

# GPB-366

## Practical Manual

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## EXERCISE NO. 1

### EMASCULATION AND HYBRIDIZATION TECHNIQUES IN WHEAT, OAT AND BARLEY

#### WHEAT (*Triticum* species)

<b>Family</b>	:	Gramineae
<b>Genus</b>	:	<i>Triticum</i>
<b>Species</b>	:	<i>aestivum</i>
<b>Chromosome Number</b>	:	$2n = 6x = 42$

#### Cultivated Species

There are two cultivated species of wheat, viz. common wheat (*Triticum aestivum*) and durum wheat (*T. turgidum* L.). Common wheat is hexaploid ( $2n = 6x = 42$ ), whereas durum wheat is tetraploid ( $2n = 4x = 28$ ). The former is more widely adapted than the later. Common wheat is used for bread, cakes, noodles, cookies, chapatti etc., whereas the durum wheat is used mainly for macaroni and some flat breads. There are 16 wild species of wheat, out of which six are diploids ( $2n = 2x = 14$ ), seven tetraploids ( $2n = 4x = 28$ ), and three hexaploids ( $2n = 6x = 42$ ). Wild species are used in hybridization programme for transfer of resistance to biotic and abiotic factors, adaptation and other desirable characters into cultivated species.

#### Wild Species:

*T. timopheevii*  
*T. dicoccoides*  
*Aegilops speltoides*,  
*A. squarrosa*.

#### Origin :

Near East is the center of origin of bread wheat. It is believed that evolution of common wheat in nature took place in two important steps. First, an amphidiploid tetraploid species originated from a cross between two diploid species, one with A genome and other with B genome. The amphidiploid after crossing with a diploid species with D genome gave birth to the common wheat as given below:

1	<i>Triticum monococcum</i> ( $2n = 14, AA$ )	X	<i>unknown diploid</i> ( $2n = 14, BB$ )	→	Tetraploid wheat ( $2n = 4x = 28, AABB$ )
2	Tetraploid wheat ( $2n = 4x = 28, AABB$ )	X	<i>Triticum tauschii</i> ( $2n = 14, DD$ )	→	<i>Triticum aestivum</i> ( $2n = 6x = 42, AABBDD$ )

The chromosome doubling took place in nature in above crosses. The other two forms of hexaploid wheat, viz. *T. compactum* and *T. sphaerococcum* originated through spontaneous mutations of *T. aestivum*. The durum wheat probably originated from cultivated emmer wheat (*T. turgidum* var *dicoccum*) after several spontaneous mutations.

**Botany:**

It is grown in *Rabi* season. It is annual plant growing up to height of 0.6 to 1.8 mts with adventitious roots. The stem is cylindrical culm with hollow internodes. Leaves are opposite with parallel venation. Leaf consists leaf sheath, blade, ligule and pair of auricles at the base of leaf blade. The uppermost leaf of plant is called flag leaf. Tillers are produced from the underground nodes by the axillary buds of the plant.

The inflorescence is of spike or ear type in which sessile spikelets are arranged acropetally in zig-zag manner on mother axis i.e. rachis. Each spikelet consists of pair of outer glumes which encloses 3 to 5 florets. Central one or two are sterile and remaining florets are fertile. Each floret consists of outer glumes represented as scales, awned lemma (flowering glume) and a palea. The lemma and palea enclose three stamens (having thread like filaments and versatile anthers), single carpel (with bifid stigma) and two lodicules. The lodicules help for opening of flowers. After fertilization, ovary develops into caryopsis, which is a single seeded fruit with pericarp.

**Crossing Technique:**

Wheat is a self-pollinating crop. Flowering begins in the upper part of the spike and proceeds in both the directions. Flowering on a spike is over within 2-3 days. For emasculation roughly  $\frac{1}{4}$  to  $\frac{1}{3}$  upper part of spike is clipped and a few basal, immature florets are removed. In the remaining 5-6 pairs of florets, the central florets are also removed and the emasculation is carried out in the remaining lateral florets of each spikelet. For this, glumes are clipped back and anthers are removed with fine pointed forceps. The emasculated spike is covered by a pollination bag. After 1-2 days, the stigmas are visible then the emasculated spike is covered by pollination bag. Thereafter in 1-2 days, the stigmas are visible and the emasculated spike is ready for pollination.

Pollination is done with the fresh pollen as pollen grains remain viable for a short period (1-3 minutes). For preparing male spike, a spike showing a few protruding anthers is removed from the male parent. Its glumes are cut without damaging the anthers. It is held in vertical position/stalk inserted in ground under sunlight for a few minutes. During this process, anthers emerge out of cut glumes. The upper portion of the pollination bag on the emasculated spike is cut with scissors. Through this opening, the male spike shedding pollen is inserted and shaken over the emasculated spike by twirling motion and the bag is closed with the help of U clip. This simple and fast process of emasculation and pollination is commonly followed at most of wheat breeding stations.

**Breeding objectives:**

- i) High grain yield.
- ii) Early maturity with short duration.
- iii) Photo and thermo-insensitive varieties.
- iv) Resistant to diseases like rust, loose smut, leaf blight etc. and pests like aphids, armyworms and gujia weevil etc.
- v) Responsive to high doses of fertilizers.
- vi) Semi-dwarf varieties having synchronies productive tillers.
- vii) Resistant to water logging and shattering.
- viii) Good milling and baking quality i.e. suitable for chapatti and bread making.
- ix) Amber grain colour and grain with high protein and lysine content.
- x) Salt and drought tolerant varieties.

**Breeding achievements:**

- 1) Introduction: Sonora 64, Lerma rajo 64A, HI 977, Sonalika, Kalyansona Malvika
- 2) Pure line selection: NP 1,6,12, HB 208, K 852, Mondya 3-2, Motia, Gulab, Baxi-288-18,
- 3) Pedigree selection after hybridization:
  - a) *T. durum*. N 59, MI 5749, Raj 1555, NIDW 15 (Panchwati)
  - b) *T. aestivum*: NI 747-19, Lok 1, HD 2189, HD 2278, Prgato (DWR 39), NI-1917 (Kadwa)
- 4) Interspecific hybridisation
  - a) *T. durum* x *T. polonicum* : MACS 9 (d)
  - b) *T. durum* x *T. dicoccum* : Jay (d)
  - c) *T. durum* x *T. dicoccum* x *T. aestivum* : Niphad 4
- 5) Interspecific hybridization and back crossing (*T. durum* x *T. aestivum*) : NP 890
- 6) Multiline varieties : NI 5439 Kharachiya 65
- 7) Mutation breeding: Pusa Lerma, Sharabti Sonora : NP 111, NP836

**Improved varieties / Hybrids :**

Sr. No.	Improved / Hybrid Varieties	Features
1	Godavari (NIDW-295) ( <i>Triticum durum</i> )	Processing purpose, medium maturity (110-115 days), 18-20 qtl/acre productivity, best suitable for macaroni making, protein content 12 %.
2	Tapovan (NIAW - 917) ( <i>Triticum aestivum</i> )	Medium maturity (110-115 days), best for chapati making, protein content more than 12.5 %, high yielding variety under timely sown irrigated condition.
3.	Netravati (NIAW-1415) ( <i>Triticum aestivum</i> )	105-110 days (Rainfed), best for chapati making
4.	Phule samadhan (NIAW-1994) ( <i>Triticum aestivum</i> )	115-120 days, Bold size, best for chapati making, high yielding variety

**Assignment :**

- 1) Dissect the floral parts of given sample and mount them on black mounting paper. Draw the figures and label properly.
- 2) Practice hybridization technique in field and laboratory on given sample.

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**OAT**  
(*Avena sativa*)

<b>Family</b>	:	Gramineae
<b>Genus</b>	:	<i>Avena</i>
<b>Species</b>	:	<i>sativa</i>
<b>Chromosome No.</b>	:	2n = 42

Oats are supposed to be of Asian origin and from there it spread to most of the countries of the world like USA, Russia, Canada, Poland, Australia, France and Germany.

**Cultivated species :**

The Oats are classified according to their chromosome numbers and there are three main groups of cultivated oats :

**Group I :**

This group of Oats contains 7 haploid chromosomes and the important of them are *Avena brevis* (short oats), *A. weistii* (desert oat), *A. strigosa* (sand oats) and *A. nudibrevis* (small naked seeded oats) etc.

**Group II :**

The oats belonging to this group contain 14 haploid chromosomes. The prominent types of this group are *Avena barbata* (slender oat), *A. absyssinica* (Absyssinian oats).

**Group III :**

These types have 21 haploid chromosomes and the important members of this group are *Avena fatua* (common wild oats), *A. sterilis* (wild red oats), *A. sativa* (common oats), *A. byzantina* (cultivated red oats) and *A. nude* (hull less oat).

**Inflorescence :**

Inflorescence of the oat plant is panicle composed of a central loose, open rachis with five to seven nodes, from which branches areas bearing spikelets. Each lateral branch terminates in a single apical spikelet. Other spikelet is born on second or third-order of branches. Each panicle may have 20 to 50 spikelets. Each spikelet consists of several florets enclosed in two empty glumes, with the tip of one glumes extending slightly above the other. Florets within each spikelet are arranged alternatively upon a central axis, the rachilla, and usually the two basal florets are fertile. The flowers are perfect zygomorphic, bracteates and hypogenous. The flower consists of a lemma and palea, two lodicules, three stamens and one pistil.

**Spikelet :**

Three to four florets are present in each spikelet, but the third or fourth floret is sterile, two glumes cover these florets.

**Glumes :**

The two outer bracts of the spikelet are broadly lanceolate, pointed boat shaped, usually labours and arched. The glumes may be pale, yellow or red.

**Lemma :**

Lemma is a rigid structure which enclosed the rachilla at the base of the flower. Its primary function is to protect the caryopsis. Lemma is bifid and varies in colour, being white, yellow gray or red to black. It may be awn or awnless.

**Palea :**

One membranous palea is present opposite to lemma. Primary function of palea is to protect the caryopsis.

**Lodicules :**

Two small, smooth, pointed and shining lodicules are present at the base inside the floret, mature lodicules are thick at the base and pointed at the tip. The action of the lodicules in opening the flowering glumes is not so important in self fertilized plants.

**Androecium :**

There are three stamens present. Stamens first appear as papillae upon the apex of the floral axis above the flowering glumes primordia. The anther consists of four locules. The filament is attached to the central axis at its lower extremity.

**Gynoecium :**

There is one ovary with bifid stigma. The ovary is elliptical in cross section. Long monocellular, epidermal hairs entirely cover the ovary and also present on the interior surface and base of styles. The tip of style and the inner surface nearly to the base, are covered with stigmatic branches. A single sessile anatropous ovule is located inside the ovary.

**Crossing Technique :****Emasculation :**

Since anthesis normally occurs in the afternoon, emasculation should be done in late forenoon or early afternoon. Select those spikelet from a panicle in which anthesis is expected one or two days after emasculation. Keep only one floret within a spikelet. By applying light pressure on the dorsal glumes, separate glumes, palea and lemma and remove all the three anthers with the forceps. When emasculation is delayed until very shortly before the time of normal anthesis, the floral structure, being better developed will likely to be less injured by operation than they would be if manipulated a day or more before pollination. Cover the emasculated floret with a glassine bag to prevent contamination from foreign pollen and tagging is to be done.

**Pollination :**

Researchers have reported different time interval for pollinating the emasculated floret. Few reported optimum time between emasculation and pollination as one to three days, while others suggested emasculating the floret in the morning and pollinating in the evening. Anthers from desired male parent are collected. The anthers will be yellow plump. Separate lemma and palea of emasculated floret and place the collected anthers with the help of forceps in the inner side of the lemma. Cover the pollinated floret with the same glassine bag used in emasculation. Approach method of pollination is also used in oats. In approach method remove secondary floret and the anthers of the primary floret. The upper portion of each spikelet, after emasculation is removed by clipping glumes, lemma and palea just above the stigma. The pollens from the male parent shed directly on the stigma of erect clipped spikelets.

**Breeding objectives :**

The broad objectives in breeding spring and winter varieties of oats are high grain yield, earliness, lodging and shattering resistance, disease resistance and quality. Winter hardiness and forage production are additional objectives in the breeding of winter oats.

- 1) Breeding for high yield.
- 2) Breeding for adaptability, salinity, water stress and temperature
- 3) Winter hardiness

**Lodging and shattering resistance :**

Oats must stand in the field until harvested, without loss either from lodging or shattering, if high yields are to be obtained.

**Breeding for disease resistance**

Several diseases have been reported on oat crop (Gupta *et. al.* 1998) causing considerable reduction in yield and deterioration in nutritive quality. Brief description of the some of the important disease is given below.

- Rusts
- Crown rust
- Stem rust
- Smuts
- Powdery mildew

**Achievements :**

Sr. No.	Varieties	Features
1	Kent	An introduction from U.S.A. which is resistant to rust, blight and lodging.
2	Algerian	It is an introduction from Algeria and is suitable for irrigated areas.
3	F OS-I/29	It is recommended for Punjab, U.P., Haryana and Delhi for irrigated and rainfed areas.
4	Brunker 10	It is suited to limited irrigated conditions and is resistant to loose smut.
5	Wetson 11	An early maturing and tall growing variety.
6	Coachman	An introduction from U.S.A. which is resistant to rust, blight and lodging.
7	HFO-114	A dual purpose variety recommended for Haryana
8	UPO-50	It is resistant to blight, rust and lodging and recommended for U.P.

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## BARLEY

(*Hordeum vulgare* L.)

<b>Botanical name</b>	:	<i>Hordeum vulgare</i>
<b>Family</b>	:	Graminaceae / Poaceae
<b>Genus</b>	:	<i>Hordeum</i>
<b>Common name</b>	:	Satu / Jav
<b>Chromosome numbers</b>	:	2n = 14

Fertility of the lateral spikelets forms the basis of barley classification and the cultivated barley may be classified into three main groups viz.,

- i) Six rowed barley (*H. vulgare* L. emend, Lam)
- ii) Two rowed barley (*H. distichum*, L. emend, Lam)
- iii) Irregular barley (*H. irregular*, E. Aberg and Wiebe)

### Botany :

The cultivated barley plant briefly consists of the following parts :

- 1) The roots, both seminal and permanent.
- 2) The stem (culm), cylindrical with hollow internodes, and from 5 to 7 solid nodes.
- 3) Leaves, borne alternatively on opposite sides of the stem and arising at each node.
- 4) The spike (head) at the top of the stem, consisting of the flowers arranged in spikelets, three of which are attached at each node of flat zig-zag rachis.
- 5) The spikelet, having two glumes and the floret.
- 6) The floret, consisting of the lemma and the palea, which enclose the male and female flower parts.
- 7) The kernel, consisting of the caryopsis in naked barleys but including the lemma, the palea and the rachilla. Which adhere to the caryopsis, in hulled barleys (Reid and Wiebe, 1979).

Each spikelet is single flowered and consists of two glumes and a floret. In six-rowed barley, three spikelets are attached at each node of the rachis, and these triplets alternate from side to side of the rachis. In two rowed barley, only the central spikelet of a triplet is fertile. The flower is enclosed in lemma and palea. The pistil has a two branched feathery stigmas. Three anthers are attached to the long slender filaments. The spike of barley besides being characterized as six-row and two-row, is also described as hooded vs. awned. The hood is a three-lobed appendage at the tip of the lemma. The hood may be either slightly elevated on a short awn segment or sessile.

### Crossing :

Flowering of barley spikelets begins in the central florets of the upper of the spike and proceeds in both the directions with the swelling of lodicules at the base of the florets, the flowers open and the filaments elongate. During elongation of the filament and emergence of the anthers, the dehiscence germinated five minutes after it reached the stigma, that within 10 minutes the two male gametes had entered the pollen tube. Within 40 minutes, the male gamete has reached the site of micropyle. Within 45 minutes, the male gamete had entered the egg sac. The first division of the fertilized egg completes five hours after pollination.

The emasculation is done in the early stage of the spike development when the spike is slightly visible through the covering of flag leaf. The upper 1/3 portion of the spike is removed. The emasculated spike is covered with butter paper bag. After 2-3 days, when the

stigma is protruding. The spike is ready for pollination are carried out by twirling a spike with ripe with ripe anthers over the emasculated spike.

