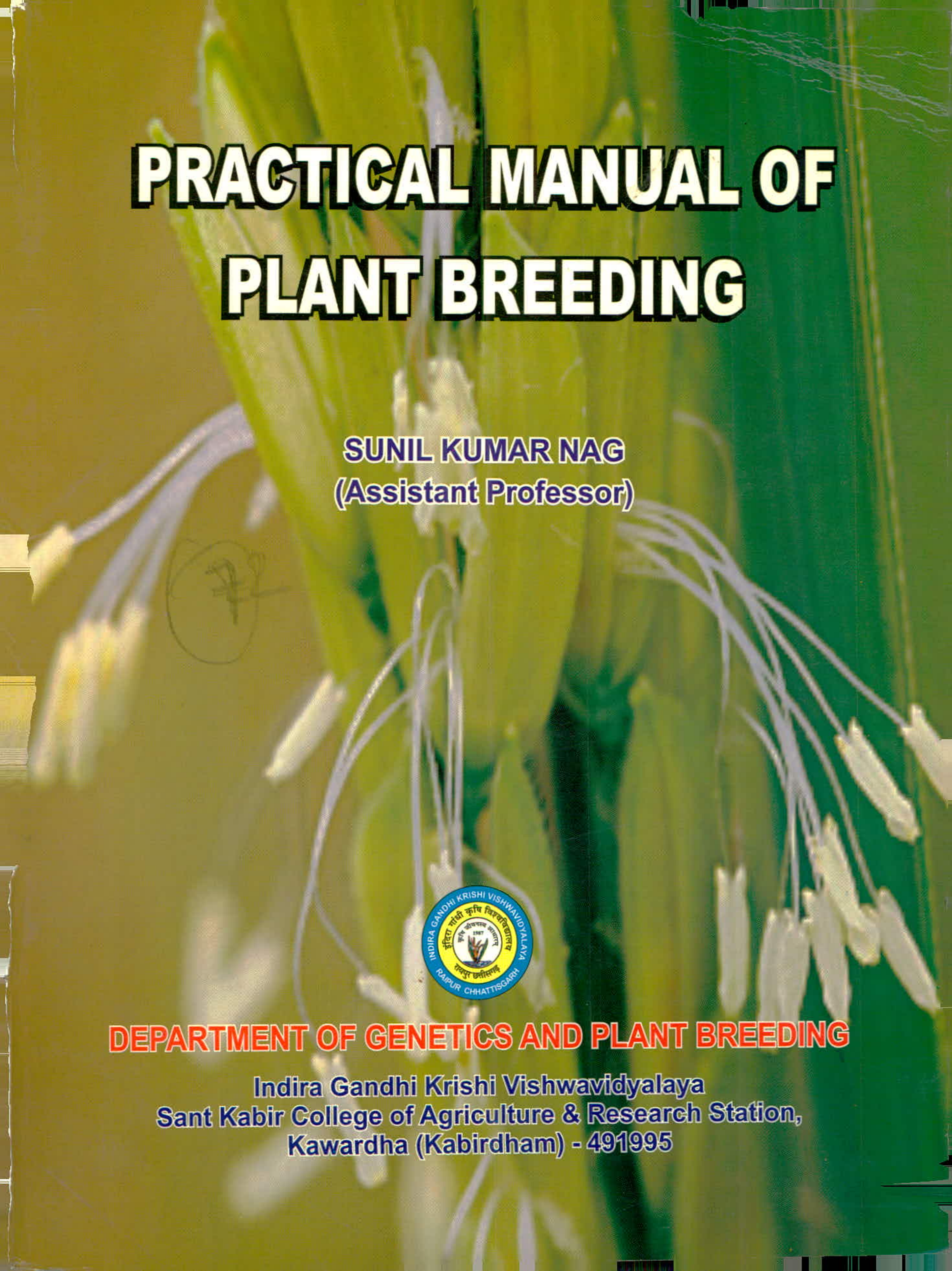

# PRACTICAL MANUAL OF PLANT BREEDING

SUNIL KUMAR NAG
(Assistant Professor)

DEPARTMENT OF GENETICS AND PLANT BREEDING

Indira Gandhi Krishi Vishwavidyalaya
Sant Kabir College of Agriculture & Research Station,
Kawardha (Kabirdham) - 491995

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# PREFACE

Plant Breeding is an essential component of curriculum for graduate programme in Agriculture. It is an effort made for keeping in view the needs and expectation of the students.

The present practical manual entitled 'Practical Manual of Plant Breeding' has been prepared for the students of B.Sc. (Ag.) second year keeping in view of their practical course outline. An attempt has been made to present different practical aspects of Plant Breeding taking help of the neat and well labeled diagrams.

This practical manual is developed for the students with the aim to provide the study material in a single source. It is hoped that the manual would be greatly beneficial to the students as well as researchers/extension workers.

I express my sincere thanks to Dr. M.P. Thakur, Dean, Sant Kabir College of Agriculture & Research Station, Kawardha for his expert guidance and constructive criticism on the manual prepared.

All necessary precautions have been taken to prepare the text free of mistakes but if you come across with any of such mistakes, it would be heartily welcomed to improve it in future.

Kawardha
Dated:

Author

**Indira Gandhi Krishi Vishwavidyalaya**
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**Kawardha (Kabirdham) - 491995**

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# FOREWORD

The discipline of Plant Breeding is one of the most pioneer branch of agricultural science which evoke a new ray of light in practical utility of crop improvement in agriculture. The teaching in agricultural science need to be more practically oriented and students should be well aware of basic practical concept in translating the knowledge into action. In view of this publication of Practical Manual on Plant Breeding by Shri Sunil Kumar Nag Plant Breeder posted at Sant Kabir Còllege of Agriculture & Research Station, Kawardha is a most welcome and timely efforts to help the students.

The practical manual encompasses the botanical description of some important crops, pollination, floral morphology, hybrid techniques and some other important approaches. This handy manual is very useful for under graduate course as well as young teachers in the field of Plant Breeding.

It gives me an immense pleasure in bringing out such a useful practical manual on behalf of Sant Kabir College of Agriculture & Research Station, Kawardha. I compliment Shri Sunil Kumar Nag, Assistant Professor for the commendable efforts made in publishing the present manual for our College students. I hope, this manual would be extremely useful to students not only in practical but in field of teaching as well.

Kawardha
Dated:

**Dean**
Sant Kabir College of
Agriculture & Research
Station, Kawardha.

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## Practical No. 01

# Botanical Descriptions of some Important Crops

| | | |
|---|---|---|
| **Crop** | : | **Rice** |
| **Botanical name** | : | ***Oryza sativa*** L. |
| **Family** | : | **Gramineae** |
| **Chromosome No.** | : | **2n = 2x = 24** |

**Botanical description of nice :**

- ☆ Rice is an annual grass belongs to the genus *Oryza*. There are about twenty three species out of which only two species are known for their commercial value and used for cultivation. These two species are *Oryza sativa* (Asian rice) and *Oryza glaberrima* (African rice).
- ☆ The *Oryza sativa* is the most commonly grown species throughout the world today, while *Oryza glaberrima* is grown only in South Africa.
- ☆ Of the two, *O. sativa* is by far the more widely utilized. and a complex group composed of two forms endemic to Africa but not cultivated.
- ☆ A third form, *O. rufipogon,* having distinctive partitions spread into South Asian, Chinese, New Guinean, Australian and American forms.
- ☆ In Asia *Oryza sativa* is differentiated into three sub-species based on geographical conditions, *viz., indica*, *japonica* and *javanica.*
- ☆ The variety *indica* refers to the tropical and sub-tropical varieties grown throughout South Asia, South-East Asia and Southern China.
- ☆ The variety *japonica* is grown in temperate areas of Japan, China and Korea, while *javanica* varieties are grown along side of *indica*s in Indonesia.

**Botanical Description:**

- ☆ Rice is a self-pollinated crop semi-aquatic plant and consists of arenchymatic tissues. The presence of arenchymatic cells on leaf, culm and roots can diffuse oxygen from aerial parts downward to roots.
- ☆ The plants are about 1m tall but certain deep water varieties can elongate upto 5m with the rise in water level.

**Root System**: The root system is fibrous.

- ☆ Rice seed gives out seminal roots out of the radical. These are temporary in nature.
- ☆ The real functional roots are secondary adventitious roots that are produced from the lower nodes of the culm.

**Shoot System:** The rice stem is known as culm. It is hollow and made up of nodes and internodes. Each node bears a leaf and bud, which may grow into a shoot or tiller. Primary tillers grow out of the main culm.

- ☆ Tillering continues in rice upto vegetative phase.

- Some tillers die during the reproductive phase due to competition for water and nutrients. Panicles bearing tillers are known as fertile or productive tillers.

  **Leaf:** Each node of the culm bears a leaf. Each leaf consists of the following parts:
- **Leaf sheath:** It originates from the node of culm and many a times encloses it and sometimes even the next upper node and a part of the leaf sheath of the upper leaf.
- **Leaf blade:** It is the upper expanded part of leaf and begins at node, where it is joined with leaf sheath. At the joint there is a thick collar.
- **Auricles:** These are hairy appendages at the base of the leaf blade.
- **Ligules**: It is a thin papery structure just above the auricles. Different parts of leaf are of importance in identifying the varieties.
- **Flag leaf:** It is the uppermost leaf just below the panicle. It is generally shorter in length and remains erect at an angle.

  **Panicle:** The inflorescence of rice plant is born on terminal shoot known as panicle. It is determinate type and at maturity it is droopy in nature. Panicle bears the spikelets.
- **Spikelet:** A spikelet is the floral unit and consists of two sterile lemmas, a lemma, a palea and the flower.
- **Lemma**: It is a 5 nerved hardened bract with a filiform extension known as awn. Rice varieties may or may not have an awn.
- **Palea**: It is a three nerved bract slightly narrower than lemma.
- **Flower**: It consists of 6 stamens with two -celled anthers and a pistil with one ovary and two feathery stigmas. The pistil consists of one ovule.
- **Grain:**
- Rice grain is the ripened ovary with lemma and palea firmly adhered to it.

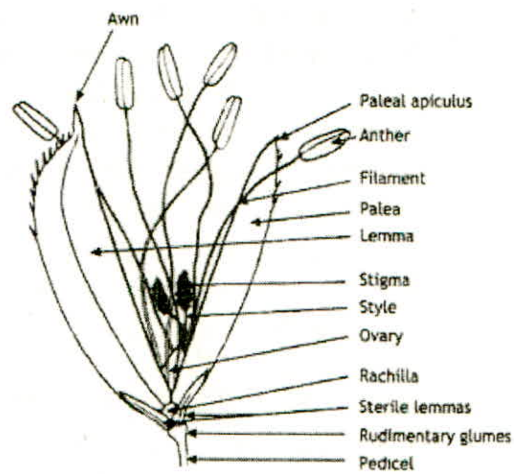



**Fig-01: Spikelet of Rice**

- The lemma and palea with other smaller components from the hull are removed in shelling rice for consumption.
- The rice fruit is a caryopsis in which single seed is fused with the wall of the ovary (pericarp).
- The seed consists of endosperm and an embryo. The embryo is very small and is found on the ventral side of the caryopsis. It contains plumule (embryonic leaves) and radicle (root).
- On submergence in water or on sowing the radicle grows as root and plumule grows as shoot.

**Crop** : **Wheat**
**Botanical name** : ***Triticum aestivum*** L.
**Family** : **Gramineae**
**Chromosome No.** : **2n = 6x = 42**

**Botanical description of wheat :**

**Roots:** During germination it produces both seminal and primary roots. The adventitious root arises later from the basal node of the plant and remains functional throughout its life. Seminal roots are slender. The root of wheat spread 10 to 15 cm and penetrates in soil from one to two meters.

**Tillers:** The tillers have the same basic structure as the main shoot. These arise from the axils of basal leaves. At anthesis most of the tillers bear productive ears, however, a few remains sterile.

**Spikelet:** Spikelet is composing of the flowers called florets. The number of floret in a spikelet may vary from 1-5. The floret in each spikelet is enclosed by two glumes.

**Kernel (Seed):** Wheat has caryopsis type of fruit. The typical wheat kernel is from 3-10 mm length and from 3-5 mm in diameter. The composition of a wheat kernel is:

- ☆ The germ (the embryo, consisting of plumule, scutellum, radical and hypocotyl) comprises about 2.5 per cent. It is high in proteins and fats.
- ☆ The brawn (pericarp, testa, nucleus and aleurone layer) comprises as much as 14 per cent. It is bi-product of milling and is used in dairy and poultry feeds. Small amounts are used in break fast cereal.
- ☆ The starchy endosperm (the storage part of the caryopsis that develops from the union polar nuclei with the endosperm nuclear comprises from 83 to 87 per cent.

**Inflorescence:**

- ☆ The inflorescence of wheat is known as 'spike of spikelets' or 'ear'. There are 2 rows of spikelets in front of each other.
- ☆ Spikelets are systematically arranged and are distributed along the central zig-zag axis, which known as 'rachis.

**Leaf:** Leaf consists of four parts:

- ☆ **Leaf sheath**: It is the basal part of the leaf. It encircles the culm (stem) and protects the growing points and auxiliary buds.
- ☆ **Blade**: It is flattened, parallel veined portion of the leaf.
- ☆ **Ligules:** It is a membranous or cartilaginous fringe at the junction of the sheath and blade of the side of the leaf next to the culm. The continuation of the sheath through the color is known as ligules.

