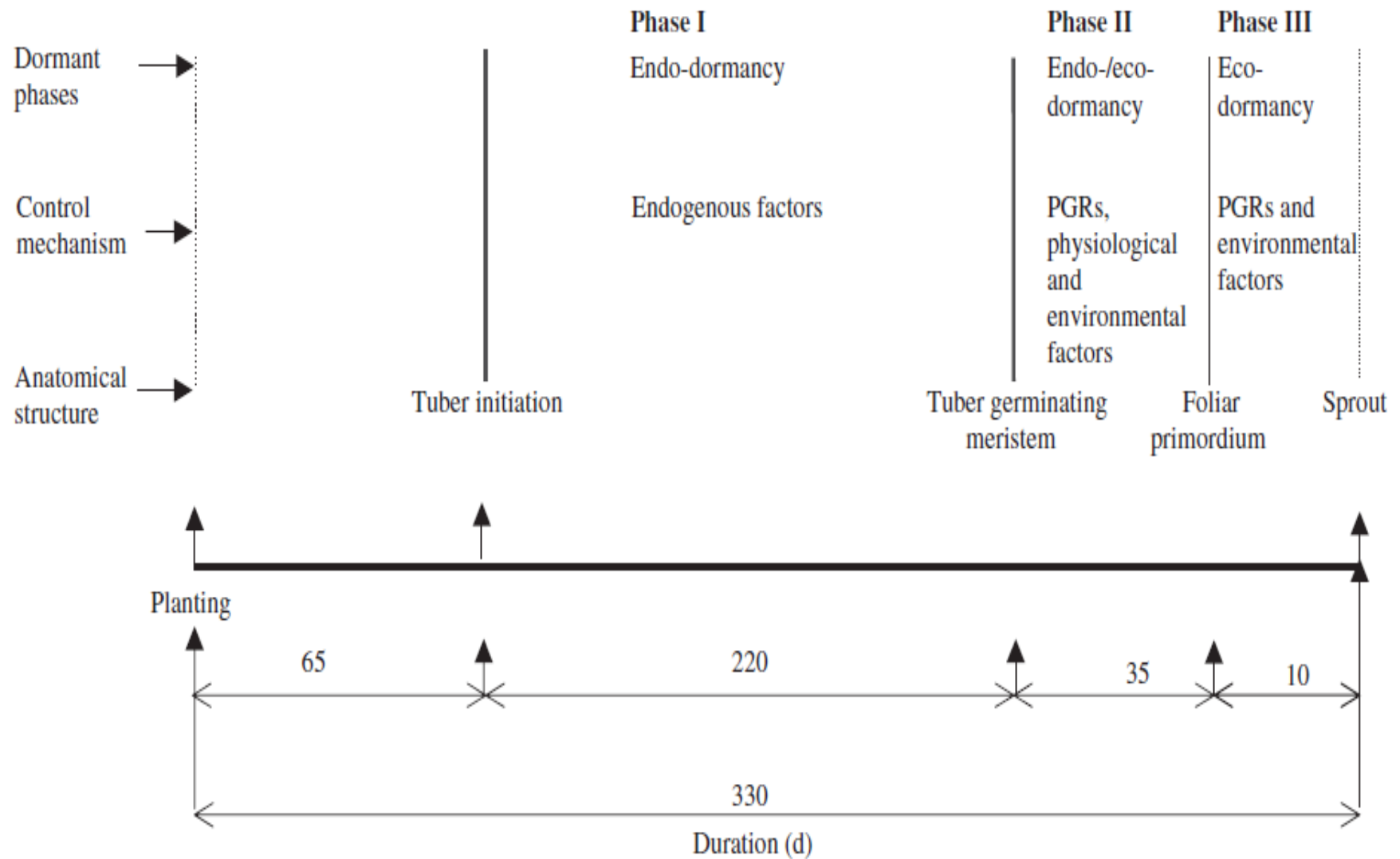


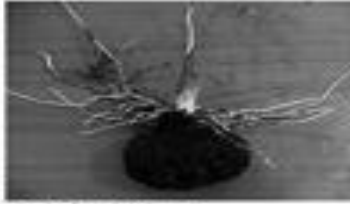
FIG. 7. Diagrammatical presentation of the phases of tuber dormancy, their potential control mechanism and their approximate duration (in days), in the yam *D. rotundata* 'TDr 131'. Durations are averages from several experiments with 'TDr 131'.

