NAVSARI AGRICULTURAL UNIVERSITY

Manual for Practical Classes in

Ag. Econ 6.4 (2+1)

Farm Management, Production and Resource Economics

For B.Sc. (Hons.) Agriculture : VI Semester

Prepared by

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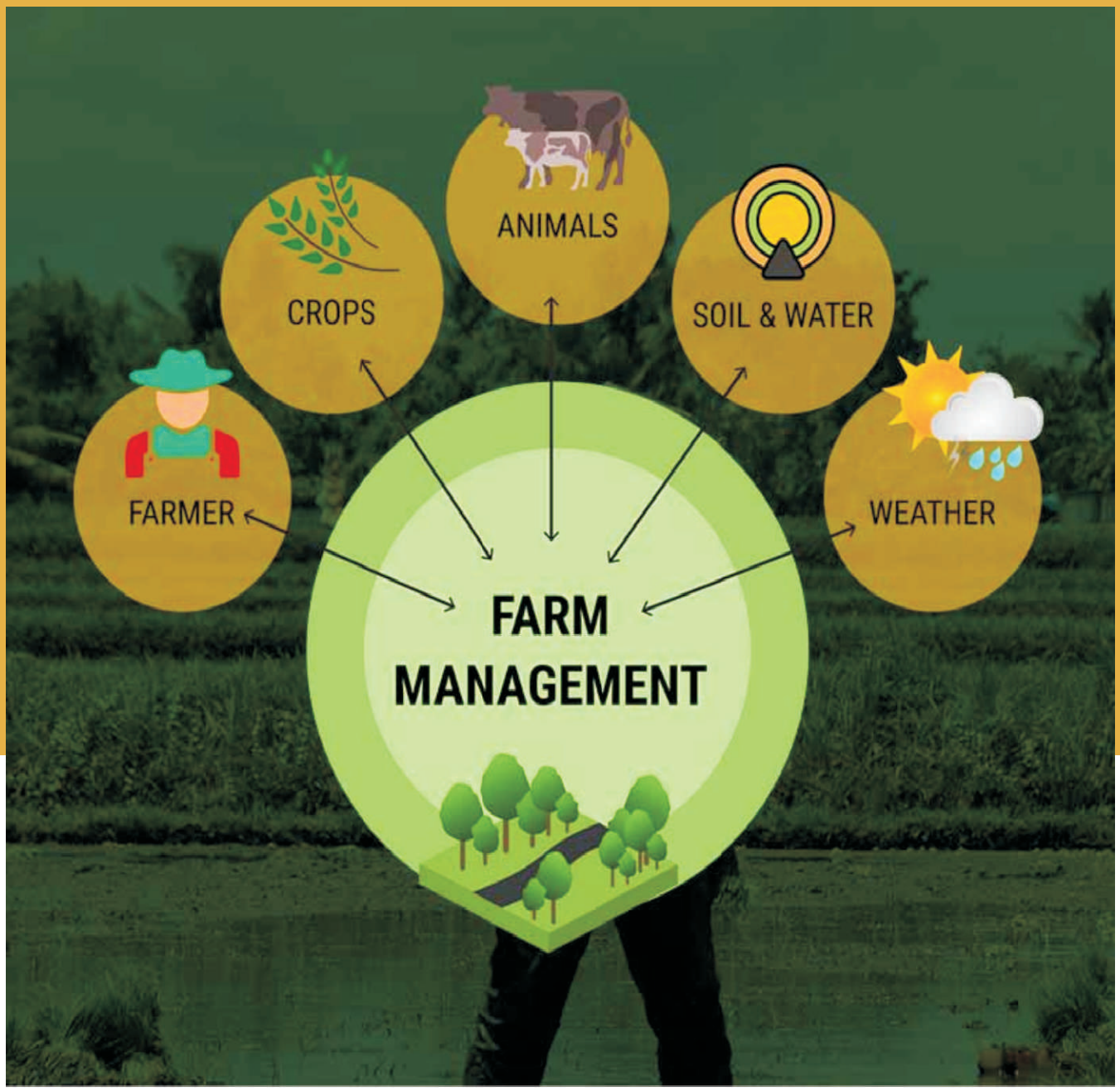
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NAVSARI AGRICULTURAL UNIVERSITY, NAVSARI

DEPARTMENT OF AGRICULTURAL ECONOMICS

College of Agriculture, NAU, Waghai - 394730

C E R T I F I C A T E

This is to certify that Mr./Miss_____

bearing Registration No._____of III B.Sc.(Agri.) student of this college has satisfactorily carried out the work assigned to him/her in the practical classes of the course Farm Management, Production and Resource Economics : **Ag. Econ – 6.4 (2+1)** in the Department during II Semester, 2019-20.

Date: **Course Teacher**

INSTRUCTIONS TO THE STUDENTS

1. Keep your manual neat and clean.
2. Use pencils to draw graphs, maps and figures.
3. Write references at the end of each practical.
4. Submit your manual for evaluation each time within prescribed date to avoid loosing of marks for late submission.
5. Do the exercise on your own. Copying from others/giving your manuals to others for copying may lead to loosing of marks.
6. Ensure that the assigned work/exercise is completed prior to submitting the manual for evaluation.
7. Attend remarks, if any after evaluation of each practical.

Course Teacher

CONTENTS

Date: **Practical - 1**

PRINCIPLE OF VARIABLE PROPORTIONS

Production may be defined as the transformation of inputs into output. In general, production means creation of utilities or addition of utilities in a commodity. In economic sense, production is not only creation of utilities, but also creates value for the products.

Production function is a mathematical relationship describing the way in which the quantity of output of a particular produce depends upon the quantities of a particular inputs used. Or it expresses the functional relationship between output and input. It can be expressed algebraically as:

$Y = f(X1, X2, X3 \ldots\ldots\ldots\ldots\ldots\ldots Xn)$

Where, Y = quantity of output

Xi = quantity of inputs

i = 1,2 ..... n

Three basic types of relationships in Production Economics are:

1. Factor - Product relationship (Principle of Variable proportions)
2. Factor-Factor relationship (Principle of Least-Cost Combination)
3. Product-Product relationship (Principle of Enterprise Combination)

Factor – Product relationship: There are three types of input-output relationships when only one input is varied and the quantities of all other inputs are fixed. They are:

a. Constant Marginal Rate of Return (CMRR) (constant productivity)

b. Increasing Marginal Rate of Return (increasing productivity)

c. Decreasing Marginal Rate of Return (decreasing productivity)

a. Constant productivity :

$$\frac{\Delta Y_1}{\Delta X_1} = \frac{\Delta Y_2}{\Delta X_2} = \frac{\Delta Y_3}{\Delta X_3} = \ldots\ldots\ldots = \frac{\Delta Y_n}{\Delta X_n} = K$$

Algebraic équation = $Y = a + bx$

Where,

Y = Output

a = Intercept

b = Accelerator (slope)

X = Input

K = Constant

In case of CMRR, the production function curve is a straight line/linear (graphically).

b. Increasing productivity:

$$\frac{\Delta Y_1}{\Delta X_1} < \frac{\Delta Y_2}{\Delta X_2} < \frac{\Delta Y_3}{\Delta X_3} \ldots\ldots\ldots < \frac{\Delta Y_n}{\Delta X_n}$$

The shape of the curve (production function) will be steeper and steeper with added inputs i.e. slope gets convex to the origin.

c. Decreasing productivity:

$$\frac{\Delta Y_1}{\Delta X_1} > \frac{\Delta Y_2}{\Delta X_2} > \frac{\Delta Y_3}{\Delta X_3} \ldots\ldots\ldots > \frac{\Delta Y_n}{\Delta X_n}$$

This is the technological law of biological responses and is applicable in almost all practical situations of agricultural production under varied situations. In this case of decreasing productivity the nature of production curve is concave to the origin.

Total product (TP): refers to the total number of units of output produced per unit of time by all factor inputs. i.e., TPP or Y or Q = f (X)

Average product (AP): is the ratio of the total product to quantity of the variable factor or input.

$$AP = \frac{Y}{X}$$

Marginal product (MP): is a measure of the rate of change in the total product to a unit change in the variable input.

$$AP = \frac{\Delta Y}{\Delta X}$$

Elasticity of production (E_p): is the ratio of proportionate change in output to proportionate change in variable input.

$$Ep = \frac{\Delta Y/Y \times 100}{\Delta X/X \times 100} \quad \text{Or} \quad \frac{\Delta Y}{Y} \times \frac{X}{\Delta X}$$

$$Ep = \frac{\Delta Y}{\Delta X} \times \frac{X}{Y}$$

$$= \frac{\Delta Y}{\Delta X} \times \frac{1}{Y/X}$$

$$= MPP \times \frac{1}{APP}$$

$$Ep = \frac{MPP}{APP}$$

If Ep = 1 indicates constant return

If Ep > 1 indicates increasing return

If Ep < 1 indicates decreasing return

The principle of Variable Proportions is mainly concerned with the behavior of the total production when only one productive resource is varied. If the quantity of one productive resource is increased by equal installments, the quantities of other productive resources remaining fixed, the resulting product will increase for a short period, then becomes constant and then will decrease. Thus, increasing, constant and diminishing returns may be regarded as various aspects of the principle of variable proportions as a movement towards or away from the optimum. This principle helps the farmer in deciding the optimum use of a single variable resource/input, keeping all other input levels fixed. This relationship can be expressed algebraically as,

$$Y = f(X_1/X_2, X_3 \ldots\ldots X_n)$$

Where, Y = output / total production, X_1 …… X_n = inputs.

Laws of returns: Laws of returns refer to the amount of extra output secured by adding additional doses of variable inputs to a fixed input. For instance, when we increase the quantities of capital and labour by keeping the quantity of land constant, the resulting total product may increase in a greater proportion than the increase in the quantities of other factors or exactly in the same proportion in which the quantities of other factors are increased or in a smaller proportion than the increase in the quantities of other factors. These three situations are called increasing returns, constant returns and diminishing returns respectively. These three situations are explained in the form of law known as Law of Diminishing Marginal Returns [LDMR].

Law of Diminishing Marginal Returns: Prof. Marshal states the law of diminishing marginal returns in the context of agriculture. “An increase in the capital and labour applied in the cultivation of land causes in general a less than proportionate increase in the amount of produce raised, unless it happens to coincide with an improvement in the art of agriculture”.

Following table (Hypothetical data) indicates the factor-product relationship and economic decisions analysis

	Physical relationships				Economic relationships				
	TP	**MI**	**MP**	**AP**	**MC**	**MR**	**TR**	**TC**	**NR**
Units of Input (N) per acre	**Total product per acre**	**Marginal input**	**Marginal product/ added output**	**Average product (col.2 ÷ col.1)**	**Marginal cost [@Rs.4/- per unit]**	**Marginal returns [@Rs.3/- per unit]**	**Total returns [Col.2x @Rs.3/-]**	**Total cost**	**Net returns [Col.8- Col.9]**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
0	2	-		-			6	0	6
1	5	1	3	5.00	4	9	15	4	9
2	9	1	4	4.50	4	12	27	8	19
3	14	1	5	4.66	4	15	42	12	30
4	21	1	7	5.25	4	21	63	16	47
5	26	1	5	5.20	4	15	78	20	58
6	30	1	4	5.00	4	12	90	24	66
7	33	1	3	4.71	4	9	99	28	71
8	35	1	2	4.37	4	6	105	32	73
9	36	1	1	4.00	4	3	108	36	72
10	36	1	0	3.60	4	0	108	40	68
11	35	1	-1	3.18	4	-3	105	44	61
12	33	1	-2	2.15	4	-6	99	48	51

Classical Production Function (curve)

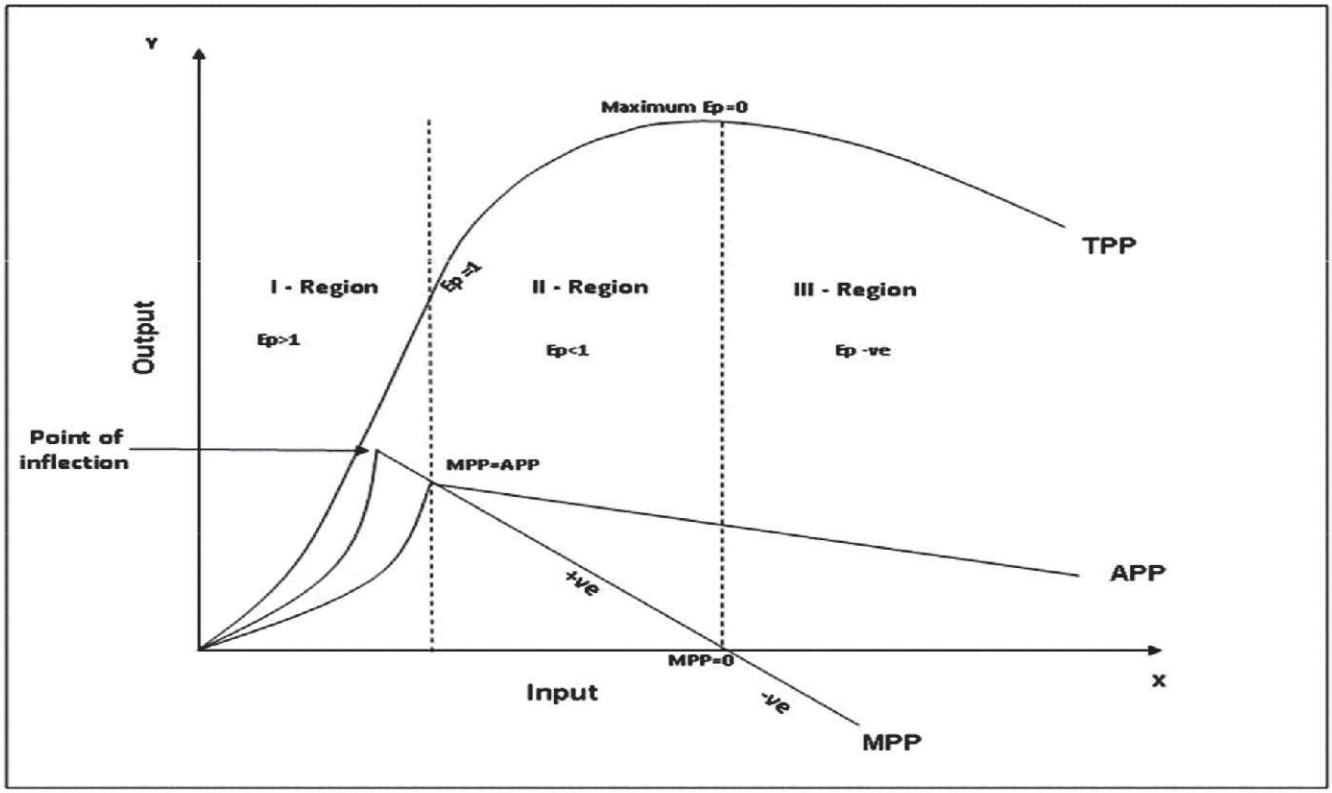


Fig-1: Relationship b/w TPP, APP & MPP (Stages of production & rational resource use)

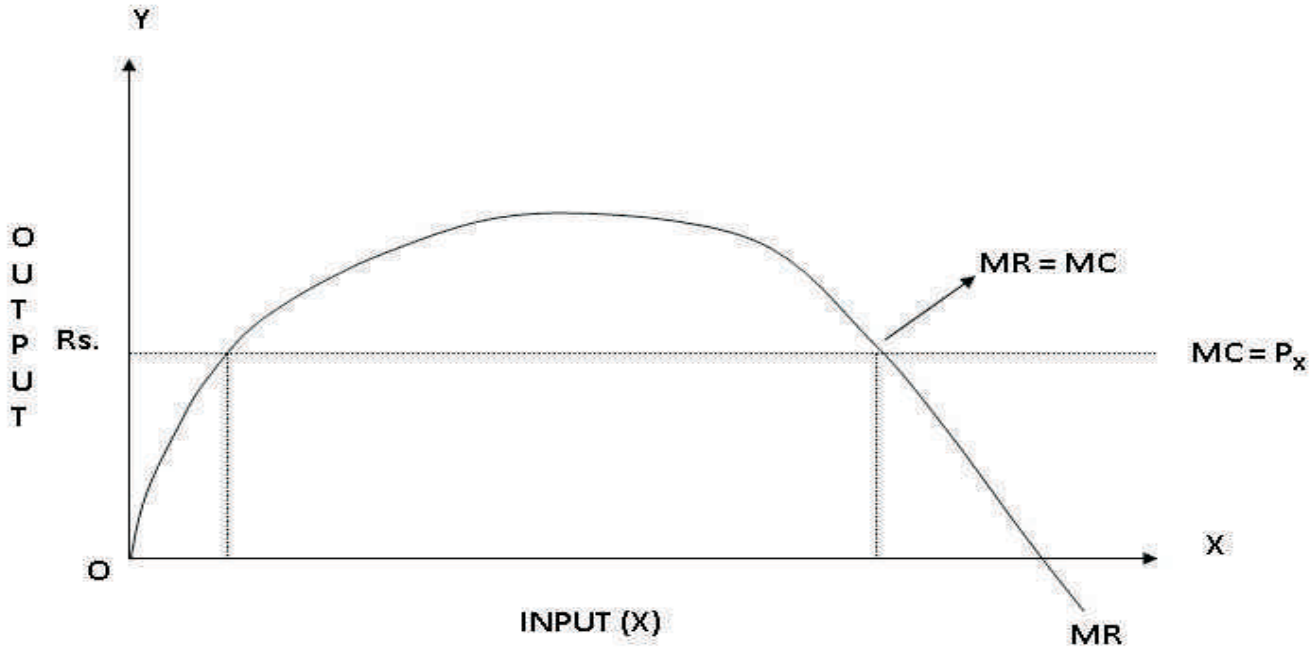


Fig 2 : Relationship between Marginal cost and Marginal revenue (curves)

EXERCISE

1. Draw a neat labeled diagram of classical production function curves and

(i). Show the following:

a) Regions of production b) Point of inflection

(ii). Trace the relationships between the following

(a) TPP and APP b) APP and MPP c) TPP and MPP

2. From the following input-output relationship table, calculate the average & marginal products and elasticity of production (Ep).

Labor (X)	Output (Y)	Δ X	Δ Y	APP [Y/X]	MPP[ΔY/XΔ]	Ep [MPP/APP]
0	0					
1	10					
2	28					
3	42					
4	52					
5	60					
6	66					
7	70					
8	72					
9	72					
10	70					

a. Draw a neat diagram of law of diminishing marginal returns, using TPP, APP and MPP values.

b. Demarcate the three stages of production & elasticity of production (Ep) on the graph sheet.

3. Complete the following production schedule.

Variable input[X]	TPP	APP	MPP
1			20
2			30
3			40
4			30
5			15
6			9
7			3
8			1
9			0
10			-3

a). what is the total output when the marginal product is zero ?

4. Determine the most profitable level of input use, when the price per kg of output is Rs. 10 and the labour wage rate is Rs. 60 per man day using the following data.

Physical relationship						**Economic relationship**				
Labour (X)	Output (Y)	Δ X	Δ Y	APP [Y/X]	MPP [ΔY/ΔX]	MC	MR	TR	TC	Profit
1	15									
2	38									
3	66									
4	96									
5	120									
6	126									
7	126									
8	120									
9	90									
10	50									

5. Determine the optimum level of fertilizer application to paddy crop when the price of fertilizer is Rs.10 per unit and price of output is Rs.2 per unit.

Physical relationship						Economic relationship				
Labor(X)	Output(Y)	Δ X	Δ Y	APP [Y/X]	MPP [ΔY/ΔX]	MC	MR	TR	TC	Profit
1	8									
2	17									
3	27									
4	36									
5	43									
6	48									
7	48									
8	50									

6. Suppose $Y=60X+12X^2 - X^3$ with reference to this production function,

   a. Find the level of variable input (X) when output (Y) is maximum.

   b. Find the level of variable input (X) when marginal is equal to average product.

7. Suppose the variable input (X) increases from 20 to 35 units and output (Y) increases from 150 to 200 units. Find the elasticity of production and state whether the nature of returns is increasing, constant or decreasing.

Date: **Practical - 2**

PRINCIPLE OF LEAST COST COMBINATION

Farmers use different inputs such as land, labour, fertilizer etc. to produce a particular output. Farmers always try to minimize their input cost and maximize output by combining the different resources. In other words, our objective is maximization of profit by minimizing the cost of production in order to produce a given level of output. Therefore, the main concern of this principle is to find out the possibilities of substituting or combining one factor (X_1) for another factor (X_2) in the production of a given output level (Y), which is economical one. This substitution depends on the cost of inputs and MRFS. In this relationship, only two factors and one output are involved.

A functional relationship between a product and two factors can be expressed as:

$$Y = f(X_1, X_2/ \bar{X}_3, \bar{X}_4, \ldots\ldots\ldots \bar{X}_n)$$

Or $Y = f(X_1, X2)$ i.e, here, the output (Y) depends on two variable inputs (X_1 and X_2) while other inputs like X_3, X_4 . . . . . X_n are held constant to produce a given level of output.

Optimization of output or profit maximization actually involves the cost minimization in the use of variable resources. There will be large number of resource-use combinations, which will produce different levels of output. But only one combination will give the maximum output with least cost. Inputs can be combined in three different ways:

i). Fixed – factor proportion

ii). Constant rate of factor substitution and

iii). Varying rate of factor substitution.

But decreasing rate of factor substitution [MRFS or MRTS] is very common in agriculture.

Steps involved in least-cost combination of inputs

1. Compute marginal rate of factor substitution ratio (MRFS)

$$MRFS = \frac{\text{No. of units of replaced resources}}{\text{No. of units of added resources}} = \frac{\Delta X_2}{\Delta X_1}$$

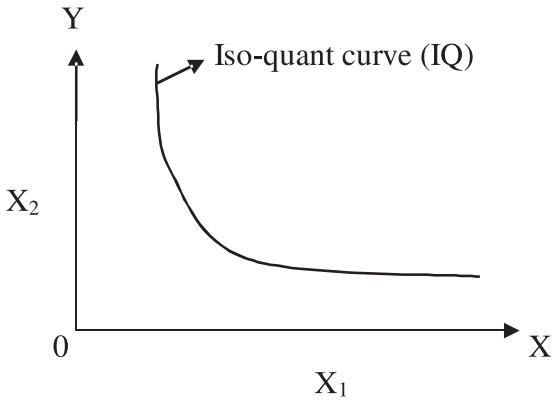
2. Compute price ratio (PR)

$$PR = \frac{\text{Cost per unit of added resources}}{\text{Cost per unit of replaced resources}} = \frac{Px_1}{Px_2}$$

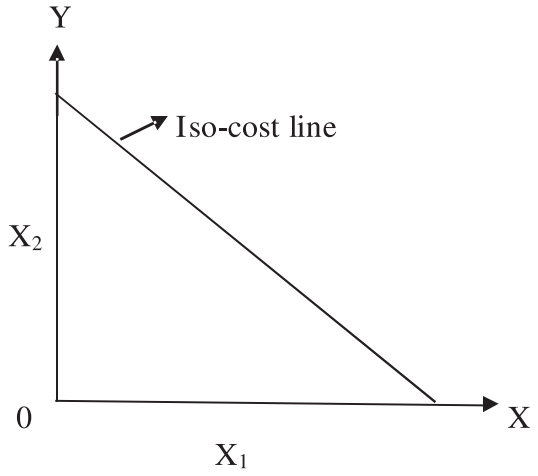
3. Equate MRFS and PR:

$$\frac{\Delta X_2}{\Delta X_1} = \frac{Px_1}{Px_2} \quad \text{or} \quad \Delta X_1 . Px_1 = \Delta X_2 . Px_2$$

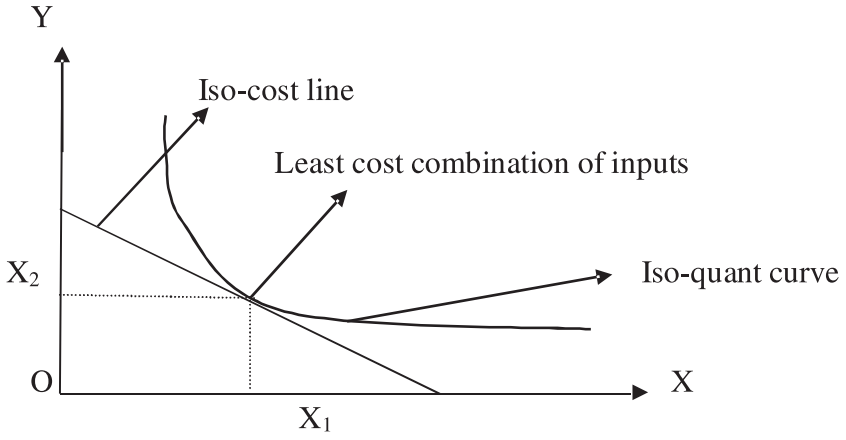
Iso-quant curve / Iso-product curve: represents different combination of two inputs, which yield the same level of output.



Iso-cost line/Budget line/outlay line: refers to all possible combination of inputs that can be purchased from a given level of outlay/funds



Graphically, least-cost combination of two factors can be obtained at a point where Iso-cost line is tangent to iso-quant curve.



Here (P), the slope of iso-quant curve will be equal to slope of iso-cost line. It means MRFS is equal to inverse price ratio of two factors.

Marginal rate of factor substitution (MRFS) is the rate at which one factor (X_1) is substituted for another factor (X_2) in a production process without affecting the quantity of output.

EXERCISE

1. The following table indicates the use of two factors in different combinations to produce a given level of output. If the price of X_1 is Rs.11 per kg and price of X_2 is Rs. 1 per kg, find out the least cost-combination of these inputs.

X_1 units	X_2 units	ΔX_1	ΔX_2	MRS	Price ratio	Total cost
0	40					
1	25					
2	14					
3	8					
4	4					
5	0					

2. Two resources like A and B are combined in different ways to produce 50 units of output. Find out the best combination of inputs if P_A = Rs.30/kg and P_B = Rs.15/kg

Fodder (A)	Feed (B)	ΔA_1	ΔB_2	MRS	Price ratio	Total cost
1	12					
2	8					
3	5					
4	3					
5	2					

3. With the help of neat diagrams explain in brief about least cost combination of two factors, iso-quant, iso-quant map, iso-cost line, ridge lines, isoclines and expansion path.

4. The following table indicates use of two resources to produce a given level of output. Three sets of prices are given below: (i). X_1 is Rs.16/kg and X_2 is Rs.4/kg, (ii). X_1 is Rs.10/kg and X_2 is Rs.3/kg and (iii). X_1 is Rs.9/kg and X_2 is Rs.2/kg, find out the least cost combination of resources and indicate nature of substitution.

X_1	X_2	ΔX_1	ΔX_2	MRS	3 sets of price ratios			Total costs		
					PR_1	PR_2	PR_3	TC_1	TC_2	TC_3
200	0									
160	10									
120	20									
80	30									
40	40									
0	50									

5. The following table indicates use of two resources to produce Y units of output. Geometrically, find out the least cost combination of the two inputs, if the price of X_1 is Rs.20/kg and the price of X_2 is Rs.10/kg; find out the least cost combination of resources

X_1 units	X_2 units	ΔX_1	ΔX_2.	MRS	Price ratio	Total cost
0	120					
10	80					
20	50					
30	30					
40	14					
50	6					
60	0					

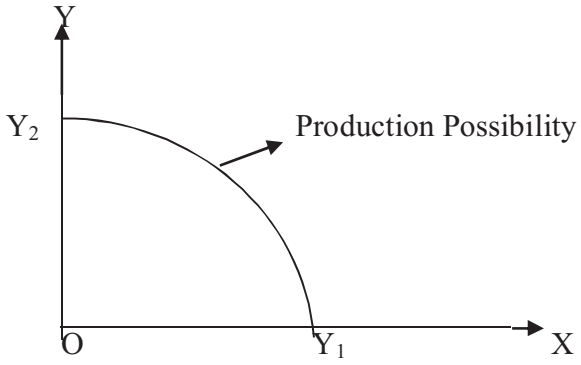
Date: **Practical - 3**

PRINCIPLE OF OPTIMUM COMBINATION OF PRODUCTS

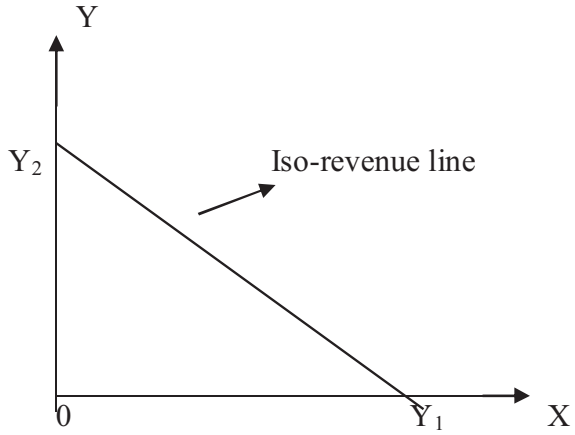
The producer is often confronted with the problem of what enterprises to select and the level at which each enterprises deal with the extent of combination of different enterprises. The rate of replacement of one enterprise by the other is known as marginal rate of product substitution (MRPS). The combination of enterprises depends upon the enterprises relationship and prices of the outputs.

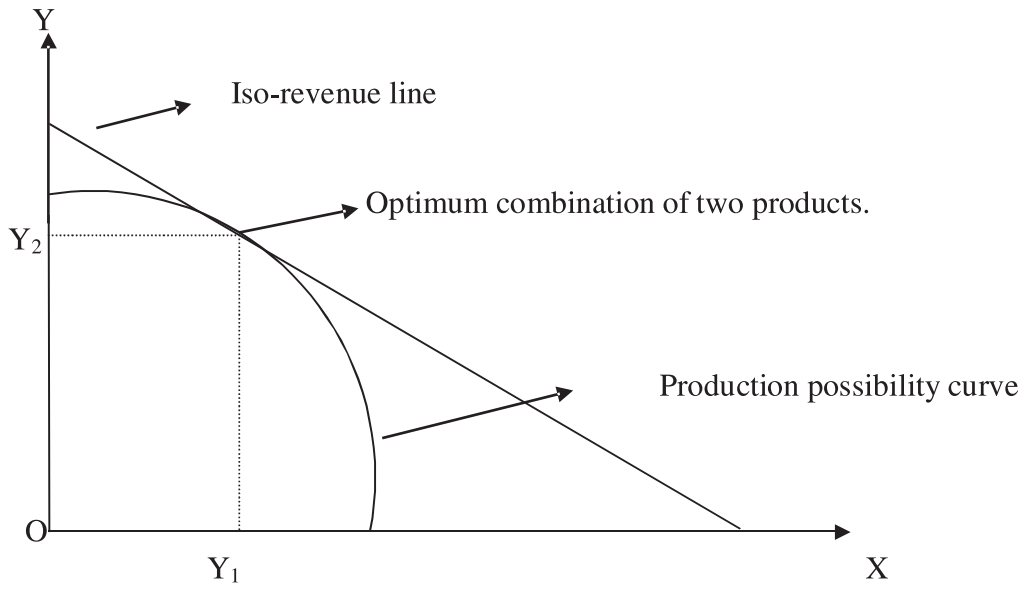
The optimum combination of two enterprises will be attained at the point where MRPS of Y_1 for Y_2 ($\Delta Y_1/\Delta Y_2$) will be equal to inverse of their price ratio (P_{Y1}/P_{Y2}). Graphically, optimum combination of two enterprises will be located at the point where iso-revenue curve is tangent to production possibility curve.