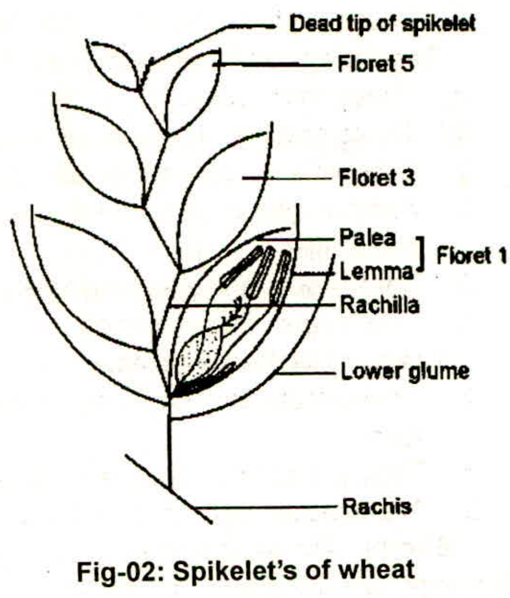



**Fig-02: Spikelet's of wheat**

☆ **Auricle**: Lobes of the leaf blade which extent downward on each side at the junction of blade and sheath. Some times it is coloured in stead of green.

**Stem (Culms):** Wheat stem generally possesses height from 60-70cm (in case of three gene dwarf verities) to 125cm (tall varieties). The stem of wheat plant is round or cylindrical. In most varieties of the bred wheat the stems are hollow, accept at the nodes where they are solid but in a few varieties of durum wheat the internodes are completely filled with the soft pith. There are 5 - 7 nodes on the stem. Stem is solid on nodes and hollow in between the internodes. Maximum portion of wheat is covered with leaf sheath. Stem is often glabrous or some times it is hairy. Height of wheat plants is governed by the genes the dose of one gene classified as tall; one dwarf (semi-tall); two gene dwarf (semi-dwarf) and three gene dwarf.

| | | |
|---|---|---|
| **Crop** | : | **Sorghum** |
| **Botanical name** | : | ***Sorghum bicolor*** L. |
| **Family** | : | **Gramineae** |
| **Chromosome No.** | : | **2n = 2x = 20** |

**Botanical description of Sorghum:**

**Plant description:** It is a single culmed *i.e.*, single solid erect stem supported by strong adventitious roots. Buds, from lowest node forms tillers depending on the cultivar and environmental conditions. The centre of the stem may be sweet or insipid, juicy or dry.

**Leaves:** Leaves are arranged alternately usually in two ranks. Each leaf originates from a node and has a sheath, blade or lamina. The leaf sheath has overlapping margins and encircles the inter-nodes.

**Root System:** The sorghum root system consists of 3 types of roots:

1. Primary roots
2. Secondary or Adventitious roots
3. Brace or Buttress roots.

**Primary roots:**

☆ These roots develop from the radicle and die subsequently.

**Secondary or Adventitious roots:**

☆ These roots develop from the first node from the mesocotyle.
☆ These roots occupy 5 to 15 cm area in the soil around the base of the stem.
☆ Adventitious roots are small, uniform and form a small portion of the root system.
☆ Another type of permanent adventitious roots develops from the second internode and above.
☆ These roots are branched laterally (about 1 sqm.) interlacing the soil vertically.
☆ These roots mainly supply nutrients to the plant.

**Brace or buttress roots:**

☆ These roots develop from the root primordia of the basal nodes above the ground level.
☆ They are stunted, thick and above ground level.
☆ These roots provide anchorage to the plant.

**Seeds:** The sorghum seed is a caryopsis which varies in colour, shape and size. The large variation for pericarp colour (white, cream, lemon yellow, red and brown), shape of seed (spherical, oval, ellipsoidal, pear shaped or turtle shaped with a flat surface on one side) and seed size (0.75 to 7.5 g/100 wt) has been observed.

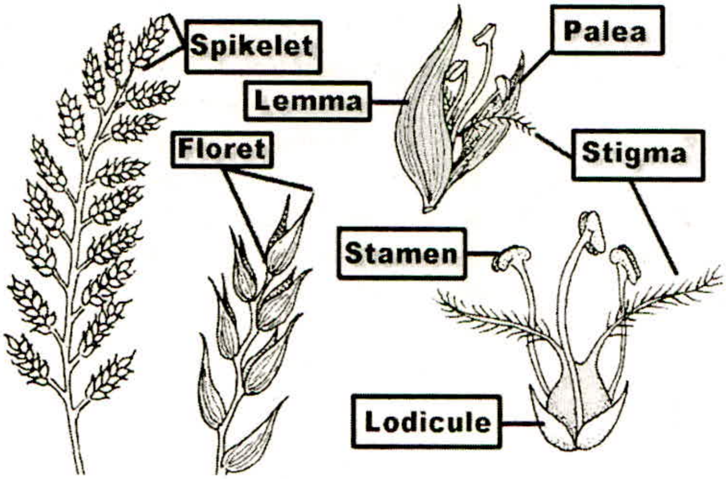



**Fig. 03. Spikelet's of Sorghum**

| | | |
|---|---|---|
| **Crop** | **:** | **Soybean** |
| **Botanical name** | **:** | ***Glycine max* L. (Merr.)** |
| **Family** | **:** | **Leguminaceae** |
| **Chromosome No.** | **:** | **2n = 2x =40** |

**Botanical description of Soybean :**

Soybean is erect, bushy and annual plant with leafy growth. The plant varied from 0.5 to 2 meter in height. The branches may be spreading or ascending depending on growing conditions. The soybean cultivars are grouped into two types based on growth habit *i.e.*, *Indeterminate* and *Determinate*.

**Seed:** Seed shaped varies as spherical, spherical-flattened, elongated and elongated. Seed has small scar of linear to oval shape known as hilum, which marked attachment of the seed to the pod. The area surrounding the hilum may be of different shades of black, brown, gray or yellow.

**Root:** The primary root grows as main root axis and penetrates soil more or less straight downward called tap root. The secondary lateral rootlets are branched from the taproot whereas, multi-branched adventitious roots also emerge. The bacterial root nodules appear after 8-10 days of planting which begin nitrogen fixation about two weeks later.

**Stem:** It is usually erect in cultivated types while, prostrate/trailing/twining in wild typed. The structure of stem is solid and cylindrical with wider base to tapering towards tip. The stem may be glabrous or pubescent with gray or tawn hairs.

**Leaves:** Cotyledons or seed leaves, simple primary leaves or unifoliate leaves, trifoliate leaves or compound leaves and prophylls with light green, medium green or dark green coloured leaves with pubescent or globrous surface are found in soybean.

**Floral Biology:** Flowers are 6-7 mm long, bisexual, self-pollinated, pedicellate, zygomorphic, pentamerous, bracteate and typical papilionaceous with tubular calyx of five unequal lobes. Calyx is persistent and attached with pods. The corolla of violet (purple) or white colour comprises of a posterior banner or standard petal, two lateral wings petals and two anterior keel petals. The keel petals are not fused. The 10 stamens in diadelphous pattern form a tube around the pistil by the fusion of nine stamens. The tenth stamen remains free. Anthers are bilobed, dorsifixed and introse. The single pistil is unicarpellary, superior and unilocular with style curved towards the free posterior stamens. The pistil has one to four campylotropous (curved) ovules with marginal placentation. Hairs are present on outer surface of ovary or calyx tube. Blooming starts in early morning but in prolonged cooler temperatures flowers do not open and behave as cleistogamous. In normal conditions anthesis occur prior to opening of flower. The pollens are heavy and seldom wind-borne. Natural crossing may occur to the extent of 0.5 to 1%.

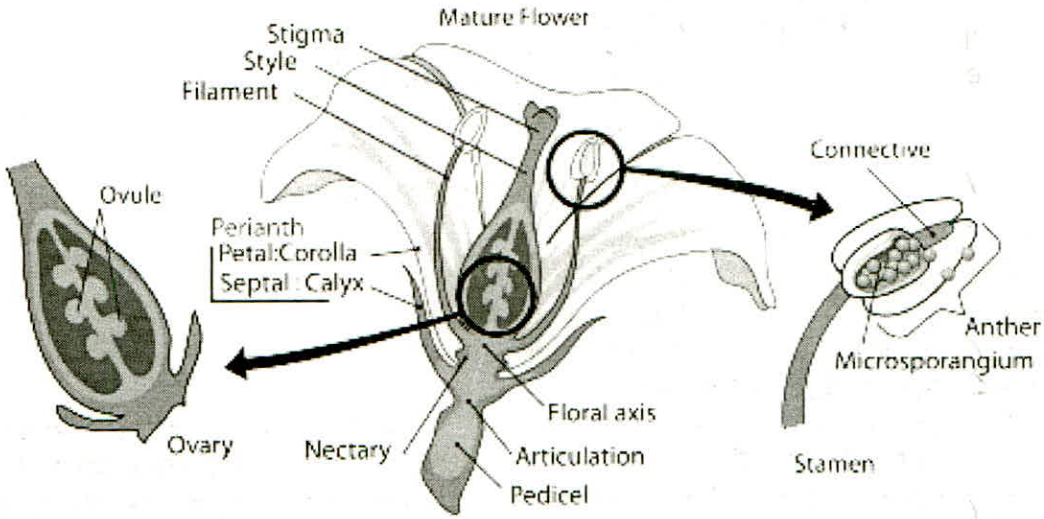



**Fig. 04. A typical flower of soybean**

**Crop** : **Mungbean and Urdbean**
**Botanical name** : ***Vigna radiata* & *Vigna mungo* L.**
**Family** : **Leguminoceae**
**Chromosome No.** : **2n = 2x = 22**

**Botanical description of Mungbean and Urdbean** :

A typical *Vigna*, plant type is an erect or sub erect twining herb, annual with plant deeply hairy.

**Root:** The taproot is well branched and fairly extensive. Smooth and round nodules varying greatly in size develop singly or in group on the root.

**Stem:** The stem is furrowed and much branched from the base. It is green or purple and is covered with dense brown hair, hairs pointing downward. The stem is 30-100 cm long occasionally trailing type.

**Leaf:** The leaves are alternate, trifoliate with pointed leaf lets, subtended by small stipules. There are two narrow stipules at the base of the petiole. The leaves are dark green. The ovate stipules and falcate stiles, leaf peltatively attached pulvinate, pinnately trifoliate sparsely hairy on both the surfaces, sub coriaceus, palmately reticulate, lateral leaflet oblique leaf lets are ovate to lanceolate with entire margin.

**Crop** : **Maize**
**Botanical name** : ***Zea mays* L.**
**Family** : **Gramineae**
**Chromosome No.** : **2n = 2x = 20**

**Botanical description of maize :**

Plants are herbaceous tall (up to 4 meter) and often single stalked.

**Roots:** Roots are adventitious. Seminal root (main) develops from the radicle with its lateral roots. Stilt and fibrous, developing from the lower nodes of the stem thick and often pigmented. The main roots may penetrate to depths of 2 meter.

**Stem:** Two to four cm thick, cylindrical, solid, slightly furrowed stem possess an average 14 internodes (8-20), those are thick at the base and tapering towards the tassel.

**Leaves:** Leaves distichous, each with leaf sheath, ligule, ligule, auricle and lamina. Sheath entire below and split above, ligule is membranous, fringed with hairs and closely invests the stem, auricle broad, lamina long and ribbon like with a strong mid rib and waxy.

**Inflorescence:** The maize is monoecious plant. The male inflorescence called tassel is terminal on the main axis. The spikelets are arranged in pairs, one sessile and another pedicelld both being identical in size, shape and structure. The female inflorescence known as the '*cob*' or the *'ear'* may be considered as a modified lateral branch derived from an auxiliary bud of the main stem. The internodes become short from a central stout axis and the overlapping sheaths of the modified leaves cover the inflorescence, forming the "*husk*" of the ear. The soft and succulent spikelets in 8 to 12 longitudinal rows are closely attached to the thickened central axis. The lemma and paleas are thin, membranous and broad. The fertile pistillate flower is found with the second lemma. The ovary has a long slender style (36 to 40 cm), emerging from the top of the husk as *silk*.

**Floral biology**

*Anthesis:* The maize plant is protandrous. In staminate inflorescence, spikelets closer to the tip of the tassel open first then anthesis proceeds downwards and complete in 14 days. The receptive style of each ovary grows in length and exerts out of the husk and after fertilization, the style begins to wither.

**Pollination:** About 95% of the ovules on a shoot are formed by cross-pollination. Pollen may be carried up to one kilometer by wind. A single tassel may produce as many as 2, 50, 00,000 pollen grains. Each shoot is composed of a shank from which the husks arise and terminates in the ear on which the pistillate flowers are borne. Fresh silks function as both style and stigma and are receptive to the fresh pollens through out their entire length. Fertilization of the ovules usually occurs with in 12 to 28 hours after pollination.

**Crop** : **Pigeon pea**
**Botanical name** : ***Cajanus cajan* L.**
**Family** : **Leguminoceae**
**Chromosome No.** : **2n=2x=22**

**Botanical description of pigeon pea:**

**Leave:** The first two leaves in the seedling called primary leave are simple, opposite and caduceus. The later leaves are pinnately trifoliate; leaflets are lanceolate to elliptical with acute ends. Pubescent leaves are arranged spirally. The plant is erect and branched. The stem is woody, leaves are trifoliate and compound.

**Root:** It possesses a taproot system. It grows into a woody shrub of 1-2 m length, which is harvested annually. As a perennial plant is can be grown in fence and agro-forestry where it may attain a height of 3-4 m. Roots are deep and wide spreading in the soil with well developed lateral roots. Short- duration genotypes have smaller root system than long- duration genotypes. Spherical, oval, elongate, branched nodules of 2-4 mm size are formed by the cowpea group of *rhizobia*, mainly on the upper 30 cm of the root system. Nodulation declines towards pod filling.

**Stem:** Strong woody stem of pigeon pea has colour varied from green, sun red or purple. For agronomic purpose pigeon pea plants can be grouped as compact (erect) semi-spreading (semi erect) and spreading types. Based on the flowering pattern it may be determinate or indeterminate. Another group is semi-determinate which behaves between the determinate and indeterminate habit.

