Plant Propagation

Gardening Study School
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What is Plant Propagation?

- The art and science of multiplying plants while preserving their unique qualities
- In nature, plants propagate themselves in order to colonize new areas and/or to maintain survival of the species
- We attempt to maintain certain forms of plants (cultivars, ecotypes, etc.) that we find interesting or useful.
  - These forms wouldn’t necessarily exist in nature

Plant Propagation is an ancient science...

- Plant propagation played a large role in the development of modern human civilization
- It took humans the mental leap of understanding and controlling the reproductive process of plants to begin agriculture 10,000 years ago
- This included the saving and planting of selected seeds, which, when combined with natural selection, led to the development of improved plants suitable for productive agriculture

Three Major Aspects of Plant Propagation...

- There are three major aspects to plant propagation, all of which are essential to successfully propagating many different types of plants

How?

- Knowledge of mechanical manipulations and technical skills
  - This is the art of propagation that cannot be taught by reading and/or listening to lectures
  - It is the skills learned by doing hands-on plant propagating

http://www.mountainsofstone.com/images/Teosinte.jpg

Splice graft to propagate a red-leaf ornamental crab apple

Side-veneer graft of Ginkgo
**Why?**

- Knowledge of plant growth and structure
  - the science of plant propagation
  - deals with the underlying reasons for certain propagation procedures and why they are possible

**The plant...**

- Knowledge of specific plants and the particular methods by which those plants must be propagated
  - a combination of art and science
- By mastering both the art and science, one can apply knowledge towards the propagation of new plants or to solving problems of poor propagation success

**Formation of callus tissue**

**What is a Cultivar?**

- This term originates from the terms “cultivated variety”
- A cultivar must be clearly distinguishable by specific characteristics (morphological, physiological, etc.) and it must retain these characteristics when propagated
- Different types of apples (Malus domestica) for sale in the grocery store are examples of cultivars that the public is familiar with
  - cultivars exist for nearly all other food crops and nursery stock, etc.

**Propagating a cultivar: Sexual vs. Asexual Reproduction**

- Plant propagation can be broken down into two categories:
  - seed propagation
  - asexual propagation (vegetative propagation)
- Seed propagation is generally much cheaper and easier to perform than vegetative propagation, but it involves the process of meiosis
  - leads to variability in resulting seedlings (some exceptions)
- Vegetative reproduction relies only on mitosis and is not variable (with some exceptions)

**Vegetative (asexual) propagation**

- Vegetative propagation relies on mitosis
  - Cells simply double and split into two exact copies (clones)
  - Mitosis does not lead to recombination – no pollen/egg cycle involved
- However, plants vary tremendously by species and cultivar as to how easy or complicated it is to propagate them asexually

**Seeds = Meiosis = Genetic Recombination**

- The normal process of seed production requires the fusion of a pollen grain with an egg cell
- The growing of seedling plants from seeds results in variable offspring
  - “Shuffling of the Deck”
- Most wild plant species and ornamental plants behave in this manner
  - Apples are a good example – they must be propagated by an asexual method (grafting)
- Growing seeds would give you a diversity of apple types unlike the parent tree
- Self-pollinated crops are the exception
  - Includes most of our seed-grown crop plants that have been domesticated over time
  - Wheat, rice, oat, barley, tomato, pepper, etc.
Self-pollination

- Self-pollination occurs when pollen fertilizes the same flower or flower from the same plant.
- Repeated self-pollination over time results in a uniform genetic makeup, which allows one to maintain the exact cultivar by seed.
  - What happens if a bee gets into one's pepper plants?
  - What about hybrid seeds?

Cross-pollination

- Cross-pollination occurs when pollen from one plant fertilizes another.
- Results in increased genetic variation and no inbreeding.
- Various mechanisms prevent self-pollination:
  - Self incompatibility (pollen won’t germinate on self flowers)
  - Dioecious plants: Male and female flowers present on separate plants (holly)
  - Dichogamy: Pollen shed occurs when stigma is not receptive.