#### **Breeding Objectives :**

- i) Yield improvement
- ii) Increased adaptability
- iii) Resistance to yellow rust, aphid and nematode
- iv) Improvement in nutritional quality
- v) Improvement in attributes related to malt industry

#### **Achievements of Barley :**

Sr. No.	Name	Parentage	Release year	Specific area of adaptation
1.	K603	K257/C135	2000	NEPZ
2.	BH393	California/ mariout	2001	Haryana
3.	NBBNOB(020)	Ratna K-425/Jyoti	2001	UP
4.	RD3592	RD2503/UBL9	2003	Rajasthan
5.	K713	RD2540/BH407	2004	NEPZ

#### **Improved Varieties / Hybrids :**

Sr. No.	Varieties	Features
1	Ratna, Jyoti, Kailas	Hulled varieties
2	Karan-750, Amber, Himadri	Huskless varieties
3	C-138, RS-6, RD-57, RD-137, Clipper	Malting varieties
4	Karan 16, Karan 18, 19, Jyoti karan-3,4 Amber, Azad	Salt tolerant varieties
5	Kailash, Himani, Dolma, NP-100, NP-13, 21, 103	Suitable for hilly areas
6	Rajkiran	Nematode resistant variety
7	Nilam and Karan 19	Better chappati making quality for barley varieties

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## EXERCISE NO. 2

### EMASCULATION AND HYBRIDIZATION TECHNIQUES IN CHICKPEA AND LENTIL

#### CHICKPEA (*Cicer arietinum*)

<b>Family</b>	: Leguminosae
<b>Genus</b>	: <i>Cicer</i>
<b>Species</b>	: <i>arietinum</i>
<b>Chromosome Number</b>	: $2n = 16$

**Cultivated species:**

**Related species** : *C. reticulatum*  
*C. pinnatifidum*  
*C. songaricum*

Two main categories of Chickpea are recognized which are distinguished mainly by their seed characteristics. They are

- 1) Desi types, which are relatively smaller, angular seeds with rough yellow to brown coloured testas.
- 2) Kabuli types, with large, more rounded and cream coloured seeds.

**Wild species :**

The wild species of *Cicer* closely related to chickpea are :

- i) *C. bijugum*
- ii) *C. echinospermum*
- iii) *C. ecticulatum*

**Origin:**

The chickpea is most probably originated in an area of present day south-eastern Turkey and adjoining Syria.

**Botany:**

Roots are robust and long. Stems are branched, flexuous or straight, erect to prostrate and usually ribbed. In general, height ranges from 20 to 100 cm. Three types of branching are defined. They are primary, secondary and tertiary branches. The leaves include rachis and leaflets. The average rachis length is 3-7 cm. Each rachis has on average 10-15 leaflets, inserted on small pedicels. The leaf is pseudoimparipinnate i.e., the ending terminal leaflet is not in true terminal position, but in sub terminal position (the central vein oblique to the rachis).

The flowers are papilionaceous. They are solitary in axillary racemes. Double flowers are rare, but are very much sought after by the breeders as possible sources of yield increase. The calyx has five deep lanceolate teeth. Peduncle and calyx are hairy. Generally, corolla is

white. The vexillum is obovate, 8-11 mm long and 7-10 mm wide. Wings are obovate, 8-9 mm long. The keel is 6-8 mm long.

The androecium is diadelphous [(9) + 1]. The ovary is ovate, pubescent, 2-3 mm long, and 1-1.5 mm wide. It has 1-3 ovules, rarely 4. The style is 3-4 mm long, generally glabrous. The stigma is globose. Number of pods/plant is highly variable, generally between 30 and 150 depending on the year, location, sowing time and other factors. The seed is beaked, and very frequently ramhead shaped and strongly wrinkled or ribbed. Pod size has been found to be a stable character and based on this, two groups viz., macrocarpa and microcarpa have been postulated in *C. arietinum*.

### **Crossing Technique :**

Crossing in chickpea is usually difficult and time consuming as is the case with most of the legumes. For emasculation, the bud is held in left hand and gentle pressure is exerted to open the standard and wing petals. The keels are opened with forceps and the stamens are removed. Pollens are collected from half-open flowers and put on stigma. For better results, it is suggested that the crossing should be attempted after formation of first pod on the plant and as far as possible and large bud sized cultivars should be used as female parent. In Chickpea anthesis starts between 9 and 10 am and may continue up to 3 pm. The flowers remain open for two days, the flowering process over early on the second day. The plant is primarily self pollinated as anther dehiscence takes place forty hours prior to opening of flowers. The process of anther dehiscence prior to opening of flowers termed as cleistogamy has been recorded in the species.

### **Breeding Objectives :**

- (i) Increased seed yield.
- (ii) Increased biomass, tall, erect and compact cultivars
- (iii) Resistance to diseases
  - (a) Ascochyta blight.
  - (b) Fusarium wilt.
  - (c) Root rot.
  - (d) Botrytis grey mould
- (iv) Resistance to insect pests:
  - (a) Pod borer.
- (v) Tolerance to stress environments:
  - (a) Cold
  - (b) Heat
  - (c) Drought
  - (d) Saline and alkaline soils.
- (vi) Mechanical Harvesting

**Improved Varieties / Hybrids :**

Sr. No.	Varieties	Features
1	BDN-9-3	Early, wilt resistant, drought tolerant
2	BDNG-797	Early, wilt resistant and high yielding
3	Phule Vikrant	Yellowish brown, medium size seeds, wilt resistant
4	Phule Vikram	Tall growth habit, suitable for mechanical harvesting, medium size, yellowish brown seeds.
5	Himali	Extra bold seeded kabuli variety, wilt resistant
6	Kripa	Extra large seeded kabuli variety, milky white seed colour
7	Digvijay	High yield potential, bold seeds, wilt resistant
8	Rajas	Yellowish brown bold seeds, wilt resistant
9	Vihar	Extra bold seeded kabuli variety, wilt resistant
10	Virat	Extra bold seeded kabuli variety, wilt resistant
11	Vishal	Attractive yellowish brown bold seeds, wilt resistant
12	Vijay	High yield potential, wilt resistant, drought tolerant
13	BDNG-798	Kabuli, medium bold
14	Jaki-9218	Deshi, high yielding, wilt tolerant
15	ICCV 2	Early, kabuli type
16	Hirwa Chaffa (AKGS-1)	Green seeded, for rainfed and irrigated areas
17	PKV Harita	Wilt and drought tolerant, recommended for rainfed cultivation, green seeded.
18	PKV Kanchan	Wilt tolerant, recommended for irrigated condition for Vidharbha region
19	Gulak 1	Bold seeded, wilt tolerant, pink seeded, suitable for roasted purpose
20	PKV Kabuli- 4	Extra large seeded, kabuli, wilt tolerant, suitable for export purpose.

**Assignment :**

- 1) Dissect the floral parts of given sample and mount them on black mounting paper. Draw the figures and label properly.
- 2) Practice hybridization technique in field and laboratory on given sample.

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## LENTIL

### (*Lens culinaris* Medik)

<b>Botanical name</b>	:	<i>Lens esculenta</i> / <i>Lens culinaris</i>
<b>Family</b>	:	Leguminaceae
<b>Sub family</b>	:	Papilionaceae
<b>Genus</b>	:	<i>Lens</i>
<b>Chromosome number:</b>		2n=2x=14

**Species :**

The genus *Lens* Miler comprises five annual species of which only *L. culinaris* Medik (*L. esculenta* Moench) is cultivated.

**Cultivated species :**

*L. culiaris* Medik (*L. esculenta* Moench) is a characteristic component of the old World Belt of Mediterranean Agriculture. Numerous varieties of lentil are described. The cultivars are conventionally grouped in two inter-grading clusters – (i) small seeded lentils (sub-sp. *Microsperma* Barul) with small pods and small seeds (diameter 3-6mm), (ii) large seeded lentils (sub-sp. *Macrosperma* Barul), with large pods and with seeds attaining 6-9 mm.

Wild species. The four wild species are delicate, small flowered annuals distributed over South-West Asia and Mediterranean basin.

**Botany :**

The flower is typical papilionaceous, small, white, pale purple or purple blue. The corolla and specially the standard is broadly obovate and measures 4-6 mm long and 3-4 mm wide. The wing petals develop separately, rarely growing together with the keel petals. The keel petals enclose the pistil and the stamens. The style usually develops at a right angle to the ovary, and usually flattened on the outer side and trichoid on the inner side. The stamens are polyadelphous or diadelphous. The ovary is flat and non-pubescent and normally contains one to two ovules. The flower primordium is enclosed in a whorl of elongated, nearly calyx lobes. Pods are 1 -2 cm long, oblong, flattened, with curved beak and persistent calyx.

**Crossing technique :**

Lentil is strictly self-pollinated due to cleistogamy and dehiscence of anthers is before the flower opens. Wilson and Law (1972) reported less than 0.8% occasional cross-pollination through thrips or other small insects.

Wilson (1972) reported successful crossing in greenhouse. Crossing was best on young vigorous plants when the relative humidity was above 50% the nature between 15 and 25°C in 12 – 15 hrs. of light and 9-12 hrs. of darkness. When the RH dropped below 35% the percentage of successful manual crosses decreased sharply. Lentil flowers continue to self-pollinate at the lower RHs, but pollen for crossing is difficult to gather transfer.

The buds (one half-three fourths the length of calyx lobes) are held between the thumb and the forefinger with the suture of the keel facing the operator. Special care is taken not to bend or twist the peduncle. Sharp-pointed forceps are used to carefully remove one or two calyx lobes nearest the suture side of the keel. The wings and keels are removed individually. The standard is either removed or folded and breaking them free from the stamina column or by pulling them outward. Manual pollinations are made immediately after emasculation. Pollen is selected from the vigorous flowers as soon after anther dehiscence as

feasible. The keel is opened with forceps so that the stamina column and the pistil could be removed as a unit. This brush like unit is used to transfer pollen to the exposed stigma of emasculated flowers. The pollen laden pistil and the anthers are brushed against the trichoid side of the stigma. After pollen transfer the standard of the maternal flower is returned its original position around the pistil.

#### Breeding objectives :

1. High seed yield.
2. Bold seed size, high protein and less cooking time.
3. Early maturity.
4. Resistance to diseases :
  - a. Ascochyta blight (*Ascochyta lentis* Bon – Mon. & Vass.)
  - b. Rust (*Uromyces fabae* (Pers.) de Bary)
  - c. Wilt (*Fusarium oxysporum* f. Sp. *Lentis* Vasd. & Srin. Gord).
5. Resistance to insects :
  - a. Pod borer (*Etiella zinckenella* Treit)
  - b. Cutworm (*Agrotis ipsilon* (Hfn.) *Ochropleura* (Agrotis) Flammatra (Schiff.)
  - c. Aphid (*Aphis craccivora* Koch., *A. Gossypii* Gl., *Myzus persicae* (Sulz.)
6. Resistance to shattering
7. Tolerance to drought

#### Achievements :

Sr. No.	Varieties	Features
1	IPL-316	Brown with orange cotyledons and resistant to rust and moderately tolerant to wilt (Yield 16-18 q/ha)
2	IPL-81 (Noori)	Tolerant to rust and wilt, medium size seeds, early maturity (Yield 25-27 q/ha)
3	Pusa Lentil 5	Small seeded, orange cotyledon, resistant to rust
4.	Pusa Vaibhav	Small seeded, resistant to wilt and rust
5	Pusa Shivalik	Resistant to wilt and rust.

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### EXERCISE NO. 3

## EMASCULATION AND HYBRIDIZATION TECHNIQUES IN FIELD PEA, RAPESEED & MUSTARD

### FIELD PEA (*Pisum sativum*)

<b>Family</b>	:	Leguminosae
<b>Sub family</b>	:	Papilionaceae
<b>Genus</b>	:	<i>Pisum</i>
<b>Species</b>	:	<i>sativum</i>
<b>Chromosome number:</b>		2n=14

#### Cultivated species :

Linnaeus distinguished two species within the genus *Pisum*. *Pisum arvense*, the coloured flower field-pea and *Pisum sativum*, the white flowered garden pea. Since then, following species have been designated.

1. *Pisum abyssinicum*
2. *P. aucheri*
3. *P. elatius*
4. *P. formosum*
5. *P. fulvum*
6. *P. humile*
7. *P. jomardi*
8. *P. transcaucasicum*

All forms of peas previously accorded species status (except *P. aucheri* and *P. formosum* which are tuber forming perennials and have been placed in genus *Alophotropis* have a diploid chromosome number of 14 and cross among themselves readily. Therefore, they are now classified as ecotypes under *P. Arvense* with white flowered garden pea considered as ecotype sativum. However, the widespread use of *P. sativum* to designate the garden pea would make it difficult to change this designation (Gritton, 1986).

#### Botany

The inflorescence is raceme arising from the axil of a leaf. The lowest node at which flower initiation occurs is quite constant under a given set of condition and is used in classifying the varieties with respect to flowering and fruiting duration. Most early cultivars produce the first flower from nodes 5 to 11 and the late cultivars start flowering at about nodes 13 to 15 (Gritton 1986).

The flowers are typical papilionaceous with green calyx comprising of five united sepals. Five petals (one standard, two wings and two keels). The stamens are in diadelphous (9+1) condition. Nine filaments are fused to form a staminal tube while the tenth is free throughout its length. The gynoecium is monocarpellary, with ovules (upto 13) alternately attached to the two placentas. Style normally bends at right angle to the ovary. Stigma is elliptical and sticky. Early cultivars are often single flowered or bear some single and some double flowers. Late cultivars are mostly double or triple flowered.

**Crossing Technique :**

Pea is strictly self-pollinated in nature. Stigma is receptive to pollen from several days prior to anthesis until 1 day or more after the flower wilts. Pollen is viable from the time anthers dehisce until several days thereafter.

For emasculation the plants to be selected should be vigorous and just beginning to flower. The flower bud chosen should have developed to the stage just before anther dehiscence, indicated by extension of petals beyond sepals. Flowers can be emasculated at any time. The first step in emasculation is to tear away with the flower and thumb in front and a light pressure is applied. This spreads the standard and wings to expose the keel. The exposed keel is slit-open by tips of forceps. Pressure can be applied by the thumb and finger on keel for increased exposure of the pistil and stamens. The 10 stamens are polled out.

Pollen can be obtained throughout the day, preferable from a freshly opened flower. For pollen collection, it is more convenient to pick the male flowers, remove the standard and wings, pull back the keel so that the style protrudes and use the pollen covered stylar brush as an applicator to transfer the pollen to the stigma of the emasculated bud. Older flowers and other flower buds not used in crossing are removed from the penduncle to increase the pod set after crossing (Gritton, 1986).

**Breeding objectives :****Garden pea**

1. High green pod yield
2. Long, attractive green pods with 9 – 11 seeds / pod
3. Sweetness
4. High shelling percentage
5. Specific maturity (early and medium)

**Field pea**

1. High grain yield
2. Bold, attractive seeds
3. Early maturity

**Resistant to diseases**

1. Downy mildew (*Peronospora viciae* (Berk) de Bary)
2. Powdery mildew (*Erysiphe polygoni* DC)
3. Rust (*Uromyces viciae – fabae* (Pers.) Schroet and *U. Pisi* (pers.) Wint.)
4. Wilt (*Fusarium oxysporum* Schl. F. Sp. *Pisi* (van Hall) Snyd. & Hans).

**Resistance to insect**

1. Leaf miner (*Phytomyza horticola* Gour (= atricornis)
2. Semi-looper (*Plusia orthichalea* Fb.)
3. Aphids (*Aphis cracivara* Koch., *A. Gossypii* Gl.)
4. Pod-borer (*Etiella zinckenella* Trcit)
5. Pea stem fly (*Ophiomyia phaseoli* Tryon).

**Important Achievements****Field pea varieties recommended for various states**

State	Varieties
Uttar Pradesh	Adarsh, Vikas, Prakash, Rachana, KPMR400, Matar3, Pant Pea 42
Bihar	Rachna, HUDP15, VL42
Maharashtra	Adarsh, Vikas, Prakash, Rachana, Ambika, KPMR400
Rajasthan	Rachna, Hariyal, DDR27
Madhya Pradesh	Adarsh, Vikas, Prakash, Rachana, Ambika, KPMR400

**Improved Varieties / Hybrids :**

Sr. No.	Varieties	Features
1	IPFD 12-2	Resistant to powdery mildew, pod borer moderately resistant to aphids and leaf miner, Yield 22-25 q/ha
2	IPFD 11-5	Resistant to powdery mildew, and moderately resistant to pod borer, Yield 19-20 q/ha
3	IPFD 2014-2	Resistant to powdery mildew, Yield 22-23 q/ha
4.	IPF 99-25 (Adarsh)	Tall, Powdery mildew resistant, Yield 20-22 q/ha
5	IPFD 99-13 (Vikas)	Dwarf, Resistant to powdery mildew, Yield 22-25 q/ha
6	IPFD 1-10 (Prakash)	Large seeds, powdery mildew resistance, Yield 22-25 q/ha.
7	Pusa Prabhat (DDR-23)	Dwarf, Early maturity, powdery mildew resistant
8	Pusa Panna (DDR-27)	Dwarf, Early (90 days), Powdery mildew resistant
9	Rachana	Smooth round seeded, yield 15-20 q/ha.
10	Khaperkheda	Yield 10-12 q/ha, for irrigated condition.