- There are three phases of dormancy in *D. rotundata* yams: Phase I (tuber initiation to tuber germinating meristem formation), Phase II (tuber germinating meristem to foliar primordium) and Phase III (foliar primordium to the appearance of shoot buds at the surface/sprouting loci). Phase I, which is the longest phase, is not influenced by external factors and is proposed to be an endo-dormant phase. Phases II and III are endo-/eco-dormant phases influenced by exogenous PGRs and environmental conditions. To manipulate dormancy to allow off-season planting and more than one generation per year requires that the duration of Phase I is shortened.(Ile *et al.*, 2006)

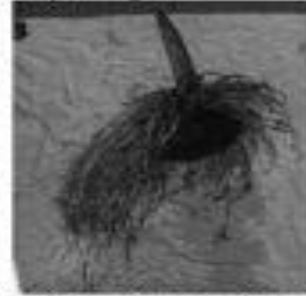
Under ground corms-Elephant foot yam

Amorphophallus corms exhibit dormancy for about **three to five months** after harvest. As a result, planting and harvesting are done at a particular time of the year. *Amorphophallus* is propagated by corms as such or by cut corm pieces having a part of apical meristem. **Sprouting percentage was greater (98%) with top cut portion of corm than the cut corms** from the lower half of the mother corm (Dhua *et al.*, 1988; Nedunzhyan and Mohankumar, 1997; Mondal and Sen, 2004; Santosa *et al.*, 2006 b).