Production possibility curve / transformation curves / iso-resource curves/ opportunity curves: Indicates all the possible combinations of two products that would be produced with a given amount of inputs.



Iso-revenue line: Indicates all the possible combinations of two products, which would yield an equal revenue or income.





Steps to find out optimum combination of two products:

1. Compute MRPS ratio:

$$MRPS = \frac{\text{Quantity of replaced product}}{\text{Quantity of added product}} = \frac{\Delta Y_2}{\Delta Y_1}$$

2. Compute price ratio (PR):

$$PR = \frac{\text{Price of added product}}{\text{Price of replaced product}} = \frac{Py_1}{Py_2}$$

3. Equate MRPS and PR:

$$\frac{\Delta Y_2}{\Delta Y_1} = \frac{Py_1}{Py_2}$$

$$\text{i.e., } \Delta Y_2 * P_{y2} = \Delta Y_1 * P_{y1}$$

OR Returns sacrificed = Returns added

EXERCISE:

1. Find out the maximum revenue combination of products. Given the following information what is the substitution ratio and price ratio at maximum revenue combination? Price of Y_1 (Py_1) is Rs.3 per unit and Price of Y_2 (Py_2) is Rs.6.3 per unit.

Y_1 units	Y_2 units	ΔY_1	ΔY_2	MRPS	Price ratio	Gross income
84	0					
66	10					
46	20					
24	30					
0	40					

2. Following data pertains to output obtained from Tomato and Onion enterprises with a given set of resources. If price of Tomato is Rs. 8/kg. and price of Onion is Rs. 10/kg. Determine the most profitable combination of output with a given 60 units of [input] X used.

Y1 (Maize)	Y2 (Bajra)	ΔY_1	ΔY_2	MRPS	Price ratio	Gross income
0	50					
5	48					
10	47					
15	44					
20	38					
25	26					
30	8					
35	0					

3. Show diagrammatically the combination of the following enterprises.
   i). Competitive enterprises
   ii). Supplementary enterprises
   iii). Complementary enterprises
   iv). Joint enterprises.

4. A farmer having 5 acres of land is interested to grow Potato and Onion. The following table indicates the allocation of land and output obtained from both the enterprises. Guide the farmer in allocation of his land resource to maximize the returns about combination of these two crops assuming price of Potato (P_p) = Rs. 1500 / unit and price of Onion (P_o) = Rs.1000 / unit.

Production possibilities						MRPS	Price ratio	Gross returns
Potato (Y_2)			Onion (Y_1)					
Acres	Yield(Q_p)	ΔY_2	Acres	Yield(Q_c)	ΔY_1			
5	40		0	0				
4	30		1	4				
3	26		2	10				
2	14		3	13				
1	10		4	16				
0	0		5	18				

5. Various combinations of two enterprises, Onion (Y_1) and Tomato (Y_2) are given in quintals per hectare in the following table. If the price of Onion is Rs.300 per unit and that of Tomato is Rs. 150 per unit and the total cost is Rs.2500, compute the total revenue, price ratio and substitution ratio. Find the best combination of these two crops.

Onion (Y_1)	Tomato (Y_2)	ΔY_1	ΔY_2	MRPS	Price ratio	Return from Y_1	Return from Y_2	TR	TC	NR
0	46									
7	41									
13	35									
18	28									
22	20									
25	11									
27	0									

Date: **Practical - 4**

PRINCIPLE OF EQUIMARGINAL RETURNS
(OPPORTUNITY COST PRINCIPLE)

When resources at the disposal of the producer are unlimited / adequate, he would not have any difficulty in deciding which commodities to produce, he would not even compare one enterprise with another. Instead, he would produce all commodities. Under such circumstances the decision rule would be simple. Select all products which can be produced and expand output as long as the added returns are greater than added cost. But in reality the resources are scarce or limited. In such a situation, the question of choice of an enterprise or combination of enterprises arises.

An optimum choice of enterprises is made based on the principle of equi-marginal returns or the principle of opportunity cost. This principle states that resources should be used where they bring not the greatest average returns, but the greatest marginal returns. Thus, the best combination of enterprises is attained not when we select profitable enterprises, but when we select the most profitable enterprises. This principle is also called as the opportunity cost principle, because it considers the returns from one enterprise sacrificed as a cost in producing another product/enterprise.

The decision rule to maximize net return is the ratio of additional returns divided by the respective input prices should all be equal across all products or the value of the marginal product divided by the respective factor prices should be equal for all resources across all products. Algebraically, it can be expressed as:

$$\frac{\text{MR of } Y_1}{P_{X1}} = \frac{\text{MR of } Y_2}{P_{X2}} \text{ ----------} = \frac{\text{MR of } Y_n}{P_{Xn}}$$

EXAMPLE:

Amount of capital used (Rs.)	**Marginal returns (Rs.)**		
	Piggery	Poultry	Dairy
1000	**1350 – III**	**1500 - I**	**1400–II**
1000	**1300– IV**	1250	1100
1000	1120	1090	1050
1000	1050	1000	980
TR from Rs.4000/-	**4820**	**4840**	**4530**
Average returns per rupee invested (TR/TC) (Rs.)	1.23	1.21	1.13
Net returns (Rs.)	900	840	530
Returns obtained as per Equimarginal returns principle i.e., TR = Rs.2650+1500+1400=Rs.5550 Average returns per rupee invested=1.3875	2650	1500	1400

The net returns are Rs.900 in piggery, Rs.840 in poultry and Rs.530 in dairy. Then the farmer should spend all his capital of Rs.4000/- on piggery only? No. He should use the principal of equi-marginal returns to maximize his profit. His capital can be spent in 4 installments of Rs.1000 each. So he should spend his 1st 1000 on poultry because it gives highest returns (Rs.1500). Similarly 2nd 1000 on dairy, 3rd

and last units on piggary as they give Rs.1400, Rs.1350 and Rs.1300 of returns respectively. If we add all these returns, we get a gross return of Rs.5550. After deducting cost we get a net return of Rs.1550. In none of the other combinations we get this much of net return. Therefore, the farmer can allocate his Rs.4000 in the following manner to get maximum net returns.

Piggary – Rs.2,000
Poultry – Rs.1,000
Dairy – Rs.1,000

EXERCISE

1. Using the following data find out how one should utilize Rs.1500/ among different crop enterprises to get greatest profit.

Amount of money spent		**Added returns from using different amount of capital**		
Marginal	Total	Onion	Tomato	Potato
250	250	425	375	325
250	500	350	325	280
250	750	325	290	275
250	1000	320	270	255
250	1250	315	260	252
250	1500	302	255	250
Total returns from Rs.1500/-				
Average returns per rupee invested				
Net profit [π =TC-TC]				
Returns by using Equi-marginal returns principle.				

2. Cultivator is having Rs.5000 with him, how he should spend the amount on different enterprises so that he will get maximum profit? What is the amount of profit?

Amount of capital used [Rs.]		**Additional returns (Rs.)**		
		Crop	**Dairy**	**Poultry**
1.	1000	1400	1500	1600
2.	1000	1400	1300	1350
3.	1000	1300	1200	1200
4.	1000	1300	1000	1100
5.	1000	1200	900	1000
Total returns from Rs.5000				
Net returns[TR-TC]				
Average returns per rupee of investment[TR/TC]				
Returns as per equi-marginal returns principle				

3. Following data indicates the yield response of three varieties of hybrid Banana to different levels of nitrogen application (Price of Banana Rs.10.50/kg and nitrogen Rs.5/kg).
   i) Find out the total fertilizer requirement assuming unlimited capital situation.
   ii) If the farmer is having only Rs.1000/- how this should be allotted in terms of nitrogen fertilizer among different varieties to maximize returns

Nitrogen applied (kgs)	Yield (kgs)		
	CSH-1	CSH-5	CSH-8
20	5285	5344	5015
20	5597	5894	5345
20	5837	6344	5643
20	6037	6654	5855
20	6122	6904	6050
20	6187	7004	6190
20	6227	7079	6270
20	6197	6976	6185
20	6153	6726	6035
20	6043	6396	5785

4. The following data indicates table indicates the generation of additional income from successive Rs.1000 rupees investment in different alternatives.

Investment	Additional returns (Rs.) from three alternatives		
	Arecanut	Coconut	Cashewnut
1	2500	2350	3000
2	2300	2200	2800
3	2100	1900	2200
4	1500	1400	1550
5	1000	1250	1100
6	900	950	975

a). If unlimited capital is available how much will be producer invest in
   i). Arecanut Rs._____ ii). Coconut Rs._____ iii). Cashewnut Rs._____

b). If only Rs.14,000 capital is available

   i). Arecanut Rs._____ ii).Coconut Rs._____ iii).Cashewnut Rs._____

c). If Rs.15,000 capital is available at 15 per cent interest per annum.

   i). Arecanut Rs._____ ii).Coconut Rs._____ iii).Cashewnut Rs._____

Date: **Practical - 5**

COMPUTATION OF DEPRECIATION

Depreciation is a decline in value of a given asset or capital equipment due to wear and tear, accidental damage and time obsolescence. It is caused by two factors-time and use. It represents the amount by which a farm resource decreases in value as a result of cause other than a change in the general price of the item. Depreciation involves prorating the original cost of an asset over its useful life. The amount of depreciation charged should therefore correspond to the loss in the value of the asset over time.

Computational methods:

There are many methods of computation of depreciation but none of these methods can be considered the most appropriate under all circumstances. The choice of the method, however, depends upon the rate at which the asset loses its value.

The most common methods of computing depreciation are:

1. Annual revaluation method: The depreciation of an asset is calculated by taking the difference between the market value of an asset at the beginning and the end of the year. This method is useful in case of livestock in the early years of life, i.e., in appreciating stage. It becomes difficult for those items which are not bought and sold frequently.

$$\text{Depreciation} = \begin{array}{c}\text{Market value of an asset} \\ \text{at the beginning of the year}\end{array} \_\_ \begin{array}{c}\text{Value of an asset at the end} \\ \text{of the year}\end{array}$$

For example:

If the market value of a tractor in the beginning of the year is Rs.1,25,000 and year end value is Rs.1,20,000. Then, depreciation of tractor for the year:

$$= 1,25,000 - 1,20,000$$
$$= \text{Rs.}5,000$$

2. Straight line method: This method assumes that assets are used more or less to the same extent every year and therefore equal amounts of costs for their use can be charged every year. This method is easy, simple and usually very satisfactory for most purposes. Junk value is also called as scrap value or salvage value or residual value.

$$\text{Depreciation} = \frac{\text{Purchase price of the asset} - \text{Junk value}}{\text{Number of useful years of life}}$$

For example: If purchase price of a pump set is Rs.12,000 and its junk value is Rs. 2400 and it can give a useful service of 12 years, Then, yearly depreciation of pump set is:

$$= \frac{12,000 - 2,400}{12} = \frac{9,600}{12} = \text{Rs.}800 \text{ per year}$$

3. Diminishing balance method: A fixed rate of depreciation is used for every year and applied to the value of an asset at the beginning of the year. The fixed rate is applied to the balance until the salvage value is reached and no depreciation is possible. Example: suppose a machine is purchased for Rs.6000 and its expected life is 10 years.

In this method a fixed percentage value of depreciation is charged every year on the reduced value of an asset.

Rs.600 is 10% of Rs.6000.this 10% i.e., Rs.600 is deducted from the value.

Therefore, Rs.6000-Rs.600 =Rs.540. hence, the depreciation is Rs.600 and the depreciated value of the machine at the end of the first year would be Rs.5400.

(6000-600) Rs.5400 at 10% → depreciation is Rs.540 → 2nd year

(54000-540) Rs.4860 at 10% → depreciation is Rs.486 → 3rd year

and so on. It goes on declining till the end of life span of an asset.

In this method, the amount of depreciation is different at different stages of the machine and gradually diminishes with the life.

This percentage of depreciation is decided usually by taking original value divided by life span converted into percentage. Alternatively it is 100/life span.

For above example, life span of asset is 10 years, then

The annual depreciation would be:

$$\frac{\text{Original cost}}{\text{Expected life}} = \frac{\text{Rs.6000}}{10} = \text{Rs.600}$$

Converting it into percentage:

$$\frac{600}{6000} \times 100 = 10\%$$

OR

$$\frac{100}{10} = 10\%$$

4. Reducing Fraction method (Sum of the years-digit method): Annual depreciation is computed by multiplying a fraction times amount to the depreciated (cost minus the salvage value). The following formula can be used to determine the fraction for any year.

$$\text{Fraction for any year} = \frac{\text{The years of life remaining at the beginning of the accounting year}}{\text{The sum of the years of life of the asset}}$$

Depreciation is charged on the assets based on the nature of the assets. If the assets lose their value at a faster rate during the beginning years compared to later years, for such of the assets for calculating depreciation this method is used.

In this method total number of years digits were added up and find out the ratio of each year to total number of years digits. This fraction is calculated as dividing the number of years of life remaining by the number of year's digits. This fraction is multiplied by original value of the asset (after taking out junk value from it) to arrive the depreciation for the year. Denominator for the fraction is calculated by the formula, n (n+1)/2

Ex.: 6 years is the life span of an asset, whose purchase price is Rs.10000 and salvage value is Rs.1000.

Then, denominator of the fraction as per n(n+1)/2 formula,

$$= \frac{6(6+1)}{2} \qquad = \frac{42}{2} = 21$$

(If number of years digits are added, 1+2+3+4+5+6, then also we arrive at 21)

Then, fraction for 1st year = 6/21

Fraction for 2nd year = 5/21

Fraction for 3rd year = 4/21

Similarly, it is 3/21, 2/2 and 1/2, for 4, 5 and 6th years respectively.

Rate of annual depreciation = [original cost -- junk value] x Fraction for the particular year.

Then, depreciation for 1st year is calculated by 10000-1000 x 6/21

i.e. 9000 x 6/21 = 2571.43

EXERCISE:

1. Compute depreciation for the following data using all the methods.

	Particulars	**Amount Rs.**
i).	Purchase price of Tractor (Expected life 10 years)	80,000/-
ii).	Junk value of Tractor	10,000/-
iii).	Market value after one year	75,000/-
iv).	Annual rate of depreciation	20%

2. Compute the annual depreciation for a machine costing Rs.63000 having expected life of 20 years and a salvage value of Rs.3000 by using

   i) Straight line method, ii) Diminishing balance method (assuming 20% rate of depreciation) and iii) Reducing fraction method.

3. Calculate the depreciation of an asset whose market value in the beginning of the year was Rs.80,000 and the market value at the end of the year was Rs.68,000/-.

Date: **Practical - 6**

COMPUTATION OF COST CONCEPTS

Cost in general refers to the expenses incurred on inputs. Cost of production is the amount of expenditure incurred to produce a commodity. Cost principle deals with the functional relationship between output and total cost. In symbolic terms, C = f(Y), Where 'C' stands for total cost, 'Y' stands for output and 'f' stands for functional relationship. This principle helps to decide the optimum level of output to be produced at different cost level. For economic analysis of production, the following concepts are used.

1. **Cash costs:** are those costs incurred when resources are purchased and used immediately in the production process. Examples: oil, fuel, fertilizer etc.

2. **Non cash costs:** consist of depreciation and payment to resources owned by the farmer. Examples: Depreciation on tractor, equipment etc.

3. **Cost of production of a commodity** is the aggregate of price paid for the factors of production used in producing that commodity.

4. **Total cost (TC):** is the sum of total variable cost (TVC) and total fixed cost (TFC).

5. **Total fixed costs (TFC)**: are the amount spent on fixed inputs. These costs remain constant (in the short run), irrespective of the level of output.

6. **Total variable costs (TVC):** are those costs incurred on variable factors. These costs vary directly with the level of output.

7. **Average fixed cost (AFC)** is total fixed cost divided by total units of output.

8. **Average variable cost (AVC)** : is the total variable cost divided by total units of output.

9. **Marginal cost (MC):** is the change in total cost associated with unit change in output.

10. **Revenue**: refers to the receipts obtained by the sale of certain quantities of output at various price.

11. **Total Revenue (TR):** is equal to the total quantity sold multiplied by the selling price of the commodity.

12. **Average Revenue (AR):** is the total revenue divided by the number of units of output sold.

13. **Marginal Revenue (MR):** Marginal Revenue (MR) is the extra revenue obtained from the sale of one unit of output **or** it is the change in total revenue associated with unit change in output.

Cost concepts:

Some of the cost concepts used in farm management studies by the Commission on Agricultural Costs and Prices (CACP) of Government of India are cost A_1, cost A_2, cost B_1, cost B_2, cost C_1 and cost C_2 which are defined as follows:

a. **Cost A_1:** All actual expenses in cash and kind included in production by farm farmer. They includes wages of hired human labour, wages of permanent labour, wages of contract labour, wages of hired bullock labour, imputed value of owned bullock labour, charges of hired machinery, imputed value of owned machinery, cost of manure, seeds, fertilizers, pesticides, herbicides, irrigation charges, imputed value of manures, imputed value of owned seeds land revenue, cess and other taxes, depreciation on farm machinery, implements, equipments, farm buildings, irrigation structures, etc. interest on working capital, miscellaneous expenses(artisans, repairs to farm equipments etc).

b. **Cost A_2**= Cost A_1 + Rent paid for leased-in land.

c. **Cost B_1** = Cost A_1 +, Interest on the value of owned capital assets (excluding land). Value of owned capital assets means interest rate of long-term government floated loans or securities.

d. **Cost B_2** = Cost B_1 + Rental value of owned land (less land revenue) + Rent paid for leased- in land.

e. **Cost C_1**= Cost B_1 + Imputed value of family labour.

f. **Cost C_2**= Cost B_2 + Imputed value of family labour.

Income measures in relation to different cost concepts:

1. Farm Business Income = Gross Return - Cost A_1.
2. Owned Farm Business Income = Gross Return - CostA_2.
3. Family Labour Income = Gross Return - Cost B_2.
4. Net Income = Gross Return - Cost C_2.
5. Farm Investment Income = Net Income + Imputed rental value of owned land + Interest on fixed capital.

EXERCISE

1. The TFC of a firm has Rs.30. Prepare cost schedules relating to TC, AFC, AVC, ATC and MC using th e following data.

Output [Q]	TVC	TFC	TC	AFC	AVC	ATC	MC
0	0						
1	10						
2	18						
3	24						
4	32						
5	50						
6	72						

Draw total cost curves [TC, TFC & TVC] on the upper portion of the graph sheet and average cost and marginal cost curves [AFC, AVC, AC and MC] on the lower portion of the graph sheet.

2. From the following cost data, calculate TFC, TVC, AFC, AVC, AC and MC.

Output	Total cost [Rs.]	TFC	TVC	AFC	AVC	ATC	MC
0	40						
11	50						
28	60						
42	70						
52	80						
60	90						
66	100						
70	110						
72	120						

3. Following is the schedule of the short run total product of a firm:

X	Y	TVC	TFC	TC	AFC	AVC	ATC	MC
1	10							
2	25							
3	50							
4	75							
5	80							
6	80							

If a unit of variable factor cost is Rs.30/- and the total overhead cost is Rs.100. Construct a schedule showing TVC, TFC, TC, AFC, AVC, ATC and MC at different levels of output.

4. Determine the most optimum level of output to maximize the returns, when price per unit of input is Rs. 30 and price of output is Rs. 1.5. Assume that TFC is Rs. 500.

X	Output[Q]	TVC	TFC	TC	TR	AFC	AVC	ATC	MC	MR	Profit
1	100										
2	300										
3	700										
4	1000										
5	1200										
6	1300										
7	1350										
8	1350										
9	1250										

5. From the following data, calculate TR, AR, MR, MC, TC, and determine the most profitable [net revenue] level of production if the price per kg of input (Px) is Rs.10 and price per kg output (Py) is Rs.5. Plot TR, AR, and MR curves.

X	Output[Q]	TVC	TFC	TC	TR	AR	AFC	AVC	ATC	MC	MR	Profit
0	0		10									
1	10											
2	28											
3	44											
4	54											
5	60											
6	66											
7	70											
8	72											
9	72											
10	70											

6. What do you mean by unit cost curves? Trace the relationship between

i) MC and AVC ii) AC and MC with a neat diagram.

7. Distinguish between money cost, real cost and opportunity cost with examples.

8. Compute the various Cost concepts [Cost-A_1, Cost-A_2, Cost-B_1, Cost-B_2, Cost-C_1 and Cost-C_2], Gross income and net income from the following data:

i. Purchase of seeds Rs. 500

ii. Rental value of own land Rs. 2000

iii. Hired human labour charges Rs.700

iv. Fertilizer cost Rs. 2500

v. Electricity charges Rs.250

vi. Irrigation charges Rs. 300

vii. Hiring machine Rs. 700.

viii. Depreciation Charges Rs. 500.

ix. Imputed value of family labour Rs.300

x. Land revenue Rs.50.

xi. Repairs of equipment Rs. 500

xii. Interest on working capital Rs. 1500

xiii. Rent paid for leased-in land Rs.2500.

xiv. Interest on fixed capital Rs. 2000

xv. Output of groundnut: 16 quintals

xvi. Price of output : Rs.1200 per quintal

Date: **Practical - 7**

NETWORTH STATEMENT

Balance sheet is the most widely used statement for measuring farm business performance. It is also called as net worth statement. It is a summary of statement showing the assets, liabilities and net worth or net deficit of a farm business over a point of time. It indicates a snapshot of a farm business on a given date.

The balance sheet indicates an account of total assets and total liabilities of the farm business revealing the financial solvency of the business. It shows whether the business is expanding or shrinking. More specifically it is a statement of the financial position of a farm business at a particular time, showing its assets, liabilities and equity. If the assets are more than the liabilities it is called net worth or equity and its converse is known as net deficit. The typical balance sheet shows assets on the left hand side and liabilities and equity on the right hand side. Both sides are always in balance hence the name balance sheet. Net worth is placed on the right hand side, along with liabilities, in order to indicate that like any other creditor the farmer has a claim against the farm business equal to the equity amount. The balance sheet can be easily prepared by the farmer in the presence of farm records. It can be prepared at any point of time to know the financial position of the farm business. It can also be prepared to study the performance of a business over years by preparing the same number of balance sheets. If the net worth increases over the different periods, it indicates efficient performance of the business.

To prepare a balance sheet the prime requisites are total assets, total liabilities and net worth or net deficit of the farm.

I. Assets: Assets are those, which are owned by the farmer. Assets are the three types, *viz.,* current, intermediate or working and long-term or fixed. This classification of assets facilitates the analysis of liquidity of the farm business.

a) Current Assets: They are very liquid or short-term assets. They can be converted into cash, within a short time, usually one year. For example, cash on hand, agricultural produce ready for disposal, i.e., stocks of paddy, blackgram, jowar, wheat, etc.

b) Intermediate or Working Assets*:* Intermediate assets are less liquid than the current assets. Examples: Machinery, equipment, livestock, tractors, trucks, *etc.*

c) Long-term Assets or Fixed Assets*:* An asset that is permanent or will be used continuously for several years is called a long-term asset. It takes longer time to convert into cash due to verification of records, legal transactions, *etc. Examples:* Land, farm buildings, *etc.*

II. Liabilities: refers to all the things, which are owed to others by the farmer.

a) Current Liabilities*:* Debts that must be paid in the short term or in very near future. Examples: Crop loans, accounts payable, hand loans, *etc.*

b) Intermediate Liabilities*:* These loans are due for the repayment within a period of two to five years. *Examples:* Livestock loans, machinery loans, *etc.*

c) Long-term Liabilities*:* The duration of loan repayment is five or more years.

1. *Ex:* Tractor loan, orchard loan, land development loan, *etc.*

III.Net worth or net deficit: shows the difference between the assets and liabilities, and if the difference is positive, it is called net worth (solvency position/ credit worthy/ owner's equity). In case the difference is negative, it is called net deficit (insolvency).

The test ratios, viz., current ratio, intermediate ratio, net capital ratio, quick ratio, current liability ratio, debt-equity ratio and equity-value ratio are used to analyze the balance sheet**.**

$$1.\ \text{Current Ratio} = \frac{\text{Total current assets}}{\text{Total current liabilities}}$$

This ratio indicates the capacity of the farmer to meet immediate financial obligations or solvency of the business.

$$2.\ \text{Intermediate Ratio or working Ratio} = \frac{\text{Total current assets + Total intermediate assets}}{\text{Total current liabilities + Total intermediate liabilities}}$$

This indicates the liquidity position of the farm business over an intermediate period of time, ranging from 2 to 5 years. This ratio should also be more than one to indicate sound running of the farm business.

$$3.\ \text{Net Capital Ratio} = \frac{\text{Total assets}}{\text{Total liabilities}}$$

If the net capital ratio is more than one, the funds of the institutional agencies are safe. This ratio is also the most important measure of overall solvency position of the farmer-borrowers in the long-run.

$$4.\ \text{Rate of capital turn over} = \frac{\text{Gross income}}{\text{Total farm assets}}$$

It is the most common measure of capital efficiency. A faster turnover rate is a good sign of farm business.

$$5.\ \text{Fixed ratio} = \frac{\text{Fixed or long-term assets}}{\text{Fixed or long-term liabilities}}$$

This ratio measures the financial safety of the business over a longer period of time.

$$6.\ \text{Acid Test Ratio or Quick Ratio} = \frac{\text{Cash receipts + accounts receivable + marketable securities (Bonds, shares etc.) available more than one year}}{\text{Total current liabilities}}$$

This reflects adequacy of cash and income surpluses to cover all current liabilities during the period of one to two years. If there is no difference in income position of a farmer within that period, current ratio and acid test ratio reflect the same position.

7. Current liability ratio $= \frac{\text{Current liabilities}}{\text{Owner's equity}}$

This ratio indicates the farmer's immediate financial obligations against the net worth. A ratio of less than one indicates a healthy performance of the farm business and over the years the ratio should become smaller and smaller to reflect a consistently good performance.

8. Debt-equity Ratio (Leverage ratio) $= \frac{\text{Total debts}}{\text{Owner's equity}}$

This ratio indicates the capacity of the farmer to meet the long-term commitments. A consistently falling ratio indicates a very heartening performance of farming and the ability of the farmer to reduce dependence on borrowings.

9. Equity to asset value ratio $= \frac{\text{Owner's equity (net worth)}}{\text{Value of assets (net assets)}}$

This ratio measures the overall financial position of the farm business.

10. Equity Ratio $= \frac{\text{Net worth}}{\text{Total liabilities}}$

EXERCISE:

1. Net worth statement of Mr. Singh on 31st October, 2008

Assets	**Amount (Rs.)**	**Liabilities**	**Amount (Rs.)**
Current assets		**Current liabilities**	
Cash on hand	12500.00	Short term loans	550.00
Cash in bank, shares etc	1500.00		
Savings in bank	500.00		
Value of grains/feeds	677.50		
Standing crops	450.00		
Sub-total	**15627.50**	**Sub-total**	**550.00**
Intermediate Assets		**Intermediate Liabilities**	
Machinery & equipment	37010.00	Loans on Machinery& equipment	28500.00
Livestock	19500.00	Loans for milch animals	9000.00
Sub-total	**56510.00**	**Sub-total**	**37500.00**
Long term assets		**Long term liabilities**	--
Land	240000.00		--
Farm buildings	8000.00		
Sub-total	**248000.00**	**Sub-total**	**------**
		Total of liabilities	38050.00
		Net worth or equity	282087.50
Total assets	320137.50	**Total liabilities + net worth**	320137.50

Work out the relevant financial ratios and comment on the financial soundness of his farm business for the following information:

Note: Net worth = Total assets – Total liabilities, Assets = liabilities + owners equity

2. If the owner's equity is Rs.25000 and total liabilities are Rs.15000, what is the value of total assets?

3. If the total assets of a business are Rs.1,75,000 and the total liabilities Rs.85,000, what is the amount of owner's equity?

4. If the total assets of a business are worth Rs.1,75,000 and the owners' equity is Rs.60000. what is the amount of the liabilities?

5. With the data given below, about assets and liabilities of farm, prepare a net worth statement as on August, 2008 and comment on the financial soundness of the farm business.

Assets	**Rs.**	**Liabilities**	**Rs.**
Bullocks and buffaloes	2000	Long term loan	2000
Poultry	450	Short term loans	1500
Cattle shed and store	5200	Bills payable(short term)	1200
Farm fences	650	Mortgage on land	35000
Land	50000		
orchard	5000		
Tube well	5300		
Power equipment	1200		
Bullock driven equipment	1500		
Fertilizers	180		
FYM	270		
Seeds and feeds	1500		
Cash in hand	1100		
Accounts receivable	1200		
Standing crops	800		
Crops in store	650		

Date: **Practical - 8**

PROFIT AND LOSS STATEMENT

An income statement is also called as Profit and Loss Statement. It is defined as a summary of receipts and gains minus expenses and losses during a specified accounting period (usually a year). It is nothing but input and output expressed in value terms. Income statement is supplemented by showing where the funds come from and where the funds are used. It reveals the success or failure of a farm business over a period of time. Income statement basically constitutes three items, *viz.,* receipts, expenses and net income.

This is entirely different from a balance sheet in the sense that in a balance sheet, we considered assets and liabilities and did not consider operational efficiency in terms of receipts and expenses. In income statement, the items included are receipts, expenses, gains and losses. It is prepared for the entire farm for one agricultural year. In income statement monetary values are assigned to inputs and output. It is also prepared over time.

Primary function of Income statement is to know the returns and expenses involved in business during given period with resultant of net profit or net loss. Income statement is opening point of cash flow statement.

Receipts: They mean the returns obtained from the sale of crop produce and other supplementary products like milk and eggs, wages, gifts, *etc.* Gain in the form of appreciation in the value of assets is also included in the receipts. However, returns from the sale of capital assets, such as livestock, machinery, farm buildings, *etc.* are not included because such returns/income are not really obtained during the period.

Expenses*:* Operating and fixed costs are recorded here. Losses in the form of depreciation on the asset value fall under the expenditure item. However, the amounts incurred on the purchase of capital assets are not considered.