**Assignment :**

- 1) Dissect the floral parts of given sample and mount them on black mounting paper. Draw the figures and label properly.
- 2) Practice hybridization technique in field and laboratory on given sample.

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## RAPESEED AND MUSTARD

(*Brassica* species)

The chief features of rapeseed and mustard are as follows :

Sr. No.	Species	Common Name	Local Name
1	<i>Brassica juncea</i> coss	Indian Mustard	Rai or Laha
2	<i>B. juncea</i> var. <i>rugosa</i>	Rugosa	Pahari rai
3	<i>B. nigra</i> Koch	Black mustard	Banarasi rai
4	<i>B. campestris</i> L. var. yellow mustard	Turnip rape	Yellow sarson
5	<i>B. comestris</i> L. var brown mustard	Turip rape	Yellow sareson
6	<i>B. campestris</i> L. var Toria	Indian rape	Toria or lahi
7	<i>B. alba</i> ; <i>B. hirta</i> Moench	White mustard	Ujli sarson
8	<i>Eruca sativia</i> Mill.	Rocket cress	Taramira

Species	Chromosome Number
<i>Brassica campestris</i> sp. <i>Olliefera</i>	$2n=20$
<i>Brassica juncea</i>	$2n=36$
<i>Brassica juncea</i>	$2n=16$
<i>Eruca sativa</i>	$2n=22$
( <i>B. nigra</i> x <i>B. oleracea</i> )	$2n=34$
<i>B. guncea</i> ( <i>B. nigra</i> x <i>B. campestris</i> )	$2n=36$
<i>B. napus</i> <i>B. oleraceae</i> x <i>B. campestris</i>	$2n=38$

### Botany :

Brassicaceae have taproot system. Stem is succulent, straight and cylindrical. The leaves are pinnately divided. Whenever they exist, trichomes are always simple. Their presence or absence may be a good taxonomic character. A simple and well known example may be that of *B. oleracea*, *B. nigra* and *B. campestris* where the first is completely glabrous and the two others hairy. The amphidiploids where one of the parents is *B. oleracea* (i.e. *B. carinata* and *B. napus*) are only very slightly hairy (Gomez Campo, 1980). The flower has typical cruciferae formula ( $K_2 + 2, C_4, A_2 + 4, G (2)$ ). The inflorescence is racemose and flowering is indeterminate beginning at the lowest bud on the main raceme. The syncarpous ovary develops into a pod (silique) with two carpels separated by a false septum.

### Crossing technique :

The flowering is indeterminate and may last for two-three weeks. Stigma is receptive for about six days (three days prior to three days after the opening of the flower). The amphidiploid species (*B. Carinata*, *B. napus*, *B. juncea*) are self-compatible and self-pollinated in nature but about 30 % cross-pollination may occur by wind and insect under field conditions. The diploid species viz., *B. nigra*, *B. oleracea* and *B. campestris* are self incompatible and consequently cross pollinated.

Selfing usually carried out by enclosing a flowering branch whose open flowers have been removed, in a muslin cloth bag in case of amphidiploids species – which are self compatible. In case of self – incompatible diploid species, selfing is done mostly by bud-pollination. In bud pollination, a flowering branch whose open flowers / young pods have been removed, is bagged by muslin cloth bag. After a few days, the bag is removed temporarily and pollen from freshly opened flowers is applied on the stigma of young buds which are preferably emasculated. The self incompatibility in Brassica is of sporophytic-homomorphic type under monofactorial polyallelic series where pollen is inhabited on the stigma. Various techniques available for obtaining a temporary break down of the self-incompatibility character are as follows (De Nettancourt, 1972).

1. Bud pollination
2. Delayed self pollination
3. Grafting
4. Heat shocks
5. Application of carbon dioxide
6. Hormones and protein inhibitors
7. Chronic irradiation
8. Acute irradiation of styles
9. Acute irradiation of pollen mother cells
10. Tetraploidization – haploidization
11. Haploidization – diploidization.

**Permanent self –compatibility can be induced by**

1. Mutation of S locus
2. Modification of the genetic background
3. Tetraploidization

**Breeding objectives**

1. High yield
2. Early maturity
3. High oil
4. Low erucic acid and glucosinolates
5. Resistance to diseases
  - a. *Alternaria* blight (*Alternaria brassicae*)
  - b. White rust (*Albugo candida*)
  - c. Downy mildew (*Pernospora parasitica*)
  - d. Sclerotinia rot (*Sclerotinia sclerotiorum*)
6. Resistance to insects
  - a. Aphids (*Lipaphis erysimi*)

**Achievements in Rapeseed / Mustard :**

- 1) Mustard : Varuna (T-59), TM2, TM4, Seetha
- 2) Brown sarson : KNS3, KOS-1
- 3) Yellow sarson : Pusa gold, YS-93
- 4) Toria : Jawahar Toria, Panchali, TS-29
- 5) Taramira : RTM-13, TMC-1.
- 6) Pusa Jai Kisan (Bio-902) : First somaclonal variety in 1993
- 7) First hybrid variety of PGSH-51 of Sobhi sarson
- 8) Frost resistant RH-781
- 9) White rust resistant varieties RH-813
- 10) NRC Sankar Sarson (NRCHB-506) & (JM-1) through heterosis breeding using moricandia cytoplasmic genetic male sterility system
- 11) Shabadi : 95-105 days duration, Blackish red, 8-12 q/ha yield, 32-40 oil percentage
- 12) NRCHB-101: 10-115 days duration, Blackish, 8-10 q/ha yield, 35-42 oil percentage
- 13) Bio-902 : 99-110 days duration, Blackish red, 6-10 q/ha yield, 39-41 oil percentage
- 14) Pusa mustard 27 : 118 days duration, Suitable for multiple cropping system, tolerant, 41.7 oil percentage, 1.53 t/ha yield.

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## EXERCISE NO. 4

### EMASCULATION AND HYBRIDIZATION TECHNIQUES IN SUNFLOWER

#### SUNFLOWER

(*Helianthus annuus*)

<b>Botanical name</b>	:	<i>Helianthus annuus</i>
<b>Family</b>	:	Compositae
<b>Genus</b>	:	<i>Helianthus</i>
<b>Species</b>	:	<i>H. annuus</i> <i>H. tuberosus</i>
<b>Chromosome No.</b>	:	$2n = 2x = 34$

#### Cultivated species :

Sunflower (*Helianthus annuus*,  $2n=2x=34$ ) is an important oilseed crop after soybean and palm in the world and accounts for about 12.8% of the world production of edible oil. Its oil content ranges from 46 to 52% and is of high quality having non-cholesterol and anticholesterol properties.

The genus *Helianthus* comprises 67 species native to the Americas. Two species, *H. annuus* and *H. tuberosus* are cultivated as food plants and several species are grown as ornamentals. *H. annuus*, the common sunflower cultivated for oil is diploid ( $2n=34$ ) and *H. tuberosus* is hexaploid ( $2n=102$ ) and is cultivated for tubers.

#### Wild relatives :

*H. decapitulus*  
*H. rigids*  
*H. annuus* sub spp. *annuus*  
*H. annuus* sub spp. *lenticularis*  
*H. annuus* sub spp. *jaegeri*

**Botany :** The inflorescence is a capitulum or head, characteristic of composite family. The number of flowers in oilseed cultivars may vary from 700 to 3000. The flower of the outer whorl of the head are called as ray florets. They have five elongated petals which are united to form straplike structures. They have vestigial styles and stigmas and no anthers. The other flowers arranged in concentric rings over the remainder of the head are called as disc flowers. Each disc flower consists of a sharp pointed chaffy bract, a basal inferior ovary, two pappus scales (often considered to be modified sepals), a tubular corolla of five petals which are united except for the tips. Five anthers are united to form a tube with separate filament attached to the base of the corolla tube. Inside the anther tube, there is the style, terminating in a stigma which is divided. The receptive surfaces of stigma remain in close contact in bud stage. The achene or the fruit of the sunflower consists of a seed often called the kernel. The adhering pericarp is usually called the hull. The seed consists of seed coat, endosperm and embryo. Major part of embryo is in the form of cotyledons (Knowles., 1978).

#### Crossing technique :

Sunflower is highly cross pollinated crop mainly through insects and to a limited extent by wind. The flower opening starts from outer side of the head and proceeds towards centre of the head, the heads bloom within 5-10 days depending upon size and season. Anthesis occurs between 5 to 8 AM. The pollen grain viability lasts for 12 hours. The stigma

remains receptive for two-three days. Selfing is done by bagging of the head. The bagging material could be cotton cloth, tiffany bags or paper bags or cheese cloth bags or plastic netting. Emasculation is done as follows :

**Hand emasculation :**

Emasculation is done by removing the anther tubes with forceps early on the morning that the flowers open. Unemasculated flowers are removed.

**Without emasculation :**

Considering hand emasculation tedious, sometimes crosses are made without emasculation. Hybrid plants are distinguished from selfed ones on the basis of vigour or the presence of marker genes.

**Chemical induction of male sterility :**

This is achieved by spraying of 0.5-1.5 mg of a 0.005% solution of gibberellic acid/plants are distinguished from selfed ones on the basis of vigour or the presence of marker genes.

**Pollination :**

Pollination is carried out by collecting pollen from heads which are already bagged prior to flowering. Pollen can be collected from flowering heads into paper bags by a light tap of the hand on the back of the head. Pollination is usually done in the same morning after emasculation. Pollen can be applied by a small piece of cotton, a camel hair brush, the corner of the cloth bag isolator, a small section of leaf, paper or other suitable material that is dipped in the pollen and gently drawn over the receptive surface of the stigmas. Freshly collected pollens are more effective in pollination. Pollen can be stored without serious loss of viability for 1-2 weeks in cork-stoppered vials at ordinary room temperature. After each cross, care must be taken to avoid contamination by wiping the hands with alcohol and cleaning or discarding the pollen applicator (Fick, 1978).

**Breeding objectives :**

- i) High seed yield
- ii) Early maturity
- iii) Lodging resistant dwarf plant type
- iv) Uniformity of plant type
- v) High oil percentage
- vi) Tolerance to stress conditions
- vii) Resistance to bird damage
- viii) Resistance to diseases : Flowing diseases are serious in India.
  - a) Leaf spots (*Alternaria helianthi*, *Cladosporium cladosporoides* )
  - b) Rust (*Puccinia helianthi*)
  - c) Root rot and damping of (*Sclerotium rolfsii*, *Rhizoctonia bataticola*, Syn. *Macrophomina phaseolina*)
  - d) Stem rot (*Sclerotinia sclerotiorum*)
  - e) Head rot (*Rhizopus* spp.)
  - f) Powdery milder (*Erysiphe cichoracearum*)

**ix) Resistance to insect-pests :**

- a) Head damaging pest (*Heliothis armigera*)
- b) Grass hoppers (*Chrotogonous* spp.)
- c) Jassids (*Amrasca bigutulla*)
- d) Leaf eating caterpillars (*Diacricia oblique*, *Spodoptera litura*, *Plusia orichalcea*).

**Achievements :****Open-Pollinated varieties and hybrids of sunflower evolved / released**

Variety / hybrid	States for which recommended	Seed yield (Kg/ha) in rainfed areas	Oil content (%)
<b>Variety</b>			
Morden	All states	600-800	36-38
EC 68414	All states	800-1,000	40-42
EC 68415	Karnataka	800-1,000	40-42
Surya	Maharashtra	800-1,000	32-35
CO 1	Tamil Nadu	500-700	38-39
CO 2	Tamil Nadu	800-1,000	38-40
TNAU-SUF 7	All States	800-1,200	38-42
GAU-SUF 15	Gujarat	800-1,200	38-42
SS 56	Maharashtra	700-900	36-38
<b>Hybrid</b>			
BSH	All states	1,000-1,500	40-42
KBSH 1	All states	1,200-1,500	42-44
KBSH 11	All states	1,000-1,500	40-42
LSH 1	Maharashtra	900-1,200	37-39
LSH 3	Maharashtra	1,000-1,500	38-40
PSFH 67	Punjab	1,000-1,500	40-42
PKVSH 27	Maharashtra	900-1,100	38-40

**Improved Varieties / Hybrids :**

Sr. No.	Varieties	Features
1	LSH-1	Downy mildew resistant, rainfed
2	LSH-2	Downy mildew resistant, rainfed
3.	LS-11	High yielding having high oil content
4.	SS-56	Suitable for rainfed conditions, oil content 32-35 %
5.	Bhanu	Tolerant to drought, oil content 35-36 %
6	Phule Raviraj (Hybrid)	Oil content 34 %, big head size with central filling head, tolerant to bud necrosis and alternaria
7	Bhaskar	Early maturing, high yield, oil content 37-38 %, dark black shiny seeds.
8	PKVSH952	92-95 days duration, Black seeded, 38-40 % oil (seeds), with 15-18 q/ha yield potential.

**EXERCISE NO. 5**  
**EMASCULATION AND HYBRIDIZATION TECHNIQUES**  
**IN POTATO AND BERSEEM**

**POTATO**  
(*Solanum tuberosum*)

<b>Botanical name</b>	:	<i>Solanum tuberosum</i>
<b>Family</b>	:	Solanaceae
<b>Genus</b>	:	<i>Solanum</i>
<b>Chromosome no.</b>	:	$2n = 4x = 48$

**Cultivated species :**

Potato is the most useful and important member of the family Solanaceae and it belongs to genus *Solanum*. Genus *Solanum* consists of seven cultivated and about 154 wild species but the commercially viable potato has only two species :

**1) *Solanum andigenum* :**

The plants of this species are characterised with thin and long stems, small and narrow leaflets having profuse flowering and long stolons. The tubers are mostly covered with deep sunken eyes on them. The yielding potential is very low and therefore, it is not very common type.

**2) *Solanum tuberosum* :**

The potato cultivated the world over is an autotetraploid species, *S. tuberosum*. This species is divided into two sub species viz. ssp. *tuberosum* (cultivated throughout the world) and spp. *andigena* (confined to the hills of South America). In addition, diploid ( $2n=24$ ), triploid ( $2n=36$ ) and pentaploid ( $2n=60$ ) forms are also cultivated in Peru and Bolivia.

**3) *Solanum demissum* and *Solanum stenotomum*** are two more species which are somewhat important as they are resistant to some types of virus and disease but they are also not in cultivation commercially.

**Flowering in potato :**

The potato requires long day lengths (around 16 h), abundant rainfall, and cool temperature to flower. Under most normal growing conditions, the day length in the early part of the season will favour constriction of the stem, and grafting of young potato shoots onto tomato or other compatible *Solanaceous* plants. Among the cultivars currently used for breeding, selecting for increased flowering and seed set does not cause reduced tuber yield. Flowering and tuber yield are uncorrelated as are berry or seed set and tuber yield.

**Crossing Techniques :**

Flower buds that are mature are selected for emasculation just prior to crossing. It is particularly important to emasculate just prior to crossing if pollinations are done in the fields the wind can break off the stigmas before pollination occurs if they are emasculated too far ahead of pollination. Mature buds are plump, with the petals ready to separate. The remaining buds and opened flowers in the bunch are removed to facilitate emasculation of the selected buds and prevent contamination of the emasculated flowers by the open flowers. There is a limit to the number of flowers from an inflorescence that will set fruit / seed, so removing the extra flowers increases the chances that the pollination will be successful. The petals of the selected flowers are gently pushed apart along the sutures and the five stamens removed with fine-pointed forceps without breaking the style. The emasculated flowers are then bagged.

Inserting a branch with one or two leaves into the bag helps in maintaining a humid climate inside the bag. In fully self-sterile parents, emasculation is unnecessary.

Pollination can be done at any time of the day as long as the temperature is not too high. Open flowers are collected from the plant to be used as a male. The flowers are laid out to dry overnight. The following morning the pollen is collected from them by shaking into gelatine capsules such as those used in the pharmaceutical industry (other small tubes can also be used). For large quantities of flowers, the pollen is shaken out by placing the flowers in the top section of a sieve, and the sieve is then shaken at high speed. The pollen falls through and is collected in the smaller capsules or tubes for storage. For smaller quantities of flowers, a modified toothbrush or doorbell buzzer is used to vibrate the pollen free. The flowers are inverted over glassine paper and the vibrating portion of the toothbrush or buzzer is touched to the anthers. The pollen falls onto the slick paper and is then transferred into the capsules or tubes. Pollen can be stored desiccated in the refrigerator for 1 – 2 weeks and in the freezer for 6 months to a year. To make the pollination, the stigma is dipped in the pollen in the capsule or tube, and then the pollination tag is attached and the bag is placed over the flower and left on until the fruit is harvested. Setting of seed may be observed in about 7 – 10 days. Average seed set per berry varies with the cultivar, but levels of 50 – 200 seed per fruit may be obtained.