Different stages of corm development



A - Sprouting corm showing the newly forming corm



B - Cataphyll enclosing the leaf and the corm showing profuse root development



C - Early stage of leaf emerging out from the cataphyll

D - Leaf emerging out from the cataphyll

E - Spreading canopy



Canopy

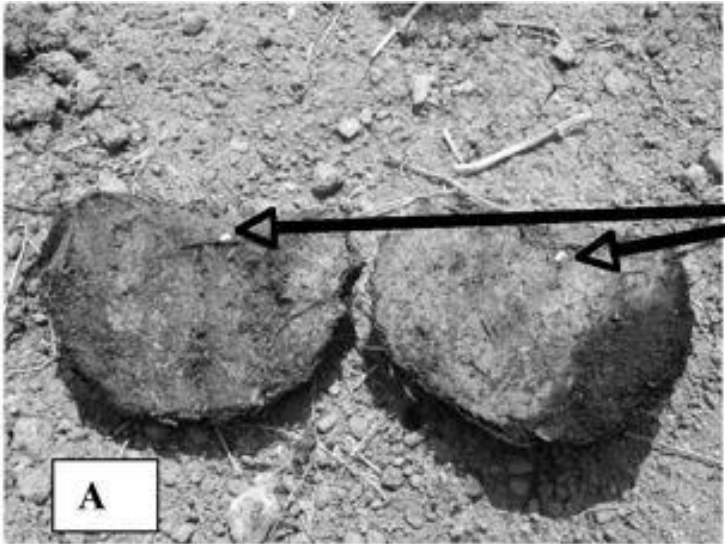
Pseudostem

F - Full plant

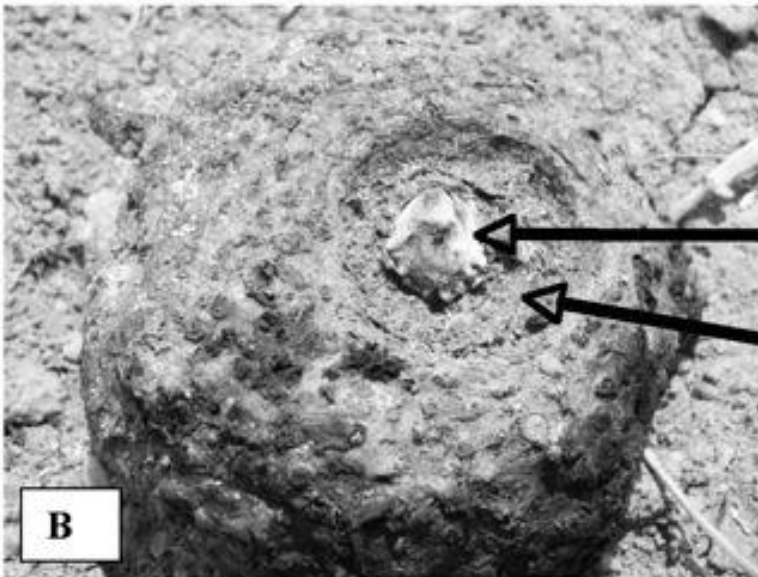


Newly developing corm

Mother corm



Emerging sprout from cut pieces of corm



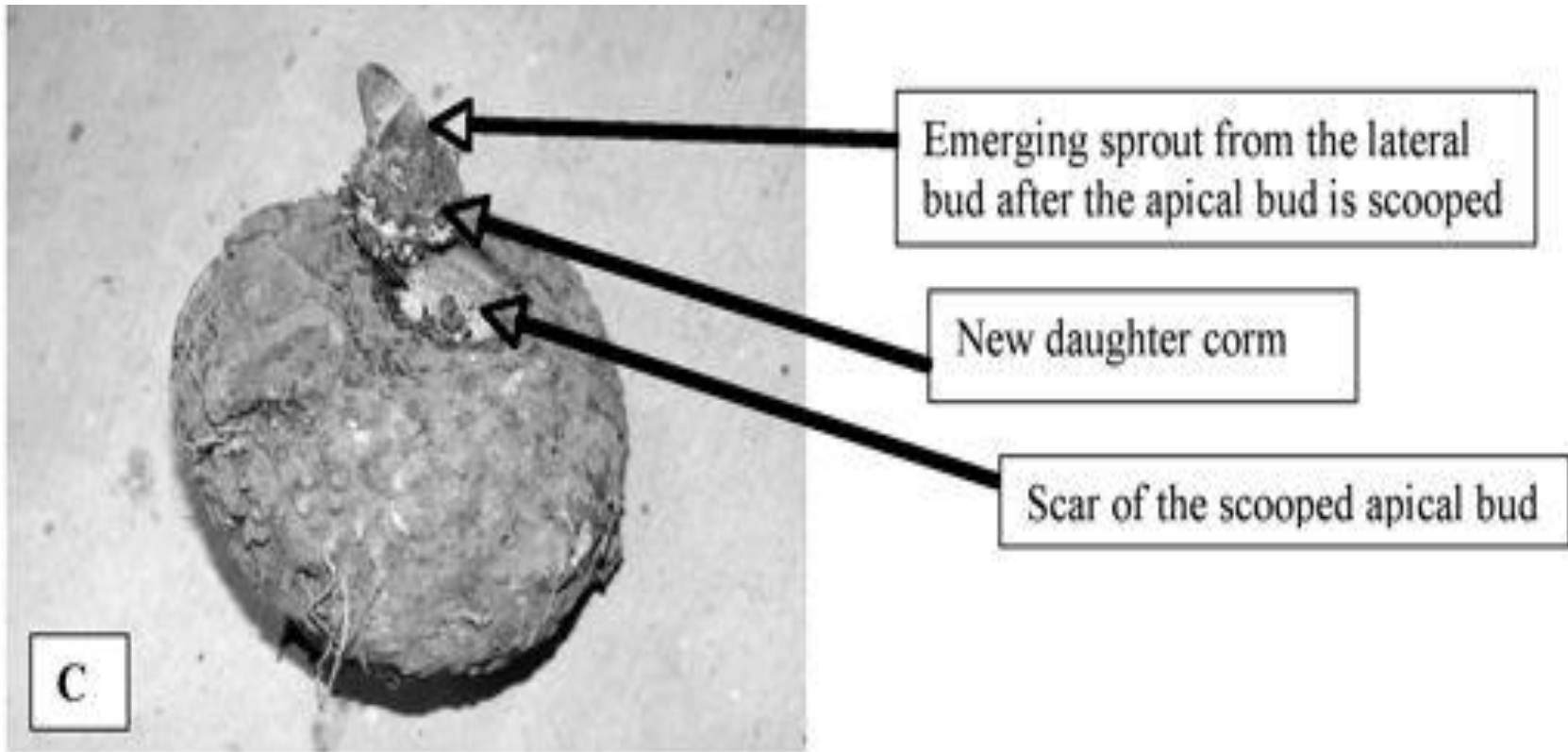
**Emerging sprout from the apical bud
Meristem zone**