**Floral biology**

Flowers with long peduncle are borne on terminal or auxiliary racemes. The raceme inflorescence forms a terminal in non-determinate type and a somewhat corymb-shape bunch in the determinate types. Flowering proceeds acropetally (in the direction of apex) in the raceme and on the branches too.

| | | |
|---|---|---|
| **Crop** | : | **Linseed** |
| **Botanical name** | : | ***Linum usitatissimum* L.** |
| **Family** | : | **Linaceae** |
| **Chromosome No.** | : | **2n= 30 (Spp. varied from 16 to 86)** |

**Botanical description of linseed :**

Linseed (*Linum usitatissimum* L.) is an annual herbaceous plant grown as a winter crop in warm climates from October-November to March-April. Two distinct morphological types namely, flax and linseed, are recognized in the cultivated species. The flax types (tall with straight culms and less number of secondary branches) are usually grown for extraction of fiber. The linseed types, which are predominantly grown in India, are meant for extraction of the oil. The plants of linseed types are relatively short and possess more of secondary branches. The linseed types grown in Northern and Central India are tall and small seeded with low oil content. The peninsular group has shorter plants with bold seeds and high oil content.

**Floral biology :** The linseed flower has five petals, which may be of white, blue, violet, purple, or pink colour. The flower has five anthers and a pistil with five slender styles. The linseed capsule is five chambered with two seeds in each chamber.

| | | |
|---|---|---|
| **Crop** | : | **Sesame** |
| **Botanical name** | : | ***Sesamum indicum* L.** |
| **Family** | : | **Linaceae** |
| **Chromosome No.** | : | **2n= 26** |

**Botanical description of sesame :**

**Root:** Usually tape and branched

**Leaves :** Lower leaves opposite, lobed with serrated and upper mostly alternate, narrow, oblong, simple, exstipulate, muclagenous, glandular, hairs present on the lower surface, upper surface glabrous.

**Inflorescence:** Cymose.

**Flower :** Pedicellate, hermophrodite, zygomorphic, complete, hypogynous, ebracteate.

**Calyx :** Five sepals, gamopetalous, sepals lanceolate, acute, hairy; Aestivation imbricate or valvate.

**Corolla:** Five petals, gamopetalous, 2- lipped, corolla 5-lobed, the upper lip consists of 2 equal sized lobes while the lower lip includes 3 petals, out of which central one is largest.

**Androecium:** Four stamens, didynamous, epipetalous, instead of $5^{th}$ stamen usually a staminode is present. Anthers 2- celled (dithecous), sagitate, introse and dehise by longitudinal slit. They are 1 to 2 mm long, while two yellow or purplish in colour with yellowish pollen grains.

**Gynaecium:** Two carpels (bicarpellary) or four carpels, syncarpous, ovary superior, placentation axile, style filiform, stigmas 2 and lobed.

**Fruit:** Loculicidal capsule, about 2.5 cm long, erect, hispid, break short, valves separating half way down, valved.

**Seed:** Small and many, smooth, albuminous with strait embryo.

| | | |
|---|---|---|
| **Crop** | : | **Cotton** |
| **Botanical name** | : | ***Gossypium spp* L.** |
| **Family** | : | **Malvaceae** |
| **Chromosome No.** | : | **2n=2x= 26 / 2n=4x=52** |

**Botanical description of cotton :**

Cotton plant has long tap-root and monopodial growth of main stem. Spirally arranged leaves have long petiole, two small stipules and broad palmately, 3-5 lobed, velvety to glabrous leaf blade with three to nine palmately arranged veins. Small nectar as a gland like cavity is present on the main vein of the lower surface of the leaf. Out of two buds present in each leaf axil normally only one develops. Lower branches of the plant, which do not bear flowers, are termed as vegetative branches or monopodial branches. Upper branches, which bear flowers are called fruiting branches or sympodial branches. Flower is surrounded by three leaf bracts. Green coloured calyx is reduced to a cup shaped structure at the base of five-lobe corolla tube. Five large petals of white to yellow colour with or without definite red or purple spot at the base are closely convoluted in the bud with twisted aestivation. Petals are slightly united to each other at base and fused with the staminal tube. A tube like structure formed by the fusion of 100-150 stamens surrounds the style. Single celled kidney shaped anthers varies in colour from white to gold. Superior ovary is composed of 3-5 carpels with several ovules in axial placentation. Flowers open in the morning with receptive stigma. Pollen grains remain viable up to twelve hours.

The boll is a spherical to ovoid (egg shaped) leathery capsule that splits at maturity along the carpel edges marked as furrows on the surface of the boll. Number of locules in a boll varies from three to five with six to nine seeds in each locule.

**Practical No. 02**

# Floral Morphology of plants

**Definition:** A flower is a branch system terminated by a series of modified leaves that are specialized for reproduction.

The flower consists of following parts:

1. **Sepals** (collectively all are referred to as the calyx) - abbreviated CA.
2. **Petals** (collectively all are referred to as the corolla) - abbreviated CO.
   CA & CO collectively called the perianth.
3. **Stamens** (collectively all are referred to as the **androecium**) - abbreviated A.
4. **Carpels** (collectively all are referred to as the gynoecium) - abbreviated G.

These floral parts are always positioned at the terminal (sometimes swollen) portion of the branch called the receptacle and always occur in the same order relative to each other. The position of each floral whorl can be visualized as occupying a location on a hemisphere. For example, the corolla is both further in or further up on the receptacle.

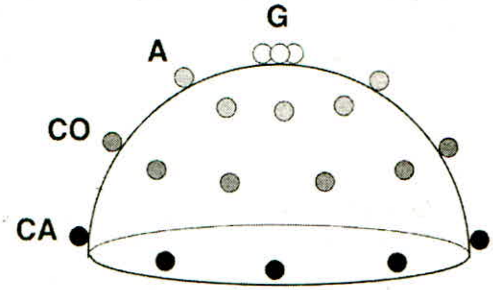



**Fig. 05. Flower Receptacle**

**Generalized flower structure showing flower with separate carpels.**

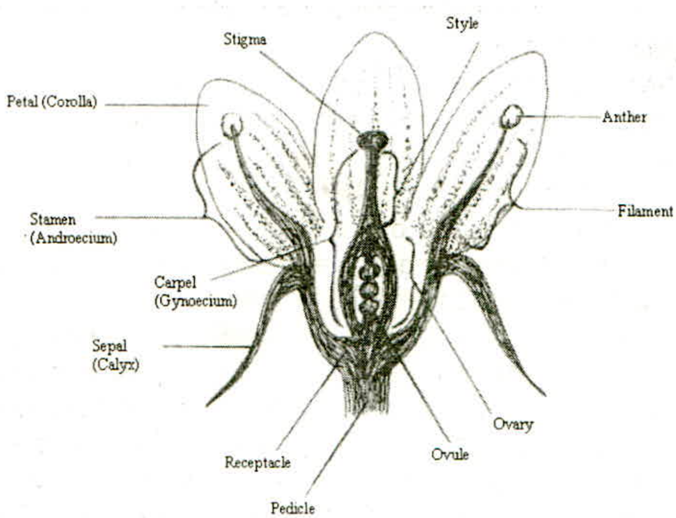



**Fig: 06. A Flower bears both androecium and gynoecium**

1. **Calyx** - Composed of sepals - lowest position on the receptacle. Usually green and leafy.
2. **Corolla** - Composed of petals - interior to the sepals. Usually the showy part of the flower (but not always!).

3. **Androecium** - composed of stamens - interior to petals. Each stamen composed of a filament and an anther (anther has sacs called thecae).
4. **Gynoecium** - composed of carpels - highest position on the receptacle. Plants may have one or many carpels and the carpels may be separate or fused to each other. When fused, referred to as a compound gynoecium. The compound gynoecium may have three regions:
   a. The stigma (receptive portion where pollen adheres and germinates).
   b. The style (where pollen tubes grow).
   c. The ovary (the swollen lower portion containing the ovules).
5. The term "pistil" is not very precise, for it can be a "simple pistil" (meaning a single carpel) or a "compound pistil" (meaning a compound gynoecium composed of fused carpels).

**How do the floral whorls of angiosperms compare to gymnosperms :** The fertile whorls (androecium and gynoecium) are foliar organs that bear micro- or megasporangia (anthers and ovules).

1. The stamen is really a microsporophyll bearing microsporangia (inside anther sac).

2. The carpel is really a megasporophyll bearing an integumented megasporangium (nucellus), otherwise known as an ovule.

**II. Sexual Conditions**

**A. Flower sexual conditions**

1. The generalized flower we just saw contained both anthers and carpels - called the essential floral parts. Since both sexes are present, the flower is called bisexual (also called hermophroditic or perfect flower).

2. If a flower lacks one or more of the four main floral whorls, it is referred to as incomplete. The missing floral whorls may be either essential (A & G) or non-essential (CA & CO). A complete flower must have all four floral whorls.

3. If a flower lacks one of the essential floral whorls, it is called unisexual (or imperfect). Since it lacks at least one whorl (essential or non-essential), it is also imperfect. Unisexual flowers contain either stamens or carpels. The former is called a staminate flower whereas the latter a carpellate (or pistillate) flower.

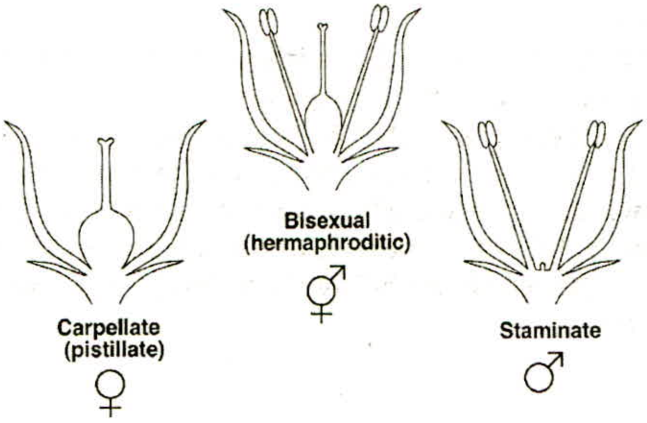



**Fig: 07. A Flower sexual condition**

**Whole plant sexual conditions :**

1. Staminate and carpellate flowers occur on the same individual plant, the species is referred to as being monoecious.

2. If staminate and carpellate flowers occur on different plants, the species is referred to as being dioecious.

3. If both bisexual (perfect) and unisexual (imperfect) flowers occur on the same plant, the species is referred to as being polygamous.

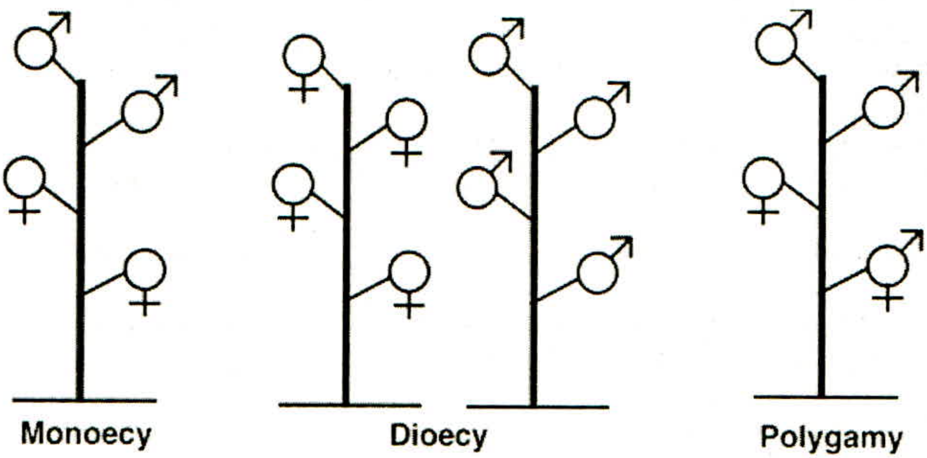



**Fig:08. Plant sexual conditions**

There are various forms of polygamy. You are not required to learn all of these types, but this diagram and the explanation below is included simply to illustrate the complexity and variation in plant sexual conditions:

**a) Andromonoecy :** Species where all individuals have staminate and bisexual flowers. *e.g. Filipendula*

**b) Androdioecy :** Species where some individuals have staminate and some have bisexual flowers. *e.g. Polygonum bistorta.*

**c) Gynomonoecy :** Species where all individuals have carpellate and bisexual flowers. *e.g.* many *Asteraceae*

**d) Gynodioecy :** Species where some individuals have carpellate and some have bisexual flowers. e.g. *Valeriana, Lobelia syphilitica*

**e) Polygamomonoecy :** Species that have individuals with staminate, carpellate and bisexual flowers (= trimonoecism) e.g. *Aesculus hippocastanum*, *Gymnocladus dioica.*

**f) Polygamodioecy :** Species where individuals have staminate and carpellate flowers, but either one or both individuals also have some perfect flowers.

**g) Trioecism :** Species where different individuals are staminate, carpellate or bisexual. *e.g. Fraxinus.*

**Practical No. 03**

# Pollination and Reproduction in plants

The knowledge of the mode of reproduction and pollination is essential for a plant breeder, because these aspects help in deciding the breeding procedures to use for the genetic improvement of a crop species. Choice of breeding procedure depends on the mode of reproduction and pollination of a crop species.

**Mode of Reproduction :** Reproduction refers to the process by which living organisms give rise to the offspring of similar kind (species). In crop plants, the mode of reproduction is of given two types:

1) Asexual reproduction

2) Sexual reproduction.