#### **Breeding objectives of potato**

1. Tuber yield
2. Maturity
3. Heat, frost and drought resistance.

#### **Breeding for disease / pest resistance**

1. Root knot nematode
2. Aphids are serious
3. Colorado potato beetle.

#### **Breeding for improved quality**

Potatoes are either consumed directly or they are processed. The amount of potatoes used for processing is increasing. Processed potatoes have various uses, including being used in the fast-food industry, made into snacks, used as a starch source, and for alcohol production, among other uses. High quality is an important breeding objective because it has direct relationships to consumer acceptance higher premium in the marketplace. Some of the desirable features of high tuber quality include good keeping quality, medium size, good grading, good shape, proper colour, no cracks, flatness of the eyes, and proper skin texture, among others. Cultivars differ markedly in the ability to be stored. Thick-skinned potatoes have better keeping qualities than thin-skinned potatoes. Keeping quality is associated with non-sprouting and resistance to storage diseases. Cultivars differ in their cooking qualities, some requiring prolonged cooking, while others cook easily. Freedom from after-cooking darkening is also desirable. White tubers are preferred to red ones and they sell at higher prices in most markets.

#### **True potato seed**

Breeders have long sought to increase potatoes by seed. The production of potato from true potato seed (TPS) has several advantages compared to tubers, including.

- Production of virus free stocks as viruses are generally not transmitted by seed.
- Reduce storage problems because refrigeration of TPS is not necessary.

- Lower shipping costs for TPS.
- Easier shipping of TPS because 100 g TPS will seed a hectare while 2,000 kg of seed tubers are needed to seed the same area and
- Consumption of all tubers produced, as none need to be saved for next years seed crop.

The objective of TPS is to have completed homogeneous progeny. This can best be accomplished by the use of  $4x$  families from  $4x \times 2n$  crosses, where the  $2x$  parent produces  $2n$  gametes. It is important that both parents be adapted to the area where the homogenous progeny are going to be grown. Studies have shown that higher seeding vigour and tuber yields resulted from this approach compared to progeny produced from  $4x \times 4x$  crosses or progeny obtained from open pollinated seed.

#### Improved Varieties / Hybrids :

Variety	Year of release	Salient features and adaptability
Kufri Chipsona 1	1997	Medium-maturing, resistant to late blight and excellent for processing, North India plains
Kufri Chipsona 2	1997	Medium-maturing, resistant to late blight and excellent for processing, Uttar Pradesh and Bihar
Kufri Giriraj	1997	Medium to late maturing and resistant to late blight, North western hills
HT/92-61	2003	Hybrid, heat tolerant, resistant to leaf hopper and mites, high dry matter content, suitable for making French-fries
JW160	2003	White hybrid, having field resistance to late blight, excellent keeping quality
MS/92-2105	2003	Red skinned, high-yielding hybrid, oval attractive tubers, field resistance to late blight
SM/87-185	2003	Late-blight resistant, white tuber hybrid with high dry matter content and better keeping quality

## BERSEEM (*Trifolium alexandrium*)

<b>Botanical name</b>	:	<i>Trifolium alexandrium</i>
<b>Family</b>	:	Leguminosae
<b>Genus</b>	:	<i>Trifolium</i>
<b>Sub-family</b>	:	Faboideae
<b>Chromosome No.</b>	:	2n = 16

### Cultivated species :

Berseem, known as king of fodder crops, is popular among livestock farmers of the world. It belongs to the clover group and internationally famous as Egyptian Clover. Botanically it is known as *Trifolium alexandrinum* L. Berseem is one of the oldest cultivated clovers, domesticated in Egypt and later introduced into many other parts of the world. Berseem belongs to the family leguminosae and genus *Trifolium* which consists of nearly 290 species as most important forage legumes. The most important species for forage and pasture are berseem (*Trifolium alexandrium*), Shaftal (*T. resupinatum*), White clover (*T. repens*), Red clover (*T. pratense*), Crimson clover (*T. incarnatum*), Alsike clover (*T. hybridum*) and Subterranean clover (*T. subterraneum*) etc.

### Origin :

Berseem is believed to be originated in Asia minor and from there it was introduced to Egypt. Because of its introduction from Egypt it is famous as Egyptian clover and it is gaining its increasingly importance as *rabi* crop.

Berseem doesn't have original wild forms.

### Botany :

It is a fast growing annual crop with 30-60 cm plant height. The stem is hollow and succulent. Both basal and /or stem branching is observed. Roots do not extend beyond two feet in general and contains nodules. It is sparingly hairy and commonly possess trifoliate, petiolate leaves. Leaves are membranous, oblong-elliptical to oblong-lanceolate and are arranged alternately except the uppermost leaf. Leaflets are mucronate at the apex and denticulate in. Inflorescence is head, terminally or auxiliary located and pedunculate with conical to ovoid in shape. There is a small involucre at the base of the head. Calyx tube displays ten prominent nerves while the corolla is almost double the height of the calyx. Each inflorescence contains around 100 papilionaceous flowers, white in colour with around 1cm length. At maturity each floret contains one single seed. Seeds are solitary and small in size. Seed is egg shaped, yellowish in colour and is of around 2mm in length. In berseem white coloured flowers are produced in cluster which are hermaphrodite in nature with five fused sepals and five free petals. The upper large petal which covers the rest of the petals in bud stage is called standard petal, while two bottom petals are fused together and formed a boat-like structure called the keel. The stamens are always ten in number and their filaments are fused in a group of 9+1. Berseem is a cross pollinated plant and is entomophilous in nature. Anthesis occurs in the morning hours which coincides with maximum pollinator activity, leads to seed setting.

Based on regeneration capacity and branching pattern three different ecotypes viz., Mescavi, Fahli and Saidi are reported in berseem. The mescavi type has very good regeneration potential and is capable of 5-6 cuts with basal or crown branching pattern and is

the most popular type with large number of varieties in India belong to this group. Fahli is a stem branching type with low regeneration potential and is suitable for single cut only. Saidi is having moderate regeneration capacity allowing 2-3 cuts and possess both basal and stem branching.

#### Achievements:

Sr. No.	Variety	Features
1	Mescavi	Varieties under this group develop short side branches at the base of the stem in advanced stage of its growth. When the plant is cut or harvested, these branches elongate and produce new growth. Therefore, it is possible to take 5-6 cuts per year from this group. Varieties : Wardan, JB-1, JB-2, JB-3, UPB-103
2	Fahl	Develop small side branches in the upper portion of the stem very freely. They do not produce branches at the base. Therefore, there is no regeneration of these varieties after harvest. They give only one cut.
3	Saidi	They develop shoots for a short time. Develops branches at upper portion less freely than in fahl. They give 2-3 cuts per year. Varieties :Khandwari, Pusa giant, ICFRI-99-1, IGFRI-54, Jawahar.

Diploid varieties like Meskavi, Fahali, Saudii, Zaidi, BL-1, BL-2, BL-10, BL-22, BL-30, BL-92, JB-3, JB-4, IGFRI-S-99-1, UPB-101, UPB-103, UPB-104, UPB-1905, and Khadrabi are very popular but newly evolved high yielding tetraploid varieties like Pusa Giant, T-526, T-724, T-780, T-529, T-560, T-561, T-674, T-678, T-730 etc. are very promising and give about 50 per cent higher fodder yield.

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## EXERCISE NO. 6

### EMASCULATION AND HYBRIDIZATION TECHNIQUES IN SUGARCANE AND COWPEA

#### SUGARCANE (*Saccharum spp.*)

**Family:** Gramineae  
**Genus:** *Saccharum*

#### **Cultivated species :**

There are three cultivated and two wild species of sugarcane. Their brief description is as follows (Rao *et. al.* 1983; Pursglove, 1988).

1. *Saccharum officinarum* ( $2n = 8x = 80$ )
2. *Saccharum barberi* ( $2n = 90, 92$ )
3. *Saccharum sinense* ( $2n = 116, 118$ ).

#### **Wild species :**

1. *Saccharum spontaneum* ( $2n = 40$  to  $128$ ).
2. *Saccharum robustum* ( $2n = 60$  to  $194$ ).

#### **Botany :**

**Induction of flowering.** Lack of flower induction and synchronization are barriers in sugarcane crossing programme. Flowering of sugarcane is rare in subtropics. Experiments of photoperiod requirements have indicated that sugarcane can be classified as intermediate day length plant (IDP) on the basis of initial induction and as short day plant (SDP) based on the development of the panicle and flowers. A dark period around 12.30 hr in general, has been found necessary for induction of flowering. Sites have been identified in India, Brazil, Barbados, Hawaii, Fiji, Indonesia and Philippines where most clones of sugarcane flower. In India Coimbatore has been chosen as the ideal place for natural profuse flowering and good seed setting in sugarcane clones. In varieties difficult to flower, exposing the plants to 4 hr extra- darkness in continuation of normal night for 6 – 8 weeks at the transformation stages has been found effective (Rao *et. al.* 1983). Synchronization of flowering between early and late flowering varieties is possible by manipulation of 4 hr extra darkness and 4 hr extra light.

#### **Floral biology :**

The inflorescence of sugarcane is an open, branched panicle and is called as an arrow due to its shape which is like an arrow. Flowering is seasonal and takes place when the day length decreases. In the northern hemisphere the flowering coincides with the onset of winter (Oct.-Nov.) and in the southern-hemisphere in May-June.

The spikelets open about sunrise, beginning at the top of the panicle and proceeding downwards and from the tips of the branches inwards, over a period of 5 – 15 days. Approximately  $1/6$  to  $1/10^{\text{th}}$  of the panicle opens each day. The swelling of the lodicules by water uptake causes the glumes to be pushed apart and the stigmas come out. The anthers dehisce about three hours after the elongation of the filaments. High humidity delays anthesis. Natural pollination is by wind.

**Crossing techniques :** Following techniques are used to facilitate convenient handling of the parents.

**Stalk preservation during crossing :**

The sulphurous acid technique is in generally use by sugarcane breeders. A sulphurous acid solution (1 part in 2000) keeps the inflorescence alive for several weeks. At the Hawaiian Sugarcane Planters Association (HSPA) Experiment Station, the solution used consists of 150 ppm SO<sub>2</sub>, 75ppm H<sub>3</sub>PO<sub>4</sub> and 375 ppm each of H<sub>2</sub>SO<sub>4</sub> and HNO<sub>3</sub> (Heinz and Tew, 1987).

**Marcotting :**

It was first used in India and now is used in many countries. Generally, a plastic sleeve containing a growth medium is secured about five to ten nodes above the bas of the stalk to induce rooting.

**Potted plants :**

For clones and species not responding to the sulphurs acid technique or marcotting, the sugarcane clones are grown in small containers.

**Crossing in field :**

This system is common in India. Pollen proof enclosures made of cloth (cloth lanterns) are used to cover the arrow of female and male parent before anthesis. Male arrow (which is also protected) is introduced into this lantern and it is shaken for 5 – 6 days once in a day.

The crossing may be done either with the arrows attached to the parent plants or with the arrows severed and transported to a central crossing area and maintained in living condition by means indicated above. Female and male arrows can be enclosed in a common lantern if they are planted close to each other.

**Breeding objectives :**

1. High cane yield.
2. Moderate high sucrose content
3. Early to full season maturity
4. Resistance to diseases.
  - a. Red rot (*Physalospora tucumanensis*)
  - b. Smut (*Ustilago scitaminea* Sydow).
  - c. Wilt (*Cephalosporium sacchari* Butler)
  - d. Mosaic (a viral disease)
  - e. Ratoon-stunting disease (caused by a bacteria)
  - f. Grassy – shoot disease
5. Resistance / tolerance to insect pests
  - a. Shoot borer
  - b. Cane borer
  - c. Pyrilla
  - d. Mealy bugs
  - e. Whiteflies
  - f. Termites
  - g. White grub
6. Tolerance to Aboitic stresses
  - a. Drought
  - b. Salinity
  - c. Flooding
  - d. High temperature

**Achievement :**

- i) Sugarcane breeding institute has been the source of germplasm and genetic variability for selection of varieties suited to different agro-climatic zones of the country. The spread of Co canes to foreign countries began when Co 285 was taken to Cuba and USA (Florida) for cultivation. Varieties bred at Coimbatore are / were being used in 28 other countries either for commercial cultivation or as parents. Co 419 released in 1933 became the most popular variety in tropical India and was rightly hailed as the wonder cane the world over.
- ii) Two outstanding varieties viz., Co 658 for Tamil Nadu and Co 740 for Maharashtra were released in 1940s. Co 740 continues to be cultivated in Maharashtra even now.
- iii) Co 997 and Co 1148, released during 1950s, became ruling varieties in Andhara Pradesh and North India respectively. Co 1148 remained the most predominate variety in sub-tropical region for over four decades.
- iv) Co 6304, a high yielder, became the most important variety in Tamil Nadu replacing Co 419.
- v) Varietal evaluation for juice quality conducted across seasons helped in the indemnification of high sucrose varieties viz. Co 7204, Co 7704, CoA 7601, CoC 671, Co 8336, Co 8338 etc.
- vi) Co 86249, an elite variety with resistance to red rot and high reasonability has been evolved by the Institute and notified for release in the East Coast zone, It is also serving as a source of resistance to red rot in the breeding programmes.
- vii) Co 86032 Combining high yield and quality evolved by the institute and identified by the AICRP (S) has been notified by the Central Sub-Committee on Crop Standards, Notification and Release of Varieties of Agricultural Crops and is occupying a major area in Tamil Nadu (90%), Karnataka, Maharashtra and Gujarat.

**Improved Varieties / Hybrids :**

Sr. No.	Variety	Features
1	Co-94012	14-16 duration months with 150 t/ha yield, Drought tolerant, non breaking of internode when lodge, high sugar 14.24 percentage, moderately resistant to smut and red rot.
2	Phule 265	14-16 months duration, 15-20 % higher sugar than Co86023, profuse tillering, easy for detrashing, suitable for saline soil, good ratoonability, moderately resistant smut, red rot and wilt.
3	Co-92005	Suitable for suru planting, 12-14 month duration, 128 t/ha yield capacity quality jaggery for high recovery with more market price, recommended for Western Maharashtra.
4	Phule 10001	Suitable for pre-season and suru cultivation, yielding 150 t/ha (pre-season), suru 133 t/ha, tolerant salinity, no pith formation, drought tolerant, excellent ratoonability early maturity, moderately resistant red rot, wilt and smut.
5	COM 09057	Non lodging, suitable for mechanical harvesting, 125-130 t/ha with best jaggery quality.
6	VSI 08005	Early, good ratoonability, 15-16 % sugar, 135-145 t/ha productivity, good jaggery quality.

## COWPEA

<b>Botanical name</b>	:	<i>Vigna unguiculata</i>
<b>Family</b>	:	Leguminosae
<b>Genus</b>	:	Vigna
<b>Species</b>	:	<i>unguiculata (sinense)</i>

**Chromosome No.** :  $2n = 2x = 22$

### Cultivated species :

Cowpeas belong to the botanical species *Vigna unguiculata* (L.) Walp. There are more than 20 synonyms for *V. Unguiculata*

Verdcourt (1970) subdivided *V. unguiculata* into five sub-species as.

<i>Unguiculata</i>	}	Cultivated species
<i>Cylindrica</i>		
<i>Sesquipedails</i>		
<i>Dekindtiana</i>	}	Wild species
<i>Mensensis</i>		

Marechal and Colleagues (1978) do not consider the three cultivated subspecies as distinct and grouped under one subspecies *V. unguiculata* subsp. *Unguiculata* and differentiate them by the intraspecific category 'cultigroup'.

### Crossing technique :

Cowpea flowers are large and showy. Mostly flowers open between 7 and 9 am. On cloudy days the flowers may open in the afternoon. Though the flowers open late in the morning, the dehiscence of the anthers is much earlier. It may vary from 10 pm to 0.45 am. The dehiscence is influenced by environmental factors like presence of moonlight, a clear sky and a dry warm atmosphere. During dark nights the dehiscence tends to be delayed. Due to dehiscence taking place before the opening of flowers, the cowpea is self-pollinated in nature.

Since the dehiscence of anthers is much in advance of the blooming, the emasculation needs to be carried out in mature flower buds in the preceding evening. The flower buds likely to bloom the next day (recognized by large size, the yellowish colour of the back of the standard petal) is selected for emasculation. The bud is held between the thumb and the forefinger with the keel side upper most. A needle is run along the ridge where the two edges of the standard unite. One side of the standards is brought down and secured in position with thumb. Same thing is done with one of the wings. After this the exposed keel is slit on the exposed side, about 1 / 16 inch from the stigma. A section of keel is also brought down and secured in position under the end of thumb. Now 10 stamens are seen. They are removed with pointed forceps. Afterwards, the disturbed parts of standard, wing and keel are brought in original position as far as possible. To prevent drying out of the emasculated bud, a leaflet may be folded and pinned around the bud. A tissue paper can be used to cover and protect the bud.