FINANCIAL MEASURES:

Net income = cash receipt – cash expenses

Net income: it constitutes net cash income, net operating income and net farm income

Net cash income: it gives the position of cash receipts minus cash expenses only during the period for which income statement is prepared.

Net operating income = Gross income – operating expenses

Net operating income: it is arrived at by deducting operating expenses from the gross income. Fixed costs are not given any consideration. Operating expenses include crop loans.

Net farm income = net operating income - fixed cost. Net farm income: Net farm income equals net operating income less fixed costs. Compared to net cash income and income operating income, it is relatively a better measure of assessing the performance of a farm. It is the return accrued to owned capital and family labour employed.

Financial Test Ratios:

1. Operating ratio = $\frac{\text{Total operating expenses}}{\text{Gross income}}$

2. Fixed ratio = $\frac{\text{Fixed expenses}}{\text{Gross income}}$

3. Gross ratio = $\frac{\text{Total expenses}}{\text{Gross income}}$

4. Capital turnover ratio = $\frac{\text{Gross income}}{\text{Average capital investment}}$

5. Rate of return on investment = $\frac{\text{Net return to capital}}{\text{Average capital investment}}$

EXERCISE: Complete the following table & Compute the relevant financial ratios and comment on the financial soundness of his farm business.

Income Statement of 'X' farm during 2008-09

Particulars	Amount (in Rs.)
RECEIPTS:	
A. Returns from the sale of crop output	20000
B. Revenue from livestock sales (products)	20500
Sub total	
C. Miscellaneous receipts:	3000
a. labour	400
b. machinery hiring out	1400
c. sale of machinery	4000
Sub total	
I. Total(gross) cash receipts	
D. Product used at home	3000
E. Increase in inventories:	
i. liquid assets	8000

ii. value of livestock	6000
iii. value of farm machinery	4000
Sub total	
II. Total Receipts	
EXPENSES:	
a. Operating expenses:	
i. Payment to Hired human labour	1500
Bullock labour	2000
Machine labour	2800
ii. Seeds	800
iii. Feeds	400
iv. Manures & fertilizers	3000
v. Miscellaneous expenses	500
Sub total	
b. Fixed expenses:	
i. payment of interest	2200
ii. Land revenue	600
Sub total	
Purchase of durable assets:	
i. Livestock	2800
ii. Equipment	9000
Sub total	
III. Total cash expenses	
Decrease in inventory:	
Depreciation of buildings, equipment & machinery	4000
IV. Total Expenses	
Net cash income : [I – III]	
Net farm income : **[II- IV]**	

Date: **Practical - 9**

FARM EFFICIENCY MEASURES

Farm efficiency measures serve as a measuring stick to know the physical and economic efficiency of resources used on the farm. Farm efficiency measures, therefore, need to be developed to express technical efficiency in various farm enterprises and to relate these to the final success. Farm efficiency measures may be defined as the capacity or the ability of the farm business as a complete unit for increasing the productivity of resources to secure the largest possible return.

There are two types of efficiency measures:

1. Physical efficiency 2. Financial efficiency measures

They can be further categorized as: Ratio measures and Aggregate measures

I. Physical Efficiency Measures:

A. Ratio Measures:

1. **Production Efficiency (yield/acre) :** The production efficiency of a farm with respect to any particular crop enterprise as compared with average yield of the locality can be expected in terms of percentage. For example:

   Yield of paddy on farm ' X ' = 800 kgs

   Average yield of the locality = 400 kgs

   $$\text{Production efficiency of Farm 'X'} = \frac{800}{400} \times 100 = 200\%$$

2. **Crop yield Index:** It is as measure of comparison of the yields of all crops on a given farm with the average yields of crops in the locality. The relationship is expressed in percentage. This yield index is a convenient measure because it combines all the yields into a single figure.

   $$\text{Crop yield index} = \frac{\text{Total percentage yield of all crops}}{\text{Area under all crops}}$$

3. **Cropping Intensity:** It measures the extent of the use of land for cropping purposes during a given year. It is expressed as percentage.

   $$\text{Cropping intensity} = \frac{\text{Gross cropped area}}{\text{Net cultivated area}} \times 100$$

4. System Index: This measures the efficiency in combining various enterprises. If system index is more than100, it shows that the combination of various enterprises is more efficient than the average farm in the locality.

Sl. No.	Enterprise	Standard net income per unit of enterprise (Rs.)	Area under units of enterprise on farm (acres)	Total potential net income of farm (Rs.)
1.	Ragi	500	3	3000
2.	Paddy	2500	1	3200
3.	Groundnut	1800	2	4400
	Total	**4800**	**6**	**10600**
	Average	**1600**		**1766.67**

$$\text{System Index} = \frac{\text{Potential net income per acre on the farm}}{\text{Avg. Std. Net income per acre in locality}} \times 100$$

$$\text{System Index} = \frac{1766.67}{1600} \times 100$$

II. Financial Efficiency Measures:

A. Aggregate Measures:

1. Gross Income: It is derived by adding together gross sales, home consumption of farm products, changes in inventory and purchases. It is a measure of size as well as volume of the business. For example, gross income of farm ' X ' is Rs.7000/-

2. Net Operating Income: The comparison of net operating income of different farms is a good measure of their relative efficiency. The returns to individual factors can be derived from this measure.

Net operating income = Gross income - (Operating expenses + Depreciation on working assets)

3. Net farm Income: It shows the earnings of the farm as a whole after making deducting the expenses.

Net farm income = Net operating income - (Fixed expenses +Depreciation on Fixed Assets)

B. Ratio Measures:

1. Cost Ratios:

a. Operating Cost Ratio: It shows the proportion of total income used in hiring labour, buying seeds, fertilizers and insecticides and also keeping equipment in operation.

$$\text{Operating cost ratio} = \frac{\text{Operating expenses}}{\text{Gross Income}}$$

b. Fixed cost Ratio : For an efficiently growing business, the ratio of increase in gross income should be faster than the rate of increase in fixed costs

$$\text{Fixed cost ratio (Overhead charges)} = \frac{\text{Fixed expenses}}{\text{Gross Income}}$$

c. Gross cost ratio: It expresses the percentage of gross income absorbed by total expenses.

$$\text{Gross cost ratio} = \frac{\text{Total expenses}}{\text{Gross Income}}$$

2. Capital Ratios: These ratios actually measure the degree of financial safety by comparing the business over time.

a. Net capital ratio: It determines the solvency of business in the long run.

$$\text{Net capital ratio} = \frac{\text{Total assets}}{\text{Total liabilities}}$$

b. Working ratio: It determines the solvency of the business in medium run.

$$\text{Working ratio} = \frac{\text{Working assets and current assets}}{\text{Intermediate and current liabilities}}$$

c. Current Ratio: This gives an idea of immediate solvency of the business.

$$\text{Current Ratio} = \frac{\text{Current assets}}{\text{Current liabilities}}$$

d. Rate of Capital Turnover: It is the most common measure of capital efficiency. A faster turnover rate is a sign of good farm business.

$$\text{Rate of capital turnover} = \frac{\text{Gross income}}{\text{Total farm assets}} \times 100$$

Similarly, the resource use efficiency in terms of return to different factors can be taken. For this purpose, different cost concepts are used, such as**:**

1. Returns to management = Gross income minus Cost-C_2
2. Return to family labour = Cost-C_2 – Cost-B_2
3. return to owned land = Cost- B_2- Cost-B_1
4. return to owned capital assets= Cost-B_1 – Cost-A_1

Date: **Practical - 10**

PREPARATION OF OPTIMUM FARM PLANS

Farm planning is the foundation of management. Farm planning precedes all other managerial functions. Without setting the objectives and line of action to be followed, there is nothing to organize, direct or control in the organization of farm business. It is the determination of a course of action to achieve the desired results. It is deciding in advance, the production management problems viz., what to produce, how to produce, when to produce; financial management problems viz., how to borrow, how much to borrow, when to borrow, where to borr ow and marketing management problems viz., where to buy and sell, when to buy and sell, how to buy and sell, etc.

Farm planning is the deliberate process of thinking, the organized foresight and the vision based on facts and past experience that is needed for intelligent action on the farm.

Characteristics of good farm plan:

The following are the characteristics of a good farm plan:

1. Plans should aim at efficient utilization of all available resources on the farm.
2. Plans should be flexible i.e., they should be adaptable to changing environmental conditions.
3. Farm plans should be simple and easily understood. Complex plans consume much time and money, hence are seldom followed. They should take into account the most important suitable farm enterprises, identifying their strengths and weaknesses.
4. Farm plans should ensure balanced production programme considering the available resources on the farm. The production programme should consist of food crops, commercial crops and fodder crops.
5. The production programme included in the farm plan should aim at maintaining/ improving soil fertility. This is possible through suitable crop rotation practices.
6. Farm plans should facilitate efficient marketing of farm products.
7. It should take into account up-to-date technology.
8. Farm plans should consider the goals, knowledge, training and experience of the farmers, besides their attitude towards risk.
9. Farm plans should avoid too risky enterprises.
10. Farm plans should provide for borrowing, using and repaying the credit.

STEPS IN WHOLE FARM PLANNING AND BUDGETING:

A systematic procedure is generally followed in making sound farm plans for the success of the farm business. The sound farm plan should be generally feasible acceptable, and adaptable. The make the farm plan successful, the following steps should be adopted with relevance to a given farm and its resources.

1. Statement of objective.
2. Diagnosis of the existing organization.
3. Assessment of resource endowment on the farm.
4. Identification of enterprises to be included.
5. Preparation of enterprise budgets.
6. Identification of risks, and
7. Preparation of a plan.

Date: **Practical - 11**

PREPARATION OF FARM BUDGETS

[COMPLETE OR WHOLE FARM BUDGETING]

Complete or Whole Farm Budgeting: It is a technique for assembling and organizing the information about the whole farm in order to facilitate decisions about the management of farm resources. It attempts to estimate all items of costs and returns and it presents a complete picture of farm business. It is generally used by beginners or by those farmers who want to completely overhaul their existing farm organization and operation. Complete and partial budgeting are mutually complementary, i.e., the partial budgeting should be used at various stages of complete budgeting in order to decide the changes to be effected in the farm organization. The process of complete budgeting involves: i)appraisal of existing farm resources, their uses and efficiency, ii) appraisal of alternatives or opportunities or various production activities that can be included and their resource requirements and iii) preparing and evaluating the alternative plans for their feasibility and profitability. The above table shows an estimated profit or net farm income of Rs.39,750, if the prices and yield are actually realized. Changes in any of these factors will obviously affect the actual profit received from operating the farm under this plan.

BUDGETING: It is an estimation of possible changes in costs and returns in a given time period when there are contemplated changes in the use of production resources. It is a financial statement of proposed farm plan. There are three types of budgets.

1. **Complete Budget**: When an estimation of the probable returns and expenses is made for the entire farm as a single unit, it is called complete budget.
2. **Partial Budget:** is the method of making a comparative study of costs and returns analysis resulting from a change in a part of the farm business organization

3. **Enterprise Budget**: is a process of an advance estimation of cost and returns from a particular farm enterprise.

1) Uses: i). It provides a basis for comparing alternative plans for profitability. This can be particularly useful when planning is carried out for growth and expansion.

ii) A detailed whole farm budget showing the estimated profit can be used to borrow the necessary operating capital.

2) Complete Budgeting and Partial Budgeting: The differences between these two are: i). Complete budgeting accounts for drastic changes in the organization and operation of the farm, while partial budgeting treats minor changes only. ii) All the available alternatives are considered in complete budgeting, whereas partial budget considers two or a few alternatives only. iii) Complete budgeting is used for estimating the results of entire organization and operation of a farm, while partial budget helps only to study the net effects in terms of costs and returns of relatively minor changes.

Steps in Complete Budgeting:

1. Estimation of expected yield, cost and prices
2. Availability of farm resources
3. Existing enterprise mix and input use
4. Weaknesses in the existing plan
5. Preparing alternative plans
6. selecting the plan
7. Implementation of selected plan

Table: Complete Budget Showing Projected Income, Expenses and Profit.

Particulars	Amount (Rs.)
I. Income realized from:	
i) Cotton	54,000
ii) Paddy	43,000
iii) Sorghum	13,500
iv) Dairy products	40,000
Total income (TR)	**1,50,500**
II. Variable Expenses:	
i) Fertilizers	11,900
ii) Seeds	3,600
iii) Plant protection chemicals	7,900
iv) Fuel and oil	4,050
v) Machine repairs	2,650
vi) Feed purchase	1,600
vii) Veterinary expenses and other expenses	30,100
viii) Custom hire charges	10,250
ix) Miscellaneous expenses	2,450
Total variable Expenses (TVC)	**74,500**
III. Fixed Expenses:	
i) Tax	2,600
ii) Insurance	1,250
iii) Interest on debt	22,000
iv) Machinery depreciation	7,200
v) Building depreciation	3,200
Total fixed expenses (TFC)	**36,250**
Total expenses {TC=TVC+TFC}	**1,10,750**
Net Farm Income (NR = **TR - TC) [**Rs. 1,50,500 – Rs. 1,10,750**] =**	**39,750**

Date: **Practical - 12**

PREPARATION OF FARM BUDGETS

[PARTIAL & ENTERPRISE BUDGETING]

Farm planning and budgeting is one of the important tools of farm management. Farm planning is a process of choice making or choosing from among the competitive alternatives. The process of making or choosing involves the selection of one or many alternatives based on the technical feasibility and economic viability.

Partial Budget: is the method of making a comparative study of costs and returns analysis resulting from a change in a part of the farm business organization. It is an estimate of costs and returns of the part of the farm business. Partial budget is used when a minor change in the existing organization of the farm business is effected on account of introduction of new technology in the production practices.

Example: Improved method of paddy cultivation versus local method of paddy cultivation.

The following four points are important in setting up a partial budget.

1. **Additional Returns**: That would accrue from the change i.e., from the increased production of new activity to be introduced.
2. **The Savings or Decrease in Costs:** This will not have to be incurred after the change or from the reduced level of an input item being used even prior to the change to be decided upon.
3. **The Decrease in Returns:** That might occur due to reduction in yield of loss from the activity which has been replaced in the change.
4. **The Increase in Costs:** On the increased use of the inputs which are being used already or the new inputs suggested in the change.

The format for partial budget:

Debit	**Credit**
a. Increase in cost Rs. _____	a. Decrease in costs Rs. _____
b. Decrease in returns Rs. _____	b. Increase in returns Rs. _____
Total (a + b) Rs._____	Total (a + b) Rs. _____

(Credit - Debit) = Net gain or loss Rs._____

EXERCISE

Estimate the net gain or loss with the help of partial budgeting technique for the following:

i. **Changing the practice/method of weeding from hand weeding to the use of weedicides**

	Herbicides	**Hand Weeding**
a. Yield of paddy (q/acre)	15	20
b. Total cost of cultivation (Rs./acre)	2,750	2,500

(Assume the price of paddy is Rs. 250 per quintal).

ii. Allocation of an acre of land from ragi to groundnut under rainfed condition.

	Ragi	Groundnut
a. Yield (qtls/acre)	6.50	4.25
Price (Rs.per quintal)	210	525
b. Total cost of cultivation (Rs.)	1,120	1,500

iii. Replacing local variety of Halubbalu (local practices) with improved by introducing improved variety of Jaya (improved practices).

	Local practices	Improved practices
a. Yield (quintal/ac)	16	22
(Price Rs.100 per quintal)		
b. Total cost (Rs./acre)	1750	2030

iv. A research study on the economics of power tilled versus bullock pair on the Saidapur farm in cultivation one hectare of paddy has indicated the following. Prepare a partial budget on the above lines:

SN	Particulars of cost	Power Tiller (Rs.)	Bullock Power (Rs.)
1.	Interest	59.84	75.30
2.	Depreciation	55.00	106.20
3.	Maintenance & Repairs	29.60	306.00
4.	Working expenses	50.00	862.92
	Labour		
5.	Human labour	50.00	121.00
6.	Bullock labour	--	194.82
7.	Wear & tear	285.00	16.00
	Total	**529.44**	**1682.24**
	Manure contribution	--	196.00

Prepare a partial budget with the above information

ENTERPRISE BUDGETING

Enterprise Budget

Preparation of enterprise budget is one of the steps of “Farm Planning". The appraisal of resources on the individual far indicates week and strong points existing in the currently followed technology. The potential enterprises of the region may be selected which help to increase the income of the farmers considering the agro-climatic conditions of the region and production possibilities of these enterprises based on the scientific findings. The enterprise budget for these enterprises must be prepared to order to know their relative economic performance which is required for the preparation of farm plans.

An enterprise budget depicts the input-output relationship in respect of a particular production activity. The enterprise budget includes only variable inputs and the expected output. As distinguished

from the cost of cultivation which includes both fixed and variable costs, the enterprise budget includes only variable costs, because the fixed costs are common to more than one enterprise.

The enterprise budget is important since it depicts the relative profitability of different enterprises or activities or alternatives which can be used to determine the relative economics of different enterprises. The enterprise or activity which gives relatively very low returns to fixed factors can be given a second thought before they are included in the planning framework. This would help in avoiding the unnecessary exercises or elements in the planning exercises which can then be attempted in a more meaningful manner.

The enterprise budget prepared for the practices followed by the farmer when compared with the one at the recommended "package of practices" provides the straight forward information about the potential that can be harnessed. The budgets may be prepared for major crops and livestock enterprises for the practices currently followed by the farmer as well as for the recommended package of practices.

USES: Enterprise budgets are used to estimate inputs required, costs involved and expected returns from a particular enterprise. It aids in selection of inputs and enterprises subject to the availability of resources.

SOURCE OF DATA :

A)**Improved practices**: (i) Published research results, (ii) Consultation with extension specialists (iii) Package of practices.

B) **Local practices**: (i) Use the data on the practices followed by the farmer.

EXERCISE:

1) Prepare enterprise budgets for cotton and groundnut.

ENTERPRISE BUDGET: PER ACRE

Crop/Variety: _____ Duration: _____

Wage Rate (i) Male labour:____(ii).Female labour:____ (iii).Bullock pair day:_____

SN	Particulars	LABOUR				INPUTS USED			
		Freq	Man Days	Women Days	B.P. Days	Wages Rs.	Name	Qty.	Value Rs.
	1	2	3	4	5	6	7	8	9
1.	Ploughing								
2.	Harrowing								
3.	Clod crushing								
4.	FYM application								
5.	Fertilizer application								
6.	Nursery preparation								
7.	Sowing/Transplanting								
8.	Thinning								
9.	Weeding								
10.	Earthing up								
11.	PPC								
12.	Irrigation								
13.	Harvesting								

14.	Hauling								
15.	Threshing								
	Total =								

COST	YIELD
a) Cost of material: Rs._____	**A].<u>Main product</u>** i) Quantity:_____ ii) Value: Rs._____
b) Cost of labour: Rs._____ c). Total Cost of cultivation Rs.:_____ (a + b)	**B].<u>By Product</u>** i. Quantity:_____ ii. Value: Rs._____ Gross Income Rs._____ Net Income Rs. _____

<u>ENTERPRISE BUDGET: PER ACRE</u>

Crop/Variety: Duration: _____

Wage Rate: (1) M.Day_____ (2) W.Day:_____ (3) B.P. Day: _____

SN	Particulars	LABOUR				INPUTS USED			
		Freq	Man Days	Women Days	B.P. Days	Wages Rs.	Name	Qty.	Value Rs.
	1	2	3	4	5	6	7	8	9
1.	Ploughing								
2.	Harrowing								
3.	Clod crushing								
4.	FYM application								
5.	Fertilizer application								
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7.	Sowing/Transplanting								
8.	Thinning								
9.	Weeding								
10.	Earthing up								
11.	PPC								
12.	Irrigation								
13.	Harvesting								
14.	Hauling								
15.	Threshing								
	Total =								

COST	**YIELD**
a) Cost of material: Rs._____	**A].<u>Main product</u>** iii) Quantity:_____ iv) Value: Rs._____
b) Cost of labour: Rs._____ c). Total Cost of cultivation Rs.:_____ (a + b)	**B].<u>By Product</u>** iii. Quantity:_____ iv. Value: Rs._____ Gross Income Rs._____ Net Income Rs. _____

Date: **Practical - 13**

FARM INVENTORY ANALYSIS

The list of all the physical property of a business along with their values at a specific point of time is called farm inventory. Inventory for a business is taken at two points of time in a year i.e., at the beginning of the agricultural year and at the end of the year. It constitutes cash assets, depreciable assets and non-depreciable assets. The difference in the inventory at the two points of time indicates the changes in the inventory.

Farm inventory forms the basis for the preparation of income statement, balance sheet, measurers of income, etc. The loss in the value of the asset due to depreciation can be worked out from the farm inventory.

As per the sub-items, inventory is presented like cash assets, depreciable assets and non-depreciable assets as presented in Table 1:

Table 1: Farm Inventory of a Hypothetical Farm on 1st June 1998 and March 1999

Sl. No.	Particulars	Beginning of the year (1-6-1998)		End of the year (31-5-1999)	
		Quantity in Q/kg	Value in Rs.	Quantity in Q/kg	Value in Rs.
I.	**Cash assets:**				
	Cash on hand	xx	xx	xx	xx
	Savings in bank,etc.	xx	xx	xx	xx
	Sub-total	xx	xx	xx	xx
II.	**Depreciable assets:**				
	Land (ha)	xx	xx	xx	xx
	Farm buildings	xx	xx	xx	xx
	Machinery and equipment	xx	xx	xx	xx
	Implements	xx	xx	xx	xx
	Dairy cattle	xx	xx	xx	xx
	Bullocks	xx	xx	xx	xx
	Sheep and goat	xx	xx	xx	xx
	Poultry birds, etc.	xx	xx	xx	xx
	Sub-total	xx	xx	xx	xx
III.	**Non-depreciable Assets:**				
	Grains ready for disposal	xx	xx	xx	xx
	Fodder and feed	xx	xx	xx	xx
	Livestock products	xx	xx	xx	xx
	Seeds	xx	xx	xx	xx
	Fertilizers	xx	xx	x	xx
	Pesticides and fungicides	xx	xx	xx	xx
	Sub-total	xx	xx	xx	xx
	Grand Total	xx	xx	xx	xx

Change in the inventory:

a). Beginning total Rs. **XXXX**

b). Closing total Rs. **XXXX**

Change [±] Rs. **XXXX**

Change in the inventory is found out by taking the difference of the value of assets during the two periods. As evident from the table the items that need to be included in the farm inventory are, the number of various assets along with their values. As far as recording the numbers of items are concerned it can be done by visual verification. The relevant weights and measures are also noted for the corresponding items of assets.

The preparation of farm inventory involves physical verification and valuation of the assets. Physical verification of the items does not pose a problem to the farmer. Problem arises, while valuing the assets, since improper evaluation leads to erroneous farm decisions.

Methods of valuation

To meet this particular objective of valuing the inventory, a look at the common methods of valuation is necessary. Following are the common methods of valuation.

2. Net selling price.
3. Cost less depreciation.
4. Market price.
5. Cost.
6. Replacement cost less depreciation and
7. Income capitalization.
8.

EXERCISE

1. Explain the above methods of valuation of farm assets
2. Prepare the Farm Inventory of Farmer that you have visited

Date: **Practical - 14**

STUDY OF FARM RECORDS

Maintaining farm records is called as farm 'Book Keeping' which is a system of farm records written to furnish the history of farm business transactions with a special reference to financial side. The farm records are used for different purposes like settling legal disputes, decision making, farm planning and budgeting.

Farm accounting is an art as well as science of recording in books business transactions in a regular and systematic manner so that their nature, extent and financial effects can be readily ascertained at any time of the year.

The main objectives of farm accounting and book keeping are

1) To analyze and judge the improvements or otherwise of the performance of the farm business at a particular time.
2) To find out the weaknesses of the farm business.
3) To effect the improvement of the farm business through the removal of weaknesses in the existing farm business.

Following are the three steps or stages of farm business analysis

i) Proper recording of accounts and activities
ii) Analysis and interpretation of results and
iii) Presentation of results

Advantages of farm records and accounts

1. Means of higher income
2. Basis for diagnosis and planning
3. Way to improve managerial ability of the farmer
4. Basis for credit acquisition and management
5. Guide for better home management
6. Basis for conducting research in agriculture and production economics
7. Basis for government policies

Problems and difficulties in farm accounting

1. Subsistence nature of farming
2. Farming is a laborious work
3. Triple role of Indian farmer
4. Illiteracy and lack of business awareness
5. Complicated nature of agriculture business
6. Inadequate extension service
7. Non-availability of suitable farm record books
8. Fear of taxation

Following are some of the important farm records; the farm manager needs to maintain them systematically.

I. Physical records

1. Farm map, soil map and contour map.
2. Land utilization record.
3. Crop production and disposal record.
4. Live stock, poultry etc., production and disposal records.
5. Labour records.
6. Feed records.
7. Stock stored (input) record.

II. Financial records

1. Farm inventory
2. Farm cash accounts
3. Capital assets sale register.
4. Cash sale and purchase register.
5. Wage register.

EXERCISE

1. Write in brief about the above mentioned physical and financial records.

Date: **Practical - 15**

VALUATION OF ANALYSIS OF NATURAL RESOURCES

Exercise:

Explain in brief the Market and non- market valuation methods of natural resources

FARM MANAGEMENT, PRODUCTION AND RESOURCE ECONOMICS

Ag. Econ. 6.4 (2+1)

SEMESTER: SIXTH **III B.Sc. (Hons.) Agri** **YEAR: 2019-20**

COURSE OUTLINE

Sl. No.	Title of the theory lectures	Details of sub-topics	Textbook/ Reference book	Page No.
1.	Production Economics	Introduction, objectives, scope, subject matter, basic terms and concepts	Ref. (1) Ref. (2)	(1-15); (155-163)
2.	Laws of Returns	Law of variable proportions, types of returns and estimation	Ref. (2)	(159-163)
3.	Seven Cost Concepts	Meaning and concept of cost, types of costs and their relationships	Ref. (3)	(80-101)
4.	Factor-Product Relationship	Optimum input and output levels	Ref. (1) Ref. (2)	(16-26); (166-171)
5.	Factor-Factor Relationship	Isoquant, iso-cost line, least cost combination	Ref. (1) Ref. (2)	(40-55) & (58-61); (177-186)
6.	Product-Product Relationship	Production possibility curve, iso-revenue line, optimal product combination, ridge line and expansion path	Ref. (1) Ref. (2)	(64-90); (187-198)
7.	Returns to Scale	Concepts and types	Ref. (2)	(200-201)
8.	Farm Cost Concepts and Income Measures	Importance of cost in managing farm business, estimation of gross farm income, family labour income and farm business income	Ref. (2)	(345-349)
9.	Farm Management	Introduction, meaning & concept, objectives, scope, relationship with other sciences	Ref. (1) Ref. (3)	(96-100); (1-7)
10.	Farm Resource Management	Meaning and definition of farm, its types and characteristics, factors determining types and size of the farms	Ref. (1) Ref. (2)	(129-133); (242-247)
11.	Farm Management Decisions	Strategic, administrative and marketing decisions	Ref. (1) Ref. (2)	(97-98); (122)
12.	Economic Principles Applicable in Farm Management	Equi-marginal, Opportunity cost, Time comparison, Comparative advantage principles	Ref. (1) Ref. (2)	(107-109); (232-234)

13.	Farm Records and Accounts	Advantages, characteristics, difficulties, systems and types	Ref. (1) Ref. (2)	(152-155); (305-330)
14.	Farm Inventory	Methods of valuation	Ref. (1) Ref. (2)	(162-164); (333-334)
15.	Farm Financial Statements	Balance sheet, Cash flow statement and Profit and loss statement	Ref. (2)	(452-463)
16.	Farm Planning	Types, characteristics and steps	Ref. (1) Ref. (2)	(187-190); (248-249)
17.	Farm Budgeting	Complete budget, enterprise budget and partial budget	Ref. (1) Ref. (2)	(190-193); (249-252)
18.	Appraisal of Farm Resources	Measures of efficiency of land, labour, capital and management	Ref. (2)	(350-359)
19.	Risk and Uncertainty in Agriculture	Types and management strategies	Ref. (2)	(361-366)
20.	Insurance in Agriculture	Crop, livestock, machinery and weather based crop insurances, Features and determinants of compensation	Ref. (7); Online resource (1)	(59-62)
21.	Resource Economics: Concepts and Properties	Natural resource classification & characteristics, management of renewable and non-renewable resources	Ref. (6)	(323-336)
22.	Positive & Negative Externalities in Agriculture	Externalities & types; market failure, market imperfections; policies for externalities	Ref. (6)	(99-101)
23.	Inefficiencies & Welfare Loss	Efficiency and types; Market efficiency levels. Reasons for inefficiencies in resource utilization solutions	Ref. (6)	(102-104)
24.	Issues in Economics and Management of Common Property Resources	Major issues in use of natural resources, productivity equity, sustainability	Ref. (6)	(111-115)

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(i) Text Books

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(ii) Online resources:

1. Handbook on crop insurance, Insurance Regulatory and Development Authority of India (IRDAI). Hyderabad. Available at: http://www.policyholder.gov.in/Crop_Handbbok.aspx

NOTES

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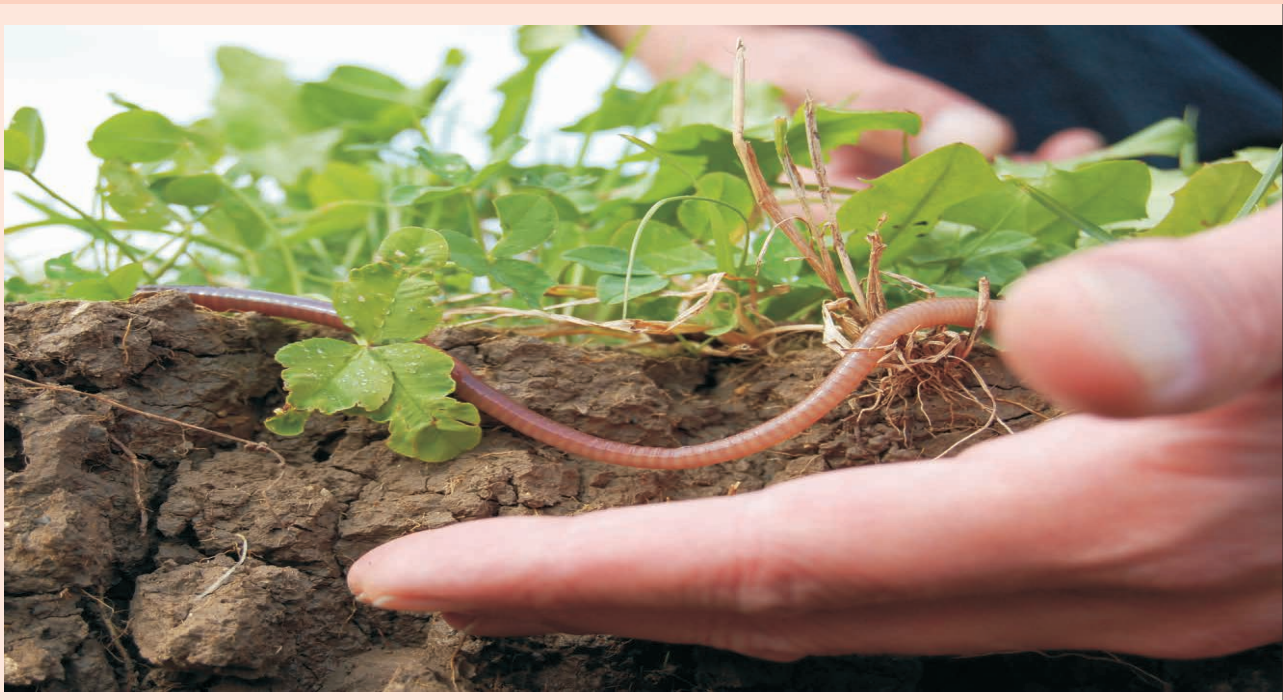
As Per The Fifth Dean Committee Recommendations For The B.Sc. (Hons.) Agri. Course Curriculum

भाकृअनुप
ICAR

कृषिमूलाः ऋद्धिः
NAVSARI AGRICULTURAL UNIVERSITY

कृषि विज्ञानस्य विकासः
COLLEGE OF AGRICULTURE
WAGHAI

Practical Manual



AGRON 6.9

PRINCIPLES OF ORGANIC FARMING (1 + 1)

PREPARED BY

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DEPARTMENT OF AGRONOMY
COLLEGE OF AGRICULTURE,
NAVSARI AGRICULTURAL UNIVERSITY,
WAGHAI (DANGS)- 394 730

Green Leaf Manure Crops


Cassia fistula


Leucaena leucocephala


Sesbania grandiflora


Calotropis gigantea


Gliricida sepium


Pongamia globra


Delonix regia


Peltophorum ferrrugenum


Azadiracta indica

As Per The Fifth Dean Committee Recommendations For The B.Sc. (Hons.)
Agri. Course Curriculum

Practical Manual

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CERTIFICATE

This is to certify that Mr./Miss._____ studying in SIXTH semester B. Sc. (Hons.) Agriculture has satisfactorily carried out required practical exercises in the course of **Agron. 6.9 :- Principles of Organic Farming (1 + 1)** at Department of Agronomy, College of Agriculture, NAU., Waghai during the year _____.