**Asexual reproduction :** The multiplication of plants without fusion of male and female gametes is known as asexual reproduction. Asexual reproduction can occur either by vegetative plant parts or by vegetative embryos which develop without sexual fusion (apomixes). Thus, asexual reproduction is of two types:

(a). Vegetative reproduction

(b). Apomixis.

**Vegetative reproduction :** Vegetative reproduction refers to multiplication of plants by means of various vegetative plant parts. Vegetative reproduction is again of two types: *viz.*, natural vegetative reproduction and artificial vegetative reproduction.

**Natural vegetative reproduction :** In nature, multiplication of certain plants occurs by underground stems, sub aerial stems, roots and bulbils. In some crop species, underground stems (a modified group of stems) give rise to new plants. Underground stems are of four types; *viz.,* rhizome, tuber, corm and bulb. The examples of plants which reproduction by means of underground stems are given below:

Rhizome : Turmeric (*Curcuma domestica*), Ginger (*Zingiber officinale*)

Tuber : Potato (*Solanum tuberosum*)

Corm : Arvi (*Colocasia esculenta*), Bunda (*C. antiquorum*)

Bulb : Garlic (*Allium sativum*), onion (*A. cepa*)

Sub aerial stems include runner, sucker, stone, etc. these stems lead to vegetative reproduction in mint (*Mentha sp*) rose, strawberry, banana, *etc.* Bulbils are modified forms of flower. They develop into plants when fall on the ground. Bulbils are found in garlic.

**Artificial vegetative reproduction**

Multiplication of plants by vegetative part through artificial is method is known as artificial vegetative reproduction. Such reproduction occurs by cuttings of stem, roots, by layering, grafting and gootee. Examples of such reproduction are given below:

**Stem cuttings:** Sugarcane (*Saccharum sp.*) grapes (*Vitis vinifera*), rose, *etc.*

**Root cuttings:** Sweet potato, citrus, lemon *etc.*

Layering, grafting and gootee are used in fruit and ornamental crops.

**Apomixis :** Apomixis refers to the development of seed without sexual fusion of male and female gametes (fertilization). In apomixis embryo develops without fertilization. Thus apomixis is an asexual means of reproduction. Apomixis is found in many crop species.

Reproduction in some species occurs only by apomixis. This apomixis is termed as obligate apomixis. But in some species sexual reproduction also occurs in addition as apomixis, such apomixis is known as facultative apomixis. There are four types of apomixis: *viz.*

(1) Parthenogenesis, (2) Apogamy, (3) Apospory and (4) Adventive embryony.

**1. Parthenogenesis.** Parthenogenesis refers to development of embryo from the egg cell without fertilization.

**2. Apogamy.** The origin of embryo from either synergids or antipodal cell of the embryosac is called as apogamy.

**3. Apospory.** In apospory, first diploid cell of ovule lying outside the embryosac develops into another embryosac without reduction. The embryo then develops directly from the diploid egg cell without fertilization.

**4. Adventive embryony.** The development of embryo directly from the diploid cells of ovule lying outside the embryosac belonging to either nucellus or integuments is referred to as adventive embryony.

**Sexual reproduction :** Multiplication of plants through embryos which have developed by fusion of male and female gametes is known as sexual reproduction. All the seed propagating species belong to this group.

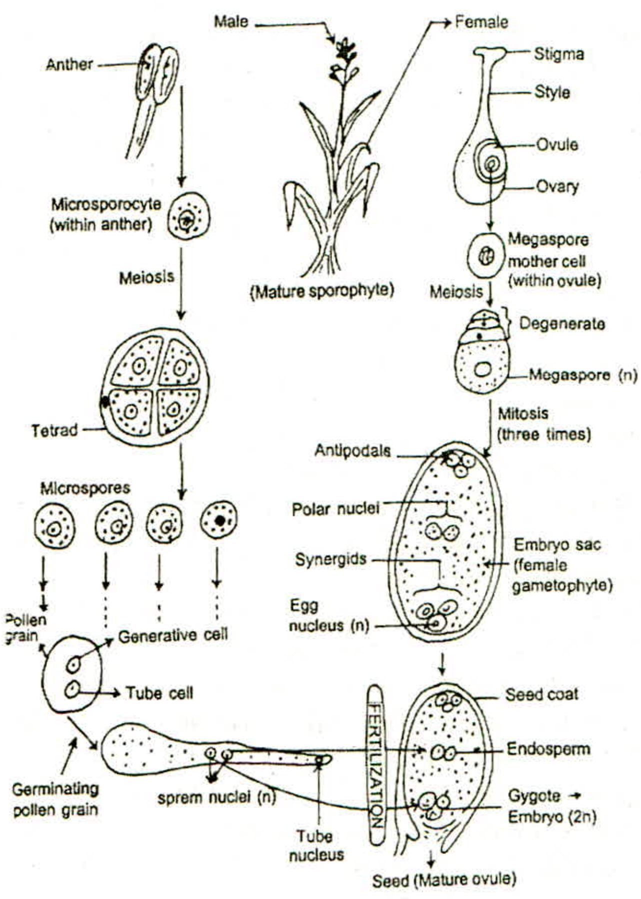



**Fig.09. Sexual reproduction of seed Plant**

**MODE OF POLLINATION :** The process by which pollen grains are transferred from anthers to stigma is referred to as pollination. Pollination is of two types: *viz.* (1) Autogamy or self pollination and (2) Allogamy or cross pollination.

**Autogamy**

Transfer of pollen grains from the anther to the stigma of same flower is known as autogamy or self pollination. Autogamy is the closest form of inbreeding. Autogamy leads to homozygosity. Such species develop homozygous balance and do not exhibit significant inbreeding depression. There are several mechanisms which promote autogamy.

**Bisexuality.** Presence of male and female organs in the same flower is known as bisexuality. The presence of bisexual flowers is a must for self pollination. All the self pollinated plants have hermaphrodite flowers.

**Homogamy.** Maturation of anthers and stigma of a flower at the same time is called homogamy. As a rule, homogamy is essential for self-pollination.

**Cleistogamy.** When pollination and fertilization occur in unopened in flower bud, it is known as cleistogamy. It ensures self pollination and prevents cross pollination. Cleistogamy has been reported in some varieties of wheat, barley, oats and several other grass species.

**Chasmogamy.** Opening of flowers only after the completion of pollination is known as chasmogamy. This also promotes self pollination and is found in crops like wheat, barley, rice and oats.

**Position of Anthers.** In some species, stigmas are surrounded by anthers in such a way that self pollination is ensured. Such situation is found in tomato and brinjal. In some legumes, the stamens and stigma are enclosed by the petals in such a way that self pollination is endured. Examples are greengram, blackgram, soybean, chickpea and pea.

**II. Allogamy**

Transfer of pollen grains from the anther of one plant to the stigma of another plant is called allogamy or cross pollination. This is the common form of out-breeding. Allogamy leads to heterozygosity. Such species develop heterozygous balance and exhibit significant inbreeding depression on selfing. There are various mechanisms which promote allogamy.

**Dicliny.** It refers to unisexual flowers. This is of two types: *viz.* i) monoecy and ii) dioecy. When male and female flowers are separate but present in the same plants, it is known as monoecy. In some crops, the male and females flower are present in the same inflorescence such as in mango, castor and banana. In some cases, they are on separate inflorescence as in maize. Other examples are cucurbits, grapes, strawberry, cassava and rubber. When staminate and pistillate flowers are on different plants, it is called dioecy. It includes papaya, date palm, spinach, hemp and asparagus.

**Dichogamy.** It refers to maturation of anther and stigma of the same flowers at different times. Dichogamy promotes cross pollination even in the hermaphrodite species. Dichogamy is or two types: *viz.*, i) Protogyny and ii) Protandry. When pistil matures before anthers, it is called Protogyny such as in pearl millet. When anthers mature before pistil, it is known as protandry. It is found in maize, sugarbeet and several other species.

**Heterostyly.** When styles and filaments in a flower are of different lengths, it is called heterostyly. It promoters cross pollination, such linseed.

**Herkogamy.** Hinderance to self-pollination due to some physical such as presence of hyline membrane around the anther is known as herkogamy. Such membrane does not allow the dehiscence of pollen and prevents self-pollination such as in alfalfa.

**Self incompatibility.** The inability of fertile pollens to fertilize the same flower is referred to as self incompatibility. It prevents self-pollination and promotes cross pollination. Self incompatibility is found in several crop species like *Brassica, Radish, Nicotiana,* and many grass species. It is two types sporophytic and gametophytic.

**Male sterility.** In some species, the pollen grains are non functional. Such condition is known as male sterility. It prevents self-pollination and promotes cross pollination. It is of three types: *viz.*, Genetic, Cytoplasmic and Cytoplasmic Genetic. It is a useful tool in hybrid seed production.

Study of floral biology and aforesaid mechanisms is essential for determining the mode of pollination of various crop species. Moreover, if selfing has adverse effects on seed setting and general vigour. It indicates that the species is cross pollinated. If selfing does not have any adverse effect on these characters, it suggests that the species is self-pollinated.

The percentage of cross pollination can be determined by growing a seed mixture of the different varieties together. The two varieties should have marker characters say green and pigmented plants. The seeds are harvested from the recessive (green) variety and grown next year in separate field. The proportion of pigmented plants in green variety will indicate the percentage of out crossing or cross pollination.

**Significance of pollination :** The mode of pollination plays an important role in plant breeding. It has impact on five important aspects: *viz.* 1) gene action, 2) genetic constitution, 3) adaptability, 4) genetic purity and 5) transfer of genes.

**Summary of modes of reproduction found in crop plants**

| | | |
|---|---|---|
| **A.** | **Asexual Reproduction** | Multiplication of plants bypassing sexual process |
| 1. | Vegetative Reproduction | Multiplication by vegetative plant parts. |
| a. | Natural | Multiplication by Rhizome, tuber, corm, bulb, runner, suckers and stolen. |
| b. | Artificial | Multiplication by stem and root cuttings, grafting, layering and budding. |
| 2. | Apomixis | Development of embryo without sexual fusion. |
| a. | Parthenogenesis | Development of embryo from egg cell without fertilization. |
| b. | Apogamy | Development of embryo either from synergids or antipodal cells. |
| c. | Apospory | Origin of embryo from diploid egg cell of another embryosac developed from diploid tissues. |
| d. | Adventive Embryony | Origin of embryosac directly from diploid cells belonging to either nucellus or integument. |

| | | |
|---|---|---|
| **B.** | **Sexual Reproduction** | Multiplication of plants by fertilized embryos. |
| | Autogamy | Fertilization of ovules by the pollens of same flower. |
| | Allogamy | Fertilization of ovules by the pollens of another plant. |

**Classification of crop plants based on mode of pollination and mode of reproduction**

| Mode of pollination and reproduction | Examples of crop plants |
|---|---|
| **A. Autogamous Species** | |
| 1. Seed Propagated | Rice, Wheat, Barley, Oats, Chickpea, Pea, Cowpea, Lentil, Green gram, Black gram, Soybean, Common bean, Moth bean, Linseed, Sesame, Lathyrus, Sunhemp, Chillies, Brinjal, Tomato, Okra, Peanut, etc. |
| 2. Vegetatively Propagated | Potato |
| **B. Allogamous Species** | |
| 1. Seed Propagated | Maize, Pearl millet, Rye, Alfalfa, Radish, Cabbage, Sunflower, Sugarbeet, Castor, Red clover, White clover, Safflower, Spinach, Onion, Garlic, Turnip, Squash, Muskmelon, Watermelon, Cucumber, Pumpkin, Kenaf, Oilpalm, Carrot, Coconut, Papaya, etc. |
| 2. Vegetatively Propagated | Sugarcane, Coffee, Cocoa, Tea, Apple, Pears, Peaches, Cherries, grapes, Almond, Strawberries, pine apple, banana, Cashew, Irish, Cassava, Taro, Rubber, etc. |
| **C. Often Allogamous Species** | |
| Seed Propagated | Sorghum, Cotton, Triticale, Rai, Pigeonpea, Tobacco, etc. |

**Practical No. 04**

# Fertilization and Life cycle of an angiospermic plant

**Angiosperms :** Division/Phylum Angiospermae is sometimes called Division Anthophyta (anthe = flower; phyto = plant) because the common name for this group is the "flowering plants." Angiosperms are so named because the seeds are enclosed within a fruit of some sort.

Division Angiospermae contains two main classes: Class Monocotyledones (the "monocots") and Class Dicotyledones (the "dicots"). These two classes can be distinguished in a number of ways, including:

**The angiosperm life cycle possesses the following advances over conifers:**

- ☆ Reproductive structures are flowers rather than cones.
- ☆ Ovules embedded in female sporophylls rather than lying bare on the surface
- ☆ Gametophyte still further reduced
- ☆ Double fertilization to produce a diploidtriploid endosperm nutritive material
- ☆ Seeds enclosed in fruits that develop from the ovary or related structures

**The parts of an Angiosperm include:**

1. **Roots**, which are generally underground and serve to absorb water and nutrients
2. **Stems**, which come in various types such as:
   1. Stolen, an above-ground "runner"
   2. Rhizome, an underground "runner"
   3. Bulb, a fleshy stem modified for nutrient storage
3. **Leaves**, which can be either simple or compound in form and which alternate with each other going up the stem or can be arranged opposite each other on the stem or as whorled leaves where more than two originate from the same place on the stem. Leaves can be many shapes from round to heart-shaped to oblong. Leaves which are entire, all in one piece, are called simple leaves, while those divided into multiple leaflets are called compound leaves. Compound leaves with their leaflets arranged like a feather are said to be pinnately compound (pinna = wing, feather) while leaves with their leaflets arranged like a person's fingers are said to be palmately compound. Leaves that arise from the branch/stem in pairs are referred to as opposite leaves, while those which alternate sides up the stem are referred to as alternate leaves, and if more than two leaves arise from the same spot, those leaves are said to be whorled.
4. **Flowers**, which are the reproductive structures of an angiosperm and consist of four whorls of modified leaves (from outside in):

- ☆ **Sepals (sepi** = fence in) (which collectively are called the calyx), which are often small and green but are colored like the petals in tulips and lilies, and which generally enclose the flower before it opens.