Pollination is done next morning from a freshly opened flower. The standard and wings of male flower are removed. By slight depression of the keel, stigma covered with pollen grains protrudes out. This itself can be used as a brush for pollination. Cowpea flowers

are highly sensitive and drop off easily with slight mechanical disturbance or injury. Therefore, much labour and time should be devoted to get enough crossed seed (Krishnaswamy, 1970).

Under improved techniques of Rachie *et al.* (1975), the time taken for both emasculation and pollination has been reduced substantially and the pod set has increased from 18.6 to 26.1 per cent. Mishra *et al.* (1985) noted parental selectivity in hybridization indicating that certain lines produce more pods and seeds/ pod when used as female parents.

#### **Breeding objectives :**

1. High green pod yield (vegetable type varieties)
2. High seed yield (dry-seed type varieties)
3. High fodder yield (fodder type varieties)
4. Dual purpose (seed and vegetable type and seed and fodder)
5. Earliness
6. Appropriate plant type (erect, determinate for vegetable and seed type cultivars and spreading type for fodder type cultivars).
7. Resistance to diseases.
  - a. Anthracnose (*Colletotrichum lindemuthianum*)
  - b. Cercospora leaf spot (*Cercospora cruenta*)
  - c. Powdery mildew (*Erysiphe polygoni*)
  - d. Fusarium wilt (*Fusarium oxysporum*)
  - e. Ascochyta blight (*Ascochyta phaseolorum*)
  - f. Bacterial blight (*Xanthomonas campestris*)
  - g. Bacterial pustules (*Xanthomonas phaseoli*)
  - h. Cowpea yellow mosaic virus.
8. Resistance to insects
  - a. Hairy caterpillar
  - b. Leaf hoppers
  - c. Aphids
  - d. Thrips
  - e. Bruchids
  - f. Pod borer
  - g. Pod sucking insects
9. Better seed quality (acceptable to consumers)  
Medium to large seed size, uniformly white / creamy / light red without black / brown scare around hilum.
10. Development of elite, high yielding 'Plant type' as a composite of following (Rachie and Rawal, 1976).
  - Tall vigorous plant
  - Deeply penetrating tap root
  - Lodging and shattering resistance
  - Low branching and or short branching
  - Narrow leaves
  - Short peduncles
  - Profusion of peduncles at nodes
  - Multiple podding of racemes
  - Long pods with many seeds
  - Weathering resistance pods and seeds
  - Medium or medium small seeds of good quality.

#### **Achievement :**

**Grain purpose varieties** : Pusa-152, Pusa Sawani (T-5269), CO.1, CO.2, CO.3, CO.4, K.11, K.14, RC.19

**Vegetable purpose** : Pusa Phalguni, Pusa Barsati, Pusa Do Fasli, Pusa Komal.

**Fodder purpose varieties** : Rassian Giant, T2, EC4216, K-391 and Cowpea-4.

Fodder purpose varieties at IGFR Jhansi : Bundela Lobia-1, Bundela Lobia-2

**Improved Varieties / Hybrids :**

Sr. No.	Varieties	Features
1	Phule Pandhari (PCP 9708)	High yielding, short duration, Erect growth habit
2	Phule Vithai (PCP 05040)	High yielding, Indeterminate, off white, kidney shape seeds, Early, Dark purple flower colour
3	Phule Rukmini (PCP 0306-1)	High yielding, Indeterminate, Pearly white, Kidney shape seeds, Early, Erect growth habit.

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**EXERCISE NO. 7**  
**EMASCULATION AND HYBRIDIZATION TECHNIQUE IN**  
**SAFFLOWER**

**SAFFLOWER**  
(*Carthamum tinctorius*)

<b>Family</b>	: Compositae
<b>Genus</b>	: <i>Carthamum</i>
<b>Species</b>	: <i>Tinctorius</i>
<b>Chromosome Number</b>	: $2n = 2x = 24$

**Cultivated species:**

*Carthamum tinctorius* L ( $2n = 2X = 24$ )

**Wild Species**

*C. palaestinus*  
*C. oxycantha*  
*C. lanatus*  
*C. flavescens*

**Origin:**

Safflower has been grown for many centuries from Egypt in north Africa eastward to India. Safflower is believed to have two centers of origin, Ethiopia & Afghanistan.

**Botany:**

It is annual, erect herb having spreading type of branching. Stem is cylindrical, slightly ribbed with spiny leaves. Leaves are simple, oblong to lanceolate. Their margin is spiny and incised. Main stem terminates into flowering head called capitulum. Inflorescence is of racemose type called head or capitulum without ray florets. The whole capitulum is surrounded by number of overlapping, green, leaf like serrated (Mostly spiny) structures called bracts which collectively known as involucre. Single capitulum may contain 20 to 200 disc florets.

Disc florets are sessile, tubular and mostly bisexual. The calyx is rudimentary. Corolla is epigynous with 5 petals united (Gamopetalous) to form a tube. Upper expanded portion of corolla is called limb, which is having different colours like yellow, orange, red or white depending upon variety. It changes its colour after fertilization. Stamens are five, in syngenious condition having hairy filaments and are epipetalous. Pistil is bicarpellary and syncarpus with inferior ovary (Unilocular) having long bifid hairy stigma. After fertilization, ovule is converted into dry indehiscent, cypsela type fruit.

**Flowering:**

It is often cross-pollinated crop. Marginal florets open first followed by florets in central (centripetal order). It is completed within 1 to 5 days. The opening of florets takes place in the morning hours between 9 to 10 a.m. The style elongates and stigma emerges from corolla tube. At the same time, corolla opens and anthesis takes place. However, hairy portion of style is still within tube.

**Breeding objectives:**

- 1) High seed yield of oil contents
- 2) Wide adaptability
- 3) Development of early and non-spiny varieties
- 4) Tolerance / Resistance to
  - A) Diseases
    - i) Wilt
    - ii) Leaf spot (particularly alternaria)
    - iii) Rust
    - iv) Powdery mildew
  - B) Pest
    - i) Gujea weevil
    - ii) Aphids
    - iii) *Heliothis armigera*
    - iv) Hairy caterpillar
    - v) Capsule
    - vi) Army worm
- 5) Tolerance to abiotic stresses:
  - i) Moisture stress (drought)
  - ii) Thermo-insensitiveness i.e. for extreme temperatures
- 6) Development of appraisal type genotypes (to accommodate more plant population)
- 7) Development of stable GMS lines
- 8) Improvement in oil quality

**Crossing Technique :****Emasculation:**

Emasculation is done in previous day of anthesis in evening. The selected parents are raised in crossing block. The selected capitulum is labeled and bagged. At the time of emasculation, first involucre bracts are clipped off and disc florets are exposed. Generally one marginal whorl of florets, which is likely to open on same day, is kept on disc and other florets are nipped off. The anther tube surrounding the stigma and style is punctured carefully at the base and slit is opened upward. This helps to remove entire column along with surrounding corolla. During emasculation, some pollens may shed in the emasculated flower which are removed by rinsing the florets with jet of water or 57 per cent alcohol and then rinsed by water. The required numbers of florets are emasculated and head is properly bagged and labeled.

**Mass emasculation:**

Hand emasculation is time consuming and causes injury to florets as a result of which seed setting is poor. For mass emasculation, cut off free laminae of involucre bracts and cover capitulum with plastic bag and tie it till opening of flowers (in case of open capitulum, the anthers dehiscence coincides with the elongation of style so that stigmas are covered with pollen of same floret during anthesis). In this method, plastic bag prevents anthesis of flower due to increased humidity inside bag. Receptive stigma of such flowers is immediately pollinated by desired pollens just after removing polythene bag. Continue this procedure for 2 to 3 consecutive days for complete pollination. Then remove plastic bags within a week.

**Pollination:**

Pollen grains from desired selfed male parents are collected in petridish and dusted over the stigma of the emasculated flowers on next day morning i.e. 9 to 10 a.m. Sometimes, male capitulum (shedding pollens) are also used for pollination by hand repeat pollination for 1 to 3 times for effective crossing. Then the head is bagged and properly labelled after every pollination.

**Achievements:**

- 1) Pure line selection: N7, N 62-8, Bhima (81), Manjira
- 2) Pedigree selection after hybridization: Tarea Annegiri 1, Girna
- 3) Development of Commercial hybrids by using GMS: DSH 129

**Improved Varieties / Hybrids :**

Sr. No.	Variety	Features
1	Bhima	Moderately tolerant to aphid and fusarium wilt, oil content 29-30 %, tolerant to moisture stress.
2	Girna	Moderately tolerant to aphid and Fusarium wilt, oil content 28-30 %.
3	Phule Kusuma	Moderately tolerant to aphid, oil content 30 %
4	Phule Chandrabhaga	Moderately tolerant to aphid, oil content 29 %
5	SSF-658 (Non spiny)	Moderately tolerant to aphid and Fusarium wilt, oil content 28 %
6	Sharda (PBN-12)	High yielding, tolerant to drought Fusarium wilt and aphids.

**Assignment :**

- 1) Dissect the floral parts of given sample and mount them on black mounting paper. Draw the figures and label properly.
- 2) Practice hybridization technique in field and laboratory on given sample.

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## EXERCISE NO. 8

### HANDLING OF GERMPLASM AND SEGREGATING POPULATIONS BY DIFFERENT METHODS LIKE PEDIGREE, BULK AND SINGLE SEED DECENT METHODS

#### 1) PEDIGREE METHOD :

The pedigree may be defined as a description of the ancestors of an individual and it generally goes back to some distant ancestor or ancestors in the past.

In Pedigree method, a detailed record of the relationship between the selected plants and their progenies is maintained. Individual plants are selected from  $F_2$  and subsequent generations and their progenies are tested. During the entire operation a record of all the parent offspring relationship is kept. This is known as a Pedigree record. Individual plant selection is continued till the progenies do not show segregation.

#### Maintenance of pedigree record:

Generally each cross is given a number, the first two digits of this number refer to the year in which the cross is made and remaining two digits denote the serial number of the cross in that year viz. e.g. 9914 denoted the cross number 14 of the year 99.

Individual plant progenies in each generation are assigned row numbers corresponding to their location in the plot. In addition each progeny in  $F_4$  and subsequent generations is assigned the row number of the progeny in the previous generation from which it was derived the procedure is outlined below.

Generation	Number	Description
$F_3$	9914-7	Progeny in the 7 <sup>th</sup> row in the $F_3$ plot
$F_4$	9914-7-4	Progeny in the 4 <sup>th</sup> row in $F_4$ plot selected from 7 <sup>th</sup> row of the $F_3$ plot
$F_5$	9914-4-14	Progeny in the 14 <sup>th</sup> row in $F_5$ plot selected from progeny in the 4 <sup>th</sup> row in the $F_4$ plot
$F_6$	9914-14-3	Progeny in the 3 <sup>rd</sup> row in $F_6$ plot selected from progeny in the 14 <sup>th</sup> row in the $F_5$ plot.

#### Procedure of Pedigree method

##### Hybridization:

The selection of parents to be used in a cross is the most important step in breeding programme during hybridization. The selected parents are crossed to produce a simple or complex cross.

##### $F_1$ generation:

$F_1$  seeds are space planted so that each  $F_1$  plant produces the maximum  $F_2$  seed. Generally 15-30  $F_1$  plants are raised.

##### $F_2$ generation:

In  $F_2$  2000-10000 plants are space planted to facilitate selection. About 100-500 plants are selected and their seeds are harvested separately.

**F<sub>3</sub> generation:**

Individual plant progenies are space planted. Each progeny should have about 30 or more plants. Individual plants are selected with superior characteristics. The number of plants selected in F<sub>3</sub> should be preferably less than the number of F<sub>2</sub> selection. If number of superior progenies is small the whole cross may be rejected.

**F<sub>4</sub> generation:**

Individual plant progenies are space planted. Desirable plants are selected mainly from superior progenies. The number of plants selected in F<sub>1</sub> is generally much lower than the number of F<sub>4</sub> progenies. Progenies with defects and undesirable characteristics are rejected. Emphasis is given on selection of desirable plants from superior progenies.

**F<sub>5</sub> generation:**

Individual plant progenies are generally planted according to the recommended spacing. Three or more rows are grown for each progeny to facilitate comparison among progenies. Many families may have become reasonably homozygous and may be harvested in bulk. The number of progenies must be reduced to a size manageable in preliminary yield trials, which is usually of 25-100 progenies.

**F<sub>6</sub> generation:**

Individual plant progenies are planted in multi row plants and evaluated visually. Progenies are harvested in bulk, since they would have become almost homozygous. Progenies showing segregation may be eliminated. Preliminary yield trials may be planted for these reasonably homozygous progenies which are and have enough seed. Inferior progenies are eliminated based on yield data from preliminary yield trial or visual evaluation.

**F<sub>7</sub> generation:**

Preliminary yield trial with three or more replications is conducted to identify few superior lines. Standard commercial variety must be included as a check for comparison.

**F<sub>8</sub> to F<sub>10</sub> generation:**

Superior lines are tested in replicated yield trials at several locations for two to five years. The line superior to best check in yield and other characteristics would be recommended for release of new variety.

**F<sub>11</sub> generation:**

The breeder usually multiplies its seed during its last year of trial when a strain is likely to be released as a variety. Thus in F<sub>11</sub> and F<sub>12</sub> seed is multiplied for distribution to the farmers.

**Assignment :**

Draw schematic representation of the pedigree method of handling the segregating generation

## **2) BULK METHOD OF BREEDING**

**Bulk Method:**

In the bulk method F<sub>2</sub> and subsequent generations are harvested in mass or as bulks to raise the next generations. At the end of bulking period individual plants are selected and

evaluated in similar manner as in the pedigree method. In this method artificial selection is not practiced.

**Procedure:**

**Hybridization:**

Parents are selected according to the objectives of the breeding programme. Simple or complex crosses are made depending on the number of parents involved.

**F<sub>1</sub> generation:**

F<sub>1</sub> is space planted and harvested in bulk. The number of F<sub>1</sub> plants should be as large as possible usually more than 20 plants should be grown.

**F<sub>2</sub> to F<sub>6</sub> generation:**

F<sub>2</sub> to F<sub>6</sub> are planted at commercial seed rates and spacing. These generations are harvested in bulk. Artificial selection is not done. The population size should be as large as possible in each generation, i.e. 30 to 50 thousand plants.

**F<sub>7</sub> generation:**

About 30 to 50 thousand plants are space planted and about 1000 to 5000 plants are selected with superior phenotype and their seed is harvested separately. Selection is based on phenotype of plants, grain characteristics, disease resistance etc.

**F<sub>8</sub> generation:**

Individual plant progenies are grown in single or multi row plots. Most of the progenies would be reasonably homozygous and are harvested in bulk. Weak and inferior progenies are rejected on the basis of visual evaluation. Only 100 to 300 plant progenies are selected with desirable characteristics.

Preliminary yield trial is conducted. Standard commercial varieties are used as checks. The yield is used as basis of selection of superior progenies. Quality test may be conducted.

**F<sub>10</sub> to F<sub>12</sub> generation:**

Replicated yield trials are conducted over several locations using standard commercial varieties as checks. The lines are evaluated for important characteristics in addition to yield i.e. disease resistance, quality etc. If a line is superior to the standard varieties in yield trials, it would be released as a new variety.

**F<sub>13</sub> generation:**

The seed of the released variety is increased for distribution to the cultivators.

### 3) SINGLE SEED DESCENT METHOD (Modification of bulk method)

In this method a single seed from each of the one to thousand F<sub>2</sub> Plants is bulked to raise the F<sub>3</sub> generation. Similarly, in F<sub>3</sub> and subsequent generations one random seed is taken from every plant present in the population and planted in bulk to raise the next generation. This procedure is followed till F<sub>5</sub> or F<sub>6</sub> when the plants would have become nearly homozygous. In F<sub>5</sub> or F<sub>6</sub> a large number of individual plants are selected and individual plant progenies and the number of progenies is sufficiently reduced to permit replicated trial in the next generation. Individual plants may be selected only from outstanding families showing segregation. Thus, preliminary yield trials and quality tests being conducted in F<sub>7</sub> or F<sub>8</sub> and co-ordinated yield trials in F<sub>8</sub> or F<sub>9</sub> generations.

The objective of the single seed descent method is to advance the generation of crosses rapidly. At the end of the scheme a random sample of homozygous or merely homozygous genotypes lines is obtained. F<sub>2</sub> and subsequent generations are grown at very high plant densities as vigour of plant is not important. In each year 2-3 generations may be raised using off season nurseries and green house facilities.

The important features of single seed descent method are :

Lack of selection, natural or artificial till  $F_5$  or  $F_6$  when the population is reasonably homozygous.