Course Teacher **Professor and Head**

External Examiner

INDEX

PRACTICAL - 1

STUDY OF DIFFERENT ORGANIC MATERIALS AND MANURES

The art of collecting and using wastes from animal, human, crop wastes and vegetable sources for improving crop productivity is as old as agriculture. Organic materials have longer residual effect besides improving soil physical, biological and chemical properties of soil. Major sources of organic materials are:

1. **Cattle shed wastes:** Dung, urine, and slurry from biogas plants
2. **Human habitation wastes:** night soil, human urine
3. **Poultry litter:** Droping of sheep and goat.
4. **Slaughter house waste:** bone meal, meat meal, blood meal, horn and hoof meal
5. **Fish wastes**
6. **By-products of agro-industries:** oil cakes, bagasses and pressmud, fruit and vegetables, processing wastes etc.
7. **Crop wastes:** sugarcane trash, stubbles and other related material.
8. **Water hyacinth:** weeds and tank silt
9. **Green manure crops and green leaf manuring material.**

Farm Yard Manure (FYM)

It is decomposed mixture of dung and urine of farm animals along with waste feed fodder, litter etc. On an average well decomposed farm yard manure contains 0.5%N, 0.2% P_2O_5 and 0.5% K_2O. Trench method of FYM preparation, use of chemicals preservatives such as gypsum, gober gas plant slurry can considerably reduce storage and handling losses of nutrients for improving the quality of FYM. Trenches of 6 m to 7 m length, 1.5 m to 2.0 m width and 1.0 m deep are dug. All available litter and refuse is mixed with soil and spread in the shed so as to absorb urine. The next morning urine soaked refuse along with dung is collected and placed in the trench. A section of the trench from one end should be taken up for filling with daily collection. When the section is filled up to a height of 45 cm to 60 cm above the ground level, the top of the heap is made into a dome and plastered with cow dung earth slurry. The process is continued and when the first trench is completely filled second trench is prepared. The manures ready for use in about four to five months after plastering.

Compost:

The process of decomposing organic waste is called composting and the decomposed material is called compost. Composting is essentially a microbiological decomposition of organic residues collected from rural area (rural compost) or urban area.

Farm compost is made by placing farm wastes in trenches of suitable size. Say 4.5 to 5 m long 1.5 to 2.0 m wide and 1.0 to 2.0 m deep. Farm waste is placed in the trenches layer by layer. Each layer is well moistened by sprinkling cow dung slurry or water. Trenches are filled up to height of 0.5 m above the ground. The compost is ready for application within five to six months. Composting is done either in aerobic or anaerobic conditions. Some methods involve both the conditions. The advantage of aerobic system is that it is fast but requires moistening and frequent turning.

Poultry Manure:

The excreta of birds ferment very quickly. If left exposed, 50% of its nitrogen is lost within 30 days. Poultry manure contains higher nitrogen and phosphorus compared to other bulky organic manures. The average nutrient content is 3.03% N 2.63% P_2O_5 and 1.4% K_2O.

Oil-cakes:

After extraction of oil from oilseeds, the remaining solid portion is dried as cake, which can be used as manure. The oil-cakes are of two types:

1. Edible oil-cakes which can be safely fed to livestock, e.g.: Groundnut cake, Coconut cake, etc. and
2. Non-edible oil-cakes which are not fit for feeding livestock, e.g. Castor cake, neem cake, mahua cake etc.

Both edible and non-edible oil-cakes can be used as manures. However, edible oil cakes are fed to cattle and non-edible oil cakes are used as manures especially for horticultural crops. Nutrients present in oil-cakes, after mineralization, are made available to crops 7 to 10 days after application. Oil-cakes need to be well powdered before application for even distribution and quicker decomposition.

Bone Meal:

Bones from carcasses of dead animals, slaughter houses and meat processing industries are the different sources of bone meal. Bones are the rich sources of phosphorus and calcium. Crushed bones are used either in raw form of after steam sterilization. The glue separated from bones has commercial value and the residue in powdered form is used either as manure or cattle feed. Bone meal is slow acting and ideal for acid soils and long duration crops.

Guano:

It is an admixture of excreta and dead remains of sea birds rich in N and P. It is collected periodically from islands. The refuse left over after extracting oil from fish in factories dried and used as manure. Known as fish guano. It is comparable to bird guano in its effect on soil and crops.

Crop Residues:

Residues left out after the harvest of the economic portions are called crop residues/straw. In the developing countries like India, we are mostly used as cattle feed. In the developed countries, harvesting is done using the field itself. Straw has good manorial value since it contains appreciable amount of plant nutrients. On an average, cereal straw and residues contain about 0.5% N, 0.6% P_2O_5 and 1.5% K_2O. The crop residues can be recycled by way of incorporation, compost making or mulch material.

Manure	Nutrient (%)		
	Nitrogen(N)	Phosphorus (P_2O_5)	Potash (K_2O)
1. Bulky Organic Manure			
Farm Yard Maure	0.5-1.5	0.4-0.8	0.5-1.9
Compost (Urban)	1.0-2.0	1.0	1.5
Compost(Rural)	0.4-0.8	0.3-0.6	0.7-1.0
Green manure (averages)	0.5-0.7	0.1-0.2	0.6-0.8
Sewage sludge dry	2.0-3.5	1.0-5.0	0.2-0.5
Sewage allivated dry	4.0-7.0	2.1-4.2	0.5-0.7
2. Non-edible cakes			
Castor cake	5.5-5.8	1.8-1.9	1.0-1.1
Mahua cake	2.5-2.6	0.9-1.0	1.8-1.9
Karanj cake	3.9-4.0	0.9-1.0	1.3-1.4
Neem cake	5.2-5.3	1.0-1.1	1.4-1.5
Safflower cake (undecorticated)	4.8-4.9	1.4-1.5	1.2-1.3
3. Edible cakes			
Cotton seed cake (decorticated)	6.4-6.5	2.8-2.9	2.1-2.2
Cotton seed cake (undecorticated)	3.9-4.0	1.8-1.9	1.6-1.7
Groundnut cake	7.0-7.2	1.5-1.6	1.3-1.4
4. Manure of animal origin			
Fish manure	4.0-10.0	3.0-9.0	0.3-1.5
Bird guano	7.0-8.0	11.0-14.0	2.0-3.0
Bone meal (row)	3.0-4.0	20.0-25.0	-
Bone meal (Steamed)	1.0-2.0	25.0-30.0	-
5. Straw and Stalks			
Pearl millet	0.65	0.75	2.50
Sorghum	0.40	0.23	2.17
Maize	0.42	1.57	1.65
Paddy	0.36	0.08	0.71
Wheat	0.53	0.10	1.10
Sugarcane trash	0.35	0.10	0.60
Cotton	0.44	0.10	0.66

PRACTICAL - 2

GREEN MANURING FOR ORGANIC FARMING

Green manuring can be defined as a practice of ploughing or turning into the soil un-decomposed green plant tissues for improving physical structure as well as soil fertility. It is obtained in two ways: by growing green manure crops or by collecting green leaf (along with twigs) from plants grown in wastelands, field bunds and forest. Green manuring is growing in the field plants usually belonging to leguminous family and incorporating into the soil after sufficient growth for the purpose of improving physical structure as well as fertility of the soil. The plants that are grown for green manure are known as green manure crops.

Methods of Green Manure

The practice of green manuring is adopted in various ways in different states of India to suit soil and climatic conditions. The methods of green manuring are

1. Green manuring in situ and
2. Green leaf manuring.

Green manuring in situ

Green manure crops are grown and incorporated in the same field where, it grown, either as pure crop or as inter crop with main crop is called as green manuring in situ. The most important green manure crops are sunnhemp, dhaincha, cowpea, cluster bean and *Sesbania rostrata.*

Biomass production and N accumulation of green manure crops

Crop	Age (Days)	Green biomass (t/ha)	N accumulated (kg/ha)
Sesbania aculeata (Dhaincha)	60	23.2	133
Sesbania juncea (Sunnhemp)	60	30.6	134
Vigna unguiculata (Cow pea)	60	23.2	74
Cymopsis tetragonaloba (Cluster bean)	50	20.0	91
Sesbania rostrata	50	25.0	96
Pillipesara	60	25.0	102

GREEN MANURE CROPS

Crotalaria juncea

Sesbania aculeata

Cow pea

Sesbania rostrata

Cluster bean

Plant	Scientific name	Nutrient content (%) on air dry basis		
		N	P_2O_5	K
Sunhemp	*Crotalaria juncea*	2.30	0.50	1.80
Dhaincha	*Sesbania aculeata*	3.50	0.60	1.20
Sesbania (Shevri)	*Sesbania speciosa*	2.71	0.53	2.21

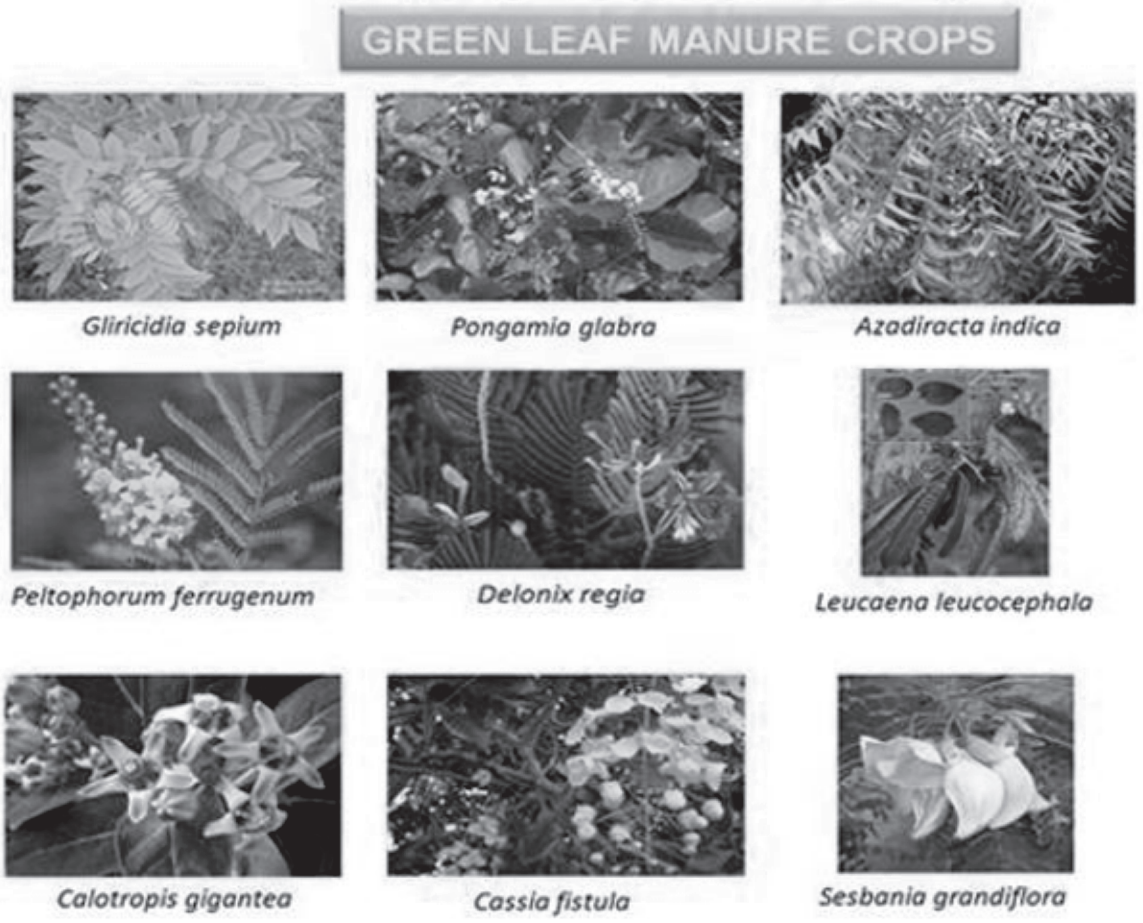
Sesbania rostrata is a stem nodulating green manure crop which is a native of West Africa. As it is a short-day plant and sensitive to photoperiod, the length of vegetative period is short when sown in August or September. A mutant (TSR-I) developed by Bhabha Atomic Research Centre, Bombay is insensitive to photoperiod, tolerant to salinity and waterlogged condition. Growth and nitrogen fixation is higher with TSR-I compared to the existing strains.

Green leaf manure

Incorporation of green leaves and twigs of trees, shrubs and herbs collected from elsewhere in to the soil is known as green leaf manuring. Forest tree leaves are the main sources for green leaf manure. Plants growing in wastelands, field bunds etc., are another source of green leaf manure. The important plant species useful for green leaf manure are neem, mahua, wild indigo, Glyricidia, Karanji *(Pongamia glabra)* calotropis, avise*(Sesbania grandiflora),* subabul and other shrubs.

Nutrient content of green leaf manure

Plant	Scientific name	Nutrient content (%) on air dry basis		
		N	P_2O_5	K
Gliricidia	*Gliricidia sepium*	2.76	0.28	4.60
Pongania	*Pongamia glabra*	3.31	0.44	2.39
Neem	*Azadirachta indica*	2.83	0.28	0.35
Gulmohur	*Delonix regia*	2.76	0.46	0.50
Peltophorum	*Peltophorum ferrugenum*	2.63	0.37	0.50



Weeds		Nutrient content (%)		
		N	P_2O_5	K
Parthenium	*Parthenium hysterophorus*	2.68	0.68	1.45
Water hyacinth	*Eichhornia crassipes*	3.01	0.90	0.15
Trianthema	*Trianthema portulacastrum*	2.64	0.43	1.30
Ipomoea	*Ipomoea*	2.01	0.33	0.40
Calotrophis	*Calotropis gigantea*	2.06	0.54	0.31
Cassia	*Cassia fistula*	1.60	0.24	1.20

Potential of green manure crops

Green manure crops	Sowing time	Seed rate (kg/ha)	Biomass production (t/ha)	N (kg/ha)
Berseem *Trifolium alexandrium*	Oct–Dec	80–100	20–22	67–70
Black gram *Vigna mungo*	June–July	20–22	08–10	38–48
Cluster bean *Cyamopsis tetragonaloba*	April–July	20–22	10–12	40–49
Cowpea *Vigna anguiculata*	April–July	45–55	15–18	74–88
Daincha *Sesbania aculeata*	April–July	80–100	20–25	84–105
Green gram *Vigna radiata*	June–July	30–40	20–25	68–85
Horse gram Dolichos biflorus	June–July	25–30	26–30	120–135
Pea *Pisum sativum*	Oct–Dec	10–12	8–10	26–33
Sunhemp *Crotolaria juncea*	April-July	80-100	15–25	60–100

Characteristics desirable in legume green manure crops

- Multipurpose use
- Short duration, fast growing, high nutrient accumulation ability
- Tolerance to shade; flood, drought and adverse temperatures
- Wide ecological adaptability

- Efficiency in use of water
- Early onset of biological nitrogen fixation
- High N accumulation rates
- Timely release of nutrients
- Photoperiod insensitivity
- High seed production
- High seed viability
- Ease in incorporation
- Ability to cross-inoculate or responsive to inoculation
- Pest and disease resistant
- High N sink in underground plant parts.

Criteria for Selection of Green manure

Criteria	Effects
High biomass production	Mobilization of nutrients from soil into vegetation; suppression of weeds
Deep rooting system	Pumping up of weathered and/or leached nutrients from soil layers not occupied by roots of main crop
Fast initial growth	Quick soil cover for effective soil protection; suppression of weeds
More leaf than wood	Easy decomposition of organic matter
Low CN ratio	Leading to enhanced availability of nutrients for succeeding crops; easy to handle during - cutting and / or incorporation into the soil
Nitrogen fixing	Increased nitrogen availability
Good affinity with mycorrhiza	Mobilization of phosphorus leading to improved availability for crops
Efficient water use	

Advantage of Green Manuring

- Has positive influence on the physical and chemical properties of soil.
- Helps to maintain the organic matter status of arable soil.
- Serves as source of food and energy for the microbes multiplies rapidly, not only decompose the GM and result in release of plant nutrients in available forms for use by the crops.
- Improves aeration in rice soils by stimulating activities of surface film of algae and bacteria.
- Additional use as source of food, feed and fuel.

Soil Structure and tilth improvement

- Green manuring builds up soil structure and improves tilth.
- Promotes formation of crumbs in heavy soils leading to aeration and drainage.
- Increases the water holding capacity of light soils.
- Form a canopy cover over the soil, reduce the soil temperature and prevents from erosive action of rain and water.

Fertility improvement of soils

- Absorb nutrients from the lower layer and leave them in surface when ploughed.
- Prevent leaching of nutrients to lower layers.
- Harbour N fixing bacteria, rhizobia in root nodules and fix atmospheric N (60 to 100 kg N/ha).
- Increase the solubility of lime phosphates, trace elements etc., through the activity of the soil microorganisms and by producing organic acids during decomposition.

Improvement in crop yield and quality

- Increases the yield of crops to 15 to 20 %.
- Vitamin and protein content of rice increased .

Amelioration of soil problems

- *Sesbania aculeata* (daincha) applied to sodic soils continuously for four or five seasons improves the permeability and helps to reclaim.
- *Argemone mexicana* & *Tamarindus indica* has a buffering effect when applied to sodic soils.

Pest control

- Pongamia and Neem leaves have insect control effects.

Limitations of green manure

- Under rain fed condition, it is feared that proper decomposition of the incorporated green manure may not take place if sufficient rainfall is not received after burying the green manure crop.
- Since green manuring for wheat loss of *kharif* crop, the practice of green manuring may not be always economical.
- Sometimes the cost of green manure crops may more than the cost of commercial fertilizers.
- Sometimes it increases disease, insects and nematode problem.
- The green manure crop may be failed, if sufficient rainfall is not available.

Observations to be recorded

1. Date of sowing
2. Burred stage of crop (flowering stage)
3. Number of root nodules/plant
4. Plant height (cm)
5. Green biomass/unit area (kg)
6. Green biomass yield (kg/ha)
7. Dry biomass (kg/ha)
8. Nitrogen available (kg/ha)

PRACTICAL - 3

PREPARATION OF ENRICH COMPOST AND VERMICOMPOST

Farm wastes can now be considered to include cattle-shed wastes such as cattle and buffalo dung and urine, other livestock and human excreta, crop wastes of cereals, pulses and oilseeds, stalk of corn, cotton, tobacco, sugarcane trash and agro-industries by products such as oil-cakes, paddy husk and bran, bagasse, press mud, fruit and vegetables wastes etc.

Estimates of agricultural waste availability suggest that the average value for crop wastes is 350 mt and that of animal wastes it is 650 mt. Hence around 1000 mt of agricultural wastes are available in the country. Recycling of wastes in agriculture brings in the much needed organic and mineral matter to the soils. Since most recyclable wastes are organic, they directly add organic matter and the plant nutrients contained in it. Now a day more efficient and versatile recycling processes and technologies have become available which if applied on the required scale can bring recyclable wastes in to the main stream of farm input management strategies.

What is enriched compost?

The enrichment of compost with nutrients and beneficial organisms like *Azotobactor*, *Azospirillum* or PSB is called enriched compost.

Nutrient Enrichment

- ✓ Feed the cattle with nitrogen rich feed materials like pulse stubbles and green manures.
- ✓ Add phosphates like rock phosphate or SSP @1-2% of the total mass of dung materials to prevent loss of N and enhance N fixation in the trench itself and enrich the manure with P.
- ✓ For K enrichment adds wood ash.
- ✓ Add bio- inoculants like *Azotobacter* and PSB culture @ 250 g per section one month after filling in order to enrich the FYM with these important micro-organisms.

Enrichment of compost with Biofertilizers:

- ✓ N-fixing bacteria-*Azotobacter*, *Azospirillum* each 2 kg/tone if solid, 1 litre/tone if liquid.
- ✓ P-solubilizing bacteria-*Bacillus polymixaetc* - 4 kg/tone if solid, 2 litres/tone if liquid.
- ✓ K-Mobilizing bacteria-*Fraturia aurantia* 4kg/tone if solid, 2 litres/tone if liquid.

Enrichment of compost with Bio-Agents:

Bio-Control agents like *Trichoderma viride*, *Pseudomonas fluorescenceat* the rate of 2 kg/tone of each if solid, 500 ml/tone if liquid form.

Composting :

Compost is the stabilized and sanitized product of composting which is beneficial to plant growth. It is estimated that the organic waste available in India can supply about 7.1, 3.0 and 7.6 million tons of N, P_2O_5 and K_2O, respectively. These organics therefore, need to be recycled and put to productive use. In view of these facts greater attention is being paid in developing composting technology.

Nutrient content in different crop residues

Sr. No.	Crop residue	Nutrient (%)			
		N	P_2O_5	K_2O	Total
1.	Rice	0.61	0.18	1.38	2.17
2.	Wheat	0.48	0.16	1.18	1.82
3.	Sorghum	0.52	0.213	1.34	2.09
4.	Maize	0.52	0.18	1.135	2.05
5.	Pearlmillet	0.45	0.16	1.14	1.75
6.	Barley	0.52	0.18	1.30	2.00
7.	Fingermillet	1.00	0.20	1.00	2.20
8.	Sugarcane	0.40	0.18	1.28	1.86
9.	Lantana	2.50	0.25	1.40	4.15

Source: Bhattacharya *et al*. (2010). Organic Farming News Letter 6(3):6-9

Principles of Composting

Compost making includes three important and vital scientific principles

1. Narrow down the carbon: nitrogen ratio to a satisfactory level (10:1 or 12: 1)
2. Total destruction of harmful pathogens and weed seeds ensured by high temperature evolved during decomposition and stabilization.
3. Optimum temperature of 60-65 ^{0}C required for decomposing all harmful pathogens.

Essential requirements for composting

1. Bulky organic refuse such as stubbles, cotton stalk, tur stalks, groundnut shells, weeds leaves, dust bin refuse, etc.
2. A suitable starter: Cattle dung, urine, night soil, sewage, urea, rock phosphate or any other readily available nitrogenous substance. The mixture should contain 1 to 1.25 % N on dry weight basis (i.e., C:N- 30:1). Microbial cultures also hasten decomposition.
3. Addition of enough water to keep the moisture content of the material at a level around 50%.
4. Presence of sufficient supply of air, especially in the initial stages of decomposition.

Method of Composting

Although utilizing crop wastes in crop production is know from the earliest times systematic work on composting was initiated only in the beginning of this century. In India Howard and Wad (1931) at Indore and Howler (1933) at Bangalore have done some pioneering work. Composting is done either in aerobic condition or in anaerobic condition. Some methods involve both conditions. The advantage of aerobic system is that it is fast but require moistening and frequent turning.

Potential of organic and biological resources in India

Sr. No.	Name of Resource	Annual production of biomass (mt)	Nutrient supply (mt)
1.	Cattle and buffaloes (wet dung & urine)	2028.0	6.96
2.	Crop residues	336.0	8.74
3.	Forest litter	100.0	-
4.	City refuse	14.0	0.294
5.	Sewage sludge	6.0	0.011
6.	Press mud	5.0	0.266

Composting is an ancient method by which farmers have been converting plant, animal and human wastes into organic manures in other words we can say value addition to organic wastes. Basically any system or design that ensures efficient decomposition of organic matter can constitute composting method.

1. **Indore method :** Around 1930, Sir Albert Howard, a British Agronomist in India studied composting in a scientific manner at Indore and developed a scientific method of composting, known as Indore method. The waste materials are mixed well and properly moistened with dung or night soil slurry and build into heaps of 4 to 6 m length, 1 m width and 1 m height or put into a pit of 30' x 5'x 3' with slopping sides. In the later method charging of a 30 ft pit done in sections of 5 ft with first section being vacant to facilitate mixing. Aerobic conditions in this method are maintained by periodic manual turning of the composting materials in heaps and mix materials. Water is added if needed. Under this aerobic process, losses of organic matter and nitrogen are to the extent of 40-50% of initial levels. The average composition of manure has been found to be 0.8%N, 0.3% P_2O_5, and 1.5% K_2O.

   Fowler developed the process of **'activated compost'** in which fresh materials were incorporated in an already fermenting heap so that the already established large microbial population could bring about quicker decomposition. This process is useful particularly where offensive materials like night soil are to be quickly and effectively disposed off.

2. **Bangalore method :** Dr. C.N. Acharya in 1938 developed a method for anaerobic composting of city garbage and night soil in pits. The trenches of following dimensions are dug in rows, roads of suitable width are provided between row for the carts to approach and unload the materials inside the trenches.

Population ('000)	Length(m)	Bradth(m)	Depth(m)
<10	4.5	1.5	1.0
10 to 20	6.0	2.0	1.0
20 to 50	9.0	2.0	1.0
>50	10.0	2.5	1.0

The refuse and night soil are spread in alternate layers of 15 cm and 5 cm until the pit is filled 15 cm above ground level, with fine layer of refuse on the top. This may be given a dome shape and covered with a thin layer of soil. The decomposition is mostly anaerobic except in surface layer and is comparatively slow. The C: N ratio is reduced to less than 20:1 in about six months. This method is also known as hot fermentation method as heat loss during decomposition is considerably reduced. Though initially worked out for towns it can be used for making compost from conveniently available organic materials. Under rural conditions, animals dung can be used to substitute night soil.

3. **Coimbatore method:** The composting of wastes is done in pits. A depth of 1.0 m and width of 1.25 m facilitate easy manipulation while filling and turning the material. The length of the pit varies with the quality of material available for composting. A layer of waste material is laid in the pit. It is moistened with sprinkling the slurry of 5-10 kg of cow dung in 2-2.5 lit. of water in which 0.5 to 1.0 kg of fine bone meal is added. Similar layers are laid one over the other till the material rises 0.75 m above ground level. It is plastered over with wet mud and left undisturbed for 8-10 weeks.

   The mud plaster is removed two months later when material is moistened, turned and formed into a rectangular heap in a shady place. It is left undisturbed till required. In the beginning there is an aerobic fermentation when the material is kept covered with mud plaster. Aeration and aerobic fermentation sets in when formed in to an open heap later. The tricalcic phosphate in the bone meal is rendered soluble by the acids produced during decomposition and the compost is enriched by addition of phosphorus. Compost is ready when the temperature in the pile approaches that of the surrounding air. The final product is dark in colour, fairly divided, rich in humus and has a C: N ratio of 10:1 to 20:1.

4. **NADEP method:** This method of composting was developed by a farmer Narayan Dev Rao Panthary Pande of Pusad village in Maharashtra for composting of farm wastes. A structure of bricks with 22 cm thick walls and having size 3.3 m L x 2.0 m W x 1.0 m H is made at high and plain site with the help of cement. For proper aeration 10 cm x10 cm holes are made in wall leaving first and last rows. This structure is called “TANKA” which can use for a longer time. It is not possible to fill up the tanka in one day; therefore, the following materials should be collected in 2-3 days.

   Cow dung 60-100 kg; crop residues, green leaves, stalks, kitchen and fodder wastes etc. 1400-1500 kg; dry sieved soil 1700-1800 kg and water 1500-2000 lit.

   Before filling the tanka, their inner sides are sprinkled with dilute cow dung slurry and then 15-20 cm thick layer of garbage (approximate 200 kg) is laid at the bottom. Second layer is made with cow dung or bio gas slurry by dissolving 4-5 kg cow dung in 150 liter of water. Over this, third layer of dry sieved soil (200-250 kg) free of stone, glasses and plastic etc. is made and water is sprinkled to moisten it. This process is repeated 7-8 times until the material reaches 35-50 cm above the walls. Then it is given a hut shape to check entrance of rain water and plastered with slurry of soil and cow dung. After45 days the material will compact 25-30 cm downwards and cracks are seen on the surface. Now, the tanka is again filled and plastered in the above manner.

In this way 3.5 t of good quality compost can be prepared in 90-110 days.

This method is especially suitable when availability of cow dung is low. Basically, it is an aerobic method in which composting is done in special perforated brick structure to improve the aeration and to minimize the nutrient losses.

Vermicompost

Vermicompost is a method of making compost with the use of earthworm, which generally live in soil, eat bio-mass and excrete it in digested form. This compost is generally called vermicompost or vermicast, it provides the vital macro elements such as Nitrogen (0.74%) P_2O_5 (0.97%), K_2O (0.45%) and Ca, Mg and micro elements such as Fe, Mo, Zn, Cu etc.