- ☆ **Petals** (**petal** = a leaf, spread out, flat) (which collectively are called the **corolla**) which are often brightly colored to attract pollinators (insects, birds, etc.) and may be very simple to highly modified.
- ☆ **Stamens** (**stam (en)** = anything standing upright, a thread), the "male" reproductive organs (they make microspores which turn into male gametophytes), which consist of a stalk (the filament) and a tip (the anther) where the microspores are produced and turn into pollen (anthe = flower).
- ☆ **Pistil** or **carpel** (**carpo** = a fruit), which consists of: Ovary (ova, ovi = egg). The bottom end where seeds are produced Style (styl, stylo = a pillar, stake, column) the "stalk" portion Stigma (stigma = spot) the outer, sticky tip where pollen sticks when it lands or is placed there.

**5.** Botanists group species of plants (or, from the other direction, the monocots and dicots can be subdivided) based on a number of characteristics. Botanists pay particular attention to how the flowers are put together:

**Angiosperm Life Cycle**

Angiosperms have alternation of generations with the 2n sporophyte being the dominant generation. The anthers, which are the equivalent of microsporangia, produce microspores by meiosis, and the microspores develop into male gametophytes (= pollen).

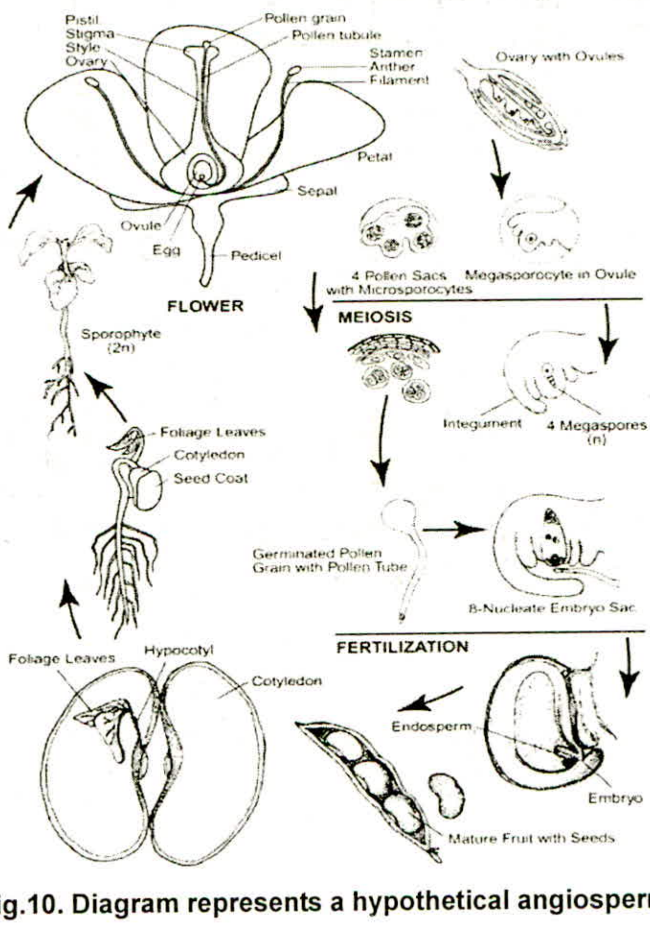



**Fig.10. Diagram represents a hypothetical angiosperm life cycle**

The ovaries, which are the equivalent of megasporangia, produce megaspores which grow into female gametophytes, each of which then produces an egg.

Note that technically the "sex organs" of a plant aren't because they produce spores (micro- or mega-) which turn into male or female gametophytes. The gametophytes bear the true sex organs, such as they are, and are where eggs or sperm are actually produced.

By some means (wind or an animal pollinator), the pollen is transferred to the stigma of the pistil, and a pollen tube grows down into the ovary. Eventually, two sperm nuclei travel down the pollen tube. Pollination is the transfer of the male gametophyte (pollen) to the stigma of the female, while fertilization is when the sperm nucleus and egg nucleus unite

Angiosperms have an unusual thing called double fertilization. When the sperm nuclei reach the female gametophyte, one sperm nucleus and the egg cell unite to form a new 2n zygote (which grows into an embryo). The other sperm nucleus and two nuclei from the female gametophyte join to form 3n endosperm which often serves as food for the embryo.

**The embryo sporophyte consists of:**

One or two nutrient-storage areas called cotyledons which are in contact with (and absorb nutrients from) the 3n endosperm. Seeds of some species store their nutrients primarily in the endosperm, having very small cotyledon(s), while others have most of their nutrients stored in their cotyledons and the endosperm is very small.

1. The epicotyl (epi = upon, over), which is the region *above* the cotyledon(s), and which will become the stem and leaves,
2. The hypocotyl (hypo = under, beneath), which is the region *under* the cotyledon(s). The lower end of the hypocotyl, which becomes the root system, is called the radicle (radix = root) and will become the roots.
3. In general, monocots tend to store food in their endosperms, and nutrients are transferred to the cotyledon only as needed. In contrast, many (not all) dicots tend to store food in their cotyledons with the endosperm being reduced to a papery coating around the embryo.

## Practical No. 05

# Study of megasporogenesis and microsporogenesis

In the sexually reproducing crop plant definite male and female sexual organs namely androecium and gynoecium produce male and female gametes respectively. The male gametes are formed from a haploid cell called microspore and the female gametes are formed from a haploid cell called megaspore.

Production of microspores and megaspores is known as sporogenesis. In anthers, microspores are formed through microsporogenesis and in ovules, the megaspore are formed through megasporogenesis.

**Microsporogenesis :**

The sporophytic cells in the pollen sac of anthers which undergo meiotic division to form haploid *i.e.*, microspores are called microspore or pollen mother cell (PMCs) and the process is called microsporogenesis. Each pollen mother cell produces four microspores and each microspore after thickening of the wall developed into pollen grains.

**Megasporogenesis :**

A single sporophytic cell inside the ovule, which undergoes meiotic division to form haploid megaspore, is called megaspore mother cell and the process is called megasporogenesis. Each megaspore mother cell produces four megaspores out of which three degenerate resulting in a single functional megaspore.

Megaspore mother cell is a diploid cell in which meiosis will occur, resulting in the production of four megaspores. This megasporcyte is formed from two distinct processes – megasporogenesis and megagametogenesis.

**Microgametogenesis :**

Microgametogenesis is the process that is a microgametophyte developing in a pollen grain to the three-celled stage of its development. In flowering plants it occurs with a microspore mother cell inside the anther of the plant.

This is nothing but the production of male gametes or sperm. On maturation of the pollen, the microspore nucleus divides mitotically to produce a generative and a vegetative or tube nucleus. The pollen is generally released in this binucleate stage. The reach of pollen over the stigma is called pollination. After the pollination, the pollen germinates. The pollen tube enters the stigma and travels down the style. The generative nucleus at this phase undergoes another mitotic division to produce two male gametes or sperm nuclei. The pollen along with the pollen tube possessing a pair of sperm nuclei is called microgametophyte. The pollen tube enters in the embryo sac through micropyle and discharges the two sperm nuclei.

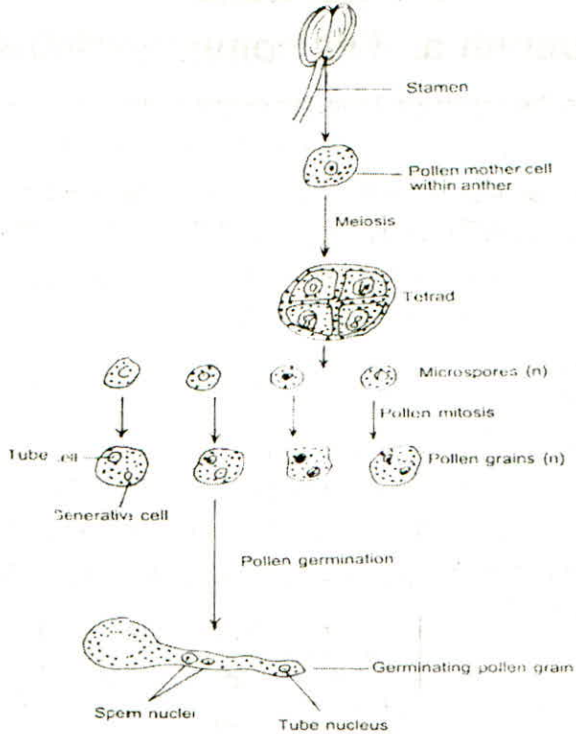



**Fig.11. Steps of Male gametogenesis**

### Megagametogenesis

The nucleus of the functional megaspore undergoes three mitotic divisions to produce eight or more nuclei. The exact number of nuclei and their arrangement varies from one species to another. The megaspore nucleus divides thrice to produce eight nuclei.

Three of these nuclei move to one pole and produce a central egg cell and two synergid cells on either side. Another three nuclei migrate to the opposite pole to develop into three antipodal cells.

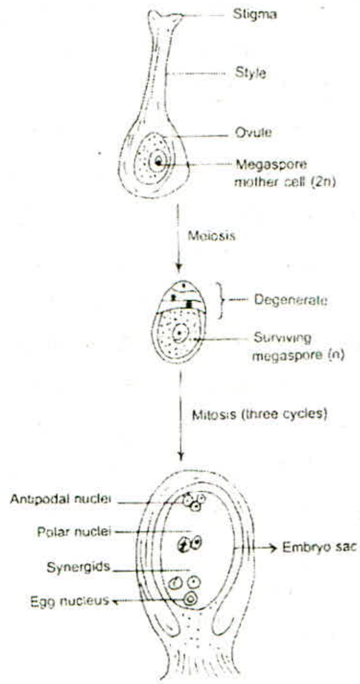



**Fig.12. Steps of female gametogenesis**

**Practical No. 06**

# Breeder kit and its components-uses

A Breeder requires the following tools for controlled selfing, artificial pollination and for field observation.

| S. No. | Magnifying lens | Purpose |
|---|---|---|
| 1. | Magnifying lens | To observe small flowers, stigmatic surface, dehiscence of anthers etc. |
| 2. | Forceps | Fine forceps are required for emasculation |
| 3. | Scissors | Required to remove unwanted buds, awns etc., |
| 4. | Needles | Required to open small buds and separating the floral parts. |
| 5. | Brushes | Camel hair brushes of size 3 or 4 for collection of pollen and transfer to stigma. |
| 6. | Bags | Parchment paper bag, khaki cloth bags, muslin cloth bag, and paper bags of different size for different crops. |
| 7. | Alcohol or Methylated spirit | A small vial of alcohol or methylated spirit is required to sterilize forceps, scissors, needles, brushes *etc.* |
| 8. | Tags | Paper, cardboard or aluminum tags are required for labeling the units in the field. In the case of paper or cardboard tags, they have to be dipped in wax after labeling and tags are tied in bamboo stakes. |
| 9. | Meter scale | Required for plant measurement in the field. |
| 10. | Field note books | Field note books are required to note down daily observation in the field, regarding germination, flowering, morphological description, initial and final stand, wet weight of grains, haulms etc. |

## Practical No. -07

# Selfing and crossing techniques in different crops

Selfing and crossing are essential procedures in crop improvement process. The exact procedures used to ensure self or cross-pollination of specific plants will depend on the floral structure and normal manner of pollination. Generally effecting cross-pollination in a strictly self-pollination species is more difficult than vice-versa because for instance preventing self-pollination occurring inside the unopened flowers is cumbersome.

**Selfing :** In the Selfing of cross-pollinated species, it is essential that the flower are bagged or otherwise protected to prevent natural cross-pollination. Selfing and crossing are essential in crop breeding. It is important that the breeder, master these techniques in order to manipulate the pollination according to his needs. The exact procedure that he may use to ensure self or cross pollination of specific plants will depend on the particular species with which he is working. The structure of the flowers in the species determine manner of pollination. For these reasons, the breeder should acquaint himself with the flowering habit of the crop.

In the case wheat, rice barely, groundnut etc, the plant is permitted to have self pollination and the seeds are harvested. It is necessary to know the mode of pollination. If the extent of natural cross pollination is more, then the flowers should be protected by bagging. This will prevent the foreign pollen to reach the stigma. Seed set is frequently reduced in ear heads enclosed in bags because of excessive temperature and humidity inside the bags. In crops like cotton which have larger flowers the petals may fold down the sexual organs and fasten, there by pollen carving insects may be excluded.

In certain legumes which are almost insect pollinated, the plants may be caged to prevent the insect pollination. In maize, a paper bag is placed over the tassel to collect pollen and the cob is bagged to protect from foreign pollen. The pollen collected from the tassel is transferred to the cob.

**Emasculation :** Removal of stamens or anthers or killing the pollen of a flower without the female reproductive organ is known as emasculation. In bisexual flowers, emasculation is essential to prevent of self-pollination. In monoecious plant, male flowers are removed. (castor, coconut) or male inflorescence is removed (maize). In species with large flowers e.g. (cotton, pulses) hand emasculation is accurate and it is adequate.

**1. Hand Emasculation :** In species with large flowers, removal of anthers is possible with the help of forceps; it is done before anther dehiscence. It is generally done between 4 and 6 pm one day before anthers dehisce. It is always desirable to remove other young flowers located close to the emasculated flower to avoid confusion. The corolla of the selected flower is opened with the help of forceps and the anthers are carefully removed with the help of forceps. Sometimes corolla may be totally removed along with epipetalous stamens *e.g.* singelly.