Seed Propagation: the most easy and efficient way to propagate crops

- Do your homework - can your “cultivar” be maintained through seed? Maybe it doesn’t matter (fun)
  - Heirloom tomato, pepper = yes
  - Apples, pink dogwoods, hollies = No
  - Pines, oaks, etc. unless specific form = ok.
- Start with good, known seed
- Buying seed from reputable sources (certified seed) ensures success if good propagation practices are followed.
- For wild species, collect seed from your growing region or somewhere with a similar climate (temperature and day length).

Seed storage: depends on seed type

- Two main types of seed: recalcitrant and orthodox.
- Orthodox seed is dry at maturity and usually can be stored for years in a dry state. Majority of crop plants have orthodox seeds.
  - Tomato, pepper, corn, wheat, beans, onions, etc.
- Recalcitrant seeds do not tolerate drying at maturity. If they dry down too far they lose viability and/or die.
  - Chestnut, oak, maple, hazelnut, willow, mango.

Orthodox seed storage

- Store in a dry state at 4 to 10% moisture
- Store seeds in a location with low relative air humidity and, preferably, low temperatures.
- Sealed container in a refrigerator a good option for long-term storage.
  - For 1-2 years, many seeds can be stored at normal temperatures, if kept dry, in sealed containers or envelopes.

Recalcitrant seed storage

- Harvest directly from plant or fruit with no drying
- Keep in plastic bag in refrigerator until sowing.
  - Can pack in peat moss, vermiculite, etc.
- May remain viable for over one year if moisture content kept high and temperatures sub-freezing (30 deg. F, non-tropical species).
What does a “viable” seed need to germinate?

- water
- proper temperature range (~70-85 deg F, but varies by species)
- oxygen
- sometimes light

If conditions are met and no germination – is the seed still dormant?

Dormancy – Regulation of Germination

- Dormancy is the condition where seeds will not germinate even when most environmental conditions are right for germination
  - Prevents immediate germination but also regulates time, conditions, and place that germination will occur

Advantages of Seed Dormancy

- Favors seedling survival
  - New Jersey winters allow for vernalization of cool season turfgrass
- Creates a seed bank
  - All seeds of a species do not germinate every year (weeds)
- Seed dispersal (birds)
- Synchronizes germination with seasons
  - Growing season optimal for seedling growth after germination
  - For example, black walnut seeds won’t germinate until period of moist chilling is met – germinates in Spring

There are multiple types of seed dormancy...

- Exogenous – Imposed by factors outside the embryo
  - i.e. seed coat: Outer integument layer of seed coat hardens and becomes impervious to water
  - Chemical – Chemicals (phenols, coumarin, ABA) that accumulate in fruit and seed-covering tissues can remain in seed and inhibit germination (Ex. citrus, apples, tomatoes, cucurbits)

Exogenous Dormancy

- Physical – Outer integument becomes hard, fibrous, or mucilaginous during dehydration and ripening (Ex. peach, coconut, cocoa)
  - Outer integument layer of seed coat hardens and becomes impervious to water
Endogenous Dormancy

- Physiological – Embryo lacks the growth potential to allow the radicle to escape from the seed coats
- Physiological
  - Nondeep
  - After-ripening – time required for seeds in dry storage to lose dormancy
  - Photodormancy – seeds requiring light or dark to germinate
  - Intermediate
  - Require chilling stratification
  - Deep
  - Require long periods of cold stratification

Breaking Dormancy

- Several methods, depends on type of dormancy
- Scarification (physical or chemical)
  - Allows water to get inside impervious seed coat
- Mechanical
  - Sulfuric Acid

Breaking Dormancy

- Removal of seed covering (mechanical)
- Leaching seeds (chemical)
- Stratification (warm or cold, or both…)
  - Alleviate dormancy (similar to natural conditions in soil)
  - 3-5 months in damp peat moss in refrigerator works for many northern temperate species

Seed collection, cleaning and germination of dogwood seed (Cornus kousa)

Seed Propagation

- Propagation systems
  - Field seeding (agronomic crops, some forest trees and ornamentals, rootstocks)
  - Plug production (annuals)

Methods of Seeding

Direct seeding (field seeding)

- Cheapest way to produce a crop
- Adaptable to mechanization
- No “transplant shock”
- Need soil preparation
- Viable high-quality seed a must
  - Needs to germinate fast and at a high percentage
  - Susceptible to environmental conditions
Methods of Seeding

Indirect seeding (plug production)
- Seeds germinated in greenhouse then placed in field
- Ensures good stand establishment
- High costs
- More difficult to mechanize
- Seasonal timing important...