Suitable species

One of the earthworm species most often used for composting is the Red Wiggler (*Eisenia fetida).* African Nightcrawlers (*Eudrilus eugeniae*) is another set of popular composter.These species are commonly found in organic-rich soils and live in rotting vegetation, compost, and manure piles.

Type of earthworms

There are about 3000 species of earthworms reported in the world. Among them 509 species are available in India. These earthworms are mainly divided into three groups

1. **Epigeics:** Are the species that live above the mineral soil surface.

   e.g. Eisenia foetida, Eudrilus eugeniae, Perionyx excavatus

   Above species are prolific feeders and can feed upon a wide variety of degradable organic wastes.

2. **Anecics:** Are the species that live in burrows in mineral soil layers.

3. **Endogeics:** Are species that inhabit mineral soil horizons

   e.g. *Lampito mauritii*

Benefits of vermicompost

1. When added to clay soil loosens the soil provides the passage for the entry of air.
2. The mucus associated with the cast being hygroscopic, absorbs water and prevents water logging and improves water holding capacity.
3. In the vermicomposting, some of the secretions of worms and the associated microbes act as growth promoter along with other nutrient.
4. It improves physical, chemical and biological properties of soil in the long run on repeated application.

5. The organic carbon in vermicompost releases the nutrient slowly and steadily in to the system and enables the plant to absorb these nutrients.

6. The multifarious effects of vermicompost influence the growth and yield of crops.

7. Earthworm can minimize the pollution hazards caused by organic waste by enhancing waste degradation.

Methods of vermicompost

In general, following are the three methods of vermicomposting under field condition.

1. Vermicompost of wastes in field pits

2. Vermicompost of wastes in ground heap

3. Vermicompost of wastes in large structures

Vermicomposting of organic wastes in field :

Pits:

It is preferable to go for optimum sized ground pits and 10 x 1.0 x 0.5m (L x W x D) can be effective size of each vermicomposting bed. Series of such beds are to be prepared at one place.

Ground heaps:

Instead of opening of pits, vermicomposting can be taken up in ground heaps. Dome shaped beds (with organic wastes) are prepared and vermicomposting is taken up. Optimum size of ground heaps may be series of heaps of dimension 5.0 x 1.0 x 1.0 m (L x W x H).

Composting in large structures:

Vermicomposting is taken up in large structures such as series of rectangular brick columns, cement tanks, stone block etc. which are filled with organic wastes and composting is taken up**.**

Each of these methods has got advantage as well as limitations. For example in (1) and (3) these would not be any mixing of soil with vermicompost unlike pit system, less incidence of natural enemies. But they need frequent watering (more of labour) compared to pit system. Similarly in places water is scarce (less rainfall tracts); pit system is good which in high rainfall areas (2) and (3) are advantageous as there would be proper drainage.

Steps:

This is irrespective of methods

Selection of site:

it should be preferably black soil or other areas with less of termite and red ant activity, pH should be between 6 to 8.

Collection of wastes and sorting:

For field composting, raw materials are needs in large quantities. The waste available should be sorted in to degradable and non-degradable (be rejected).

Pre-treatment of waste:

Lignin rich residues – chopping and subjecting to lignin degrading fungi and later to vermibeds.

Crop stalks and stubbles – dumping it in layers sandwiched with garden soil followed with watering for 10 days to make the material soft and acceptable to worm.

Agro-industrial wastes – mixing with animal dung in 3:1 proportion and later subjecting it for vermicomposting

Insecticidal treatment to site:

treating the area as well as beds (in case of pit system) with chlorpyriphos 20 EC @ 3.0 ml/liters to reduce the problem of ants, termites and ground beetles.

Filling of beds with organic wastes:

wastes are to filled in the manner given below and each layer should be made wet while filling and continuously watered for next 10 days. In heaping and composting in special structures, the waste is to be dumped serially as done in pits.

7th Layer	A thick layer of mulch with cereal straw	(Top of bed)
6th Layer	A layer of fine soil (Black/garden soil)	(Top of bed)
5th Layer	Dung/FYM/Biogas sludge	(Top of bed)
4th Layer	Green succulent leafy material	(Top of bed)
3rd Layer	Dry crop residues	(Top of bed)
2nd Layer	Dung/FYM/Biogas spent sludge	(Top of bed)
1st Layer	Coconut coir waste/ sugarcane trash	(Bottom of bed)

Except 3rd and 4th layer (which is the material to be degraded) each layer should be 3 to 4 inch thick so that the bed material is raised above the ground level. Sufficient quantity of dry and green wastes is to be used in the beds.

Introduction of worms in to beds:

The optimum number of worms to be introduced is 100 No./length of the bed. The species of earthworms that are being used currently for compost production worldwide are *Eisena foetida, Eudirlus eugeniae, Periony excavates, Lumbricus rubella* etc.

Provision of optimum bed moisture and temperature:

Bed moisture: by watering at regular intervals to maintain moisture of 60 to 80% till harvest of compost. Temperature requirement for optimal results is 20-30°C by thatching (during summer)

Monitoring for activity of natural enemies and earthworm and management of enemies with botanicals. Promising products: leaf dust of neem, *Acorus calamus* rhizome dust, neem cake etc.

Harvesting of vermicompost and storage:

Around 90 days after release of worms, the beds would be ready for harvest.

Stop watering 7days prior to harvest so that worms settle at bottom layer. Collect the compost, shade dry for 12 hours and bag it in fertilizer bags for storage.

Harvest of worm biomass:

The worms are to be collected and used for subsequent vermicomposting.

Vermicomposting technique

Sheds:

For a vermicomposting unit, whether small or big could be of thatched roof supported by bamboo rafter and purling, wooden trees and stone pillars.

Vermi beds:

prepare 90 cm width, 45 cm height and length as per availability of dung and organic waste.

Land:

About 0.5 to 1 acre of land will be needed to set up a vermi compost unit cum extension centre.

Seed stock:

Worms @350 per M^3 of bed space should be adequate to start with and build up the required population in about 2 to 3 cycles.

Water supply system:

To maintain optimum moisture content (40%) in vermibed ,spray &apply water on vermin bed. Frequency & quality is regulated by prevailing climatic conditions.

Collection of VC:

When vermin compost is ready for collection, top layers apex somewhat dark granular and it used dry tea leaves have been spread over the layer. Watering should then stopped for 2-3 days and ready compost should be scrapped form top layers or to a depth.

Storage:

It should be stocked separately in bags. Before packing it should be sieved out from 2 cm galvanized mesh. The compost should not be exposed to sun.

Average nutrient content of vermicompost

1.	Organic matter	-	30 to 40%
2.	Nitrogen	-	1.50 to 2.0 %
3.	phosphorus	-	2.0 to 2.50%
4.	potash	-	0.6 to 0.80%
5.	Ca	-	150 to 160 ppm
6.	Fe	-	120000 to 125000 ppm
7.	Zn	-	100 to 150 ppm
8.	Mn	-	200 to 250 ppm
9.	Cu	-	20 to 30 ppm

Application of vermicompost

Crop		**Quantity required**
Pearlmillet	-	2.5 ton VC/ha
Maize	-	3.0 ton VC/ha + 50% RDF
Paddy	-	1.0 ton VC/ha + 75% RDF
Green gram	-	2/5 ton VC/ha
Soyabean	-	3.0 ton VC/ha
Sunflower	-	5.0 ton VC + 50% RDF
Tomato	-	4.0 ton VC + 50% RDF
Potato	-	4.0 ton VC + 50% RDF
Coriander	-	2.5 ton + 50% RDF
Oat	-	10 ton VC + 75% RDF
Safed musali	-	5 ton VC

PRACTICAL - 4

BIO FERTILIZERS/BIO INOCULANTS FOR ORGANIC FARMING

Biofertilizers are defined as preparations containing living cells or latent cells of efficient strains of microorganisms that help crop plants uptake of nutrients by their interactions in the rhizosphere when applied through seed or soil. They accelerate certain microbial processes in the soil which augment the extent of availability of nutrients in a form easily assimilated by plants.

Microorganisms are not as efficient in natural surroundings as one would expect them to be and therefore artificially multiplied cultures of efficient selected microorganisms play a vital role in accelerating the microbial processes in soil.

Use of biofertilizers is one of the important components of integrated nutrient management, as they are cost effective and renewable source of plant nutrients to supplement the chemical fertilizers for sustainable agriculture. Several microorganisms and their association with crop plants are being exploited in the production of biofertilizers. They can be grouped in different ways based on their nature and function.

Sr. No.	Groups	Examples
N_2 Fixing Biofertilizers		
1.	Free- living	Azotobactor, Beijerinkia, Clostridium, Klebsiella, Anabaena, Nostoc
2.	Symbiotic	Rhizobium, Frankia, Anabaena azolla
3.	Associative Symbiotic	Azospirillum
P Solubilizing Biofertilizers		
1.	Bacteria	*Bacillus megaterium var. phosphaticum, B. subtilis, B. circulans, pseudomonas striata*
2.	Fungi	*Penicillium sp, Aspergillus awamori*
P Mobilizing Biofertilizers		
1.	*Arbuscular mycorrhiza*	*Glomus sp., Gigaspora sp., Acaulospora sp., Scutellospora sp. & Sclerocystis sp.*
2.	*Ectomycorrhiza*	*Laccaria sp., Pisolithus sp., Boletus sp., Amanita sp.*
3.	*Ericoid mycorrhizae*	*Pezizella ericae*
4.	*Orchid mycorrhiza*	*Rhizoctonia solani*

Biofertilizers for Micro nutrients		
1.	Silicate and Zinc solubilizers	*Bacillus sp.*
Plant growth promoting Rhizobacteria		
1.	Pseudomonas	*Pseudomonas fluorescens*

Benefits of bio- fertilizers in organic farming

- Bio-fertilizers are eco-friendly and do not have any ill effect on soil health and environment.
- They reduce the pressure on non-renewable nutrient sources/fertilizer.
- Their formulations are cheap and have easy application methods.
- They also stimulate plant growth due to excretion of various growth hormones.
- They reduce the incidence of certain disease, pathogen and increase disease resistance.
- The economic benefits to cost ratio of bio-fertilizers is always higher.
- They improve the productivity of waste land and low land by enriching the soil.

Types of Bio-fertilizers

- Biological N fixing micro organisms
- Phosphate solubilizing and mobilizing micro-organisms
- Potash solubilizing micro-organisms
- Sulphur mobilizing micro-organisms
- Arbuscular mycorrhizal fungi
- Growth promoting substance excreting micro-organisms

NITROGEN FIXING BIOFERTILIZERS

(a) Symbiotic nitrogen fixers

1. ***Rhizobium:*** Among all bio-fertilizers, *rhizobium* inoculants are widely used by farmers throughout the world. These organisms colonize roots of leguminous plants to form root nodules, which act as the factories of nitrogen production for the host plant. These bacteria live in these nodules and takes nitrogen of air to convert into an organic form that the plant can use. As the bacteria live right in root it transfers nutrients directly into the plants. *Rhizobium*- legume symbioses can fix 100-300 kg N/ha on a season depending upon crop and live substantial quality of N in surroundings rhizosphere for the succeeding crop.

   In chick pea, nitrogen fixation starts about 15 days after sowing when nodules are small but pink and attain peak level at the time of flowering and early stage of seed

formation. Because of this fact it is advisable to give starter dose of 20-25 kg N/ha to legume crops. *Rhizobium* can meet more than 80% of N need of the legume crops with 10-25% increase of grain yield of pulses. The response varies depending on soil conditions and effectiveness of native population.

2. **Azolla:** Azolla is a floating water fern and is ubiquitous in distribution. It has an algal symbiont viz., Anabaena Azollae within its central cavity. The alga fixes atmospheric nitrogen and is present at all stages of growth and development of fern. Azolla contains 0.2-0.3 % N on fresh weight basis and 3-5 % on dry weight basis. It's used as bio-fertilizer for rice in many countries and relatively more advantageous over urea. Under ideal conditions, it has potential of fixing more than 10 kg N/ha/day. One crop of Azolla provides 20-40 kg N/ha to the rise in about 20-25 days. Farmers can take two such crops during rice cultivation. Technology of *A. pinnata* cultivation is developed and well domesticated, which paddy growers could easily adopt. Azolla fern has greater potential as sole crop in specific areas viz; low land paddy, water logged waste lands, seepage water, shallow ponds, natural fresh water lagoons, burrow pits, Khet talawadi etc. and thereby it generates employment in rural areas. Over all, Azolla is widely accepted as fertilizer, feed, food and fodder.

(b) Non Symbiotic Nitrogen Fixers:

1. ***Azotobacter*:** These are free-living gram-negative rod shaped nitrogen-fixing bacteria in loose association for plants. They are normal inhabitants of soils, ubiquitous in geographic distribution an can a variety of C and energy for their growth. These bacteria can substitute 20-40 kg N/ha for different crops. In India, depending upon soil fertility most probable number (MPN) of N fixers slime, which helps in soil aggregation. Seed germination and plant stand are improved in plants upon inoculation with improved strains. Various species of *Azotobacter* are *A. agilis, A. chrococcum, A. beijerinckii, A.vinelandi, A. ingrinis*. Out of these A. chrococcum happens to be the dominant inhabitant in arable soils and is most effective and widely used.They increase crop yield by 10-15% and help in mineralization of plant nutrients and proliferation of other useful micro-organism.

2. ***Azospirillum :*** *Azospirillum* are non-symbiotic N fixing bacteria. This is very important and widely used biofertilizer in present day agriculture for many crops. These bacteria have intimate association with roots of cereals and grasses. Individual cells are gram-negative curved rods, 1 mm in diameter, size and shape vary. There are four common species viz; *A. lipoferrum, A. brazillense, A. amazonense* and *A. halpraeferans*. The mechanism by which inoculated plants derive positive benefits is same as *Azotobacter* and fix 20-40 kg N/ha in field conditions with increase in yield by 10-15 %.

3. ***Acetobacter*:** This is a sacharophillic bacteria and associate with sugarcane, sweet potato and sweet sorghum plants and fixes 30 kg N/ha/year. Mainly this bacteria is

commercialized for sugarcane crop. It is known to increase yield by 10-20 t/ha and sugar content by about 10-15%.

PHOSPHATE SOLUBILIZING BIOFERTILISERS:

PSMs includes different group of microorganisms such as bacteria, yeast and fungi, which convert insoluble inorganic phosphates into soluble form. The common genera like *Bacillus, Pseudomonas, Aspergillus, Penicillium, , Fusarium, Micrococcus* etc have been reported to be active in bioconversion of PO_4. It is estimated that in most tropical soils only 25% is available for plant growth and 75% of super phosphate applied get fixed. Important species of PSM includes *Bacillus polymaxa, B. coagulans, B. circulans, Psuedomonas striata, Aspergillus awamori and Penicillum digitatum.* PSMs can be mass multiplied on Pikovasky's broth and mixed with carrier material for field use. These organisms possess the ability to bring phosphate solubilization by secreting organic acids such as formic, acetic acids, propionic, lactic, glycolic, succinic acids etc. These acids lower the p^H and bring about the dissolution of bound form of phosphates. The integrated use of PSMs could bring benefits from the low-grade rock phosphates available to the tune of 230 million tons in our country. PSMs are recommended for all crops in India and have shown to replace 20-50 kg P_2O_5/ha in different crops due to inoculative applications.

c. Potash solubilizing micro-organisms

The bacterium, *Frateuria aurantia* was isolated from banana plant from Orissa soil. These bacteria have solubilizing power of 90% within 22 days when the mineral source of K is in fixed form. These bacteria were tested on banana and paddy which increased the yield by 20 & 25%, respectively. It can be used as soil application for all types of crops @ 2.5 kg/ha. It can be mixed with @ 200-500 kg FYM in furrows before sowing. The bacterium can save up to 50-60 % of cost of K fertilizer.

d. Sulphur mobilizing micro organisms.

Sulphur present as insoluble sulphur form at 30-35 cm deep in soil and are associated with oxides of iron and aluminium. *Acetobacter pasteurianus* helps in converting this non-usable form to usable form. The use of 625 g/ha of *A. pasteurianus* influenced the levels of sulphur in crops like vegetables, cabbage, turnip, onion etc.

e. Arbuscular mycorrhizal fungi (AMF)

AMF improve plant growth through better uptake of nutrient like P, Zn, Cu etc. and make the plant root more resistant to pathogens, improve soil texture, WHC, disease resistance and better plant growth. AMF saves 25-50 kg P/ha in addition increase the yield up to 10-12%.

f. Growth promoting substance erecting micro organisms.

The specific strain of plant growth promoting rhizobacteria (PGPR) could colonize roots of crops like potato, beet root, apple and legumes. They enhance plant growth indirectly by

depriving the harmful micro organisms. PGPR belong to many genera including *Agrobacterium, Arthrobacter, Azotobacter, bacillus, Pseudomonas, cellublomonas, Rhizobium* etc.

LIQUID BIOFERTILIZERS – A NEW PANORAMA:

Successfully developed **Anubhav liquid formulations of bio-fertilizers** based on native Azotobactor and Phosphate culture, product is having minimum cell count of 10^9/ml and with shelf life of 1 year, suitable for drip irrigation and green house cultivation as against currently marketed carrier based (lignite) products having shelf life of 6 months. Following demonstrations at farmers' field in tribal areas of Gujarat in maize, wheat, mung etc. during last decade, **Lab to Land,** Showed saving up to 50% N+P with significant yield increase. Sale of liquid bio-fertilizers to the end users since 2005 is up to 3000 lit at affordable price Rs. 100/-lit. This technology is ready to be transferred to the farming community using concept of public private partnership.

Dosage of liquid Bio-fertilizers in different crops

Recommended liquid Bio-fertilizer and its application method, quantity to be used for different crops are as follows:

Crop	Recommended Bio-fetillizer	Application method	Quantity to be used
Field crops, pulses, Chickpea, Pea, Groundnut, Soybean, Beans, Lentil, Lucern, Berseem, Green gram, Black gram, Cowpea and pigeon pea	*Rhizobium*	Seed treatment	500 ml/acre
Cereals, Wheat, Oat, Barley	*Azotobactor / Azospirillum*	Seed treatment	500 ml/acre
Rice	*Azospirillum*	Seed treatment	500 ml/acre
Oil seeds, Mustard, Seasum, Linseeds, Sunflower, Castor	*Azotobacter*	Seed treatment	500 ml/acre
Millets, Pear millets, Finger millets, Kodo millet	*Azotobacter*	Seed treatment	500 ml/acre
Maize and Sorghum	*Azospirillum*	Seed treatment	500 ml/acre
Forage crops and Grasses Bermuda grass, Sudan grass, Napier Grass, Para Grass, Star Grass etc.	*Azotobactor*	Seed treatment	500 ml/acre
Other Misc. Plantation Crops Tobacco	*Azotobactor*	Seedling treatment	1250 ml/acre
Tea, Coffee	*Azotobacter*	Soil treatment	400 ml/acre
Rubber, Coconuts	*Azotobactor*	Soil treatment	2-3 ml/plant

Agro-Forestry/Fruit plants All fruit/agro-forestry (herb, shrubs, annuals and perennial) plants for fuel wood fodder, fruits, gum, spice, leaves, flowers, nuts and seed purpose	*Azotobacter*	Soil treatment	2-3 ml/plant at nursery
Leguminous plants/trees	*Rhizobium*	Soil treatment	1-2 ml/plant

Note : Doses recommended when count of inoculums is 1 x 10^8 cells/ml then doses will be ten times more besides above said Nitrogen fixers, Posphate solubilizers and potash mobilizers at the rate of 200 ml/acre could be applied for all crops.

Application of Bio-fertilizers

1. Seed treatment or seed inoculation
2. Seedling root dip
3. Main field application

Seed Treatment:

One packet of the inoculant is mixed with 500 ml of rice kanji to make a slurry. The seeds required for ha are mixed in the slurry so as to have a uniform coating of the inoculants over the seeds and then shade dried for 30 minutes. The shade dried seeds should be sown within 24 hours. One packet of the inoculants (200 g) is sufficient to treat 10 kg of seeds.

Seedling root dip:

This method is used for transplanted crops. Five packets of the inoculants is mixed in 100 liters of water. The root portion of the seedlings required for one ha is dipped in the mixture for 5 to 10 minutes and then transplanted.

Main field application:

Ten packets of the inoculants is mixed with 50 kgs of dried and powdered farm yard manure and then broadcasted in one hectare of main field just before transplanting.

Rhizobium:

For all legumes *Rhizobium* is applied as seed inoculants.

***Azospirillum/Azotobacter*:**

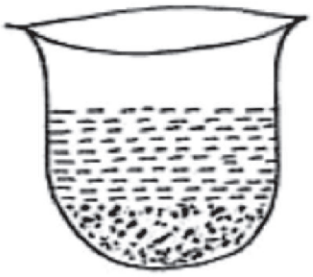
In the transplanted crops, *Azospirillum* is inoculated through seed, seedling root dip and soil application methods. For direct sown crops, Azospirillum is applied through seed treatment and soil application.

Phosphobacteria:

Inoculated through seed, seedling root dip and soil application methods as in the case of *Azospirillum*.

Combined application of bacterial biofertilizers:

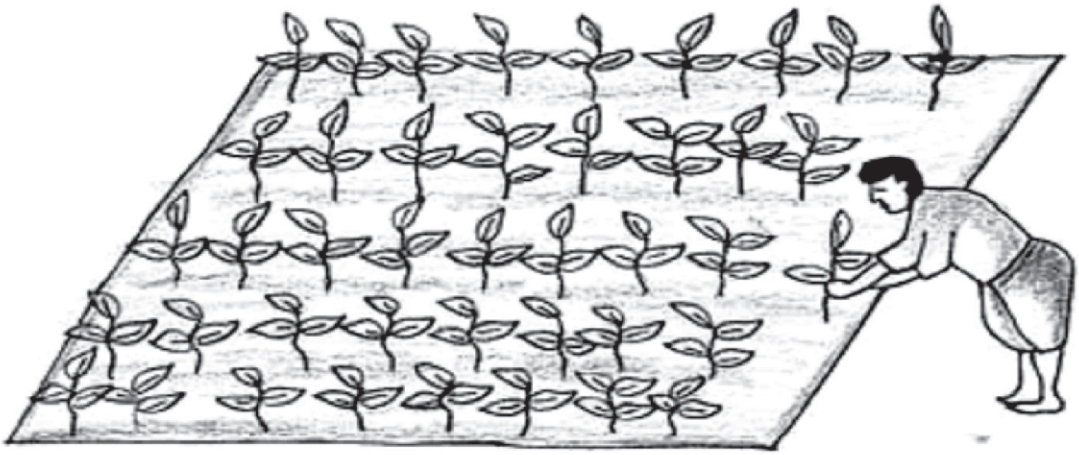
Phospho bacteria can be mixed with *Azospirillum* and *Rhizobium*. The inoculants should be mixed in equal quantities and applied as mentioned above.



1 kg. bio-fertilizer in
50 litres of water

Seedlings

Dipping seedlings
for 30 min.



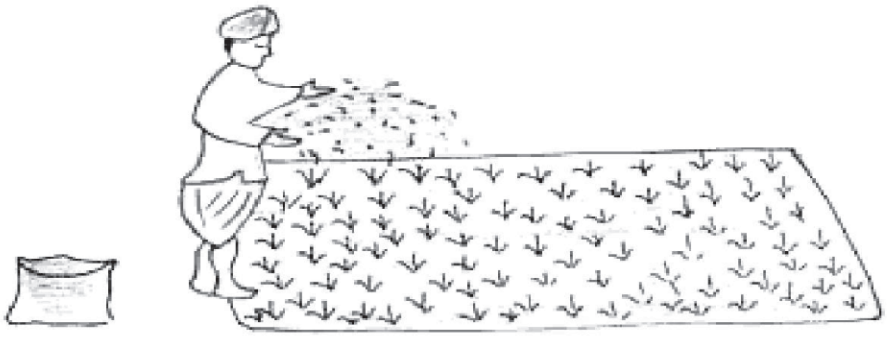
Transplanting the seedlings

Seedling Dip

Bio-fertilizer (5 kgs)

Mixing bio-fertilizer with 100 kgs of farm yard manure (FYM)

Bio-fertilizer mixture ready for use



Spreading the mixture in the field

Soil application of bio-fertilizers

Points to Remember:

- Bacterial inoculants should not be mixed with insecticide, fungicide, herbicide and fertilizers.
- Seed treatment with bacterial inoculants is to be done at last when seeds are treated with fungicides.

Bio-fertilizers recommendation (one packet- 200 g)

Sr. No.	Crops	Seed	Nursery	Seedling dip	Main field	Total requirement of packets per ha
1.	Rice	5	10	5	10	30
2.	Sorghum	3	-	-	10	13
3.	Pearl millet	3	-	-	10	13
4.	Rangi	3	-	5	10	18
5.	Maize	3	-	-	10	13
6.	Cotton	3	-	-	10	13
7.	Sunflower	3	-	-	10	13
8.	Castor	3	-	-	10	13
9.	Sugarcane	10	-	-	36(split)	46
10.	Turmeric	-	-	-	24(split)	24
11.	Tobacco	1	3	-	10g/pit	14
12.	Papaya	2	-	-	10	-
13.	Mandarin orange	2	-	-	10 g/pit	-
14.	Tomato	1	-	-	10	14
15.	Banana	-	-	5	10 g/pit	-

***Rhizobium* (only Seed application is recommended)**

Sr. No.	Crop	Total requirement of packets per ha
1.	Soybean	5
2.	Groundnut	5
3.	Bengal gram	5
4.	Black gram	3
5.	Green gram	3
6.	Red gram	3
7.	Cow pea	3

Phosphobacteria :

The recommended dosage of *Azospirillum* is adopted for phosphor-bacteria inoculation; for combined inoculation, both bio-fertilizers as per recommendations are to be mixed uniformly before using.

PRACTICAL - 5

ITK FOR NUTRIENT MANAGEMENT

PANCHGAVYA

Panchagavya, an organic product has the potential to play the role of promoting growth and providing immunity in plant system. Panchagavya consists of nine products viz. cow dung, cow urine, milk, curd, jaggery, ghee, banana, Tender coconut and water. When suitably mixed and used, these have miraculous effects.

- Cow dung - 7 kg
- Cow ghee - 1 kg

Mix the above two ingredients thoroughly and keep it for 3 days with regular mixing both in morning and evening hours

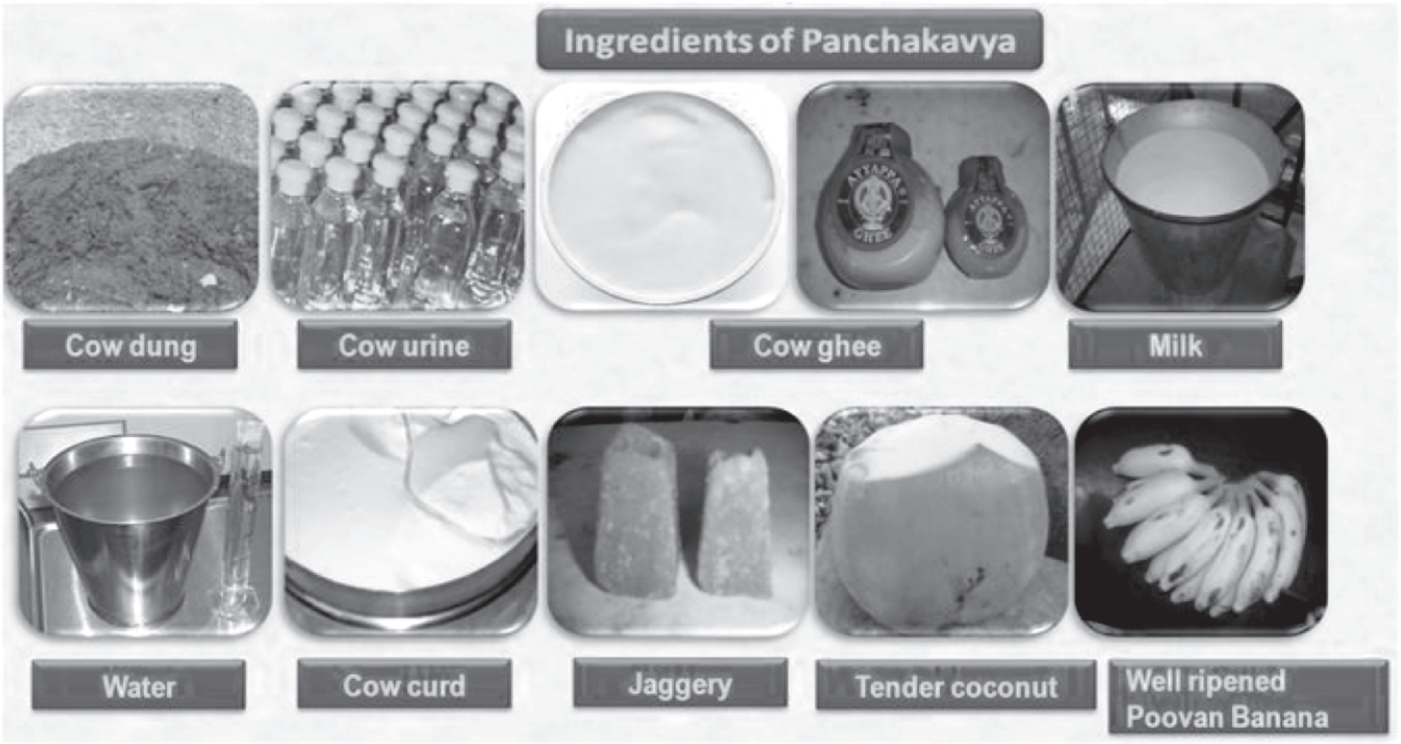
- Cow Urine - 10 liters
- Water - 10 liters

After 3 days mix cow urine and water and keep it for 15 days with regular mixing both in morning and evening hours. After 15 days mix the following and panchagavya will be ready after 30 days.

- Cow milk - 3 liters
- Cow curd - 2 liters
- Tender coconut water - 3 liters
- Jaggery – 0.500 kg or Sugarcane juice 3 liters.
- Well ripened poovan banana – 12 nos.

Preparation

All the above items can be added to a wide mouthed mud pot, concrete tank or plastic can as per the above order. The container should be kept open under shade. The content is to be stirred twice a day both in morning and evening. The Panchagavya stock solution will be ready after 30 days. (Care should be taken not to mix buffalo products. The products of local breeds of cow is said to have potency than exotic breeds). It should be kept in the shade and covered with a wire mesh or plastic mosquito net to prevent houseflies from laying eggs and the formation of maggots in the solution. If sugarcane juice is not available add 500 g of jaggery dissolved in 3 liter of water.