In cereals, one third of the empty glumes will be clipped off with scissors to expose anthers. In wheat and oats, the florets are after removing the anthers without damaging the spike lets. In all cases, gynoecium should not be injured. An all efficient emasculation technique should prevent self pollination and produce high percentage of seed set on cross pollination.

**2. Suction Method :** It is useful in species with small flowers. Emasculation is done in the morning immediately after the flowers open. A thin rubber or a glass tube attached to a suction hose is used to suck the anthers from the flowers. The amount of suction used is very important which should be sufficient to suck pollen and anthers but not gynoecium. In this method considerable self-pollination upto 10% is like to occur. Washing the stigma with a jet of water may help in reducing self- pollination; however self pollination can not be eliminated in this method.

**3. Hot Water Treatment :** Pollen grains are more sensitive than female reproductive organs to both genetic and environmental factors. In case of hot water emasculation, the temperature of water and duration of treatment vary crop to crop. It is determined for every species. For sorghum-42-48 C for 10 minutes is found to be suitable. In the case of rice, 10 minutes treatments with 40-44 C adequate. Treatment is give before the anthers dehiscence and prior to the opening of flower. Hot water is generally carried in thermos flask and whole inflorescence is immersed in hot water.

**4. Alcohol Treatment :** It is not commonly used. The method consists of immersing the inflorescence in alcohol of suitable concentration for a brief period by rinsing with water. In Lucerne the inflorescence immersed in 75% alcohol for 10 second was highly effective. It is better method of emasculation than suction method.

**5. Cold Treatment :** Cold treatment like hot water treatment kills the pollen grains without damaging gynoecium. In the case of rice, treatment with cold water 0.6 C kills the pollen grains without affecting the gynoecium. This is less effective than hot water treatment.

**6. Genetic Emasculation :** Genetic/ cytoplasmic male sterility may be used to eliminate the process of emasculation. This is useful in the commercial production of hybrids in maize, sorghum pearl millet, onion, cotton, and rice etc.

In many species of self-incompatible cases, also emasculation is not necessary, because self-fertilization will not take place. Protogyny will also facilitate crossing without emasculation (e.g.) Cumbu.

**7. Use of Gametocide :** Gametocide is also known as chemical hybridizing agents (CHA). The chemicals which selectively kills the male gametes without affecting the female gametes. *eg.* Sodium methyl arsenate, Zinc methyl arsenate in rice, Maleic hydrazide for cotton and wheat.

**Bagging :** Immediately after emasculation the flower or inflorescence enclosed with suitable bags of appropriate size to prevent random cross-pollination.

**Crossing :** The pollen grains collected from a desired male parent should be transferred to the emasculated flower. This is normally done in the morning hours during a thesis. The flowers are bagged immediately after artificial crossing.

**Tagging :** The flowers are tagged just after bagging. They are attached to the inflorescence or to the flower with the help of a thread. The following may be recorded on the tag with pencil.

| | | |
|---|---|---|
| 1. | Date of emasculation: | DOE: |
| 2. | Date of pollination | DOP: |
| 3. | Parentage: | Parents: |
| 4. | No. of flowers emasculation | No. of flower Emas: Signature: |

## Practical No. 08

# Lay out of different yield trials

**Lay out of different yield trials**

The basic objective of plant breeding is the ultimate crop improvement. It results in development of high yielding varieties hybrids etc. over the existing cultivars and so on. The performance of the new varieties is confirmed from the results obtained from the field experiments. To be explained scientifically the field experiments are laid out following certain rules and data thus collected are analyzed statistically. The steps involved in this process are explained here under.

**Any designing of experiments involves tree major steps.**

1. Selection of experimental units

   The object on which the treatments are applied is known as experimental units. *eg.* Plots in the plant etc.

2. Fixing of treatments

   The objects of comparison are known as treatments *eg.* varieties, spacing etc.,

3. Arrangement of treatments in the experimental unit.

   It comprises of three basic principles of design:

**1. Replication** : repetition of treatments

**2. Randomization:** unbiased allocation of treatments to the experimental unit.

**3. Local control:** minimizing the effect of heterogeneity of the experimental units.

The objective of replication, randomization and local control is to minimize the Experimental Error (EE). Experimental error is nothing but differences in the responses from the experimental unit to experimental unit under similar environments. Apart from these, experimental error can be reduced further by proper selection of the experimental unit and choosing of most appropriate experimental design for a given number of treatments.

**Types of basic experimental designs**

1. Completely Randomized Design (CRD)
2. Randomized Block Design (RBD)
3. Latin Square Design (LSD)
4. Split Plot Design (SPD)
5. Augmented design etc

Among all these, RBD is the widely used design.

**Laying out of RBD.**

**A. The experimental material (field)** is divided first into blocks consisting of homogenous (uniform) experimental units. Each block is divided into number of treatments equal to the total number of treatments.

**B. Randomization** should be taken within each block and the treatments are applied following the random number table.

**C. Collection and analysis of data:** After the collection of data from the individual experimental unit (treatments) ANOVA (Analysis of variance) table is formed.

The signification of the ANOVA table is that it indicates the sources of variation exhibited by the treatments, the magnitude of variation derived from different sources and their worthiness (significant/non significant)

**D. Computation of Critical Difference (CD)**

Critical Difference is the difference between the treatment means, which places the treatments statistically as well as signification apart. Otherwise if the difference of two treatments mean is less than CD it can conclude both the treatments are on at par.

**RT: Row Trial**

Row trial is generally conducted in $F_3$ and $F_4$ when the seeds are not sufficient for replication with individual plant progeny rows. Each row consists of about 20 or more plants. Individual plants with desirable characteristic are selected from superior progeny rows. Pest, Disease and lodging susceptible progenies with undesirable characteristics are eliminated.

**RRT-Replicated Row Trial**

It is generally conducted from $F_3$ generation onwards. Depending on availability of seeds, 3-4 more rows are grown for each progeny to facilitate comparison among progenies adopting suitable replications. Families, with have become reasonably homozygous may be harvested in bulk. From those families showing segregation, single plants are selected for characters under study. The breeder has to visually assess the yielding potential of progenies and reject the inferior ones in the field and the yield potential has to be assessed in the laboratory for confirmation.

**PYT-Preliminary Yield Trial or (IYET) Initial Yield Evaluation Trial**

It is conducted from $F_5$ generation onwards. Preliminary yield trials with three or more replications are conduct to evaluate the comparative performance of the culture and to identity the superior cultures among them. The cultures are evaluated for plant height, lodging, pest and disease resistance, flowering time, duration and yield, etc., Quality tests may also be carried out. Standard commercial varieties must be included as checks for comparison. Ten to fifteen outstanding cultures, if superior to checks, would be advanced to the Advanced Yield Trails.

**AYT-Advanced Yield Trial**

Advanced yield trial is conducted from $F_8$ generation onwards. The superior cultures identified from preliminary yield trial are tested in Replicated Yield Trial. In this trial, the cultures are evaluated for yield, pest, disease and lodging resistance, duration, quality etc.

**ART-Adaptive Research Trial**

It is conducted after Multi-Location Trials for 3 years by the Department of Agriculture. Nearly 3-4 cultures are tested and based on the performance of 3 years in the farmers field, the best culture over the check may be proposed to SVRC (State Variety Release Committee) for releasing.

If the SVRC finds that the cultivar is suitable any particular area or through out the state, then the variety is released and is notified by the State Departments of Agriculture.

## Practical No. 09

# Estimation of heterosis and inbreeding depression

Heterosis refers to the superiority of $F_1$ hybrid in one or more characters over its parents. In other words, heterosis refers to increase of $F_1$ in fitness and vigour over the parental values. Heterosis is estimated in three different ways, *viz.*, Relative heterosis or mid parent heterosis, heterobeltiosis and Economic heterosis / useful heterosis. Thus on the basis of estimation, heterosis are of three types as given below.

**1. Relative heterosis:** When the heterosis is estimated over the mid parent *i.e.*, mean value or average value of two parent, it is known as mid parent heterosis, which is estimated as follows.

$$\text{Relative heterosis (RH)} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

Where, $\overline{F_1}$ is the mean value of $\overline{F_1}$ and MP is the mean value of two parent involved in cross. MP= $[(P_1+P_2)/2]$

**2. Heterobeltiosis:** When the heterosis is estimated over the superior or better parent *i.e.*, it is referred to as heterobeltiosis, it is worked out as follows.

$$\text{Heterobeltiosis (H)} = \frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$$

Where, BP is the mean value of the better parent of the particular cross.

**3. Useful heterosis:** It refers to the superiority of $F_1$ over the Standard commercial/ local check variety. It is also called as economic heterosis,. This type of heterosis is of direct practical value in plant breeding. It is estimated as follows.

$$\text{Economic heterosis (EH)} = \frac{\overline{F_1} - \overline{CV}}{\overline{CV}} \times 100$$

Where, $\overline{CV}$ is the mean value over replications of the commercial variety of the particular cross.

**1. Standard heterosis:** sometimes, heterosis worked out over the standard commercial hybrid. It is estimated in those crops where hybrids are already available for comparison. It is called as standard heterosis. This type of heterosis is also of direct practical value in plant breeding. It is estimated as follows

$$\text{Standard heterosis (SH)} = \frac{\overline{F_1} - \overline{SH}}{\overline{SH}} \times 100$$

Where, SH is the mean value over replications of the commercial local hybrids.

**Inbreeding depression:** Inbreeding depression refers to decrease in fitness and vigour due to inbreeding. The degree of inbreeding is measured by the inbreeding coefficient.

Inbreeding depression is estimated when both $F_1$ and $F_2$ populations of the same cross are available. It is measured as follows.

$$\text{Inbreeding depression (ID)} = \frac{\overline{F_1} - \overline{F_2}}{\overline{F_1}} \times 100$$

Where, $\overline{F_1}$ and $\overline{F_2}$ are the mean value over $\overline{F_1}$ and $\overline{F_2}$ progeny respectively of the same cross for a given characters.

**Practical No.10**

# Study on different wild species in crop plant

Wild species are nothing but genetically related uncultivated species of cultivated ones. Wild species are believed to have evolved into the cultivated crops. They offer wide scope for studying the evolutionary process of creation of a cultivated species. Besides, the wild types usually abundant in nature for every crop promise to deliver to benefit the mankind through their genes transferred to the cultivated species by way of hybridization etc., make the letter to be more drought tolerant and pests and disease resistant. Here the important wild species of a few cultivated crops have been enlisted:

| **Crop** | **Cultivated species** | **Ploidy level** | **Wild species** |
|---|---|---|---|
| Rice | *Oryza sativa* | 2n =2x = 24 | *O. nivara* |
| | | | *O. rufipogan* |
| | | | *O. longistaminata* |
| | | | *O. officinalis* |
| | *Oryza glaberrima* | 2n = 4x = 48 | *O. minuta* |
| | | | *O. latifolia* |
| | | | *O. ridleyi* |
| | | | *O. longiglumis* |
| Wheat | *Triticum monococcum* | 2n = 2x = 14 | *T. dischasians* |
| | | | *T. tauschii* |
| | *Triticum turgidum or* | 2n = 4x = 28 | *T. timopheevi* |
| | *Triticum dicoccum* | | |
| | *Triticum aestivum* | 2n = 6x = 42 | |
| Maize | *Zea mays* | 2n = 2x = 20 | *Z. diplopernnis* |
| | | 4x | *Z. perennis,* |
| | | 2x , 4x | *Tripsacum, Z.maxicana* |
| Cotton | *Gossypium herbacium* | 2n = 2x = 26 | *G. anomalum* |
| | *G. arboreum* | | *G. stuntrianum* |
| | | | *G. stocksii* |
| | | | *G. longicalyx* |
| | | | *G. bickii* |
| | | | *G. thurberi* |
| | *G. hirsutum* | 2n =4x = 52 | *G. armorianum* |
| | *G. barbadense* | | *G. tomentosum* |
| | | | *G. caicoense* |

| | | | |
|---|---|---|---|
| Groundnut | *Arachis hypogea* | 2n = 4x = 40 | *A. syltvestris* |
| | | | *A. monticola* |
| | | | *A. villosulicarpa* |
| | | | *A. glaberata* |
| Sesamum | *Sesamum indicum* | 2n = 26 = 52 | *S. occidentale* |
| | | | *S. laciniatum* |
| | | | *S. prostratum* |
| Sunflower | *Helianthus annus* | 2n = 34 | *H. tuberosus* |
| | | | *H. petioloris* |
| | | | *H. gigantus* |
| Sugarcane | *Saccharum officinarum* | 2n =8x =80 | *S. robustum* |
| | | | *S. sinense* |
| | | | *S. spontaneum* |
| | | | *S. barberi* |
| Redgram | *Cajanus cajan* | 2n =2x = 22 | *Atylosia barbata* |
| Soybean | *Glycine max* | 2n = 2x =22 | *G. soja* |
| | | | *G. tomentella* |

**Practical No 11**

# Studies on segregating generations and maintenance of records

**Maintenance of Records**

1. Accession Register
2. Germplasm Bank
3. Descriptive blank register
4. Cropping programme
5. Single plant selection register

**Field Note Book**

6. Row test
7. Replicated row test
8. Preliminary/Initial evaluation trial
9. Comparative yield evaluation trial
10. Multilocation I, II trials.
11. Quality observation note book
12. Record of crosses
13. $F_1$ generation
14. $F_2$ segregation generation note book.

Accessing Register

This will contain the details of the seeds/planting material with regard to receipt date, source, their number, number assigned at the receiving unit, short description of the planting material to whom sent for evaluation, date feed back information about the genotype, now maintained etc. Accession number given by the serial number followed by year of entry *i.e.* serial 145 in 1991. Then accession number will be 145191 or 91145. It will be mentioned as EC= Exotic collection IC = Indigenous collection.