Raising of  $F_5$  and later generations from a bulk of one seed from each  $F_2$  and subsequent generations.

**Assignment :**

Draw the diagrams of scheme for Bulk method of Breeding & single seed descent method

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**EXERCISE NO. 9****STUDY OF FIELD TECHNIQUES FOR SEED PRODUCTION AND  
HYBRID SEED PRODUCTION IN *RABI* CROPS****Selection of Appropriate field :**

Selection of appropriate field is the key to success of a seed production programme. The field should be such that it enables the seed crop to express all the passport traits uniformly in all the individual plants of the crop. Passport traits are those traits that form the basis of unambiguous identification of the variety concerned. This is possible when the field is ideal for the crop and does not exhibit heterogeneity with respect to various gradients, such as, Fusarium wilt of legumes, the field soil must be free from these pathogens. The field for seed production should not be deficient in mineral nutrients or suffer from mineral toxicity as these may influence seed yield and quality. For example, deficiency of boron is known to cause sterility in cereals and 'hallow heart' abnormality in pea seed. The field should also be free from weed seeds; this would not only facilitate crop cultivation, but would also ensure seed purity. In general the seed crop should be planted in a clean, fertile and problem free field in an area for which the variety is recommended.

**Sowing a class of improved seed :**

After the land is suitably prepared, a class of improved seed (nucleus, breeder, foundation) is sown following the recommended method. As a rule, the class of seed sown is one time higher than the class of seed targeted for production, except in extraordinary situations when a stage I seed can be used to produce the stage II seed of the same class. The row-to-row spacing is kept such that there is enough space for movement in the field for rouging, inspection, etc. In case of breeder seed plots, where seed drills are used one row space is left blank between two runs of the seed drill.

**Maintenance of recommended isolation :**

Isolation literally means keeping the seed production plots aloof from other fields of the same crop. Seed production plots should be located at such a distance that there is no risk of contamination by pollen from the neighbouring fields; the contamination in a seed plot by volunteer plants; of mixture with seed transported by birds or water; of contamination through cross-fertilization by wind borne pollen. A volunteer plant is a plant of the same crop that has arisen from seed dropped in the field from the crop grown during the previous crop season. Isolation is not only important for maintaining genetic purity, but is also necessary for controlling seed-borne disease, such as loose smut of wheat and barley (caused by *Ustilago tritici* and *U. nuda*, respectively) and dwarf bunt of wheat (caused by *Tilletia species*).

Isolation between seed plots can be effected by distance (*spatial isolation*) or time (temporal isolation). The distance used for isolation largely depends on the distance that can be travelled by the pollen from the contaminating source to cause a significant level of contamination. Thus it is decided by the mode of pollination and sometimes on the velocity and the direction of prevailing wind. Adoption of distance isolation is relatively easy in self-pollinated crops, where isolation distance is few meters. In cross-pollinated crop the isolation distances are generally in the range of few hundred meters (Table) therefore, it is not easy to practice space isolation in these crops. The isolation distance also depends on the type of seed class to be protected by isolation as well as the nature of the material from which isolation is sought. For example, the isolation distance for nucleus and breeder seeds are much more stringent than for the seeds of later generations. *viz.*, foundation and certified seeds.

**Minimum seed certification standards of certified seed of some crops**

Crop	Seed	Isolation (m)	Purity (%)	Germination (%)	Moisture (%)	Weeds / kg
Wheat	Pure lines	3	98	85	12	5
	Hybrids	100	98	85	12	5
<i>Rabi</i> Sorghum	OPVs	100	98	75	12	10
	Hybrids	200	98	75	12	10
Pea	Pure lines	5	98	75	9	0
Rapeseed / mustard	Pure lines / OPVs	50	97	85	8	10
Sunflower	OPVs	200	98	70	9	0
	Hybrids	400	98	70	9	0
Potato	Potato seed	50	98	80	8	10

When space isolation is not possible, time isolation can be used. In case of time isolation, different sowing is done so that anthesis in a seed field does not coincide with that in the other fields. Obviously, the flexibility in time isolation is determined by the length of the crop season. In almost all crops, late sowings are not admissible due to yield reductions and greater chance of occurrence of biotic and abiotic stresses.

When both time and space isolations are not possible, mechanical barriers may be used. Mechanical barrier is generally achieved by growing thick stands of fast growing crops having greater height e.g., *Sesbania* in the case of hybrid rice. Occasionally, use of walls or artificial barriers like cloth or plastic sheets may also be used.

Before the emergence of seed technology, what was considered to be adequate isolation was solely based on practical experience. With expansion in knowledge, experimental evidence was accepted as the basis for such decisions. For example, in the case of wheat, the earlier recommendation for isolation distance was three meters. But experiments suggested that in case of loose smut infestation, the appropriate isolation distance should be 150 meters. In general, the greater the isolation distance, the smaller is the possibility of contamination. However, it is difficult to achieve complete isolation for seed plots of a given variety in the crop production regions of a crop. Therefore, seed production plots are so isolated as to keep level of contamination below the prescribed minimum for the concerned seed class.

### **Appropriate Male : Female Ratio**

Male : female ratio is relevant only in the case of hybrid varieties where the  $F_1$  seed (that is to be used for commercial crop production) is the result of cross-pollination between two parents. In such cases, only the female parent (which is mostly genetically emasculated) bears the hybrid seed; it is, therefore, harvested separately. Further, yields of hybrid seeds are lower than from fields where the whole populations are harvested, e.g., in the case of pure line, synthetic, etc., varieties; this is one of the reasons for the higher cost of hybrid seeds. In order to minimize the seed cost male : female ratio is generally kept in favour of the female parent. The male : female ratio is decided on the basis of experimental investigations, and may be 1 : 1, 1 : 2, 1 : 3, 2 : 4

**Commonly used male : female ratio in the hybrid seed production of some crops.**

<b>Crop</b>	<b><i>Male : female ratio</i></b>
Maize	1 : 2, 2 : 4, 2 : 6
Rice	1 : 4, 2 : 10, 2 : 8
Cotton	1 : 2
Pearl millet*	2 : 4, 2 : 10, 2 : 16
Sorghum	2 : 4

\* varies from hybrid to hybrid

**Following recommended agronomy**

Seed production must be done following the recommended package of agronomy for the concerned crops. Beginning from sowing through fertilizer application, irrigation, weed and pest control and till harvest, the field crop condition must be maintained around the optimum. This would not only enable a seed grower to harvest the maximum possible yields, but would also reduce the environmental effects and genotype x environment interactions that create undesirable variability in plant populations. A uniform application of package of practices helps in the detection of off-types facilitating their rouging, and helps in satisfying field inspection requirements. An uneven or variable plant population cannot be critically inspected for genetic purity, hence is considered unfit for seed production.

**Field inspection**

Field inspection refers to the scrutiny of seed production plots by a team of qualified persons. The primary objective of field inspection is to ensure that the seed production pertains to the designated variety and that it has not been contaminated genetically physically beyond certain specified maximum limits. Field inspections also ensure that the steps necessary to minimize genetic and physical contamination have been taken properly and in time to make them effective. The aims of field inspections are fulfilled by verifying the following about the seed crop.

1. It has been raised from such seed whose source is approved.
2. It has been grown in a field area, which satisfies the prescribed land requirements.
3. In case of hybrids, the planting is as per the prescribed male : female ratio.
4. The prescribed isolation or border rows (in case of hybrids) have been provided.
5. Seed crop has been properly rouged to remove off-types, objectionable weeds and inseparable other crop plants so as to conform to the maximum limits of standards prescribed for these factors.
6. The crop is true to the varietal characteristics descriptive of the concerned variety.
7. The seed crop is harvested properly to avoid mechanical admixture.
8. The disease incidence, particularly of specified disease, is below the maximum permissible limits.
9. The crop complies with such other special requirements that may be specified for the crop concerned.

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## EXERCISE NO. 10

### ESTIMATION OF HETEROSIS, INBREEDING DEPRESSION AND HERITABILITY

#### Introduction :

Heterosis refers to the superiority of  $F_1$  hybrid in one or more characters over its parents. In other words, heterosis refers to increase in fitness and yield over parental values. Heterosis is also called as hybrid vigour. There are three possible genetic causes of heterosis, viz. dominance, over dominance & epistasis. Out of these causes, dominance is widely accepted. In crop plants, there are three main ways of fixing heterosis, viz. asexual reproduction, apomixis and polyploidy.

Heterosis is estimated in four ways, viz. (1) over mid parent, (2) over better parent, (3) over commercial cultivar, and (4) over commercial hybrid(check). These are called as average heterosis, heterobeltiosis, useful heterosis (economic heterosis) and standard heterosis, respectively; Standard heterosis is estimated in those crops where hybrids are already available for comparison. Various types of heterosis are estimated as follows:

1. Mid-parent heterosis	$= \frac{F_1 - MP}{MP} \times 100$
2. Heterobeltiosis	$= \frac{F_1 - BP}{BP} \times 100$
3. Useful or economic heterosis	$= \frac{F_1 - CC}{CC} \times 100$
4. Standard heterosis	$= \frac{F_1 - SH}{SH} \times 100$

Where,

$F_1$	= Mean value of a particular cross
$Mp$	= Mean of two parents involved in the cross
$BP$	= Mean Value of better parent of a cross
$CC$	= Mean value of a commercial cultivar
$SH$	= Mean value of Standard (check) hybrid.

In plant breeding, useful and standard heterosis has direct practical significance. Positive heterosis denotes the excelled performance of hybrid suggesting increased value of particular character eg. + ve heterosis for grain yield, fruits/tree, branches /tree etc.indicates high yielding ability of hybrid over parents. Where as, Negative heterosis shows reduced performance of hybrid as compared to parents. Such type of – ve heterosis is useful where we want the hybrid should have reduced performance for particular character viz. dwarfness, earliness in flowering /maturity etc.

**Inbreeding depression:** - Inbreeding depression refers to decrease in fitness and vigour in  $F_2$  due to inbreeding (mating plants with similar genetic constitution) Inbreeding depression is estimated when both  $F_1$  and  $F_2$  populations of the same cross are grown simultaneously. It is estimated with the help of following formula.

$$\text{Inbreeding depression} = \frac{F_1 - F_2}{F_1} \times 100$$

Where  $F_1$  = Mean value of  $F_1$  Cross  
 $F_2$  = Mean value of above  $F_1$  cross in  $F_2$  generation

**Solved Problems****Problem –1**

In rice, grain yields (q/ha) of parents (P1 and P2), their  $F_1$  and  $F_2$  progenies are given below:

Parent 1	Parent 2	$F_1$ Hybrid	$F_2$ Progeny
18.94	22.69	29.38	15.18

Calculate average heterosis, heterobeltiosis and inbreeding depression.

**Solution:**

$$\text{Mid-Parent heterosis} = \frac{F_1 - MP}{MP} \times 100$$

Here, Value of  $F_1$  = 29.38

$$\begin{aligned} \text{Mean of Parents (MP)} &= \frac{18.94 + 22.69}{2} \\ &= 20.81 \end{aligned}$$

$$\begin{aligned} &= \frac{29.38 - 20.81}{20.81} \times 100 \\ \text{Heterosis} &= 41.12\% \end{aligned}$$

$$\begin{aligned} \text{Heterobeltiosis} &= \frac{F_1 - BP}{BP} \times 100 \\ \text{Better Parent Value} &= 22.69 \end{aligned}$$

$$\begin{aligned} &= \frac{29.38 - 22.69}{22.69} \times 100 \\ \text{Heterobeltiosis} &= 29.48\% \end{aligned}$$

$$\begin{aligned} \text{Inbreeding depression} &= \frac{F_1 - F_2}{F_1} \times 100 \\ &= \frac{29.38 - 15.18}{29.38} \times 100 \\ &= 48.33\% \end{aligned}$$

**Answer :**

Average heterosis = 41.12%  
 Heterobeltiosis = 29.48%  
 Inbreeding depression = 48.33%

**Problem for exercise:****Problem- 1**

In Tur, yield data per plant (g) for parents (P1 and P2), their  $F_1$  and  $F_2$  progeny, and for a commercial cultivar and hybrid are given below.

P1	P2	F <sub>1</sub>	F <sub>2</sub>	Check Cultivar	Check hybrid
50	40	90	35	70	80

Calculate useful heterosis, standard heterosis and inbreeding depression.

### Problem -2

2. (a) Define heterosis.
- (b) Estimate useful Heterosis and standard Heterosis from the following data of yield per plant (g) in Nagli.

Parent 1	Parent 2	F <sub>1</sub>	F <sub>2</sub>	Commercial Check	Commercial Hybrid
45.5	56.2	110.4	50.6	65.0	85.5

### Problem 3 :

What will be the yield of F<sub>2</sub>, when Inbreeding Depression is 39.77 per cent and the grain yield of F<sub>1</sub> is 24.68 g/plant?

### Problem 4:

Work out the yield of F<sub>1</sub>, when heterobeltiosis is 67.80 per cent and grain yield of better parent is 52.45 g/plant

### Problem 5:

Explain the genetic reason for reduced yield in F<sub>2</sub> generation as compared to F<sub>1</sub>.

## ESTIMATION OF HERITABILITY

### Introduction:

Heritability is an index of the transmission of characters from parents to their offspring. Heritability is of two types, viz. broad sense heritability and narrow sense heritability. Broad sense heritability is the percentage ratio of genotypic variance to the phenotypic variance, whereas narrow sense heritability is the ratio of additive variance to the phenotypic variance.

### Broad Sense Heritability

The broad sense heritability, from different materials, is estimated in different ways. From replicated data of several genotypes, heritability is calculated as follows:

$$\text{Heritability (bs)} = \frac{V_G}{V_P} \times 100$$

Where, V<sub>G</sub> = genotypic variance, V<sub>P</sub> = Phenotypic variance

From generation mean analysis, the heritability is worked out with the help of following formula

$$\text{Heritability (bs)} = \frac{VF_2 - VF_1}{VF_2} \times 100$$

Where,  $VF_1$  = Variance of  $F_1$  progeny  
 $VF_2$  = Variance of  $F_2$  progeny

### Narrow Sense Heritability

It is also calculated in different ways from different breeding materials and biometrical techniques.

#### From Diallel Analysis :

The following formula is used for calculation of heritability (ns).

$$\text{Heritability (ns)} = \frac{\frac{1}{2}D + \frac{1}{2}H_1 - \frac{1}{2}H_2 - \frac{1}{2}F}{\frac{1}{2}D + \frac{1}{2}H_1 - \frac{1}{4}H_2 - \frac{1}{2}F + E} \times 100$$

Where,  $D$  = Variance due to additive effect of genes  
 $H_1$  = Variance due to dominance effect of genes

$H_2 = H_1 [1 - (u - v)^2]$ , where  $u$  and  $v$  are proportion of positive and negative genes in the parents.

$F$  = the mean of  $Fr$  over the array, where  $Fr$  is the covariance of additive and dominant effects in a single array.

$E$  = Expected environmental component of variance

Verhalen and Murray (1969) proposed the following formula for calculation of heritability from  $F_2$  generation of a diallel cross.

$$\text{Heritability (ns)} = \frac{\frac{1}{4}D}{\frac{1}{4}D + \frac{1}{16}H_1 - \frac{1}{8}F + E} \times 100$$

#### From Partial Diallel Analysis

The heritability is calculated by the following formula:

$$\text{Heritability (ns)} = \frac{2V_{gca}}{2V_{gca} + V_{sca} + V_E} \times 100$$

Where,  $V_{gca}$  = Variance due to general combining ability  
 $V_{sca}$  = Variance due to specific combining ability  
 $V_E$  = Error variance.

#### From Line X Tester Analysis

The heritability is calculated by the following formula:

$$\text{Heritability (ns)} = \frac{V_{gca}}{V_{gca} + V_{sca} + V_E} \times 100$$

#### From Generation Means

Mather (1949) and Warner (1952) have suggested separate method of calculating heritability from generation means as given below:

$$\text{Heritability (ns) as per Mather (1949)} = \frac{D}{D + H + E} \times 100$$

Where, D = Additive variance

H = Dominance variance, and

E = Error variance

$$\text{Heritability (ns) as per Warner (1952)} = \frac{\frac{1}{2} D}{V F_2} \times 100$$

Where

$V F_2$  = Variance of  $F_2$  generation

### Solved Problems

#### Problem –1

In Pigeonpea, 33 genotypes were evaluated for grain yield in RBD with three replication and following mean square values were obtained for genotypes and error:

MSS treatments (genotypes) = 16.47, MSS error = 2.83,  $\bar{X}$  = 11.68

Find out the value of heritability

#### Solution :

First we have to calculate genotypic and phenotypic variances as follows:

$$\begin{aligned} \text{Genotypic Variance (V}_G\text{)} &= \frac{\text{MSS tr} - \text{MSS e}}{\text{Replication}} \\ &= \frac{16.47 - 2.83}{3} \\ &= 4.547 \end{aligned}$$

$$\begin{aligned} \text{Phenotypic Variance (V}_P\text{)} &= V_G + V_E \\ &= 4.547 + 2.830 \\ &= 7.377 \end{aligned}$$

$$\text{Heritability} = \frac{V_G}{V_P} \times 100$$

$$\text{Heritability} = \frac{4.547}{7.377} \times 100$$

$$= 61.64\%$$

$$\text{Heritability (bs)} = 61.64\%$$

#### Problem – 2

In a 8 x 8 diallel cross of cotton, following parameters were obtained for fibre length

D	H <sub>1</sub>	H <sub>2</sub>	F	E
6.47	3.39	2.86	2.00	0.61

Calculate heritability in narrow sense.