Physico-chemical and biological properties of Panchagavya

Chemical composition			Microbial Load		
pH	:	5.45	*Fungi*	:	38800/ml
EC dSm^2	:	10.22	*Bacteria*	:	1880000/ml
Total N (ppm)	:	229	*Lactobacillus*	:	2260000/ml
Total P (ppm)	:	209	*Total anaerobes*	:	10000/ml
Total K (ppm)	:	232	*Acid formers*	:	360/ml
Sodium	:	90	*Methanogen*	:	250/ml
Calcium	:	25			
IAA (ppm)	:	8.5			
GA (ppm)	:	3.5			

Physico-chemical properties of Panchagavya revealed that they possess almost all the major nutrients, micro nutrients and growth hormones (IAA & GA) required for crop growth. Predominance of fermentative microorganisms like yeast and lactobacillus might be due to the combined effect of low pH, milk products and addition of jaggery/sugarcane juice as substrate for their growth.

The low pH of the medium was due to the production of organic acids by the fermentative microbes as evidenced by the population dynamics and organic detection in GC analysis. Lactobacillus produces various beneficial metabolites such as organic acids, hydrogen peroxide and antibiotics, which are effective against other pathogenic microorganisms besides its growth.

3. Recommended dosage

Spray system

3% solution was found to be most effective compared to the higher and lower concentrations investigated. Three liters of Panchagavya to every 100 liters of water is ideal for all crops. The power sprayers of 10 liters capacity may need 300 ml/tank. When sprayed with power sprayer, sediments are to be filtered and when sprayed with hand operated sprayers, the nozzle with higher pore size has to be used.

Flow system

The solution of Panchagavya can be mixed with irrigation water at 50 liters per hectare either through drip irrigation or flow irrigation.

Seed/seedling treatment

3% solution of Panchagavya can be used to soak the seeds or dip the seedlings before planting. Soaking for 20 minutes is sufficient. Rhizomes of Turmeric, Ginger and sets of Sugarcane can be soaked for 30 minutes before planting.

Seed storage

3% of Panchagavya solution can be used to dip the seeds before drying and storing them.

Periodicity

1.	Pre flowering phase	:	Once in 15 days, two sprays depending upon duration of crops
2.	Flowering and pod setting stage	:	Once in 10 days, two sprays
3.	Fruit/Pod maturation stage	:	Once during pod maturation

Time of application of Panchagavya for different crops is given as follows

Crops	Time schedule
Rice :	10, 15, 30 and 50th days after transplanting
Sunflower :	30, 45 and 60 days after sowing
Black gram :	Rain fed: 1st flowering and 15 days after flowering Irrigated: 15, 25 and 40 days after sowing
Green gram:	15, 25, 30, 40 and 50 days after sowing
Castor :	30 and 45 days after sowing
Groundnut :	25 and 30th days after sowing
Bhindi :	30, 45, 60 and 75 days after sowing
Moringa :	Before flowering and during pod formation

Tomato	:	Nursery and 40 days after transplanting: seed treatment with 1 % for 12 hrs
Onion	:	0, 45 and 60 days after transplanting
Rose	:	At the time of pruning and budding
Jasmine	:	Bud initiation and setting
Vanilla	:	Dipping setts before planting

Effect of Panchagavya

Leaf

Plants sprayed with Panchagavya invariably produce bigger leaves and develop denser canopy. The photosynthetic system is activated for enhanced biological efficiency, enabling synthesis of maximum metabolites and photosynthates.

Stem

The trunk produces side shoots, which are sturdy and capable of carrying maximum fruits to maturity. Branching is comparatively high.

Roots

The rooting is profuse and dense. Further they remain fresh for a long time. The roots spread and grow into deeper layers were also observed. All such roots help maximum intake of nutrients and water.

Yield

There will be yield depression under normal circumstances, when the land is converted to organic farming from inorganic systems of culture. The key feature of Panchagavya is its efficacy to restore the yield level of all crops when the land is converted from inorganic cultural system to organic culture from the very first year. The harvest is advanced by 15 days in all the crops. It not only enhances the shelf life of vegetables, fruits and grains, but also improves the taste. By reducing or replacing costly chemical inputs, Panchagavya ensures higher profit and liberates the organic farmers from loan.

Drought Hardiness

A thin oily film is formed on the leaves and stems, thus reducing the evaporation of water. The deep and extensive roots developed by the plants allow to withstand long dry periods. Both the above factors contribute to reduce the irrigation water requirement by 30% and to ensure drought hardiness.

5. Cost : Cost of Panchagavya is Rs. 40/Lit

Note : Generally panchagavya is recommended for all the crops as foliar spray at 3.0 % level (3 litre panchagavya in 100 liters of water).

JIVAMRUT

PREPARATION

Ingredients of *JIVAMRUT*

- 10 kg Cow fresh dung
- 5 kg cow urine
- 2 kg jaggery
- 2 kg pulse flour (cow pea)
- 1 kg *sajiv* soil
- 200 lit. water

All the above items can be added to a wide mouthed plastic tank having a capacity of 300 liters. Add 200 lit water in it. The container should be kept under shade. This mixture is to be stirred twice a day in clock wise direction both in morning and evening. The *jivamrut* stock solution will be ready after 7 days. (The products of local breeds of cow is said to have potency than exotic breeds). It should be kept in the shade and the mouth of the tank is tied with a cotton cloth. The volume of the final solution obtained is 200 liters. The rate of application is 500 lit./ha. It may be applied on soil when it is wet. If possible apply after noon (preferably after 16.00 hrs.). It can also be applied along with irrigation water.

BIJAMRUT

PREPARATION

Ingredients of *BIJAMRUT*

- 5 kg Cow fresh dung
- 100 g lime
- 5 lit cow urine
- 50 g sajiv soil
- 20 lit water

Take 5.0 kg fresh cow dung in cotton cloth and dip it in water. The soluble elements in the dung will be dissolved in water. In another separate vessel take 100 g lime and add 1 lit. water in it. Keep it for 12-16 hours. The solid portion of the cow dung will be separated by squeezing it and in this solution add 5.0 lit cow urine + 1 lit lime water + 50 g soil (forest uncultivated soil) + 20 lit water. Keep this mixture for 12-16 hours. Filter it and it can be used for seed treatment.

BIODYNAMIC FARMING

Bios = life dynamic = energy

Dr. Rudolf Steiner explained how modern science and therefore chemical agriculture was based on the study of dead things in laboratories, rather than on the observation of living nature and the complex relationships constantly changing therein. Among this web of life he also included the cosmos with its moving planets and stars, and he spoke of how in the past, farmers instinctively knew about the effects of this movement on the life of plants and also animals and human beings. As modern human

beings, we must find this connection once more to understand how to work best with nature, but this time in a very conscious, measurable way.

Today there are many people around the globe who concentrate on understanding and recording the effects of the cosmos on our planet Earth, including Maria Thun in Germany who publishes a planting calendar for gardeners and farmers to use. Rudolf Steiner introduced a few preparations based on homeopathic medicine to enhance the beneficial cosmic influences on plants and the soil, and encouraged people to experiment and find new ones as well.

Life is a study of energy from the coarse to the fine, and Biodynamics is primarily concerned with the higher forces, the finer energies and how they influence plants, animals, and human beings. This knowledge and work with the life forces brings balance and healing to the soil, and therefore to anything that grows in that soil and every being that eats those plants.

Main effects of using biodynamic in agriculture

1. To increase the vitality of food
2. To regenerate natural resources such as the soil (by restoring the organic matter present in the soil), the seeds, and the water
3. To create a personal relationship with the world in which we live, with Nature of which we are apart of, and to learn to work together
4. Most of all, to be of service to the Earth and its beings by aiding nature where it is weak due to constant use

DEMETER = Greek goddess of the Earth

Biodynamic methods produce a living soil with revitalized natural forces, in alignment with planetary cosmic rhythms. At the heart of this activity is the intelligence and consciousness of the human being *who* is caring for this piece of the Earth, and who is the 'ordering principle'. This deep awareness is based on observation and relationship with the land and with Nature; it's based on love.

Advantages

1. Production of top quality fruits and vegetables, with strong flavours and high levels of nutrients (protein and vitamin content)
2. Yields always above the average level, higher on average than those produced by organic farming, and consistently high throughout the years as opposed to the falling yields obtained by chemical farming as the soil is mineralized and pest populations become unbalanced and become a problem
3. Little trouble with livestock and plant diseases
4. No spreading of insect pests, and no great economic damage due to their presence: the question of insect pests is one of balance and control which can be restored by proper management such as planting shrubs and trees which will house natural predators

HOMA THERAPY OR AGNIHOTRA:

Homa is a Sanskrit word used synonymously with yajna or havan. Yajna is the technical term from the Vedic science of bio-energy, which denotes the process of removing the toxic conditions of the atmosphere through the agency of fire. This means the healing and purification of the atmosphere

with fire as the medium. You heal the atmosphere and the healed atmosphere heals you. This is the central idea in homa therapy. This knowledge can be used in agriculture, environment, medicine, psychotherapy, biogenetics, etc.

Agnihotra is the basic homa for all homa fire practices mentioned in ancient Vedic science. It is tuned to the biorhythm of sunrise and sunset. The process involves preparing a small fire in a copper pyramid of fixed size and putting some grains of rice into the fire exactly at sunrise and sunset accompanied by the chant of two simple mantras.

Farmers in more than 60 countries practice Homa therapy. There are many reports from India and abroad which claim that the use of homa therapy in agriculture improves degraded lands, controls pests and diseases and improves the quantity and quality of the produce.

PRACTICAL - 6

NON CHEMICAL APPROACH FOR INSECT, PEST, DISEASE AND WEED MANAGEMENT

In organic agriculture, incidence of insect and disease attacks can be reduced by sound cultural practices and biological approaches. These practices are region and crop specific.

A. CULTURAL PRACTICES:

The cultural methods are the traditional practices followed by farmers for modulating crop growth through selection of seed varieties, appropriate time of sowing and maintenance of specific plant population density for altering the microclimate.

1. Crop rotation:

Rotating the crop belonging to one family with one of a different family helps to reduce pest incidence to a large extent. Rotating groundnut with maize will reduce the attack of white grubs. Rotating pigeon pea or chickpea with other non-leguminous crop helps to control fusarium wilt and nematode problems.

2. Trap crops:

Insects are strongly attracted by certain plants and when these are sown in the field or along the border, they will gather on them rather than on the main crop. Later they can easily be destroyed. Mustard is a trap crop along with cabbage for the control of diamond back moths, aphids and leaf webbers. The African marigold is a good trap crop for the American bollworm and it also attracts the adults of leaf miners to lay eggs on its leaves. Maize plants are a trap crop to attract fruit flies which are a pest in vegetable cultivation and the cotton bollworm *Helicoverpa armigera*.

3. Intercropping:

Intercropping generally has positive effects in terms of reducing the occurrence of insect pests. Insects find it difficult to locate host plants as the visual and chemical stimuli for the host plants are not so strong and the aromatic odour of other plants can disrupt the insects' ability to locate such host plants. Intercropping also interferes with the population development and survival of insect pests. For example, cabbage along with carrot or tomato is an important intercrop combination to effectively manage diamond back moth. Sowing cowpea as intercrop with groundnut minimizes leaf miner infestation. Green gram intercropped with sugarcane reduces the incidence of sugarcane early shoot borer. Growing short-duration pulses like black gram, cowpea, soybean and green gram as intercrops in cotton, increases the effectiveness of natural predators like coccinellids, syrphids, trichogrammatids, etc.

4. Use of resistant / tolerant varieties:

Genotypes showing tolerance and resistance to insect pests and diseases are to be selected for sowing. Plants have sophisticated mechanisms to protect themselves from attacks by insects. Certain genotypes act as deterrents and antifeedants and some encourage the predators of pests. There should be a constant watch to update such genotypes in the region. A number of resistant varieties are available for every crop from all agro climatic zones.

B. BIOLOGICAL APPROACHES :

Biological approaches to pest management comprise the use of:

- plants or botanicals
- microbial pesticides
- biocontrol by insects
- biorationals

1. Botanicals:

The plant kingdom is a rich storehouse of biologically active compounds. Various plant products have been in use for many centuries in India to minimize losses in crops and grain storage.

A large database of plant species that possess pest-controlling insecticidal, antifeedant, repellant, attractant and growth inhibiting properties exists in every village. Some of the plants widely used in the preparation of botanical pesticides are *Anona sp, Azadirachta indica, Chrysanthemum sp., Cymbopogan sp., Nicotiana sp, Pongamia sp, Vitex sp.* , etc. Seeds, leaves, extracts, fruits, kernels, oil and decoctions from botanicals are used to control the pests. The following are some of the botanical pesticides that can be prepared by using plants having insect repellant properties:

Neem seed kernel extract (NSKE)

NSKE can be easily prepared by using neem seed kernels and it is very effective for a variety of insect pests.

Method

- Collect 25 kg of neem seeds and crush them into a coarse powder.
- Tie the crushed seeds in a muslin or cotton cloth and immerse overnight in 50 litres of water.
- Squeeze the cloth containing the crushed neem seeds and remove the extract entirely. Dip the cloth containing the crushed neem seeds again in 50 liters of water and squeeze again.
- Add 400 liters of water to the concentrated solution of 100 liters extract. A 5% solution can be used as a foliar spray. For every 100 litres of the spray solution add about 50 gm of khadi

soap or soap nut which acts as an emulsifier to spread the spray solution uniformly on the foliage. NSKE should be used within 2–3 days of preparation.

- This spray is effective for a variety of leaf eating insects and is also undertaken as a prophylactic or preventive measure for pests.

Precautions

- Spray the solution during evening hours.
- Khadi soap or soap nut are mild emulsifiers. Strong detergents (with enzymes) should never be used.

Liquid manure for pest management

A variety of plants (weeds) which have pesticidal value are used to make liquid manure. Plants that have strong disagreeable odour, e.g., *Parthenium, Lantana, Vitex, Calotropis,* etc., are ideal for this preparation.

Method

- Collect 30 kg of leaves and tender parts of plants which have pesticide qualities.
- Chop them into small pieces and put them into a 200 liter barrel.
- Add 30 kg of cattle dung to the barrel and fill it up with water.
- Add about 5 kg of local soil to the barrel to facilitate faster degradation.
- One set of biodynamic preparation (502–507) can be added to the barrel and is optional.
- The barrel is stirred every day for seven days and then stirred once a week for the next three weeks. The preparation will be ready in 30 days.
- The concentrated solution is diluted ten times in water and used as a foliar spray.
- These sprays are very efficient in managing a variety of pests.

Precautions

- The liquid manure has to be diluted ten times before spraying on the crop otherwise it scorches the plant.
- The solution has to be sieved through a cloth or gunny bag before spraying to avoid blockage of nozzles.
- The solution has to be used within one month as its efficacy diminishes after that period.

2. Microbial pesticides or biopesticides:

The use of microorganisms as bio control agents is gaining importance in recent years. Biopesticides are living organisms or their derived parts which are used as biocontrol agents to protect crops against insect pests.

Table Commercially important microbial bio-pesticides and biorationals used in India

Sr. No.	Category	Products	Target pest	Major crops
1.	Bacteria	*Bacillus thuringiensis* *Bacillus sphaericus* *Bacillus subtilis* *Pseudomonas fluorescens*	Lepidoptera Mosquitoes, flies Fungal pathogens	Cotton, maize, vegetables, soybean, groundnut, wheat, peas, oilseeds, rice
2.	Fungi	*Trichoderma viride* *Trichoderma harzianum* *Trichoderma hamatum*	Fungal pathogens	Wheat, rice, pulses, vegetables, plantations, spices and sugarcane
		Beauveria bassiana *Verticillium lecanii* *Metarhizium anisopliae* *Paecilomyces lilacinus* *Nomuraea rileyi*	Insect pests such as bollworms, white flies, root grubs, tea mosquito bugs	Cotton, pulses, oilseeds, plantation crops, spices and vegetables
3.	Viruses	Nuclear Polyhedrosis Virus (NPV) of *Helicoverpa armigera, Spodoptera* sp. and *Chilo infescatellus*	American Boll worm, tobacco caterpillar and shoot borer	Cotton, sunflower, tobacco and sugarcane
4.	Biorationals	Pheromone traps Pheromone lures, sticky traps and mating disruptants	*Bactocera sp.* *Chilo sp.* *Dacus sp.* *Earias vittella* *Helicoverpa armigera* *Leucinodes orbonalis* *Pectinophora gossypiella* *Plutella xylostella*	Cotton, sugarcane, vegetables, fruit crops

Entomopathogenic viruses of the baculovirus group, bacterial insecticides, particularly *Bacillus thuringiensis*, entomo-fungal pathogens, protozoans and insect parasitic nematodes have been found to control important pests of crops. These bio pesticides are commercially available and are quite difficult to formulate in field conditions.

Types of microbial biopesticides:

- Bacterial bio pesticides
- Fungal bio pesticides
- Viral bio pesticides

3. Biorationals

Biorationals comprise of the use of pheromones and sticky traps in pest management. There are three main ways in which pheromones are used to control pests:

- to trap insects;
- to disrupt mating;
- for survey and monitoring.

Method of application of biopesticides

a) Seed treatment:

- Prepare 5% jaggery solution by boiling 500 gm of jaggery in ten litres of water for 15–20 minutes. Depending on the quantity of seeds to be treated, sufficient solution has to be prepared.
- Cool the solution.
- Mix the contents of the bio pesticide packet in the above solution. The general recommendation is 10 gm of bio pesticide/kg of seed.
- Heap the seeds to be treated on a polythene sheet and pour the bio pesticide solution over the seeds and mixed thoroughly.
- Dry the seeds in the shade and sow immediately.

Nursery bed

- One kilo of biopesticide is mixed with 100 kilograms of good quality soil. Forest soil can also be used. In areas where forest soil is not available, 30 kg of well-rotted dung can be mixed with 70 kg of soil to prepare a good soil mixture.
- The soil mixture can be used as a nursery soil or it can be mixed with soil in the nursery bed.

Soil drenching

- Prepare a solution by adding 10 grams of biopesticide to a litre of water and stir the solution well.
- Drench the soil with the solution using a water can.

Seedling dip

- Prepare a solution by adding ten grams of biopesticide to a litre of water.
- Dip the seedlings in this solution for 30 minutes.

4. Biocontrol by insects:

Beneficial insects are predators of insect pests and damage the latter during various stages of their development like egg, larva, pupa, etc. Accordingly these biocontrol agents are categorized as:

Egg parasites

These parasites damage the egg stage of the insect pest. Some of the commonly used egg parasites are *Trichogramma spp. Telenomus spp.* and *Testrastichus* sp. These parasites control top shoot borer in sugarcane, internode borer in sugarcane, cotton bollworms, paddy stem borer, sorghum stem borer, fruit borers, etc.

Larval parasites

These parasites destroy the larval stages of the insect pest. Some examples are the *Bracon spp*., which is used in controlling the black-headed caterpillar in coconut and *Goppniozus nephantidis* which is used against the coconut leaf-eating caterpillar.

Pupal parasites

The pupal stage of the pests is destroyed by the pupal parasites. *Testrastichus sp*, is widely used to control pests like American bollworm, paddy leaf rollers, black-headed caterpillars, etc., in their pupal stages.

Predators

Predators like *Chrysopa sp, Menochilus spp*. are very useful in controlling a wide variety of insects like aphids, white flies, cotton bollworms, leaf insects, etc. The eggs of these parasitoids are commercially available on egg cards. Each egg card (e.g., *Trichogramma*) contains 20,000 live parasitised eggs which have 90–96% hatching rate within 7– 10 days of parasitisation. These are applied @ 3–5 cards/ha. Each egg card costs Rs.20 to Rs. 50. *Chrysopa sp.* is available in vials containing 1,000–5,000 live eggs/larvae. The standard recommendation for crops like cotton, sunflower, tobacco, groundnut, mustard and vegetables is 5,000–10,000 eggs/larvae per ha. Each vial costs Rs.150 to Rs.200.

PREPARATION 501 (HORN SILICA):

This preparation is made from a crystal of quartz (silicon oxide, SiO_2). It is important to have good quality quartz crystals, well formed and clear, which allow the light to flow right through them. A good clear crystal will cause refraction of light in the same way as a prism.

Method

- Collect translucent quartz crystals and grind them into a fine powder, as smooth as talcum powder.

- Moisten the quartz powder with water and fill the cow horn with it.
- Bury the horn in the soil (similar to BD 500) during spring and summer (April/May).
- Remove the horn from the soil during the ascending moon phase in September/October.

Usage

- Preparation 501 is stirred in a manner similar to preparation 500. It is stirred for one hour, using one gram in 13.5 litres of water, which is sufficient for one acre of land. It is sprayed in the morning in a fine mist, using a high pressure spray, allowing the mist to be suspended briefly in the air so that the sunlight can shine momentarily through the mist on the plant and the fine mist is allowed to drift over the crop. For smaller areas a knapsack sprayer may be used turning its fine nozzle skywards to produce the desired misting effect.
- As a general rule, 501 should be sprayed during the early stages of the plant's growth and after fruit set. Preparation 501 is generally sprayed in the morning, during spring and early summer, and sometimes in the autumn if the lushness of growth demands it. As the season advances during summer, 501 is sprayed progressively early in the morning.
- Because of the stimulation of the light, it is advised not to use 501 in drought conditions and it should be used only once in the spring on pasture as overuse can accentuate drought conditions. Due to the enhancement of photosynthesis of the plant, the starches, sugars and cellulose in the plant improve thereby improving the overall quality of the produce as well.

Mineral based pesticides for managing diseases:

Sulphur

Sulphur is probably the oldest known pesticide in use. Sulphur can be used as dust, wettable powder, paste or liquid. It is very effective in controlling powdery mildews, rusts, leaf blights and fruit rots. Wettable sulphur @ 2–3% foliar spray is very effective to control a variety of plant diseases.

Lime sulphur

Boiling lime and sulphur together makes lime sulphur. The mixture is used as a dormant spray on fruit trees to control diseases such as blight, anthracnose, powdery mildews and some insect pests such as scales, thrips and eriophyid mites. The general recommendation is 1% lime sulphur as a foliar spray

PRACTICAL - 7

COST OF ORGANIC PRODUCTION SYSTEM

No-cost inputs are those inputs which cost nothing or cost the bare minimum but have high benefits. The following are important no-cost inputs useful for organic farmers:

1. Indicator plants
2. Use of planting calendar
3. Homa therapy or agnihotra

INDICATOR PLANTS:

When a nutrient is not present in sufficient quantity in the soil or is not supplied in sufficient quantity to the plant, the plant will show deficiency symptoms described below to a greater or lesser degree, depending on the extent of the deficiency. However, some plants have been found to be especially useful as indicators of particular deficiencies. These plants are markedly susceptible to a particular deficiency and deficiency symptoms like poor growth and colour changes in leaves are shown more prominently by such indicator plants.

List of such indicator plants suitable to indicate various deficiencies.

Deficient element	Indicator plants
1. Nitrogen	Cauliflower, cabbage
2. Phosphorus	Rapeseed
3. Potassium	Potato, cauliflower, broad beans
4. Calcium	Cauliflower, cabbage
5. Magnesium	Potato, cauliflower
6. Iron	Cauliflower, cabbage, oats, potato
7. Zinc	Citrus, cereals, linseed
8. Copper	Wheat, oats
9. Manganese	Oats, sugar, beet, potato
10. Boron	Sugarbeet, cauliflower
11. Molybdenum	Cauliflower

In addition, sunflower and crotons are indicators of moisture stress in the soil. Farmers can irrigate the crop looking at the wilting symptoms of these plants.

Use of the planting calendar:

The life patterns of all living organisms are woven into the cosmic rhythm. The modern science world may not accept the influence of these cosmic rhythms and constellations on life forms. However, human life, as well as animal and plant life, is all strongly dependent on the rhythms of the earth. Similarly, plant and animal life is also influenced by the syndic relationships of the sun, earth, moon and other planets. On the basis of such influences, the planting calendar is prepared for agricultural operations, during different timings of the year.

The moon opposite to Saturn :

Occurs approximately once in 29.5 days.

Activities to be undertaken:

1. Seed sowing, transplanting, grafting, pruning and layering.
2. Spraying BD 501 (cow horn silica) to manage pests.
3. Spraying liquid manures and foliar sprays.

Full moon :

Occurs every 29.5 days

Activities to be undertaken:

1. Sow seeds two days before sowing.
2. Apply liquid manures and CPP (cow pat pit) manure.
3. Spraying bio pesticides to control pests and diseases.
4. Drenching the animals to remove internal parasites (48 hours before).

New moon :

Happens once in 27.5 days

Activities to be undertaken:

1. Avoid sowing seeds.
2. Cutting timber.

Ascending periods:

The moon moves in an arc from east to west and when this arc gets higher, the moon is ascending.

Activities to be undertaken:

1. Sowing of seeds.
2. Spray BD 501.
3. Spray liquid manures and CPP.

Descending periods :

The moon moves in an arc from east to west and when this arc gets lower, the moon is said to be in descending phase.

Activities to be undertaken:

1. Transplanting of seedlings.
2. Spraying BD 500 (cow horn manure).
3. Making and spreading compost.
4. Pruning trees.
5. Land preparation activities.

Nodes: These are the days when the moon passes the sun's path. It creates negative influences on the growth of plants. Avoid all agricultural activities during nodes.	
Apogee: The moon's orbit around the earth is elliptical. The point where the moon is furthest away from the earth is called its apogee. **Activities to be undertaken:** 1. Planting potatoes. 2. Irrigating the field.	
Perigee The moon moves around the earth in an elliptical path. The point where the moon is closest to the earth is called its perigee. Spray biopesticides to manage pests and diseases.	
Seed and fruit days	These days influence the growth of seed and fruit crops and are good for sowing and harvesting of the same, e.g., paddy, wheat, brinjal, bhendi and tomato.
Root days	These days influence the growth and development of root crops and are good for sowing and harvesting of them: potato, carrot, beet root, etc.
Flower day	These days influence the growth and development of flowers and are good for sowing and harvesting of them: cut flowers, cauliflower, rose, jasmine, etc.
Leaf days	These days help in the growth and development of leafy vegetables and are good for sowing and for harvesting them: green leafy vegetables, cabbage.

PRACTICAL - 8

POST HARVEST MANAGEMENT: QUALITY ASPECT, GRADING, PACKAGING AND HANDLING

Processing

Processing of organic food products and handling should be optimized to maintain the development of pest and diseases. Processing and handling of organic products should be done separately in time or place from handling and processing of non-organic products.

Processing of organic fresh produce requires cleaning, grading followed by peeling, stoning or slicing. At this stage fruits and some vegetable such as onion and peppers are ready for freezing, but most vegetables need to be blanched with hot water or steam at 80^{O}C to 100 ^{o}C to inactivate enzymes that could otherwise lead to a loss in vitamin C and flavour. Fruit can be coated in sugar or in syrup that contains an antioxidant like ascorbic acid. Coating retards browning, avoids the cooked tests after defrosting and increases product quality. The products may be packaged before or after freezing.

The following techniques are adopted for processing.

1. Freezing :

Freezing is quite often applied to vegetables but rarely used for fruits, as they do not handle it well. Nutritional quality is maintained when the product is sold from colour, odour and taste are retained well by freezing. The degree of freezing depends on the duration of storage eg.

Practical storage life of frozen products

Products	Practical storage life (Month)		
	-18^{o}C	-25^{o}C	-30^{o}C
Fruits in sugar	12	18	24
Cauli flower	15	24	<24
Carrots	18	24	<24
Potatoes	24	<24	<24

2. Drying :

Drying facilitates for easy transportation and storage of fruits. Dried vegetables are produced in low quantities for the local market but can be useful for soup mixes. The major risks with dried products are microbiological attack and physiological deterioration which leads to browing, loss of vitamins and the development of off-flavours.

3. Water content :

Dry fruit products have a water content of 8 to 12 % and dry vegetable around 7%. Under these conditions, there are no microbiological problems during storage of the products.

4. Additives and processing aids:

Permitted processing aids helps to retain quality of dry produce, such as ascorbic acid, citric acid, tartaric acid, which resulting in low pH, it limits the development of micro organisms and browing. The product is treated by dipping in or spraying with acids or lemon juice. Salt can be used for drying.

5. Blanching :

A brief period at high temperature destroys most of micro organisms and inactivates eazymes which promote browning and degradation i.e.

Fruits /Vegetables	Process
Banana	Boiling water for 5 min
Mango, Papaya	Hot water (56^{o}C) for 1 min
Cabbage	Boiling water 3 min
Carrot	Boiling water 4-6 min

6. **Rapid Drying** :

Sun drying is mostly used for organic fruits such as figs, bananas etc, but there is risk to quality and the difficulty of maintaining a high degree of sanitation. Hence, a rapid drying is followed.

Drying condition, moisture content and storage life of food products.

Fruits/ vegetable	Drying temp (^{o}C)	Moisture content (%)	Storage life (Month)
Mango	55	14	6
Banana	55	12	6
Tomato	55	6	6
Onion	50-55	5	3-12

Labeling :-

The label should convey clear and accurate information on the organic status of the product. The labels for organic products should be distinquishable by different coloured labels. The details like name of the product, quality of the product, name and address of the producer name of the certification agency, certification, lot number etc. are to be given in the label. for example;

Information required on the label

Crop	OG (Organic Ginger)
Country	I (India)
Field No.	05
Date of harvest	32 (1st Feb.)
Year	2009
Lot No.	OG I 05 32 2009

Lot No. is helpful in tracking back the product particularly field number in which it is grown in case of contamination. Lot number should include the crop, country, field number, date of harvest and production year.

Packing :

For packing, recycling and reusable materials like clean jute bags should be used. Use of biodegradable materials can also be used. Un necessary packaging material should be avoided. Various types of packaging materials are used for packing such as bamboo baskets, gunny bags, card board, paper, glass, metal, wooden box, plastic crates and ventilated corrugated fibre board (CFB) box for safe handling.

PRACTICAL - 9

CERTIFICATION FOR ORGANIC FARMING

Organic certification -standards and procedures (as per OHGA STANDARDS)

Converting a farm as organic:

Converting a farm to organic requires the development of a viable and sustainable farm-ecosystem over a period of time. The certification process aims to convert the growing area to comply with requirements of this standard within a period of 3 years.

Procedures:

1. Initially, a farm is inspected and a report is lodged with the certification review committee (CRC). If CRC recommends the farm enter the certification system, it will be placed "Under Supervision" for the first 12 months. During this time, produce or products cannot be sold as 'Certified Organic" or as 'IN CONVERSION TO Organic".
2. After 12 months, the farm may be upgraded to "In Conversion" if the second inspection is satisfactory. The farm must then complete two years "In Conversion" before it is considered for certifying as "Organic"(otherwise known as "A GRADE Organic")
3. The "In conversion" period may be reduced - but only where it can be demonstrated a farm had, during the years immediately preceding conversion,used techniques closely allied to those of organic agriculture and which meet all testing and inspection requirements .Whatever the length of the conversion period,product may not be sold as "In conversion to Organic" until a farm has been under an inspection system for 12 months.