**Proforma for Accession Register**

| Accession No. 1 | Name of varietyx 2 | Date of Receipt 3 | Source of seed 4 | Source No. 5 | Pedigree record material 6 | Description of the 7 | How disposed to whom sent 8 | Feed back information 9 | Remarks 10 |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

**Standard form of a Field Note Book.**

Each field note should contain the following information.

**A. Yield trial**

**i) First Page**

a) Number and title of the project
b) Season of raising the crop
c) Unit under which the trial is being conducted

**ii) Second page**

a) Full plant of the field showing the location of the trial with the approach path.
b) North East directions should be specified.

**iii) Third page**

a) Plant of the experiment.
b) Experiment details.
c) Name of the experiment.
d) Season.
e) Number of variants.
f) Design of the experiment.
g) Replication.
h) Size of the plot (Block/Plot/Row., etc.).
i) Spacing (Between rows and within the row in cm).
j) Date of sowing/planting.
k) Date of harvest.
l) Name of the principal investigator.

**iv) Fourth Page**

Details of cultural practices following for the plot/field.

a. Date of ploughing.
b. Date of layout of the trial.
c. Manurial schedules adopted.
   Basal :
   Topdressing :
d. Irrigation schedules with date from life irrigation onwards.
e. Plant protection schedules following.
f. Details of intercultural operations (hoeing, weeding and earthing up etc.)
g. Date of harvest.
h. Date of harvest Duration of processing till storage.
i. Rainfall received during the crop growth.
j. General remarks on the seasonal condition prevailed and its effects on crop growth including the occurrence pest and disease.

**v) Fifth Page**

One page for each variant per replication allotted.

The following information has to be recorded in each page.

1. Date of germination.
2. Date of gap filling.
3. Initial stand.

4. Date of first flowering.
5. Date of general flowering.
6. Date of harvest.
7. Final stand.
8. Wet weight of grain.
9. Wet weight of haulms/straw etc.
10. Dry weight of production after cleaning.
11. Yield per ha in kg.

The page will have additional information on observations about the variant, recorded by the breeder in relation to the object the project.

The fifth page will also contain the following information and their modification depending upon the crop.

*e.g.* Rice : Date of earhead emergence in the main shoot number of tillers.
: Date of earhead emergence in tillers and
: Number of tillers.

Cotton : Number of sympodial branches.
: Number of monopodial branches.

Maize : Date of emergence of female flowers.
: Date of emergence of male flowers.

Sunflower : Duration of flowers opening etc.

**Generation study**

This filed note book will contain the following information.

a. Plant for the segregation generation
b. Details of the generation

1. Name of the generation study
2. Number of crosses
3. Details of cross

Cross No. Female parent, Male parent, Number of families, number of seed sown.

4. Length of row
5. Spacing (cm)
6. Date of sowing
7. Dates of harvest.
8. Name of the principal investigator

## Practical No. 12

# Hybrid seed production techniques of Rice

**Hybrid Seed Production :** Hybrid vigour in rice has first reported by Jones (1926). This has led to speculation regarding the production of hybrid rice utilizing cytoplasmic male sterility. Most *japonica* rice normal cytoplasm, but *indica* varieties with sterile cytoplasm and fertility restoring system have been identified. But difficulties have been encountered in obtaining sufficient seed set by cross pollination to make hybrid rice seed production economically feasible. After the implementation of UNDP/FAO project entitled "Development and use of hybrid rice technology in India" – the hybrid rice production in India has become a success story.

Hybrid rice seeds were produced using (Cytoplasmic Genic Male Sterility) three line system. The two genes $Rf_1$ and $Rf_2$ are the genes for fertility restoration.

The process of hybrid rice production involves continuous supply of agronomically improved cytoplasmic male sterile line (A), Maintainer line (B) and fertility restorer (R) line in system. Maintainer and restorer lines are maintained by selfing. While, CMS line and $F_1$ seed are produced with efforts to enhance the cross pollination in field. F and S refer to fertile and sterile cytoplasm. *Rf* and *rf* are fertility restoring and non restoring gene respectively.

*Row ratio and spacing of A and R lines in the main field*

| R | R | A | A | A | A | A | A | A | A | R | R |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | * | * | * | * | * | * | * | * | 0 | 0 |
| 0 | 0 | * | * | * | * | * | * | * | * | 0 | 0 |
| 0 | 0 | * | * | * | * | * | * | * | * | 0 | 0 |
| ↕15cm | | | | | | | | | | | |
| 0 ↔ | 0 ↔ | * ↔ | * | * | * | * | * | * | * | 0 | 0 |
| 30cm | 20cm | 15 cm | | | | (Male: female ratio = 2:8) | | | | | |

**Technique of hybrid rice seed production**

The following points are to be taken in to account for a successful hybrid rice production.

**1) Choice of field:** Fertile soil, protected irrigation and drainage system, sufficient sunshine. No serious diseases and insect problems.

**2) Isolation:** To ensure purity of hybrid seed and avoid pollination by unwanted pollen isolation is a must.

**a. Space isolation:** No other rice varieties should be grown except pollen parent with a range of 50 to 100m distance.

**b. Time isolation:** A time of over 20 days is practiced (The heading stage of other variety over a 100m range should be 20 days earlier or later over the MS line)

**c. Barrier isolators:** Topographic features like wood lot, tall crops to a distance of 30m/artificial obstacles of (Plastic sheet) above 2m height.

**3) Optimum time for heading and flowering**

Favourable climatic conditions for normal flowering are

(i) Mean temperature – (24-28°C).
(ii) Relative humidity- (70-80%).
(iii) Day and night temperature difference – (8-10°C).
(iv) Sufficient sunshine
(v) Sufficient breeze.

**4) Synchronization of flowering**

As the seed set on MS line depends on cross pollination it is most important to synchronize the heading date of the male and female parents, in order to extend the pollen supply time, the male parent is usually seeded twice or thrice at an interval of 5-7 days.

**5) Row ratio, row direction and planting pattern**

**What is a row ratio.**

- ☆ Row proportion or row ratio refers to the number of rows of the male parent (B or R line) to that of the female parent (A line) in a seed production plot.

  For example, if we plant 2 row the B or R line for every 8 rows of A line, we say we have a row ratio of 2:8

- ☆ The row ratio of the pollen parent to seed parent will vary from region to region, depending on weather, management, and parental lines. R and A lines can be planted in several row ratios 2:8, 2:12, 3:10, etc.

- ☆ In this manual, we take an R: A line ratio of 2:8 as normal and use it in most examples.

The layout of row ratio depends on
(i) The growth duration of the R line
(ii) Growth vigor of the R line
(iii) Amount of pollen shed and
(iv) Plant height of the R line.

**The principles include**

* R line should have enough pollen to provide

* The row direction should be nearly perpendicular to the direction of winds prevailing at heading stage to facilitate cross pollination.

Practically, a row ratio of 2:8 is currently widely used in indica hybrid seed production.

Generally, the R line is transplanted with two to three seedlings per hill and separated by a spacing of 12cm from plant to plant. 30cm from one row of restorer to another and 20cm from CMS line. The MS line is transplanted with one to two seedlings per hill with a spacing of 12x12cm.

A good population structure to get more seed yield is given below:

| | | |
|---|---|---|
| A line = 1-2 | A line = 30 | A line = 300 |
| R line = 2-3 | R line = 5 | R line = 120 |

**6) Prediction and adjustment of heading date**

Even if the seeding interval between both parents is accurately determined, the synchronization of their flowering might not still be attained because of variation in temperature and difference in field management. Hence it is necessary to predict their heading date in order to take measures as early as possible to make necessary adjustments by examining the primordial initiation of panicle.

Adjustment of flowing sate can be made by applying quick releasing nitrogen fertilizer on the earlier developing parent and the developing parent should be sprayed with 2% solution DAP. By this measure a difference of 4 to 5 days may be adjusted.

**7) Leaf clipping, gibberellin application and supplementary pollination**

These techniques are very effective for increasing the out crossing rate.

**Leaf clipping:** The leaves taller than the panicles are the main obstacles to cross pollination and, therefore, should be cut back. Generally leaf clipping is undertaken 1-2 days before the initial heading stage. And more than 2/3 rd of the blades of flag leaves are cut back from the top.

**Application of gibberellin ($GA_3$):** $GA_3$ can adjust physiological and biochemical metabolism of rice plant and helps in hybrid seed production by stimulation the elongation of young cells. In most of the CMS lines, about 20-30% of spikelets of a panicle are inside the flag leaf sheath (exertion is only 70%) $GA_3$ affects exertion of panicle completely out of flag leaf sheath. In India recommended dose of $GA_3$ is 50g/ha using knapsack sprayer and 25 g/ha with ultra low volume sprayer.

* Enhances panicle and stigma exertion
* Speed up growth of late tillers and increase effective tillers
* Flag up growth is increased
* Reduces unfilled grains
* Enhances seed setting and seed yield

**Spraying stage** : 5% of panicle emergence.

**Spraying time** : 8-10 am is the best time.

**Supplementary pollination:** Shaking the R lines panicles by rope- pulling or rod driving during anthesis can enhance the crossing rate. This is carries out during peak anthesis (10-12 AM).

**8) Roguing and why is it necessary**

- Roguing is the removal of undesirable rice plants from hybrid seed production plots.
- Undesirable rice plants are plants in either the A line or R line rows that differ from plants that are true to type. They may be volunteer plants from an earlier crop or off-types.
- Roguing prevents off-types from cross pollinating with true-to-type A-line plants and lowering the purity of the hybrid seed.
- Roguing ensures that the hybrid seed produced will be a cross between only the A- line and R line parents. That in turn ensures that the commercial plantings of the hybrid seed produced will give high yields.
- High purity hybrid seed will increase your reputation as a seed grower.

**9) Harvesting and processing**

- The male parent harvested first
- Care should be taken to avoid admixture male and female line.
- Female line should be threshed separately in a well cleaned threshing floor
- Seed field dried shade to 12% moisture content
- Packed in suitable, cleaned gunny bags after grading

## Practical No. 13

# Assessment of variability parameters

The phenotype may be described according to a mathematical model to facilitate statistical analysis and interpretation. The phenotypic mean *i.e.*, x of a given genotype from the trial may be expressed as m,

$\overline{x} = \mu + g + e + ge$

where,

$\overline{x}$ = Phenotypic mean

$\mu$ = General population mean

g = Effect of genotype

e = Effect of environment

ge = Interaction between genotype and environment

**Analysis of variance for genotypes grown in a replicated trial according to RBD**

| Source of variation | d.f. | Expectation of MS |
|---|---|---|
| Replications | r-1 | $\sigma_e^2 + g\sigma_r^2$ |
| Genotypes | g-1 | $\sigma_e^2 + r\sigma_g^2$ |
| Error | (r-1) (g-1) | $\sigma_e^2$ |
| Total | (rg)-1 | |

Where, g and r are the number of genotypes and replications respectively and $\sigma_e^2$ ,$\sigma_r^2$, $\sigma_g^2$ denote the variances due to error, replication and genotypes respectively.

Genotypic variance ($\sigma_g^2$) = (MS due to genotypes – MS due to error)/R

Phenotypic variance ($\sigma_p^2$) = $\sigma_g^2 + \sigma_e^2$

*Genotypic Co-efficient of variation*

$$GCV = \frac{\sigma^2 g}{\mu} \times 100$$

*Genotypic Co-efficient of variation*

$$PCV = \frac{\sigma^2 p}{\mu} \times 100$$

Heritability:

$$h^2 = \frac{\sigma^2 g}{\sigma^2 p} \times 100$$

Genetic advance

$$GA = \frac{\sigma^2 g}{\sqrt{\sigma^2}\, p} \times K$$

K= selection differential which is constant for the known selection intensity (k at 5% selection intensity = 2.06).