**Solution :**

From diallel analysis, heritability is estimated with the help of following formula:

$$\begin{aligned}
 \text{Heritability (ns)} &= \frac{\frac{1}{2}D + \frac{1}{2}H_1 - \frac{1}{2}H_2 - \frac{1}{2}F}{\frac{1}{2}D + \frac{1}{2}H_1 - \frac{1}{4}H_2 - \frac{1}{2}F + E} \times 100 \\
 &= \frac{\frac{6.47}{2} + \frac{3.39}{2} - \frac{2.86}{2} - \frac{2.00}{2}}{\frac{6.47}{2} + \frac{3.39}{2} - \frac{2.86}{4} - \frac{2.00}{2} + 0.61} \times 100 \\
 &= \frac{4.93 - 2.43}{4.93 - 1.715 + 0.61} \\
 &= \frac{2.500}{3.825} = 65.36\%
 \end{aligned}$$

**Problem –3**

Genotypic and phenotypic variances and covariances of two characters (x and y) are given below:

$$GV_x = 3.252, PV_x = 5.044, G \text{ Cov } xy = 1.657$$

$$GV_y = 4.728, PV_y = 5.520, P \text{ Cov } xy = 2.142$$

Calculate heritability of X and Y

**Solution:**

$$\begin{aligned}
 \text{Heritability of X} &= \frac{GV_x}{PV_x} \times 100 \\
 &= \frac{3.252}{5.044} \times 100 \\
 &= 64.47\% \\
 \text{Heritability of Y} &= \frac{GV_y}{PV_y} \times 100 \\
 &= \frac{4.720}{5.520} \times 100 \\
 &= 85.51\%
 \end{aligned}$$

**Problem – 4**

Following estimates were obtained from generation mean analysis

$$VF_1 = 0.051, VF_2 = 0.218, D = 0.084$$

Calculate heritability in broad sense and narrow sense.

**Solution:**

$$\begin{aligned}
 \text{Heritability (bs)} &= \frac{VF_2 - VF_1}{VF_2} \times 100 \\
 &= \frac{0.218 - 0.051}{0.218} \times 100 \\
 &= \frac{0.167}{0.218} \times 100 \\
 &= 76.60\%
 \end{aligned}$$

$$\begin{aligned}
 \text{Heritability (ns)} &= \frac{\frac{1}{2}D}{VF_2} \times 100 \\
 &= \frac{\frac{0.084}{2}}{0.218} \times 100 \\
 &= \frac{0.042}{0.218} \times 100 \\
 &= 19.26\%
 \end{aligned}$$

**Problem – 5**

Calculate broad sense heritability from the following estimates obtained from generation mean analysis .

$$D = 0.842, H = 1.465, E = 0.072$$

**Solution:**

$$\begin{aligned}
 \text{Heritability} &= \frac{D}{D + H + E} \times 100 \\
 &= \frac{0.842}{0.842 + 1.465 + 0.072} \times 100 \\
 &= \frac{0.842}{2.379} \\
 &= 35.39\%
 \end{aligned}$$

**Problem – 6**

The following estimates were obtained from a diallel analysis

$$V_{gca} = 381.26, V_{sca} = 147.43, V_e = 3.65$$

Calculate heritability in narrow sense.

**Solution:**

The following formula is used for calculation of heritability (ns) from above estimates obtained either from diallel cross or partial diallel cross.

$$\begin{aligned}
 \text{Heritability} &= \frac{2 V_{gca}}{2 V_{gca} + V_{sca} + V_e} \times 100 \\
 &= \frac{2 (381.26)}{2 (381.26) + 147.43 + 3.65} \times 100 \\
 &= \frac{762.52}{762.52 + 147.43 + 3.65} \times 100 \\
 &= \frac{762.52}{913.6} \times 100 \\
 &= 83.46\%
 \end{aligned}$$

### Problem – 7

In Rice, following estimates were obtained for Line X Tester analysis.

$$V_{gca} = 34.15, V_{sca} = 12.27, V_e = 0.32$$

Calculate heritability in narrow sense.

### Solution:

The following formula is used for estimation of heritability from above estimates obtained from line X tester analysis.

$$\begin{aligned}
 \text{Heritability} &= \frac{V_{gca}}{V_{gca} + V_{sca} + V_e} \times 100 \\
 &= \frac{34.15}{34.15 + 12.27 + 0.32} \times 100 \\
 &= \frac{34.15}{46.74} \times 100 \\
 &= 73.06\%
 \end{aligned}$$

### Problem –8

In a study, following estimates of genotypic, environmental, dominance and epistatic variances were obtained for a character.

Variance Estimates	$V_G$	$V_E$	$V_D$	$V_I$	$V_P$
	160	240	40	15	400

Calculate heritability in narrow sense.

### Solution

The following relationship is observed in variances

$$\begin{aligned}
 V_P &= V_G + V_E \\
 V_G &= V_A + V_D + V_I \\
 V_G &= 160, V_E = 240, V_D = 40, V_I = 15 \\
 V_P &= 160 + 240 + 400
 \end{aligned}$$

$$\begin{aligned}
 160 &= V_A + 40 + 15 \\
 \text{or } V_A &= 160 - 55
 \end{aligned}$$

$$= 105$$

$$\begin{aligned}\text{In narrow sense heritability} &= \frac{V_A}{V_P} \times 100 \\ &= \frac{105}{400} \times 100 \\ &= 26.25\end{aligned}$$

**Ans.** Heritability (ns) = 26.25%

### Problem For Exercise :

1. (a) Define broad sense heritability.  
(b) Analysis of variance was performed with 33 genotype of Tur tested in Randomized Block Design with 3 replications and following values of mean squares were obtained for test weight.  
MSS (genotype) = 16.55, MSS (error) = 2.40, X = 41.70  
Calculate heritability and genetic advance.
2. (a) Define narrow sense heritability.  
(b) In cotton, following, parameter were obtained from a 8 x 8 diallel cross for lint index

D	H <sub>1</sub>	H <sub>2</sub>	F	E
0.41	0.39	0.23	0.21	0.09

Find out heritability in narrow sense.

3. (a) Define heritability.  
(b) Calculate heritability from the following statistics.  
VG x = 7.12, VP x = 8.42 VG y = 0.130, VP y = 0.150
4. (a) Define heritability  
(b) From generation mean analysis, following values of D, H and E were obtained. Calculate heritability in narrow sense.  
D = 0.263, H = 0.481, E = 0.024
5. (a) Define generation mean analysis  
(b) From generation mean analysis, the following estimates were obtained  
D = 0.036, VF<sub>1</sub> = 0.074, VF<sub>2</sub> = 0.154  
Calculate heritability in broad sense and also in narrow sense
6. (a) Define Partial diallel  
(b) Following estimates were obtained from partial diallel analysis  
V<sub>gca</sub> = 1.46, V<sub>sca</sub> = 1.18, V<sub>e</sub> = 0.14  
Calculate heritability in narrow sense.
7. (a) Define Line x tester cross  
(b) In blackgram, following estimates were obtained from Line X tester analysis. V<sub>gca</sub> = 16.72, V<sub>sca</sub> = 42.16, V<sub>e</sub> = 1.42  
Calculate heritability in narrow sense.
8. (a) Define additive variance  
(b) Calculate heritability from the following estimates of genotypic, environmental, dominance and epistatic variances for ear length in corn.

Variance	VG	VE	VD	VI
Estimates	210	190	60	25

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**EXERCISE NO. 11****LAYOUT OF FIELD EXPERIMENTS****Techniques in conducting field trials:**

The proper conduct of field trials is of major interest to the plant breeder. In his search for a new variety the breeder usually finds it necessary to grow a very large assortment of experimental strains. Most of the strains will be inferior in some respects. If their undesirable features can be recognized, they may immediately be eliminated from further consideration. In ordinary practice, the procedure is first to grow large numbers of new strains, which have a limited seed supply, in small observation plots where the breeder evaluates their maturity, height, lodging, disease resistance, and other characteristics including over-all vigour. From these visual observations the breeder selects what appears to him to be the superior strains. The superior strains are then grown in replicated field trials to determine more accurately their potential performance, including yield, in comparison with standard commercial varieties. Since replicated field trials are more expensive to conduct, fewer strains are tested in them in comparison with the very large number of strains that may be grown in the preliminary observation nurseries. Even when outstanding experimental strains are encountered, their yield superiority over the best commercial varieties will generally be small. This need to measure small yield differences accurately is most important in advanced trials in which only elite strains are being tested. By this time the breeder might have already eliminated the strains those were found grossly inferior by the observation in nurseries and in preliminary yield trials.

**Nursery vs. Field Plots.**

Nursery plots are small. Single or multiple row plots in which varieties of field crops are grown for observation or yield trials. The size of the plots will vary with the crop, the amount of seed available, and the nature of the observations which the breeder expects to make. The nursery plot is used when (a) the seed supply of the strain is limited, and when (b) a large number of strains are to be tested.

Field plots are of such size and shape that they may be planted and cultivated with standard farm implements. Usually, field plots vary from 1/10 to 1/100 acre in size. Field plots more closely related actual field conditions than do nursery plots. They are valuable as observation plots, because their size makes it easy for the breeder to make visual observations of the performance of a variety. They are useful for making preliminary seed increase. Field plots require more seed and are more expensive for testing a given number of varieties than are nursery plots. In general, field plots are used only for testing a few elite experimental strains and standard varieties, after the superiority of a strain or variety has been demonstrated in nursery plots.

**Principles in Plot Technique:**

The purpose of conducting variety performance trials is to measure comparative yields, maturity, height, lodging, disease resistance, and other characteristics of varieties and experimental strains of particular crop.

In order to have accurate results, the experimenter must follow careful and proven procedures that are uniformly carried out with all the strains included in the test and he must eliminate personal bias in recording notes and in interpreting the data.

**Soil variability:**

The variation in the soil is one of the important sources of error in field plot trials. Even in small plots the soil may differ in fertility, drainage and texture and plants of similar variety growing within a few feet of each other may perform differently. Previous soil treatments often leave residual effects that affect the growth of the succeeding crop.

Therefore, experimental site used for performance trials should be selected carefully considering topography, drainage, fertility, previous treatments and uniformity. It is often helpful to observe the uniformity of the preceding crop before selecting the exact area to be used for a performance trial. Generally, plots that are long and narrow will most effectively sample the soil variations, if the long dimension of the plot is in the direction of the gradient in soil fertility.

**B) Competition and Border Effect:**

Plants of different varieties in adjacent rows compete for the soil moisture and plant nutrients. A vigorously growing variety may adversely affect the performance of a variety in an adjacent row, especially if moisture or nutrients are limited. Tall growing varieties may shade shorter varieties in adjacent rows. The performance of varieties growing in adjacent rows may also be affected by differences in maturity, lodging or type of growth. To reduce the error resulting from competition between varieties, it is a common practice to plant nursery yield tests in three- row plots and harvest only the center row, or to plant four-row plots and harvest two center rows. To eliminate border effect, it is common practice to plant along sides of the plots several rows of standard variety which are discarded before harvest. Ends of the plots are also discarded before harvest.

**Replication:**

The recorded yield of a plot is always subject to some error in the conduct of yield trials. Depending upon the extent and the direction of the error, true yield of an individual plot will be either larger or smaller than the recorded yield. If the error is due to chance, it may be expected that the yield of different individual plots of the variety will fluctuate around the true yield. If the yields of several plots of the variety are averaged, the chance fluctuations will be less. For this reason, the mean yield of several plots of a variety is a better estimate of the true yielding ability of a variety than the yield of a single plot. The number of times a treatment (variety) is repeated in an experiment is commonly referred to as the number of replications. This may range from design of the experiment, the accuracy desired in the yield data, and the amount of land and seed available. In most standard yield trials, either four or five replications are planted. Replication is necessary to sample effectively the variations in soil fertility. Replication provides the means for experiment. Adequate number of replications are used for performance trials that are harvested for yields.

**Location and Seasonal Variation:**

Varieties perform differently in different locations and in different seasons. On fertile lands with adequate soil moisture throughout the growing season, early varieties may be out yielded by the late varieties. In another situation, where moisture is a limiting factor at the end of the season, the early varieties may yield more than late varieties. Or consider the yield of two adapted varieties of wheat, one resistant to black rust and the other susceptible. In a season without rust damage, the susceptible variety might out yield resistant but in a severe rust damage, resistant variety would out yield than susceptible.

**.Assignment :**

Give Diagrammatic representation of field plot designs.

## MAINTENANCE OF RECORDS & REGISTERS

### Keeping accurate records / registers:

Plant breeder does evaluate thousands of strains to select for desirable characters, to be tasted during another season. Detailed records of such selections are made in various records. Unless these records are complete and accurate, the breeder will be unable to evaluate the performance of the breeding materials..

Every breeder has his own system of record-keeping. However, an efficient system of record-keeping should possess the following requisites:

**1. Completeness:** The breeder should be able to identify from his record the parentage of particular strains as well as their current performance. The notes recorded on performance will vary with the crop, but generally they should include such observations as height, lodging, relative earliness of maturity, reaction to prevailing diseases or pests, and over-all vigour. If a yield test, they will also include yield and quality evaluation of the grain, fibre, or forage. Special identifying characteristics may be desirable to note, even though they have little or no relation to performance.

**2. Accuracy:** Most important requirement of any experiment is accuracy in observations and the manner in which they are recorded. Accuracy in making observation comes with experience and careful attention to details. Notes recorded in a clear, legible manner will reduce the number of errors. Field notes are usually taken with a pencil of moderate hardness to prevent smearing and should be made in hard bound notebooks.

**3. Simplicity:** Any system of record-keeping should be simple in its operation. Otherwise the breeder will bog down in the detail of its upkeep and will fail to maintain up-date records. The record system should be sufficiently simple for the breeder or any of his helpers to be able to maintain it and to interpret the notes recorded.

### Precautions to breeder in taking notes :

1. Every row or plot in the nursery should be easily and accurately identified by a row or plot number. This is easily done by dividing blocks into ranges and by following a uniform system of numbering ranges and rows (or plots). i.e., all plots within a block may be numbered by starting from a certain corner, say the northwest, and proceeding from left to right.

2. Adequate plot markers should be placed on a plot quickly and easily. Rows may be marked at regular intervals, and if groups of related materials are planted together, a separate marker may be set to identify the first row of each group.

3. Crosses and advanced strains may be given permanent accession numbers. Each cross may be identified by a separate number, and selections from these crosses may be numbered so as to identify the year or generation selected. All strains advanced into yield should receive permanent accession numbers.

4. Permanent records may be recorded on standard notebook forms that are easily summarized. For yield tests, printed field notebook forms may be used with appropriate column headings, according to the date to be recorded.

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**EXERCISE NO. 12****STUDY OF QUALITY CHARACTERS, STUDY OF DONOR PARENTS  
FOR DIFFERENT CHARACTERS****QUALITY BREEDING IN SOME IMPORTANT CROPS**

Quality refers to the suitability or fitness of an economic plant product in relation to its end use. The concept of quality breeding is complex and varies with the crop and its use. There is an urgent need to incorporate quality evaluation in breeding programmes.

Quality includes several features of a product. For example, in wheat grain quality consists of colour, shape, size and luster of grain; milling and baking qualities; and nutritional quality which includes protein content. Thus the quality is of three main types, viz. (1) Market quality (2) Industrial quality, and (3) nutritional quality.

**1. Market quality :**

The market quality refers to fitness of a product for marketing. It includes uniformity in shape, size, colour and texture in food and vegetable crops.

**2. Industrial quality :**

The industrial quality includes suitability for baking in wheat, malting in barley, crushing in sugarcane, canning in fruit crops, etc.

**3. Nutritional quality :**

The nutritional quality refers to the suitability or fitness of a plant product for human and animal consumption.

**Quality traits in some important crops :**

The genetic improvement of crop plants in relation to various quality attributes is referred to as quality breeding.