   It is similar to an insurance company converting life insurance quotes into a complete life insurance contract. First there must be an examination, then once the person's suitability is confirmed the contract is then finalized. In this case, the farm must tick all the boxes and prove itself to be fully organic for a set time. Once satisfied, the committee will then recognize the farm as organic.

   In this case, the farm must tick all the boxes and prove itself to be fully organic for a set time. Once satisfied, the committee will then recognize the farm as organic
4. In the case of other farm activities not being certified, those activities must be clearly separated and the products must be of a different nature from the certified produces or products. There can not be organic and non-organic growing (parallel production)of the same species on the same property-or on any other property under the same grower's management or control.
5. When a defined area is certified, the remainder of the farm must be converted to organic within 10 years.

Organizations inspecting and certifying :

1. TNAU-Coimbatore.Tamilnadu
2. APOF-Association for promotion of organic farming,Bangalore-560046.
3. INDOCERT- (refer also-'useful links' page
4. ECOCERT-Chennai.
5. Low-cost internal certification schemes like PGS-www.ofai.or

FROM- 1A

APPLICATION FOR REGISTRATION OF ORGANIC UNIT

REGISTRATION NO: O(F)_____

1.	Name & Address of the organic producer	
	Phone No./ Fax. (e-mail)	
2.	Total area of (operation) Farm Survey No. Map attached	
3.	Total no. of plots/segments	
4.	Cropping system followed	
	(i) Name of the crops	
	(ii) Extend of each crop grown	
	(iii) Rotation followed	
5.	Inputs applied to previous crops	
6.	Buffer zone details	
7.	Boundary of the farm	
8.	Plant protection measures followed	
9.	Source of manure	
10.	Source of seed	
11.	Soil type	
12.	Specify, if soil problems any	

13.	Weed management practices followed		
14.	Source of irrigation Well Canal Tank Rain fed		
15.	Contaminants risk, if any		
16.	Equipment details Ploughing Weeding Harvesting	Hired	Own
17.	Thrashing Drying yard facility		
18.	Storage facility		
19.	Animal husbandry details		
20.	Other details		

DECLERATION

I declare that I shall abide by the rules and regulations of TNOCD and carry out the organic production according to the norms prescribed by TNOCD.

Signature of farmer

Enclosures:

1. Farm general details
2. Field map
3. Copy of soil test analysis
4. Copy of water test analysis
5. Annual plan

FOR OFFICE USE ONLY

Date of receipt :

Registration No. Allotted: O(F) :

Allotted to OCI :

Tentative Inspection Date :

Fees remitted details :

Verified by: **Signature of Quality Manager**

Annual Cropping Programme

Name and Address of the operator	
Year	
Total area	acre

Crop and Variety	Plot No.	Season wise cropped area (acre)		
		Kharif	***Rabi***	**Summer**

FROM- 1D

ORGANIC CERTIFICATION DEPARTMENT (OCD)

APPLICATION FOR REGISTRATION OF ORGANIC UNIT

REGISTRATION NO: O(F)_____

1. Name & Address of Group/unit/Society/Farm :

2. Name of contact Person, Phone & Fax No. :

3. Brief information about the Group :

Name of the location	Number of members	Total area of the Group (ac)	Total area of the members of the group having > 10.00 acres	Source of water	Farm animal Nos.	Remarks

4. Rout map of organic production area with distance:

5. Field map of organic area with surrounding information/activities:

6. Information about Agriculture Crop season:

Farmer code/ Sl.No.	Name of Farmer	Name of Father/ Husband	Total area (in ac)	Details of area & Animals			
				Name of the crops grown and area (in ac)		Animal Husbandry (in No.)	
				Organic (ac)	In conversion (ac)	Organic (ac)	In conversion (ac)

Note: List may be enclosed

7. Contamination risk noticed:

DECLERATION

I declare that I shall abide by the rules and regulations of OCD and carry out the organic production according to the norms prescribed by OCD. All the above information is correct.

Date:

Signature of the responsible person of the Organic Group

Enclosures:

1. Farm general details
2. Field map
3. Copy of soil test analysis
4. Copy of water test analysis
5. Annual plan

FOR OFFICE USE ONLY

Date of receipt :

Registration No. Allotted: O(F) :

Allotted to OCI :

Tentative Inspection Date :

Fees remitted details :

Verified by :

Signature of Quality Manager

ORGANIC CERTIFICATION DEPARTMENT (OCD)
FROM- 11

OCD Agreement with operator

I (we) affirm that I (we) will:

1.	Provide complete and accurate information on all questionnaires and other application materials representing my/our organic or transitional organic operation;
2.	Comply with the applicable India organic NSOP organic production and handling regulations;
3.	Establish, implement and update annually an organic production or handling system plan;
4.	Permit on-site inspections with complete access to the production or handling operation, including non certified production and handling areas, structures and offices;
5.	Additional inspections may be announced or unannounced at the discretion of OCD or as required by APEDA.
6.	Have an authorized representative knowledgeable about the operation present during the inspection;
7.	Maintain all records applicable to the organic operation for not less than 5 years beyond their creation;
8.	Allow authorized representatives OF OCD the Secretary of Agriculture, APEDA or other substances for testing to be in the assessment of compliance to certification standards;
9.	Allow authorized representatives of OCD to take samples of plants, soil, crops or other substances for testing to be used in the assessment of compliance to certification standards;
10.	Consent to the use of subcontractors working under the direction and authority of OCD;
11.	Submit the applicable fees charged by the certifying agent;
12.	Comply with all requirements and/or conditions levied by OCD as a result of its review of our application file and associated documents including inspection information;
13.	Immediately notify the certifying agent concerning any;
	a. Application, including drift of a prohibited substances to any field, production unit, site, facility, livestock or product that is part of an operation and; b. Change in a certified operation or any portion of a certified operation that may affects its compliance with the regulations;
14.	Represent products as being “Certified by OCD” only when those products are listed on a current certification certificate from OCD
	a. Any use of the OCD name, without current certification by OCD or written permission from OCD, is strictly prohibited and constitutes an infringement of the OCD trademark.
15.	Upon surrender, suspension or revocation of certification, discontinue use of any lables or advertising materials that contain any reference to certification by OCD and return or destroy all certificates and packaging material containing references to OCD

I (we) affirm that I (we) are owner(s) of or authorized to sign on behalf of

_____.

I (we) agree to the above requirements and understand that any willful misrepresentation may because for denial, suspension or revocation of certification.

Name_____ Signature date _____

Name_____ Signature date _____

PRACTICAL - 10

VISIT OF ORGANIC FARMS TO STUDY THE VARIOUS COMPONENTS AND THEIR UTILIZATION

Major components of organic farming are crop rotation, maintenance and enhancement of soil fertility through biological nitrogen fixation, addition of organic manure and use of soil microorganisms, crop residues, bio-pesticide, biogas slurry, waste etc. Vermiculture has become a major component in biological farming, which is found to be effective in enhancing the soil fertility and producing large numbers of horticultural crops in a sustainable manner. The various components of organic farming have been discussed in details below:

1. Crop rotation:

Crop rotation is a systematic planning for the growing of different crops in a regular sequence on the same piece of land covering a period of two years or more. Crop rotation is important for soil fertility management, weed, insect and disease control. **Legume crops are essential in any rotation**, because legumes are able to fix atmospheric nitrogen through symbiotic relationship with N-fixing bacteria enables organic farming systems to be self sufficient in nitrogen.

2. Crop Residue

There is a great potential for utilization of crop residues of the major cereals and pulses. Incorporation/composting of crop residues in conjunction with organics have been shown to improve availability of plant nutrients, soil organic matter, aggregate stability, infiltration rate, microbial population etc.

3. Organic manure

The organic manure is derived from biological sources like plant, animal and human residues. Aggregate stability, decrease in pH, resistance to compaction and water holding capacity increase by addition of organic manure in the soil. Moreover, it showed the beneficial effect on soil microorganisms and their activities and thus increases the availability of major and minor plant nutrients.

4. Industrial and other waste

By products like molasses and pressmud from sugar industry possess good manurial value. Addition of pressmud improves the soil fertility and enhances the microbial activity. While municipal and sewage waste also forms an important component of organic farming. Sewage sludge particularly from industrialized cities is contaminated with heavy metals and these pose hazards to plants, animals and human beings. Separation of the toxic waste at the source will minimize the concentration of such elements in the sludge.

5. Biofertilizers

Bio-fertilizer offers an economically attractive and ecologically sound means of reducing external inputs and improving the quality and quantity of products. Microorganisms are capable of mobilizing nutritive elements from non-usable form to usable form through biological process. These are less expensive, eco-friendly and sustainable. The Biofertilizers containing biological nitrogen fixing organism are of utmost important in agriculture in view of the **following advantages:**

1. They help in establishment and growth of crop plants and trees.
2. They enhance biomass production and grain yields by 10-20%.
3. They are useful in sustainable agriculture.
4. They are suitable organic farming.
5. They play an important role in Agroforestry / silvipastoral systems.

6. Bio-pesticide

Bio-pesticides are natural plant products that belong to the so-called secondary metabolites. Botanical insecticides are ecologically and environmentally safer generally affect the behaviour and physiology of insects rather than killing them. Neem (*Azadirachta indica*) has justifiably received the maximum attention. All parts of the Neem tree possess insecticidal property but seed kernel is most active.

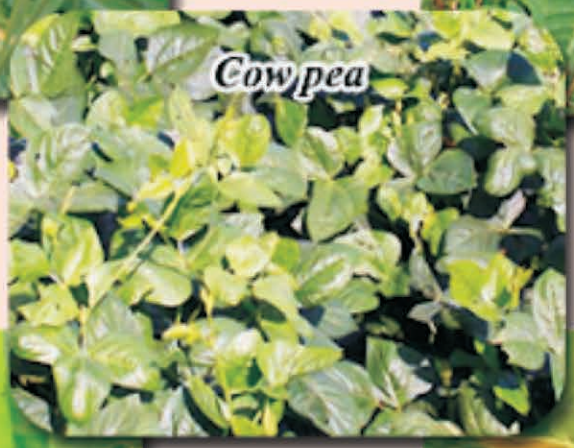
7. Vermicompost

It is organic manure produced by the activity of earthworms. It is a method of making compost with the use of earthworms that generally live in soil, eat biomass and excrete it in digested form. It is generally estimated that 1800 worms which is an ideal population for one sq. meter can feed on 80 tones of humus per year. These are rich in macro and micronutrients, vitamins, growth hormones and immobilized microflora. The average nutrient content of vermicompost is much higher than that of FYM. Application of vermicompost facilitates easy availability of essential plant nutrients to crop.

Green Manure Crops

Crotalaria juncea

Sesbania rostrata



Cow pea

Cluster bean

Sesbania aculeata

NAVSARI AGRICULTURAL UNIVERSITY

COLLEGE OF AGRICULTURE,
NAVSARI AGRICULTURAL UNIVERSITY,
WAGHAI (DANGS)- 394 730

As Per The Fifth Dean Committee Recommendations For The Sixth Semester, B.Sc. (Hons.) Agri. Course Curriculum

भाकृअनुप
ICAR

कृषिम्‌ला ह्यनर्थकम्‌

NAVSARI AGRICULTURAL UNIVERSITY

कृषि विज्ञानस्य विकासः

COLLEGE OF AGRICULTURE
WAGHAI

PRACTICAL MANUAL

AGRON 6.10

RAINFED AGRICULTURE AND WATERSHED MANAGEMENT (1 + 1)

PREPARED BY

Prof. Jyoti Kokani
Assistant Professor

Dr. A. P. Patel
Professor& Head

Dr. V. M. Patel
Associate Professor

Dr. R. R. Pisal
Assistant Professor

DEPARTMENT OF AGRONOMY
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Sprinkler Irrigation

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:: FOREWORD ::

It gives me great pleasure to write the foreword of the Practical Manual of "Rainfed Agriculture and Watershed Management" prepared by Prof. Jyoti Kokani, Dr. A. P. Patel, Dr. V. M. Patel and Dr. R. R. Pisal of the Department of Agronomy. This is one of the most unique and fundamentals practical books available for fulfilling the requirements of the undergraduate students and has been prepared as per the latest syllabus prescribed by the ICAR. However, it is equally useful for the Post-graduate students, scholars, teachers and scientists working in the basic and applied aspects of Rainfed Agriculture.

This manual entitled **"**Rainfed Agriculture and Watershed Management**"** A Practical Manual has been design for better understanding of various aspects of managing rainwater and soil moisture more effectively and using supplemental and small-scale irrigation in combination with increased use of organic and inorganic fertilizer, better access to markets, and increased security over land and water resources; as well as improving the livelihoods of farmers in rainfed areas. I am sure that sixth semester students will be benefitted by this revised and updated manual.

I appreciate and congratulate *Prof. Jyoti Kokani, Dr. A. P. Patel, Dr. V. M. Patel and Dr. R. R. Pisal* for their commendable efforts in bringing out this practical manual for their efforts.

(J. J. Pastagia)

CERTIFICATE

Reg. No. : _____ **Batch no.: _____**

Roll No.: _____ **Uni. Seat No.: _____**

This is to certify that Mr./Miss …… studying in Sixth Semester, B.Sc. (Hons.) Agriculture has satisfactory carried out …….. Practical exercises out of ....…….. in the subject of **Agron. 6.10 (Rainfed Agriculture and Watershed Management)** at the College of Agriculture, NAU, Waghai during the year…….

Course Teacher **Professor & Head**

External Examiner

:: INDEX ::

Practical -1: Studies on climate classification

The behaviour of atmospheric phenomenon at a given place and time is defined as **weather** and the composite day-to-day weather elements for a given place or region over a period is referred as **climate**.

Dry climate

A dry climate is one in which the average annual precipitation is definition in relation to evaporation. It can be divided into arid and semi-arid climate.

Arid climate

It can be defined as an extreme dry climate where the average annual precipitation is less than 500 mm and usually in the range of 250 to 500 mm. Generally, the rainfall is well short of evapotranspiration demand of the atmosphere. The precipitation is insufficient for crop production.

Semi-arid climate

It can be defined as a climate where the average annual precipitation is greater than 500 mm and generally, crop production is possible with dry farming methods or with supplemental irrigation.

The tropical retreat and semi-arid climate I have many features in common the distinct character of this climate is lake of sufficient rainfall to sustain crop production. They are centre on the latitudes from 20 to 25 degree north and south.

Classification of dry climate:

Variations in climate from place to place determine a large number of climatic types and identification and classification of respective types facilitate description and mapping of climatic region. Climatic region may be defined as an area of earth's surface over which the combined effects of climatic factors result in an approximately homogenous set of climatic condition.

Principles of climatic classification

1. It should provide concise description of climatic types of the truly active factors (moisture, heat, wind, sunshine, pressure changes etc.)
2. It should provide a system ranging from microclimate to macroclimate.
3. It should be made from adequate records with respect to periods and distribution.
4. It should reflect the causes of climate
5. It should consider the systematic relationship between climatic factors and pattern of vegetation.
6. It should consider the factors like human health and comfort (style of clothing, housing etc.)

The most widely used systems of regional climatology are

1. Koppen's classification
2. Thornthwaite's classification
3. Martonne's classification
4. Meig's classification

1. Koppen's classification of dry climate:

Koppen related climate to vegetation and gave emphasize to climatic factors like temperature,

rainfall and their seasonal characteristics. The classification of climate was made with a capital letter designation B and to represent main climatic types Koppen added additional symbols.

Table 1.1: Dry climate types in Koppen's classification

Sr.No.	Symbol	Climate type
1	BSh	Tropical steppe, Semi-arid and Hot
2	BSk	Mid latitude steppe, Semi-arid, Cool or Cold
3	BWh	Tropical desert, Arid, Hot
4	BWk	Mid latitude desert, Arid, Cool or Cold

Modified Koppen's classification

Koppen's modified system of classification was based on average annual temperature (denoted as't') and average annual values of precipitation (denoted as 'r ') in degree Fahrenheit and inches, respectively.

Table 1.2: Koppen's modified system of climate classification

Sr.No.	Symbol			Description
	Ist	IInd	IIIrd	
1	**B**			70% or more of annual precipitation falls either During warmer months (April to September) and the average annual precipitation (r) is less than 0.44 t-3.5 or During cooler months (October to March) and the 'r' is less than 0.44 t-14 or Neither half of the year receive with more than 70% of annual precipitation and 'r' is less than 0.44 t-8.5
2		**S**		Average annual precipitation is less than upper limit for B, but more than half that amount.
3			**H**	Average annual temperature greater than 64.4^0 F
4			**K**	Average annual temperature lesser than 64.4^0 F

2. Thornthwaite's classification of dry climate

Thornthwaite's classification is based on expressions of precipitation effectiveness (P.E.Index) and temperature efficiency (T.E.Index). P.E. Index corresponds to 5 humidity provinces and vegetation types. T.E. index designates to temperature provinces. Further subdivisions where made with the use of terms to express seasonal distribution of precipitation. Combination of P.E. and T.E. indices and seasonal distribution of precipitation represent 32 actual climatic types, among which line represent semi-arid and arid types of climate in the world.

Precipitation Effectiveness Index (PEI)

PEI = Sum of twelve monthly values of $115 \times (P/T-10)^{10/9}$

Where, P= Mean monthly precipitation in inches

T= Mean monthly temperature on ^{0}F.

Temperature Efficiency (TE)

TE = Sum of twelve monthly values of T-32/4

T= Mean monthly temperature on ^{0}F.

Arid and semi-arid climatic types in Thornthwaite'sclassification:

Thornthwaite defined his classification of climate with precipitation and water needs (Evapo-transpiration). He defined a climate as moist when precipitation exceeds evapo-transpiration and as dry when evapo-transpiration is in considerable excess of precipitation. He developed a system for arid climate with potential evapo-transpiration (the amount of water transpired and evaporated under ideal conditions of soil moisture and vegetative cover) in comparison with precipitation, as the actual evapo-transpiration in arid climate (which will be low simply because of limited moisture supply) may not form the true representation.

He also described that when precipitation is adequate to supply the water need for potential evapo-transpiration, the moisture index is considered as equal to zero. Moist climate will have positive and arid climate will have negative values of the index. The arid and semi-arid climatic types along with the type of vegetation and seasonal distribution of precipitation are given in Table 3.3.

Table 1.3 : Thornthwaite classification of dry climate

Sr. No.	Humidity Province	Vegetation	P.E. Index	Temp. Province	T.E. Index	Seasonal distribution of precipitation
1.	Semi-arid (D)	Steppe	16-31	Tropical (A')	>128	Deficient in winter or Deficient in all seasons
				Mesothermal (B')	64-127	Deficient in winter or Deficient in summer or Deficient in all seasons
				Microthermal(C')	32-63	Deficient in all seasons
2.	Arid (E)	Desert	<16	Tropical (A')	>128	Deficient in all seasons
				Mesothermal (B')	64-127	Deficient in all seasons
				Microthermal(C')	32-63	Deficient in all seasons

Moisture index

It is an overall measure of precipitation effectiveness for plant growth that takes into consideration the weighted influence of water surplus and water deficiency as related to water need and they vary according to season. For a given station, it can be calculated by the formula

$$lm=\frac{100s-60_d}{n}$$

Where, lm is the moisture index, s is water surplus, d is water deficiency and n is water need. Calculation of s and d is made on a normal month-to-month basis, with s being the total surplus from all months having a water surplus and d the total of all monthly deficiencies; each is represented by the difference between monthly precipitation and monthly potential evapo-transpiration (in centimeters or inches). Here n is the annual potential evapo-transpiration.

Table 1.4: Moisture regions and their limits as per Thornthwaite's classification

Climatic Type	Symbol	Moisture Index Range
Per Humid	A	100 and above
Humid	B4	80 to 100
Humid	B3	60 to 80
Humid	B2	40 to 60
Humid	B1	20 to 40
Moist Sub humid	C2	0 to 20
Dry Sub humid	C1	-33.3 to 0
Semi-arid	D	-66.6 to -33.3

Aridity Index:

Aridity index (AI) is a numerical indicator of the degree of dryness of the climate at a given location. AI is defined as

$$AI_T = 100 \times d/n$$

Where the water deficiency d is calculated as the sum of the monthly differences between precipitation and potential evapo-transpiration for those months when the normal precipitation is less than the normal evapo-transpiration and where n stands for the sum of monthly values of potential evapo-transpiration for he deficient months.

3. Martonne's classification of dry climate:

Martonne expressed the relationship between precipitation and temperature as Aridity Index. This term can refer to a selected period of a few days, a month, a season or whole of the year and this enables to define a dry climate accurately.

$$\text{Index of Aridity (AI)} = \frac{P}{T + 10}$$

Where, P (cm) is the annual precipitation and

T (^{0}C) is the annual mean temperature

On annual basis, the areas characterised by an aridity Index less than 20 is classified as arid and between 20 and 30 is classified as semi-arid. However, Martonne;s index was undefined for polar Regions which have the temperature of -10 ^{0}C and less. In these regions, lower temperature lead automatically to negative indices.

4. Meig's classification of dry climate

Meig made refinement in Thornthwaite's system and divided the climatic regions based on aridity as extremely arid, arid and semi-arid using Thornthwaite;s Moisture Index as under.

Extreme arid climate: Moisture index of -57 as outer limit

Arid climate –Moisture index of -40 to -57 and

Semi-arid –Moisture index of -20 to -40.

According to him the precipitation is not the main risk for crop production in semi-arid climate and in semi-arid to arid climate, it can be attempted with appropriate dry farming techniques. In extreme arid climate, there is no seasonal distribution of rainfall.

5. UNESCO's Aridity Index:

UNESCO proposed a simple method for aridity mapping from the ratio of precipitation (P) to potential evapo-transpiration (PET) as follows:

AI = P/PET

Where, P is average annual precipitation in mm

PET is calculated by Penman's formula in mm

Based on the AI values, five climatic regions are proposed by UNESCO as given in Table 3.5

Table 1.5 : Classification based on UNESCO Aridity Index

Sr. No.	Classification	Aridity Index
1	Hyper Arid	Less than 0.05
2	Arid	0.05 to 0.20
3	Semi-arid	0.20 to 0.50.
4	Dry Sub Humid	50 to 0.650
5	Humid	0.65 and above

*****

Practical -2 : Studies on rainfed pattern in rainfed areas of India

Precipitation:

Precipitation refers to all forms of water derived from atmospheric vapour and deposited on the earth surface. Precipitation occurs due to the condensation of atmospheric water vapour.

Hydrologic cycle is the water transfer cycle which occurred continuously in nature. The hydrologic cycle consists of different phases.

a. Evaporation and evapotranspiration

b. Precipitation and

c. Runoff

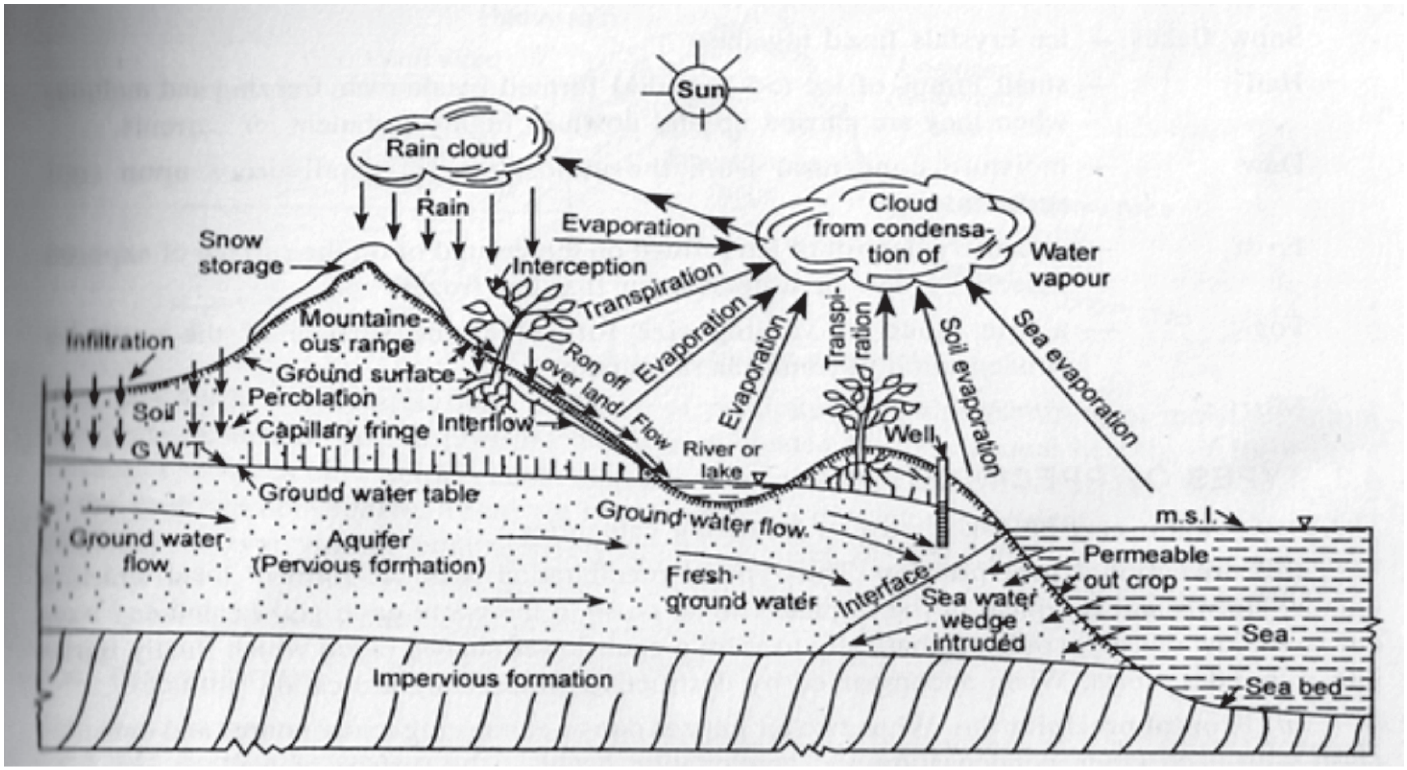

Fig.2.1: The hydrological cycle

The globe has one third land and two third oceans. Evaporation from the surface of ponds, lakes, reservoirs, ocean surfaces etc. and transpiration from vegetation surface i.e. from plant leaves of crop land and forests etc. take place. These vapours rise to the sky and are condensed at higher altitude by *condensation nuclei* and form clouds, resulting in droplet growth. The clouds melt and sometime burst resulting in precipitation of different forms like rain, snow, hail, sleet, mist, dew and frost. A part of this precipitation flows over the land called runoff and a part infiltrates into the soil which ultimate builds up the groundwater table. The surface runoff joins the streams and the water is stored in reservoirs. Surface runoff and groundwater flows back to Ocean. Of these three phases, runoff phase is important for agriculturist and farmers for *in-situ* water conservation and water harvesting and recycling it to the crop during dry spell period.

Rain: Water vapour condenses around condensation nuclei (such as dust) and falls when the droplet is heavy enough.

Sleet: Same formation as rain, but it freezes somewhere along its path from the clouds to the ground. Sleet is a mixture of snow and rain.

Snow: Water droplets form and then freezing occurs slowly, allow ing for the development of uniquely designed ice crystals know as **snow**. Snow is formed when water vapour is deposited in the higher reaches of the atmosphere at a temperature less than zero degrees Centigrade, and then falls to the ground. **Snowflakes** are typically symmetrical, hexagonally shaped groups of ice crystals that form while falling in and below clouds. Simply put - Snow forms if the air in a cloud is below freezing. The water vapour then turns to ice instead of rain and the tiny ice crystals stick together until they form snowflakes. When they get heavy enough to fall, they drop out of the clouds. At this point though, we still don't know whether they will end up as rain or remain as snow. This depends on the temperature of the air they travel through on the way down to the ground. If it gets warmer, they turn into rain, but if the air stays close to freezing all the way down, then the snowflakes will make it without melting and so fall as snow. If this occurs in a mountain area, it is possible for snow to be falling on the mountaintop while lower down in the valley the air is warmer and so it is raining instead.

Hail: Water droplets are carried high into the atmosphere by thunderstorm updrafts, which cause them to freeze. Multiple drops tend to freeze together, which is why the diameter of hail can be large.

Dew: Water vapour on the ground condenses on objects such as blades of grass when the surface temperatu re is equal to the dew point

Frost: Dew forms and then it freezes. This commonly occurs when nigh time. Radiational cooling drops the ground temperature down enough. There are three kinds of frost: Delicate crystallized ice on windowpanes is called **Hoar frost**. **Glazed frost** consists of thick coatings of ice on cold surfaces. **Rime frost** is formed when super-cooled water droplets freeze on contact with cold surfaces. It often occurs when freezing fogs or drizzle blanket the ground.

Freezing rain: Forms and falls as rain. At the surface or near the surface, the temperature is at or below freezing, which causes the rain to freeze on contact.

Fog: A thin cloud of varying size formed at the surface of the earth by condensation of atmospheric vapour.

Mist: A very thin fog.

Drizzle: A light steady rain in fine drops (0.5 mm) and intensity < 1 mm/hr.

Types of precipitation

Precipitation may be classified into following categories:

1. **Conventional precipitation**: This type of precipitation is in the form of local whirling thunderstorms and is typical of the tropics. The air close to the warm earth gets heated and rises due to its low density, adiabatically to form a cauliflower shaped cloud which finally bursts into thunder storm. When accompanied by destructive winds, they are called '**tornadoes'**.
2. **Frontal precipitation**: When two air masses due to contrasting temperatures and densities clash with each other, condensation and precipitation occurs at the surface contact. This surface contact is called a **front or frontal surface**. If a cold air mass dries out a warm air mass it is called **cold front** and if you warm air mass replaces the retreating cold air mass, it is called a **warm front**. On the other hand, if the two air masses are drawn simultaneously the low pressure area, the front developed stationery and is called a **stationary front**. Cold front causes intense precipitation on comparatively small areas, while the precipitation due to warm front is less intense, but it is spread over a comparatively larger area. Cold front is more faster than warm front and usually overtake them, the frontal surfaces of cold and warm air sliding against each other. Phenomenon is called **occlusion** and the resulting frontal surface is called as an **occluded front**.