Asexual propagation: cloning a plant and retaining its characteristics

Specialized Stems and Roots
- Vegetative structures that function primarily in the storage of food, nutrients, and water during adverse environmental conditions
- These structures are also important in the vegetative propagation of many species

Other Seeding Methods...

Hydroseeding
- Spray application of primed seed in a mix containing mulch and fertilizer

Asexual propagation: procedures may vary but same principle applies
- Specialized stems and roots
  - Bulbs, corms, stolons, rhizomes
- Rooting cuttings
  - Stem, leaf, root
- Layering
  - Simple, mound, trench, air
- Grafting & budding
  - T-bud, chip bud, splice graft, whip and tongue graft, cleft graft, etc.
- Micropropagation/tissue culture
  - Cell culture, meristem culture, etc.

Specialized Stems and Roots...
- Plants possessing these specialized structures are typically herbaceous perennials
  - Plants that survive part of their annual lifecycle as dormant, fleshy, underground structures
  - Shoots die down at the end of a growing season or during adverse environmental conditions
  - capable of producing new shoots when suitable environmental conditions return)
Geophyte structures
- Bulbs, corms, rhizomes, stolons, tubers, pseudobulbs, and other similar structures.
- Most are monocots (*Lilium*, *Fritillaria*, *Amaryllidacea*, *Orchidaceae*).
- There are a few dicot genera with storage structures:
  - Tuberous Anemone, *Cyclamen*, *Claytonia*, *Corydalis*, *Eranthis*, *Oxalis*, *Begonia*, *Tuberous Pelargonium*, *Sinningia*, *some Crassula*.

Geophyte Propagation
- Plant propagators take advantage of these unique structures as stable propagules for asexual propagation.
- Both division and separation techniques are used when propagating by specialized stems and roots.

Bulbs
- Bulbs are produced mainly by monocots.
- A bulb is a specialized underground organ consisting of a short, fleshy stem axis with an apical growing point enclosed by thick fleshy scales that are modified for storage.

Tunicate Bulbs
- Garlic is a tunicate bulb in which axillary buds grow to form many offsets.
- The offsets (cloves) are all attached to the basal plate.
- Garlic is asexually propagated by separating the cloves and planting them individually.
Non-Tunicate Bulbs

- Lack the dry, outer bulb scales found on the tunicate bulbs.
- This makes non-tunicate bulbs more sensitive to drying out and mechanical damage than the tunicate types.
- Scales are looser, and more separated.

Ex: Lily

Bulb Propagation: Based on environmental requirements

- Propagators have worked out the fine details for the manipulation of most bulb species in order to shorten the vegetative stages and obtain a commercial product as soon as possible.
- Period of dormancy - when bulbs are dug, stored, and distributed.
- The commercial value of most bulbs depends on size and weight at the time of digging.

Bulb Propagation: Offsets

-Offsets develop into small bulbs growing around the base of the parent bulb.
-If left undisturbed, offsets can remain attached to the mother bulb for several years.
-Depending on the species, these offsets will develop into a suitable size for flowering in one to three years.

Bulb Propagation: Cross cutting or scooping

- Cross cutting or scooping bulbs can be done to develop more daughter bulbs.
- Cross cut across the base of the bulb, through the basal plate.
- Place in warm, moist area for several weeks.
- Bulblets will form throughout the wounded area.
Tulip bulb scooping: Bulblets formed after 2-5 weeks incubation in moist peat at 75°F.

**Bulb Propagation:**

- Non tunicate bulbs can be scale propagated. *Lilium* and *Fritillaria* are representative species.
- Individual scales are removed, treated with specific environmental manipulation and induced to form bulblets along their base.
- Scales can be removed from the outer ring of a 2-3 year old bulb. If you leave the inner layers and replant, the bulb will be able to continue blooming. If you remove most of the scales, the parent bulb will fail.
- This method is very efficient.
  - 1 bulb scale produces 3-5 bulblets.

**Lily bulblet formation from base of scales.**

**Corms:**

- Corms resemble bulbs but are formed in a different manner.
- Like bulbs, they are made up of stem and leaf tissue - but a majority of their mass is stem.
- Common corm producing plants are *Gladiolus* and *Crocus*.