The bottom portion of the corm is not generally used as planting material due to its lower sprouting efficiency

(Dhua *et al.*, 1988; Nedunzhian and Mohankumar, 1997; Mohankumar and Ravi, 2001).

Therefore, a greater portion (about 25%) of the harvested produce is again lost as source of planting materials. Also, the apical bud from the corm can be excised and used as planting material. Removal of the apical bud results in development of one or two adjacent buds within two weeks which also can be excised and used as planting material (Fig. 5). Ethrel or ethephon was reported to induce early sprouting in *Amorphophallus corm* (Dhua *et al.*, 1988; Bala and Indira, 1992).

Emerging sprout from the lateral bud after the apical bud is scooped.



Treating cut pieces of corms from the lower half with chemicals significantly improved sprouting, subsequent growth and yield. Among the different chemicals used, thiourea, potassium nitrate and CCC were effective in promoting sprouting.

Thiourea (200 ppm) and KNO₃ (1000 ppm) and kinetin (5 ppm) increased corm sprouting by 24.3-92.0, 17.8 and 13.4% in plants from corms treated with the respectively as compared to control (Dhua *et al.*, 1988; Kumar *et al.*, 1998). However, mean corm weight was greater thiourea (100ppm), potassium nitrate (KNO₃) (500 ppm) and CCC (0.02 ml l⁻¹) yielding 722, 821 and 806 g per plant respectively (Dhua *et al.*, 1988).

Exposing the whole corms to smoke for 6 h per day for six weeks increased sprouting by 58.3% as compared to untreated corms presumably due to ethrel in smoke. Similarly exposing the corms to high temperature (32-45oC) increased sprouting by 83.3% as compared to untreated corms (Mohankumar and Ravi, 2001; Archana *et al.*, 2009).

Pre-harvest, foliar application of potassium nitrate (2%) and thiourea (1%) had greater influence on breaking dormancy and inducing early sprouting (Bhagavan et al., 2008).

This may be due to an increase in the availability of sugars as a result of an increase in respiration at higher temperature .

Compared to smoke and heat treatments, soaking corms in different chemicals [KNO₃, thiourea, ammonium sulphate (NH₄SO₄)] for a short period (20-30 min) for 1-2 hr had no significant effect on inducing early sprouting (Mohankumar and Ravi, 2001).

However, treating the apical portion of corm (after removing the apical bud) with thiourea and subsequently wetting the apical portion for a period of 10 days induced early sprouting with more sprouts (Archana *et al.*, 2009). *Darkness had an adverse effect on sprouting (Kumar et al., 1998).*

In A. konjac, abscisic acid (ABA) and ferulic acid were extracted from the dormant corms and exogenous application of ABA (10 mg l⁻¹) and ferulic acid (400 mg l⁻¹) inhibited sprouting and growth of the terminal buds of non-dormant corms, suggesting that ABA and ferulic acid are inhibitors of sprouting of dormant corms (Sun et al., 1996). Corms are acid before dormancy, but it decreases after dormancy (Santosa et al., 2003).