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

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

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

**3) Pulses :** In pulse crops attractive shape, size and colour of grains, high protein contents; high methionine and tryptophan, and less flatulence are desirable characters.

**4) Oilseeds :** In oilseed crops, attractive shape, size and colour of seeds, high oil content free from antinutritional factors and more proportion of unsaturated fatty acids are the important quality characters.

**5) Sugarcane :** Moderate hardness, long internodes, optimum (low) fibre for milling, sucrose ratio, high sucrose content and good quality of juice are desirable traits in sugarcane.

**6) Forage crops :** Greater nutritive value, more palatability and freedom from toxic substances are the desirable characters in forage crops.

Thus, quality differs according to economic use of plant 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.

### **Breeding methods :**

Breeding methods used for improvement of quality do not differ from methods used for any other character. Breeding methods used for improvement of quality traits include backcross, pedigree method, single seed descent, recurrent selection, progeny selection and mutation breeding.

### **Quality Assessment:**

The system for quality assessment in plant breeding programs should be quick, cheap and economical of material since plant breeder thousands of stocks each year, having limited time and limited material for testing.

#### **1) Organoleptic Characters:**

Effected to characterize flavours chemically have failed. So the breeder, aided by a taste panel looks at, smells and taste his fruits and vegetables and pulses and takes decisions. If material to be examined after processing, he will take care to standardize the preparation procedure as closely as possible.

#### **2) Chemical Quality Assessment:**

The emphasis of assessment of chemical quality is given on small scale and speed viz. In sugar plants sucrose content an optical measurement of total dissolved solids in juice (Brix) is sufficiently highly correlated with sucrose to be good enough for which refractometer is used while in barley, low protein content (in beer) and high extract of soluble (fermentable) oligosaccharides after malting are desired. Hence, nitrogen content and soluble carbohydrates after micro malting of few grains in vitro is enough than protein per se.

#### **3) Mechanical assessment of quality:**

The measuring of characters of fibers will predict the industrial performance of the product. The breeder use visual methods to some extent in cotton but relies mostly on various mechanical devices for measuring length, strength and fineness. He also considers maturity is a condition as well as a quality factor. Breeder should aim at a determined market standard.

#### **1. Biological Assessment of Characters :**

The quality objective of forage fodder breeding programmes are biological in character and would be met by testing animal growth. The chemical proxies for nutritional value are sought. Thus soluble carbohydrate content, fiber content and digestibility of fodder / forage crops is estimated **by chemical / physical methods.**

The industrial scale testing is generally essential before a new variety is marketed so wheat's are milled, barely malted, potatoes crisped, cotton spun, apples stored, strawberries Jammed and bananas shipped before final decisions are taken. However, instead of testing fodders by animal growth, in practice decision is taken on analysis basis.

## SOURCE OF DONAR PARENTS FOR DIFFERENT CHARACTERS

Sr. No.	Name of Crop	Name of cultivated and wild species	Salient features
1) WHEAT		<b>A) Cultivated species</b>	
		i) Bread Wheat <i>Triticum aestivum</i> L. Thell	
		ii) Durum wheat <i>Triticum turgidum</i> var. durum	
		iii) Dicoccum/Emmer wheat <i>Triticum turgidum</i> var. dicoccum	
		<b>B) Wild species</b>	
		i) <i>T. monococum</i>	Stem rust and Herbicide resistance
		ii) <i>A. curviflarum</i>	Resistance to leaf spot disease
		iii) <i>A. Squarrosa</i>	Resistance to Kermel Blunt. Higher tiller / plant grains / spike and bolder sedds.
		iv) <i>A. speltoides</i>	Heat tolerance
		v) <i>A. ovata</i>	High Protein content and kernel weight
		vi) <i>T. dicoccides</i>	Stripe rust resistance, powdery mildew resistance.
		vii) <i>T. timopheevii</i>	Cytoplasm shows stable male sterility after interaction with nuclear factor of <i>T. aestivum</i> , Improment in grain character.
2) SUGARCANE		<b>A) Cultivated species</b>	
		i) <i>S. Barberi</i>	
		ii) <i>S. Sinese</i>	
		iii) <i>S. Officinarum</i>	
		<b>B) Wild species</b>	
		i) <i>S. spontaneum</i>	High fibre content, perennial grass with free, tillering & often aggressive rhizomes, long internodes with waxy bloom. Resistance to moisture stress, diseases.
		ii) <i>S. robustum</i>	It is perennial. Grow upto 10m. Stems are hard & pithy in center & contain little juice. Inflorescence rachis is without long hairs. Resistance to water logging.
3) CHICK PEA		<b>A) Cultivated species</b>	
		i) <i>Cicer arietinum</i>	
		<b>B) Wild species</b>	
		i) <i>C. reticulatum</i>	Resistance to fusarium wilt, seed beetle, cold Ascochyte blight.
		ii) <i>C. bijugum</i>	Resistance to Ascochyte blight, cyst, nematode, seed beetle, cold.
		iii) <i>C. echinospermum</i>	Leaf minor, seed beetle, cold.
4) SUNFLOWER		<b>A) Cultivated species:</b>	
		i) <i>Helianthus annus</i> L.	

	<b>B) Wild species:</b>	
	<i>i) H. argophyllus</i>	Drought tolerance
	<i>ii) H. praecox</i>	Resistance to alternaria rust & downy mildew.
	<i>iii) H. giganteus</i>	Resistance to Sclerotia wilt.
	<i>iv) H. petiolaris</i>	Source for high oil content & for alteration of fatty acid composition, Cytoplasmic male sterility
	<i>v) H. debilis</i>	Source for salt tolerance
	<i>vi) H. tuberosus</i>	Source of resistance to leaf spot / blight, Downy mildew.
<b>5) SAFFLOWER</b>	<b>A) Cultivated species</b>	
	<i>i) Carthamus tinctorius L.</i>	
	<b>B) Wild species</b>	
	<i>i) C. oxyacantha</i>	For resistance to leaf spot disease.
	<i>ii) C. palaestinus Eig</i>	For seed dormancy & earliness (drought avoidance)
	<i>iii) C. palestinus</i> <i>C. flavescens</i>	For resistance to stem fly
	<i>iv) C. flavescens</i>	For cold tolerance
	<i>v) C. lanatus</i>	For resistance to rust.

**Chickpea :****Donors for different characters**

<b>Lines</b>	<b>Characters</b>
ILC 72., 196, 201, 202, 3279, 3346, ICC 8920, 8922, G 130, Caina, NEC 249, P 336, 6099, 6308.	Tall upright growth
ICC 364, 552, 4945, 4951, 8284, P 271, 311, 1482, JG 62.	Double pods
ICC 11520, 11521, 12206, 12208, 12212, 12213, NEC 989, P 99, 431, 1198-1, ILC 194, 306, 2484, 2552, 2647	Multiseeds
ILC 95, 96, 97, 99, 100, 101, 148, 149, T 3, K 850, Rabat, L 144.	Bold seed
<b>Multiple disease resistance</b>	
ICC 12237, 11269	<i>Fusarium</i> wilt, dry root rot, black root rot
ICC 1069	<i>Fusarium</i> wilt, Ascochyta blight, Botrytis gray mold
ICC 10466	<i>Fusarium</i> wilt, dry root rot, stunt
ICC 858, 959, 4918, 8933, 9001	<i>Fusarium</i> wilt, Sclerotinia stem rot
<b>Insect resistance</b>	
ICC 506, 1381, 4856, 5264, 6663, 7510, 7559, 7966, 10667, 10761, 10870	Pod borer
ILC 726, 1776, 2319, 2618	Leaf miner
G 109-1	Bruchids
P 636, H 208, PGM 442, BG 305, L 550, BG 405	Root rot nematode

Environmental stresses	
ICC 4973, 5003, 11514, BG 2, 209, 390, Ujjain 24, NP 57	Salt
ICC 4958, 10448, C 214, H 208, G 24	Drought
ILC 666, 668, 1071, 2487, 2505, 3081, 3287	Cold
Annigeri, 850-3/27, H 208	Heat
C 214	Frost

**Lentil :****Important donors for A lentil Breeding Programme**

Genotype	Source	Chief features
PL 406	Pantnagar	High yield, resistant to wilt and rust
Lens 830	IARI	Yield, earliness, drought tolerance
L 4076	IARI	Yield, adaptability
RAU 101	Dholi	Yield, adaptability
LG 231	Gurdaspur	Resistant to rust
LL 147	Ludhiana	Resistant to rust
PL 639	Pantnagar	Yield and resistant to rust
Sehore 74-3	Sehore	Yield and drought tolerance
L 3991	IARI	Drought tolerant
L 4163	IARI	Yield
JLS 1	Jabalpur	Drought tolerant and yield
LG 170	Gurdaspur	Yield
PL 77-2	Pantnagar	Wilt resistant
Vipasha	Pantnagar	Blight resistant
K 75	Kanpur	Yield

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### EXERCISE NO. 13

#### VISIT TO SEED PRODUCTION PLOTS

**Observations to be recorded by student :**

1	Name of the crop and variety	
2	State of seed production	
3	Name of Producer / Grower	
4	Isolation method and Isolation distance	
5	Area of the crop	
6	Season of the crop	
7	Source of seed a) Tag size b) Tag colour	
8	Expected date of harvesting	
9	Expected yield (kg/ha)	

#### Certification Plot

1	Address of the seed certification agency where registration of plot made	
2	Date of Registration	
3	Fee of registration	
4	Field inspection	
5	Name of certification officer	
6	Expected date of harvesting	
7	Expected yield (kg/ha)	
8	Location of purchasing nit / marketing	
9	seed packing Rate of 1.0 kg packed seed	
10	Rate of 1.0 kg packed seed	
11	Name of the Purchaser	

**EXERCISE NO. 14**  
**VISIT TO AICRP PLOTS OF SAFFLOWER AND CHICKPEA**

**A) SAFFLOWER**

**Observations to be recorded by student :**

1	Name of the crop	
2	Season of the crop	
3	Name of the trial	
4	Objectives	1. 2. 3.
5	Gross plot size	
6	Net plot size	
7	Spacing - Plant to plant	
8	Spacing - Row to Row	
9	Recommended Fertilizer dose	
10	Observations to be recorded	1. 2. 3. 4. 5. 6. 7. 8. 9.

**B) CHICKPEA****Observations to be recorded by student :**

1	Name of the crop	
2	Season of the crop	
3	Name of the trial	
4	Objectives	1. 2. 3.
5	Gross plot size	
6	Net plot size	
7	Spacing - Plant to plant	
8	Spacing - Row to Row	
9	Recommended Fertilizer dose	
10	Observations to be recorded	1. 2. 3. 4. 5. 6. 7. 8. 9.

**EXERCISE NO. 15**  
**VISIT TO AICRP PLOTS OF SUNFLOWER AND *RABI* SORGHUM**

**A) SUNFLOWER**

**Observations to be recorded by student :**

1	Name of the crop	
2	Season of the crop	
3	Name of the trial	
4	Objectives	1. 2. 3.
5	Gross plot size	
6	Net plot size	
7	Spacing - Plant to plant	
8	Spacing - Row to Row	
9	Recommended Fertilizer dose	
10	Observations to be recorded	1. 2. 3. 4. 5. 6. 7. 8. 9.

**B) *RABI* SORGHUM****Observations to be recorded by student:**

1	Name of the crop	
2	Season of the crop	
3	Name of the trial	
4	Objectives	1. 2. 3.
5	Gross plot size	
6	Net plot size	
7	Spacing - Plant to plant	
8	Spacing - Row to Row	
9	Recommended Fertilizer dose	
10	Observations to be recorded	1. 2. 3. 4. 5. 6. 7. 8. 9.

## SYLLABUS

<b>Course :</b>	GPB 366		<b>Credit:</b>	2(1+1)	<b>Semester-VI</b>
<b>Course title:</b>	Crop Improvement- II ( <i>Rabi crops</i> )				

**Theory**

Centers of origin, distribution of species, wild relatives in different cereals; pulses; oilseeds; fodder crops and cash crops; vegetable and horticultural crops; Plant genetic resources, its utilization and conservation; study of genetics of qualitative and quantitative characters; Major breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, adaptability, stability, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional); Hybrid seed production technology of *rabi* crops. Ideotype concept and climate resilient crop varieties for future.

**Practical**

Floral biology, emasculation and hybridization techniques in different crop species namely Wheat, Oat, Barley, Chickpea, Lentil, Field pea, Rajma, Horse gram, Rapeseed Mustard, Sunflower, Safflower, Potato, Berseem. Sugarcane, Tomato, Chilli, Onion; Handling of germplasm and segregating populations by different methods like pedigree, bulk and single seed decent methods; Study of field techniques for seed production and hybrid seeds production in *Rabi* crops; Estimation of heterosis, inbreeding depression and heritability; Layout of field experiments; Study of quality characters, study of donor parents for different characters; Visit to seed production plots; Visit to AICRP plots of different field crops

**Teaching Schedule****a) Theory**

Lecture	Topic	Weightage (%)
1	Cereals –Wheat, oat and barley - Centers of origin, Distribution of species, wild relatives, Floral biology, Major breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional)	10
2	Pulses –Chickpea- Centers of origin, Distribution of species, wild relatives, Floral biology, Major breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional)	8
3	Oilseeds –Sunflower and Safflower- Centers of origin, Distribution of species, Wild relatives, Floral biology, Major breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional)	10
4	Oilseeds –Linseed, Rapeseed and Mustard- Centers of origin, Distribution of species, wild relatives, Floral biology, Major	8

Lecture	Topic	Weightage (%)
	breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional)	
5	Fodders –Napier, Bajra, Sorghum, Maize and Berseem- Centers of origin, Distribution of species, wild relatives, Floral biology, Major breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional)	5
6	Cash -Sugarcane - Centers of origin, Distribution of species, wild relatives, Floral biology, Major breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional)	6
7	Vegetable-Potato- Centers of origin, Distribution of species, wild relatives, Floral biology, Major breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional)	5
8	Vegetable-Field pea- Centers of origin, Distribution of species, wild relatives, Floral biology, Major breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional)	5
9	Horticultural crops-Mango, Aonla and Guava- Centers of origin, Distribution of species, wild relatives, Floral biology, Major breeding objectives and procedures including conventional and modern innovative approaches for development of hybrids and varieties for yield, abiotic and biotic stress tolerance and quality (physical, chemical, nutritional)	8
10-11	Plant genetic resources, its utilization and conservation	8
12	Adaptability and stability	5
13- 14	Hybrid seed production technology in Rabi crops -Sunflower, Safflower, Castor, Rabi Sorghum	12
15 - 16	Ideotype concept and climate resilient crop varieties for future- Wheat, Rice, Maize, Sorghum and Cotton	10
	<b>Total</b>	<b>100</b>

**b) Practical**

Experiment	Exercise
1	Emasculation and hybridization techniques in wheat, oat & barley
2	Emasculation and hybridization techniques in chickpea & lentil
3	Emasculation and hybridization techniques in field pea, rapeseed & mustard
4	Emasculation and hybridization techniques in sunflower
5	Emasculation and hybridization techniques in potato & berseem
6	Emasculation and hybridization techniques in sugarcane & cowpea
7	Emasculation and hybridization techniques in safflower
8	Handling of germplasm and segregating populations by different methods like pedigree, bulk and single seed decent methods
9	Study of field techniques for seed production and hybrid seeds production in Rabi crops
10	Estimation of heterosis, inbreeding depression and heritability
11	Layout of field experiments
12	Study of quality characters, study of donor parents for different characters
13	Visit to seed production plots
14	Visit to AICRP plots of Safflower & Chickpea
15	Visit to AICRP plots of Sunflower & Rabi sorghum

**Suggested Readings:**

Sr. No	Title of Book	Author/Authors	Publisher
1.	Crop Breeding and Biotechnology	HariHar Ram	KalyaniPublication New Delhi.
2.	Breeding of Asian Field crops	D. A. Sleper J.M. Poehlman	Blackwell Publishers
3.	Principle and Procedures of Plant Breeding Biotechnological and Conventional Approach	G. S. Chahal S. S. Gosla	Narosa Publishers House. New Delhi.
4.	Plant Breeding Principle and Methods.	B. D. Singh	KalyaniPublication New Delhi.

**MAHATMA PHULE KRISHI VIDYAPEETH,  
RAHURI**

**College of Agriculture, \_\_\_\_\_**

**CERTIFICATE**

This is to certify that Shri / Miss .....  
Reg.No..... a student of **VI (New) Semester, B.Sc.  
(Hons.) Agriculture** has completed all the exercises successfully for the Course  
: Crop Improvement - II (*Rabi* crops), Course No. : **GPB - 366 (Credits 1 + 1  
= 2)** during Summer Semester 20 - 20 .

Place :

Date :

**COURSE TEACHER**