**Corm:**

- Primarily by cormels - natural increase in new corms.
  - Cormels - miniature corms developed between old and new corms.
  - 1-2 years of growth required to reach flowering size.
  - Production of cormels increases when in a shallow planting depth.
- 2-3 large corms are cut into sections with a bud on each section.

**Rhizomes:**

- Specialized stem that grows horizontally above or just below the soil surface.
- Found on many grasses including bamboo, sugar cane, ginger, *Iris* and *banana*. 
Rhizome - Propagation

- **Division** - Propagation is generally done by division, ensuring that each piece of the rhizome has at least one lateral bud.
- **Culm Cuttings** - Culm cuttings can be taken from large rhizome-bearing plants (i.e., bamboo) and the aerial shoot is laid down horizontally in a trench, new branches arise from the nodes.

Rooting Cuttings

- a portion of stem, leaf, or root from a parent plant, which when placed under favorable conditions, forms new roots and/or shoots, resulting in progeny identical to the parent.
- Typically, a stem piece of the most recent growth is used, although leaves and roots can also be used (depending on the species).

Rooting stem cuttings: how to

- Planning ahead is critical to success:
  - Identify the plant you want to propagate
  - Choose healthy, newest stem growth (timing of year will depend on species)
  - Use best rooting media (clean, well-drained potting mix) and proper environmental conditions (greenhouse, home, outdoors, etc).
- When collecting, keep cuttings from drying out by using mister and placing them in plastic bags (in cooler if hot)
- Cuttings can be trimmed to fit well in mist bench or other rooting container

Rooting stem cuttings: how to

- Most species need application of rooting hormone (auxin; Powder or liquid)
- Cover the bottom 1" of stem with rooting powder and tap off excess or hold in liquid for 4-5 second dip
- Dibble hole in rooting media, insert stem, and firm media
- Water in well (powder hormone must dissolve in water)
- Mist or plastic tent to maintain high relative humidity
- Mist is not for watering media – it is to reduce transpiration (water leaving the leaf surface)
- Rooting may take 6-8 weeks or more

Benefits – Cont’d.

- Cuttings are technically simple
  - Almost anyone can be trained to select, prepare, and stick cuttings
- Cuttings are a very efficient use of space
- Cuttings are usually the least expensive method of cloning plants
  - If plants can be propagated this way, they generally are
- Compared to grafting, cuttings generally produce a more uniform crop

Mist nozzles used to keep cuttings from losing moisture
Layering

- A form of rooting cuttings where roots are initiated on a stem while it is still attached to the mother plant
- Once roots develop, the stem is detached and established on its own
- Layer – term for a rooted stem that is detached from a mother plant

Why layering works

- Maintaining a physical attachment (to mother plant)
  - This allows for a continual supply of water, minerals, carbohydrates, and hormones
  - Water stress is avoided, as is the nutrient leaching associated with misting cuttings
  - Layering is only usually done when one can’t root stem cuttings

Layering – Cont’d.

- Allows for the propagation of a relatively small number of large size plants
  - Cuttings are generally very small
- Short period of time
  - In an outdoor environment
- Minimal amount of supplies and facilities

Layering – Cont’d.

- Does not require a greenhouse, mist bench, etc.
- Ensures the cultivar stays on its own roots
  - Unlike grafting
- Perfect for amateur horticulturists looking to reproduce a small number of an important cultivar using a simple method

Mound (stool) layering hazelnut

1) Wound stem slightly,
2) Spray on liquid rooting hormone (auxin),
3) Then cover with potting mix,
4) Dig rooted stems in the fall once leaves drop
Air Layering

- Stems are wounded or girdled and enclosed with rooting media to produce rooted layers in the upper portions of the plant.

Air Layering Ficus elastica: 8 weeks later

Grafting

- Grafting: the art of connecting two pieces of living tissue together so they unite and develop as one.
  
  Scion wood:
  - the piece of stem with one or more buds that forms the upper portion of shoot on a grafted plant
    - The genotype you want to multiply

Budding:

- form of grafting in which the scion is reduced to a single bud and a small section of the stem.