**Practical No. 14**

# Parentages of some important varieties released at IGKV, Raipur

Various varieties have been released from Indira Gandhi Krishi Vishwa Vidyalaya, Raipur (C.G.) of different crops. Out of these released varieties, some varieties are depicted as crops, varieties, their parentage and important feafures.

| Crop | Varieties | Parentage | Important features |
|---|---|---|---|
| Rice | Poornima | Poorva x IR 8608-298 | It escapes most of the diseases and pests under field condition |
| | Mahamaya | Asha x Kranti | It also escapes most of the diseases and pests under field condition |
| | Shyamla | R 60-2713x R238-6 | This variety showed much better than higher reaction to other purple leaf varieties for major pest and diseases. |
| | Danteshwari | Samridhi x IR 8608-298 | Resistance to gall midge and tolerant to Brown spot.It escapes most of the diseases and pests in *Kharif* season as being early. |
| | Indira Sughandhit Dhan-1 | Madhuri x Sulekha | Resistance to gall midge and tolerant to Brown spot and field tolerant to Blast & stem borer. |
| | Bamleshwari | RP 2154-40 x IR 9828-23 | Resistance to BLB and tolerant Sheath blight and Brown spot. Its also tolerant to gall midge & WBPH. |
| | Samleshwari | R 310-37 x R 308-6 | Resistance to GM 1 & 4, moderately resistance to Blast and tolerant to Brown spot and Neck blast. |
| | Jaldubi | A selection of local germplasm (AR 1023) from Surguja district of C. G. | Resistance to Blast and gall midge biotype-1. |
| | Chandrahasini | Abhaya x Phalguna | Resistance to GM-1, moderately resistance to BPH, leaf folder, WBPH and Neck blast and tolerant to Leaf Blast, Brown spot & Sheath rot. |
| | Indira Sona (Hybrid) | IR 58025 x R 710 | Resistance to gall midge and moderately resistance to Blast. |
| | Karma Mahsuri | Mahsuri x R-296-260 | Resistance to gall midge biotype-1,4 & 5 and moderately resistance to Leaf Blast |

| | | | |
|---|---|---|---|
| Pea | Paras | DDR 12 x Rachna | Resistance to powdery mildew, tolerant to *H. armigera* and *M. testulalis* pod borers. |
| | Ambika | DMR-22 x HUP-7 | Resistance to powdery mildew, tolerant to *H. armigera* and *M. testulalis* pod borers |
| | Shubhra | Rachna x JP-885 | Resistance to powdery mildew, tolerant to *H. armigera* and *M. testulalis* pod borers |
| Lathyrus | Mahateora | Ratan x JRL-2 | ODAP content (0.074 %), |
| | Ratan | Selection from Pusa-24 | ODAP content (0.085 %), |
| | Pratik | LS 8246 X a-60. | (ODAP 0.076%), moderately resistance to powdery and downy mildew diseases. |
| Wheat | Arpa | HD 2234 x HUW 309 | Resistance to brown and black rusts under field conditions. |
| | Ratan | HUW 325 x DL 2307 | Resistance to brown and black rusts under rainfed conditions. |
| Pigeon pea | Rajiv Lochan | Selection from ICPL-92060 | Resistance to *Fussarium* wilt, sterility mosaic, moderately resistance to *H. armigera* and *M. testulalis* pod borers |
| Cowpea | Khalleshwari | Gamma (Gy-200) radiation mutant of cultivar of (V 130) | It has large seeds (9.4 q/100 seeds) and suitable for rice based cropping system of Chhattisgarh. |
| Mung | Pairy mung | TARM-1 x J-781 | Resistant for two genes of powdery mildew upto pod filling stage. Its plants are determinate with synchronous podding. |
| | Pragya | Selection from local germplasm from Durg District. | This variety is photo and thermo sensitive hence, it is recommended for cultivation in winter season only. It has high level of resistance to powdery mildew disease |
| Musturd | Chhattisgarh Sarson | PCR 20 x RH 819 | It has tolerance to major diseases like white rust, powdery mildew and Alternaria blight. |
| Soybean | Indira Soya-9 | Selection of JS 80-21 | It is resistant to rust & bacterial pustules. It contains about 40% protein and 20% oil. |
| Linseed | Deepika | Kiran x Ayogi | It is moderately resistant to rust, wilt, Alternaria blight and budfly. |
| | Kiran: | (R-1 x Afg.8) x R-1 | It has resistance to rust, wilt and powdery mildew |
| | Indira Alsi-32 | Kiran x RLC 29 | This variety is moderately resistant to powdery mildew and moderately susceptible to Alternaria blight and wilt |

| | | | |
|---|---|---|---|
| | Kartica | Kiran x LCK 88062 | Moderately resistant to rust, wilt and Alternaria blight. It is also resistant to powdery mildew and moderately resistant to budfly |
| | RLC 92 | Jeevan X LCK 9209 | It is tolerant to bud fly, resistant to wilt, powdery mildew, tolerant to A. blight. |
| Spine Gourd | Indira Kankoda-1 | Selection from local material of Surguja district. | It is resistant to drought and major diseases and pests. |
| Sweet Potato | Indira Madhur | Clonal selection from CIP | It is soft & easy to cook having excellent test. |
| | Indira Navin | Clonal selection from Shreevardhini. | It is soft & has good cooking quality. It has semi spreading growth habit. |
| | Indira Nandini | Clonal selection of a poly cross between Sree Nandini x open pollinated varieties. | Belongs to medium maturity group. |
| Ivy Gourd | Indira Kundru-35 | Selection of local material collected from Orchha, Abujhmarh Bastar. | Plants having field tolerant to stem borer and powdery mildew. |
| | Indira Kundru-5 | Selection from local material of Chittaud, Durg. | It tolerant to stem borer and powdery mildew and also tolerant to frost and drought |
| Colo-casia | Indira Arvi-1 | Selection from local material of Mahkapal, Bastar. | This variety has field tolerant to major pests and leaf blight disease. |

## Practical No. 15

# Study of quality characters

**Quality Breeding:** Genetic improvement of crop plant in relation to various quality attributes.

Quality refers to the suitability or fitness of an economic plant product to its end use. Quality includes several feature of a product.

**Quality traits:** Quality traits differ from species to species depending upon the plant part used an economic product. The important quality traits of different crop plants are briefly presented below:

**Wheat:** In wheat, white or amber grain colour, medium to bold size, hard vitreous texture, lustrous appearance are important feature for good market quality. High lysine content and good baking quality are essential for use in biscuit and bread manufacturing.

**Rice:** White coloured long slender grains, taste and fragrance, less breakage in milling, more hulling recovery, better cooking quality, high protein and lysine content are important quality character.

**Maize:** Bold flint grains with attractive colour, high lysine, oil and sugar contents are main quality traits. The seed colour should be yellow or white.

**Sorghum:** White grains of attractive shape and size, high protein and lysine contents are preferred.

**Pearl millet:** Pearl millet has bold lustrous and pearly amber colour grains with high iron contents are desirable characters.

**Barley:** In malting barley, low protein content and high extract of soluble oligosaccharides after malting are desirable characters. Low protein produces haze in beer and high oligosaccharides are suitable for fermentation.

**Pulses:** In pulse crops, attractive shape, size and color of grains, high protein contents; high methionine and more proportion of unsaturated fatty acids are desirable characters.

**Oil seeds:** In oil seed crops, attractive shape, size and colour of seeds, high oil content free from antinutritional and more proportion of unsaturated fatty acids are desirable characters.

**Sugarcane :** In sugarcane, moderate harness, long internode, optimum (low) fibre for milling, sucrose ratio, high sucrose content and good quality of juice are desirable traits.

**Cotton:** In cotton, fiber length, strength, fineness, maturity, uniformity and colour are desirable characters.

**Jute, kenaf and Sunhemp: -** In jute, kenaf and Sunhemp, length, strength, colour, luster and freedom from knots and specks are desirable characters.

**Tobacco: -** In tobacco, short and thin leaves with branched veins are preferred for cigar. Thin leaves are also preferred for pipe smoking. Thick leaves are suitable for cigarettes. High nicotine content for bidi, hookah and chewing and low for cigarettes are preferred. High sugar content is also preferred.

**Potato:** In potato, attractive shape, size and colour of tuber, taste, cooking quality, thin skin, keeping quality and high starch content are desirable characters.

**Vegetables:** In vegetable crops, high vitamin and mineral contents, good taste, keeping quality and cooking quality are important desirable traits.

**Forage crops:** In forage crops, greater nutritive value, more palatability and freedom from toxic substances are the desirable characters.

**Medicinal plants:** In medicinal crop plants, high content of active is the desirable quality trait. Thus, quality differs according to economic use of the product. There are four major goals of breeding for improved nutritional quality. These are breeding for (1) high content and quality of protein, (2) high content and quality of oil, (3) high vitamin contents, and (4) low toxic substances which are harmful for human health.

**Table.01. Limiting amino acids in some vegetarian protein foods**

| SNo. | Food items | Limiting amino acids |
|---|---|---|
| 1. | Cereals | Lysine, threonine, sometime tryptophan |
| 2. | Pulses | Methionine, tryptophan |
| 3. | Nuts and oilseeds | Lysine |
| 4. | Green leafy vegetable | Methionine |
| 5. | Leaves and grasses | Methionine |

**Table.02: Genetics of nutritional quality characters in some crop plants**

| Crops species | Quality character | Inheritance controlled by |
|---|---|---|
| Sorghum | High lysine | Single partially dominant gene |
| Barley | High lysine | One major gene and several minor gene |
| Oats | Protein content | Complex, low content is dominant over high |
| Maize, Sunflower, Safflower | Seed oil content | Additive genes |
| Sesame | Seed oil content | Additive genes with partial dominant for low oil content |
| Rape seed | Erucic acid and eicosenoic acid | Two genes with multiple allele |
| Turnip rape | Erucic acid and eicosenoic acid | One gene with multiple allele |
| Safflower | Fatty acid composition | Three major alleles at one locus |
| Tomato | High beta carotene content | Two major genes plus modifiers |
| Carrot | Carotenoid content | The inheritance is complex |

## Practical No. 16

# The Hardy-Weinberg Principle

The mathematical concept, called the Hardy-Weinberg principle, is a crucial concept in population genetics. It predicts how gene frequencies will be inherited from generation to generation given a specific set of assumptions. The Hardy-Weinberg principle states that in a large randomly breeding population, allelic frequencies will remain the same from generation to generation assuming that there is no mutation, gene migration, selection or genetic drift. This principle is important because it gives biologists a standard from which to measure changes in allele frequency in a population.

The Hardy-Weinberg principle can be illustrated mathematically with the two equations that must be memorized:

$p^2 + 2pq + q^2 = 1$ *and* $p + q = 1$

Where 'p' and 'q' represent the frequencies of alleles.

p = frequency of the dominant allele in the population

q = frequency of the recessive allele in the population

$p^2$ = percentage of homozygous dominant individuals

$q^2$ = percentage of homozygous recessive individuals

2pq = percentage of heterozygous individuals

**It is important to note that p added to q always equals one (100%).**

Hardy and Weinberg came up with a hypothesis/idea that explained how populations could grow or change. It had 5 parts to it.

In order for a population to be at equilibrium (not changing), it must

1. Have no mutations occur
2. Have nothing moving in (immigration) or moving out (emigration)
3. Have no natural selection
4. Have a large breeding population
5. Random mating

**Hardy-Weinberg states that:**

P= the frequency of the dominant allele (so the % of A are in the population)

Q= the frequency of the recessive allele (so the % of a in a population)

So, p + q = 1

Using the equation:

$p^2 + 2pq + q^2 = 1$

$p^2$ = frequency of *AA* (homozygous dominant) 2*pq* = frequency of *Aa* (heterozygous) $q^2$ = frequency of *aa* (homozygous recessive)

**Problem-01:** In a certain population of 1000 fruit flies, 640 have red eyes while the remainder has sepia eyes (360). The sepia eye trait is recessive to red eyes. How many individuals would you expect to be homozygous for red eye color?

**Solution:**

1. $q^2$ for this population is 360/1000 = 0.36
2. q = "0.36= 0.6
3. p = 1 - q = 1 - 0.6 = 0.4

4. The homozygous dominant frequency = $p^2$ = (0.4)(0.4) = 0.16.

5. Therefore, you can expect 16% of 1000, or 160 individuals, to be homozygous dominant.

**Problem-02:** In the United States, one out of approximately 10,000 babies is born with the disorder. Approximately what percent of the population are heterozygous carriers of the recessive PKU allele?

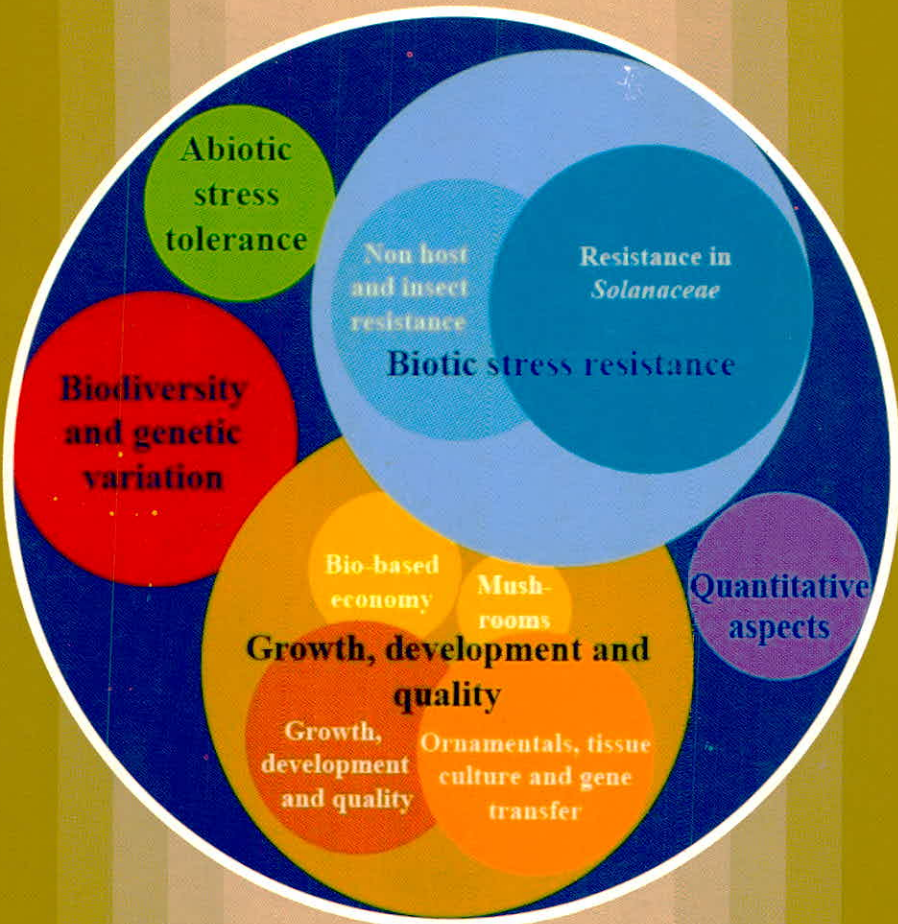
**Solution:**

$q^2$ = 1/10,000 = 0.0001

q ="0.0001 = 0.01 p = 1 - q = 1 - 0.01 = 0.99

The carriers are heterozygous.

Therefore, 2pq = 2 (0.99) (0.01) = 0.0198= 1.98%


Abiotic stress tolerance
Non host and insect resistance
Resistance in *Solanaceae*
Biotic stress resistance
Biodiversity and genetic variation
Bio-based economy
Mush-rooms
Quantitative aspects
Growth, development and quality
Growth, development and quality
Ornamentals, tissue culture and gene transfer