Chip bud of hazelnut

Rootstock:

- The Rootstock (also referred to as the stock or understock) forms the lower portion of the grafted plant
  - includes the root system and perhaps (depending on the placement and type of graft) the trunk and part of the scaffolding branches
- The rootstock may be a seedling, rooted cutting, layer, or micropropagated plant
Reasons for Grafting

- It is difficult to propagate some species by other methods
  - Not all species, especially fruit and nut trees, readily initiate adventitious roots from stem cuttings or by other methods
- It may be possible to layer some species, but this is generally slower to initiate than grafting and is limiting (inefficient) when one needs to propagate large numbers quickly

Reasons for grafting: mature phase of plant

- It is possible to propagate the mature phase of the selected plant
  - For example grafted fruit cultivars like apples and pecans come into bearing much sooner than seedlings 2-6 years instead of 8-15+

Reasons for grafting: Dwarfing, etc.

- Obtain the benefits of particular rootstocks and interstocks
  - dwarfing habit, disease resistance, or tolerance to different biotic and abiotic stresses

Limitations of Grafting

- Grafting is more expensive than rooting cuttings as it requires more land, skillful labor, and facilities
- Some plants are difficult to graft, i.e. nut trees need specific temperatures to callus

Apple rootstock have been developed to let you predict the size of the tree Smaller trees are easier to harvest and more can be planted per acre; higher yields per acre!
Plant Tissue Culture (Micropropagation)

- techniques used to multiply plant tissues under sterile conditions on a nutrient culture medium
- Typically, a very small piece of tissue is cut-out and placed in sterile culture in a test tube, petri dish, or other sterile container containing a special culture medium (agar – like gelatin).
- PTC relies on the fact that every plant cell has the ability to regenerate a whole plant
  - All cells contain the entire genetic makeup of the organism – can grow one cell into a complete plant
  - Need correct environmental conditions/hormones to trigger dedifferentiation of cells

PTC advantages over traditional methods of propagation

- Very efficient multiplication system – some species cannot be economically propagated otherwise
  - Low amount of starting material can yield exponential increases
- The production of plants from seeds that otherwise have very low chances of germinating and growing, i.e.: orchids
- The production of plants in sterile containers that allows them to be moved with greatly reduced chances of transmitting diseases, pests, and pathogens (no soil).
- Ability to clean particular plants of viral and other infections and to quickly multiply these plants as cleaned, “certified stock” for horticulture and agriculture

Laminar flow hood

- Uses HEPA filter to “clean” air that blows towards you as you work.
- Provides sterile work surface but “sterile technique” must also be followed to have success
- Growth media is ideal for microbes...
  - Use sterile media, sterile tools, disinfested plant tissue (bleach soak), etc.
  - Sterile technique is an art

Orchid seed is very tiny and has no endosperm (storage tissue): outside of in nature, only way to germinate is in culture

Propagation of African Violet through tissue culture

- From one cell you can develop millions of identical (clonal) plants...
Thank you

- If you want to learn more about plant propagation, please take my class in the spring semester
  - Plant Propagation
  - 11:776:310
  - Thursday 10:55-12:15, Friday 12:35-3:35
  - molnar@aesop.rutgers.edu for more information

Detached Scion Graftage: Apical Grafts

- Splice (Whip) Graft
  - Very simple graft consisting of single slanting cuts made on the scion and rootstock of equal size

Splice (Whip) Graft (cont.)

- Scion and RS are placed together and tied with rubber bands, poly tape, string, etc
- When scion is a smaller diameter than RS, scion can be placed off to one side carefully matching cambial layer on one side

Limitation – scion and RS need to be held together when tying to make sure cambial layers stay aligned
- This takes some practice
- Useful for small diameter material, ¼ to ½ inch
- The graft union is weaker than the whip and tongue graft for 1st season

Splice (Whip) Graft (cont.)

- Useful for small diameter material, ¼ to ½ inch

Whip and Tongue Graft

- Modification of the splice graft
- Requires more technical cutting skill than the splice graft, but interlocking cuts make tying scion and RS much easier
- Make splice graft cut on RS and scion with an additional reverse cut

Chip Budding:

- Requires some experience and skill
- Make cuts with sharp tools
- Bud union is stronger than other types of grafts
- Bud grafts are easier to make than other aid methods