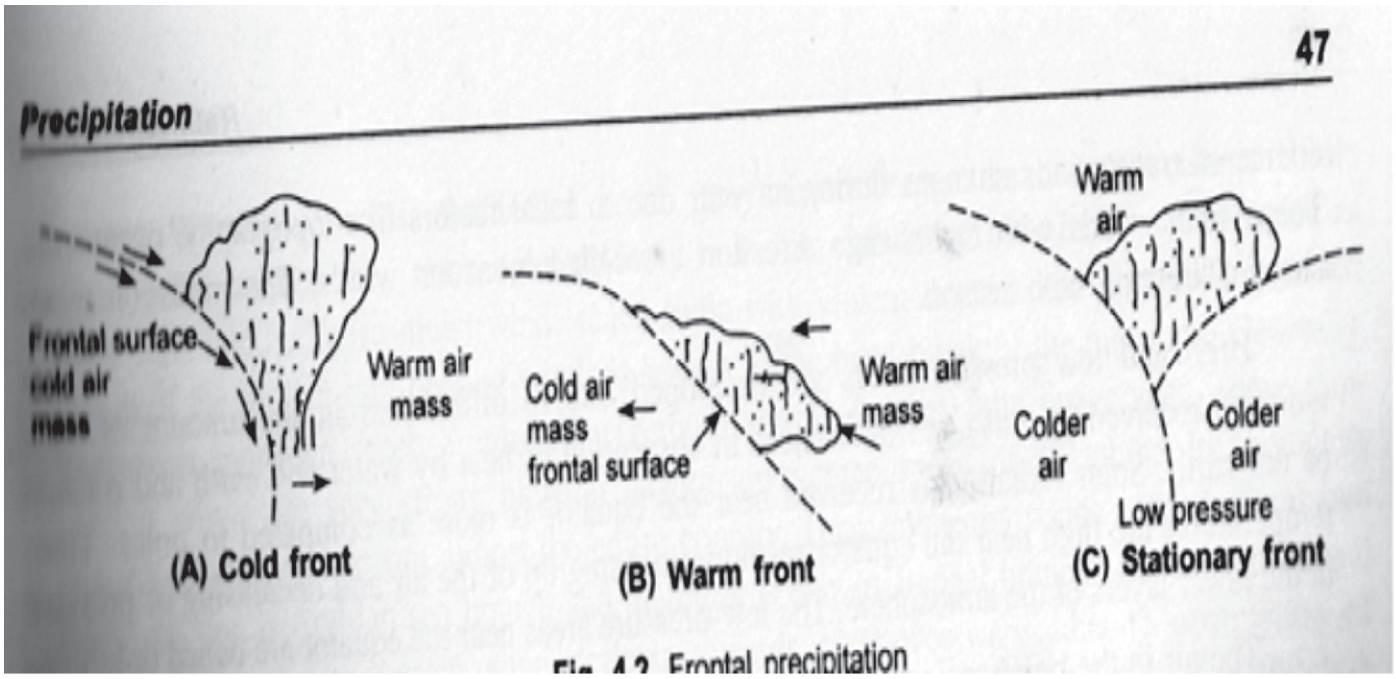

Fig. 2.2: Frontal Precipitation

3. **Orographic precipitation**: The mechanical lifting of moist air over mountain barriers causes heavy precipitation on the wind ward side. Cherrapunji in the Himalayan range and Agumbe in the Western Ghats of South India get very heavy orographic precipitation of 1250 mm and 900 mm (average annual rainfall), respectively.

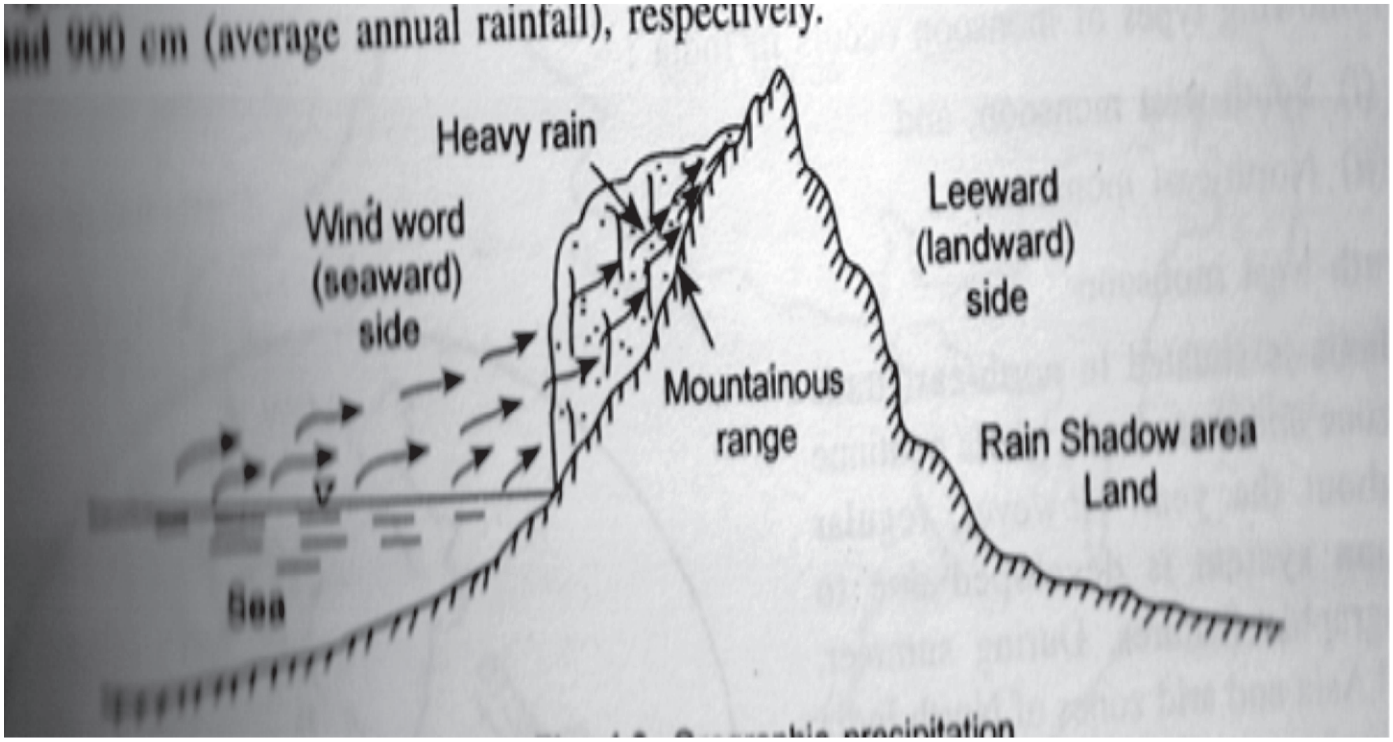

Fig. 2.3: Orographic Precipitation

4. **Cyclonic precipitation:** This type of precipitation is due to lifting of moist air into a low pressure belt due to pressure differences created by the unequal heating of the Earth's surface. The winds blow spirally inward counter clockwise in the Northern hemisphere and clockwise in the Southern hemisphere. There are two main types of cyclone **tropical cyclone**, also called, **hurricane or typhoon** of comparatively small diameter of 300- 1500 km causing high wind velocity and heavy precipitation, and the extra tropical cyclone of large diameter up to 3000 km causing widespread frontal type precipitation.

Rainfall pattern in India

Rainfall plays a major role among different weather elements for crop production. Rainfall in arid and semi-arid regions is very meagre and in India, which possesses monsoon type of climate, the annual precipitation average is to 1160 mm. A minimum of 100 mm per year is observed at *Lah* region to a maximum of 11000 mm at *Cherrapunji*. Monsoon type of climate in India is characterized by the role of winds from cooler ocean to warmer dry land during one half of the year, followed by the flow of dry air from Asiatic heartland area to warm Indian Ocean during next half of the Year.

Monsoons

The world monsoon has originated from the Arabic term which means season. Arabs, however, used this word with reference to winds only, but later on, it is used to refer rainfall. The course of trade winds changes during an year due to local factors like topography, ocean etc. These trade winds with the change direction are called **monsoon winds**. The monsoon winds change direction with season.

In general, the term monsoon is used in the context of cyclic reversal of pressure and wind system, in association with sequential changes in the cloud and weather patterns mainly in the tropics. Reversal of wind system between summer and winter, extensive clouding and heavy rainfall are the characteristic features of the monsoon regions.

Trade winds and monsoon

Winds that provide the motives for sailing ships used in trade are referred as trade winds. They are characterized by equator ward flow from subtropical high (around latitude 30^0 North and 30^0 South) and they acquire east wise movement due to super imposition of the effect of Earth rotation. They are called as North Eastern trade winds and South Eastern trade winds.

Types of monsoon in India

1. Southwest monsoon, and
2. North East monsoon

1. Southwest monsoon

India is situated in north east trade wind zone and these trade winds continue throughout the year. However, regular monsoon system is developed due to physiographic features. During summer, central Asia and arid zones of North India get heated up resulting in in low pressure areas.

The presence of vast Indian Ocean on the southern side develops high pressure area. Actually the trade winds have to start from north of India towards equator. Because of the presence of Indian Ocean in the south and dry areas in Northi.e due to local factors the direction of the trade winds is changed. The south East trade winds initiated from the south of equator. When they across the Indian Ocean, they absorb large amount of moisture. While crossing the equator, they are caught suddenly in the air circulation over India and deflected as south West Winds.

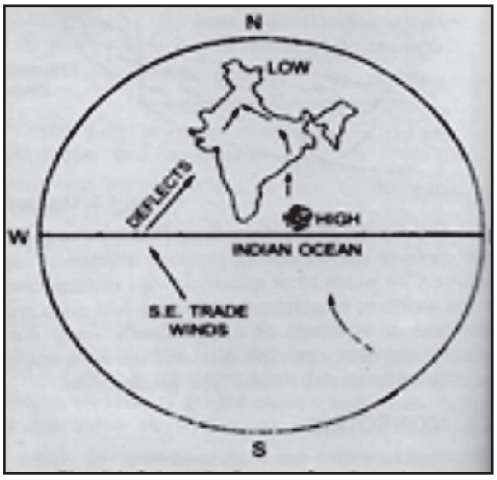

Fig. 2.4: Schematic diagram of south-west monsoon

These moist winds reach India with violent thunder and lightning. The sudden advent of the violent rain bearing winds is known as the *burst break of the monsoon*. Generally, south west monsoon rich South India (Kerala) around 1st of June every year. This rain bearing winds are very strong blowing having an average speed of 30 km/hr. In about 1 months' time, they overrun almost the entire country. This monsoon winds cover India has two branches, one is **Arabian Sea branch** and the second is **Bay of Bengal branch**. The Bay of Bengal branch moves up to Assam, then deflects towards north westward due to obstruction of the Himalayas. The Arabian Sea branch moves north wards. Both this branches occasionally clash near Delhi.

The Southwest monsoon period is called **grand period of rainfall** in India. Bulk of the rainfall (75 % of total rainfall) is received during this season in almost every part of India except east cost of Tamil Nadu. The orographic influence presence of mountains on the distribution of rainfall is also especially pronounced during this season. For instance, the windward side of Western Ghats receives around 2500 mm of rainfall while the leeward side receives only 500 mm.

2. Northeast monsoon

It occurs in winter because of movement of sun towards south of equator resulting in high pressure area. Low pressure areas are developed over the Indian Ocean due to high temperature. Thus, air moves from high pressure areas in China and Russia to low pressure areas in the Indian Ocean. These winds are cool and dry, while they reach in India, they are obstructed by the Himalayas and deflected to east.

This north East winds subsequently deflect to southwest and they become worm and very little rainfall occurs due to this winds. On moving burger south westerly across the Bay of Bengal, the air masses pick up moisture and are warmed. As they strike the cool land surface of South coastal Andhra Pradesh and Tamil Nadu, the air masses are cold and rainfall occurs. South coastal Andhra Pradesh and Tamil Nadu get sufficient rainfall during this period.

Fig. 2.5: Schematic diagram of north-east monsoon

Table 2.1: Hail and its characteristics in dry lands

Characteristics		**General effects**	**Effects in crop growth**
General	**In dry regions**		
1.Rare occurrence in tropics 2.Rare occurrence in high latitudes 3.Common in warm season	1.Common in sub-montane areas in India 2.Rare occurrence in southwest monsoon season	1.Floods under high temperature/storms 2.Road or path closure 3.Mechanical damage to trees 4.Hazards to air crafts	1. Mechanical damage to plants 2. Shredding of leaves 3. Shattering of flower and seed heads

Table 2.2: Rainfall and its characteristics in dry lands

Characteristics			Effects on crop growth	
General	**In dry region**	**General effects**	**If excess**	**If deficient**
1.Seasonal distribution 2. Dependability 3. Frequency 4. Intensity	1. Highly unreliable 2. Frequency less 1. Intensity more 3. Highly seasonal (maximum in winter) 4. Often insufficient	**1. High intensity and heavy rainfall** a. Denudation and soil erosion b. Run off and floods c. Destruction of soil crumbs d. Loss of soil fertility e. Loss of soil fertility f. Poor germination, pollination and flowering **2. Wet weather due to rainfall leading to pest spread** **3. Failure or poor rainfall** a. Soil salinity/alkalinity b. Crop loss/ damage	1. Run off 2. Leaching of plant nutrients 3. Reduction in germination 4. Crop lodging 5. Impair in pollination 6. Crops affected by anaerobic conditions	1. Drought 2. Yield loss 3. Problem soils 4. Famine 5. Crop damage

Table 2.3: Snow and its characteristics in dry lands

Characteristics		General effects	Effects in crop growth
General	**In dry regions**		
1. Present in mountainous regions in mid-latitudes 2. Release by rising temperature 3. Ground water recharge 4. Generally more on leeward side of mountains and uplands from oceans	Significant to water users in arid lands adjacent to snow-capped mountains	1. Floods under high temperature/ storms 2. Road or path closure 3. Mechanical damage to trees 4. Problems in housing 5. Sheet or reel type of erosion	1. Run off 2. Soil erosion 3. Suffocation to crop plants

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Practical -3 : Studies on rainfall pattern in rainfed areas of India

Crop planning in rainfed areas based on….

1. Rainfall amount and its distribution
2. Length of growing season and water availability period
3. Water demand of crops / cropping system
4. Matching the length of growing season and crop duration.

Length of growing season depends on…

1. Amount and distribution of rainfall
2. Water holding capacity of the soil
3. The evaporative demand

Index of Moisture Adequacy (IMA) = $\frac{AET}{PET}$

AET = Actual Evapotranspiration

PET = Potential Evapotranspiration

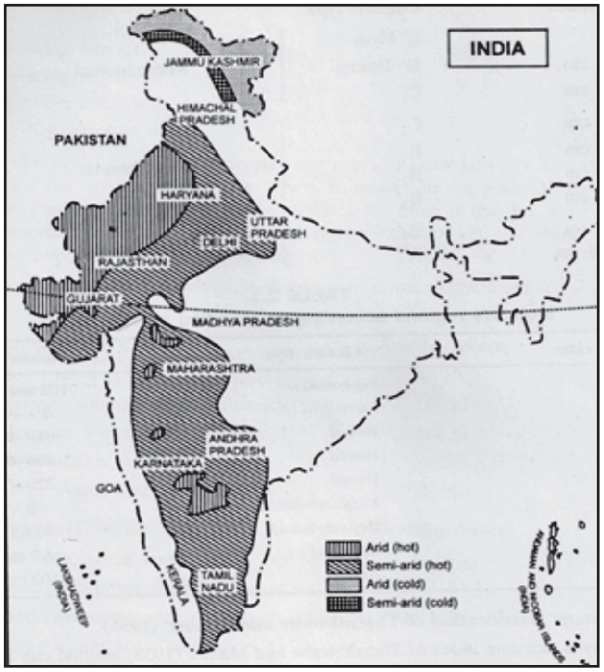

Fig. 3.1 Arid and semiarid zones of India

Table 3.1: Value of IMA and type of water availability

Value of IMA	Type of water availability
0.00 to 0.24	Dry
0.25 to 0.49	Semi-dry
0.50 to 0.74	Sub-moist
0.75 to 0.99	Moist
>1.00	Humid

In this classification, the length of the growing season is assumed to commence from the period when IMA is 0.5 or more. There is a large variability. There is a large variability in the length of growing season and its commencement.

Soil depth and texture (Water holding capacity) determine length of growing season in a region of the same rainfall conditions. It enables to grow a longer duration crop or to adopt intercropping or sequence cropping.

Table 3.2: Suitable cropping systems based on rainfall and water availability period

Rainfall (mm)	Soils	Water availability period (Weeks)	Potential cropping system
350-600	Alfisols and shallow Vertisols	20	Single *Kharif* cropping
350-600	Andisols and Entisols	20	Single cropping either *Kharif* or *Rabi*

350-600	Deep Vertisols	20	Single *Rabi* Cropping
600-750	Alfisols, Vertisols and Entisols	20-30	Intercropping
750-900	Entisols, Deep Vertisols, Alfisols and Inceptisols	>30	Double cropping with monitoring
>900	Entisols, Deep Vertisols, Alfisols and Inceptisols	>30	Assured double cropping

The selection of crops is closely related to the length of the humid periodi.e. the period for which the rainfall exceeds evaporation. In the coastal regions as well as in the eastern parts of India wherever the average weekly rainfall is greater than twice the evaporative demand for a period of 12 weeks or more, rice is grown under rainfed conditions. However, the regions having 1000 to 1200 mm rainfall and it is normally greater than twice the evaporative demand for about 10 to 12 weeks only. Thus, rice cultivation is restricted to lowlands.

Table 3.3: Approximate values of daily PET in India

Climate	**Daily rate of PET (mm/day) during**			
	Summer (March-May)	SW Monsoon (June-Sept.)	Post rainy season (Oct.-Nov.)	Winter (Dec.-Feb.)
Arid	8-12	4-6	4-5	2-4
Semi-arid	6-10	4-5	4	2-4
Sub-humid	5-8	3-4	4	2-4
Humid	4-6	3-4	4	2-4

In areas having uncertain rains in the early part of the season, early planting of deep rooted, long duration, drought tolerant crop like Pigeonpea or cotton would be useful followed by the planting of medium duration companion crop with the start of the active rainy season. While in the areas of uncertain rains in the later season, the base crop should be of shorter duration with the companion crop of longer duration. In the areas of ununiformed distribution of rainfall, the selection of the crops should be depended upon the length of the growing season.

Table 3.4: Length of the water availability period and suggested cropping system

Sr. No.	**Water availability Period (Days)**	**Cropping system**
1	<75	Grasses, shrubs, trees and short duration crops
2	75 to 130	Pulses
3	130 to 180	Mono-cropping
4	>180	Intercropping, double cropping

A. ARID ECOSYSTEM

Agro eco region number 1 (cold arid eco region)					
Location	**Climate**	**Soil type**	**Cropping pattern**	**Constraints**	**Potential of the region**
North Western Himalayas covering *Ladakh* and *Gilgit* districts of Jammu and Kashmir and consisting of 15.2 million hectare.	Mild summer and severe winter with the mean annual rainfall less than 150 mm. Precipitation is always lesser than potential evapotranspiration.	Skeletal and calcareous soils with alkalinity and low to medium organic matter content.	Sparse forest trees. Regular cropping programs include vegetables, millet, wheat, fodder, pulses, barley and fruit crops like apple and apricot.	➢ Severe climatic conditions limiting crop growth ➢ Length of growing season is less than 90 days in a year which limits crop production ➢ Nutrient imbalance due to Sandy and gravelly and moderate to calcareous soil	➢ Dry fruit crops apricot and off season vegetables peas
Agro Eco region number 2 (Hot arid eco region 1)					
South western part of Punjab and Haryana, Western parts of Rajasthan, *kutch* and North *kathiyawad* Peninsula in Gujarat. Area under this Zone extends to 31.9 million hectares.	Hot summer and cold winters with a minimum annual rainfall less than 400 mm. Potential evapotranspiration demand ranges between 1500 and 2000 mm annually. Length of growing season is less than 90 days per year.	Desert and Sandy soils with calcareous and alkaline nature	Drastically reduced, spares and tropical thorn forest. Rainfed mono-cropping with short duration crops like pearl millet and pulses. In irrigated land crops like sugar cane, cotton, mustard, gram and wheat are grown.	➢ Indiscriminate deforestation ➢ Scanty and Erratic rainfall pattern leading to draught at critical stages of Crop growth ➢ Soil salinity and nutrient imbalance	➢ Developing irrigation sources can further increase the productivity ➢ Dryland Agroforestry and forestry may sustain the productivity

Hot arid ecoregion 2					
Deccan Plateau covering the districts of Bellary ,Tumkur, North Chitradurga, South west parts of Bijapur, Raichur of Karnataka and Anantapur of Andhra Pradesh. The total spread of the region is 4.9 million hectares.	Hot and dry summer and mild winters with the mean annual rainfall ranging from 400 to 500 mm. Severe drought prone area throughout the year and length of growing period is less than 90 days in a year.	Shadow to medium red loam soil and deep clayey black soil	Tropical dry deciduous and tropical thorn forests. Irrigated farming includes growing of sugarcane, cotton, safflower and groundnut. Rainfed Mono-cropping is carried out with during rainy season pearl millet or post rainy season with stored residual moisture sorghum or safflower	➢ Soil erosion during rainy season ➢ Poor and ill distributed rainfall and occasional crop failure due to prolonged dry spell ➢ Poor Workability of black soil	-

B. SEMI ARID ECOSYSTEM

Agro Eco region number 4 (Hot semi-arid ecoregion 1)					
Parts of Gujarat (5 districts), Haryana (8 districts), Punjab(7 districts), Union Territory of Delhi, Uttar Pradesh (29 districts) and Rajasthan (11 districts). This region extends to 2.2 million hectares.	Hot and dry summers and cold winters with the mean annual rainfall ranging between 500 to 1000 mm. Length of growing period is 90 to 150 days in a year.	Course to fine loam and sand dunes	Tropical deciduous and tropical thorn forest. Irrigated farming is followed in 65% of the total cultivable area and the crops cultivated are wheat, rice, millet,maize, pulses, berseem, mustard and sugarcane. Rainfed agriculture is followed in 35% of the area with mono-cropping of seasonal crops like sorghum, soybean and pigeon pea and post seasonal crops like ok pulses, lentil and wheat on residual moisture.	➢ Nature of soil with low water holding capacity ➢ Lowering water table ➢ Salinity and sodicity due to in perfect drainage condition	➢ Introduction of irrigation facilities and changes in cropping pattern from low value crops like millets to high value crops like cotton, sugarcane and wheat ➢ Crop diversification to oil seeds

Agro Eco region number 5 (Hot semi-arid ecoregion 2)					
Western Madhya Pradesh (10 districts), South Eastern parts of Rajasthan (5 districts) and Gujarat (10 districts) and Union Territory of Diu. This zone covers 17.6 million hectares.	Hot and wet summer and cold winter with a mean annual rainfall of 500 to 1000 mm and the length of growing period 90 to 150 days. Certain districts of the states of Madhya Pradesh, Rajasthan and Gujarat are prone to drought once in three years.	Deep loam to clay and black soils. Coastal areas in Gujarat have clay and sandy soils with slight alkalinity.	This region is characterized by dry deciduous forest. Dry farming is practised in most areas with *kharif* crops like sorghum, pearl millet, pigeon pea, groundnut, soybean,maize and pulses and with Rabi crops like safflower, sunflower and gram	➢ Intermittent or occasional drought occurrence ➢ Soil salinity or alkalinity due to imperfect drainage or inundation of seawater leading to crop failure	➢ Development through minor irrigation project ➢ Forestry and dryland horticulture activities
Agro Eco region number 6 hot semi-arid eco region 3)					
Western parts of Maharashtra (20 districts), Northern parts of Karnataka (6 districts) and Western parts of Andhra Pradesh (2 districts). The zone spreads over 31 million hectares.	Hot and humid summer and mild and dry winter with an annual rainfall of 600 to 1000 mm. Length of growing period is between 90 and 150 days. Some districts are drought prone and the drought spell may be severe once in 3 years.	Shallow loam to Clay soils with calcareous or alkaline nature	The region is found with tropical dry deciduous tropical thorn forest. Mono-cropping is followed under rainfed condition with *kharif* crops like pearl millet or post rainy season crops like safflower and sunflower. With irrigation facilities crops like cotton and groundnut are grown.	➢ Prolonged dry spells leading to reduced growth and crop failure ➢ Soil erosion ➢ Nutrient imbalance in soil	➢ Achievable high productivity with better water management practices ➢ Dryland Agroforestry and horticulture

Agro Eco region number 7 (Hot semi-arid eco region 4)					
Deccan Plateau and Eastern parts of Andhra Pradesh (14 districts). This region spreads over 16.5 million hectares.	Hot and moist summer and mild and dry winter with the mean annual rainfall of 600 to 1100 mm. Length of the growing period is ranging between 90 and 150 days in a year. In this zone 6 districts are prone to drought.	Black cotton soils are calcareous and strong alkaline in nature. Isolated track are found with red soils, which is non-calcareous and neutral in reaction.	Tropical dry deciduous and thorny forest. Traditional farming under rainfed condition is followed with *kharif* crops like sorghum, cotton, pigeon pea, rice, groundnut and castor and *rabi*crops like sorghum, sunflower, safflower and other oil seeds, rice is the major crop under irrigated condition.	➢ Soil erosion due to high runoff leading to loss of soil and nutrients ➢ Crop failure due to frequent drought under rainfed condition ➢ Imperfect drainage under irrigated conditions leading to salinity and sodicity	➢ Achievable high productivity with better water management practices ➢ Dryland Agroforestry and horticulture ➢ Watershed program
Agro Eco region number 8 (Hot semi-arid ecoregion 5)					
Eastern *Ghats* and Southern parts of *Deccan* Plateau covering the parts of Andhra Pradesh (one district), Karnataka (9 districts) and Tamil Nadu (15 districts) and extending over an area of 19.1 million hectares.	Hot and dry summer and mild winter with a mean annual rainfall of 600 to 1000 mm and the length of growing period is 90 to 150 days in a year. Parts of Karnataka receive rainfall in summer season and rest of the region receives rain during winter.	Red loamy soil	Tropical dry deciduous and thorny forest. Under irrigated conditions, cotton, sugar cane and rice are the major crops. Rainfed cultivation is the traditional practice with crops like millets, pulses and oilseeds especially groundnut in *kharif*season and with crops like sorghum and oilseeds especially safflower in Karnataka in *Rabi* season.	➢ Severity of soil erosion ➢ Severity of drought due to poor moisture holding capacity of soil	➢ Dryland Horticulture with suitable fruit crops ➢ Floriculture under irrigated condition

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Practical-4: Estimation of meteorological data

INTERPRETATION OF METEOROLOGICAL DATA

INTRODUCTION

Agricultural meteorology is the science that applies knowledge in weather and climate to qualitative and quantitative improvement in agricultural production. Basic agricultural meteorological data are largely the same as those used in general meteorology. These data need to be supplemented with more specific data relating to the biosphere, the environment of all living organisms, and biological data relating to the growth and development of these organisms. Agronomic, phenological and physiological data are necessary for dynamic modelling, operational evaluation and statistical analyses. Most data need to be processed for generating various products that affect agricultural management decisions in matters such as cropping, the scheduling of irrigation, and so forth.

Additional support from other technologies, such as geographical information and remote-sensing, as well as statistics, is necessary for data processing.

Many agro-meteorological indices, such as the drought index, the critical point threshold of temperature and soil water for crop development, are also important for agricultural operations. Weather and climate data play a crucial role in many agricultural decisions. Agro-meteorological information includes not only every stage of growth and development of crops, floriculture, agroforestry and livestock, but also the technological factors that affect agriculture, such as irrigation, plant protection, fumigation and dust spraying. Moreover, agricultural meteorological information plays a crucial role in the decision making process for sustainable agriculture and natural disaster reduction, with a view to preserving natural resources and improving the quality of life.

DATA FOR AGRICULTURAL METEOROLOGY

Agro-meteorological data are usually provided to users in a transformed format; for example, rainfall data are presented in pentads or in monthly amounts.

Nature of the data

Basic agricultural meteorological data may be divided into the following six categories, which include data observed by instruments on the ground and by remote-sensing.

(a) **Data relating to the state of the atmospheric environment**. These include observations of rainfall, sunshine, solar radiation, air temperature, humidity, and wind speed and direction;

(b) **Data relating to the state of the soil environment.** These include observations of soil moisture, that is, the soil water reservoir for plant growth and development. The amount of water available depends on the effectiveness of precipitation or irrigation, and on the soil's physical properties and depth. The rate of water loss from the soil depends on the climate, the soil's physical properties, and the root system of the plant community. Erosion by wind and water depends on weather factors and vegetative cover;

(c) **Data relating to organism response to varying environments.** These involve agricultural crops and livestock, their variety, and the state and stages of their growth and development, as well as the pathogenic elements affecting them. Biological data are associated with phenological growth stages and physiological growth functions of living organisms;

(d) **Information concerned with the agricultural practices employed**. Planning brings the best available resources and applicable production technologies together into an operational farm unit. Each farm is a unique entity with combinations of climate, soils, crops, livestock and equipment to manage and operate within the farming system. The most efficient utilization of weather and climate data for the unique soils on a farm unit will help conserve natural resources, while at the same time promoting economic benefit to the farmer;

(e) **Information relating to weather disasters and their influence on agriculture**;

(f) **Information relating to the distribution of weather and agricultural crops**, and geographical information, including digital maps;

(g) **Metadata that describe the observation techniques and procedures used**.

Data collection

Some useful suggestions with regard to the storage and processing of data can be offered, however:

(a) **Original data files**, which may be used for reference purposes (the daily register of observations, and so on), should be stored at the observation site; this applies equally to atmospheric, biological, crop and soil data;

(b) The most **frequently used data** should be collected at national or regional agro-meteorological centres and reside in host servers for network accessibility. Steps should therefore be taken to ensure that possible users are aware of the existence of such data, either through some form of data library or computerized documentation, and that appropriate data exchange mechanisms are available to access and share these data;

(c) Data resulting from **special studies** should be stored at the place where the research work is undertaken, but it would be advantageous to arrange for exchanges of data among centres carrying out similar research work.

(d) All the usual **data storage media** are recommended:

(i) The original **data records**, or agro-meteorological summaries, are often the most convenient format for the observing stations;

(ii) The format of **data summaries** intended for forwarding to regional or national centres, or for dissemination to the user community, should be designed so that the data may be easily transferred to a variety of media for processing. The format should also facilitate either the manual preparation or automated processing of statistical summaries (computation of means, frequencies, and the like). At the same time, access to and retrieval of data files should be simple, flexible and reproducible for assessment, modelling or research purposes;

(iii) Rapid advances in electronic technology facilitate effective exchange of data files, summaries and charts of recording instruments, particularly at the national and international levels;

(iv) Agro-meteorological data should be transferred to electronic media in the same way as conventional climatological data, with an emphasis on automatic processing.

Recording of data

Recording of basic data is the first step for agricultural meteorological data collection. When the environmental factors and other agricultural meteorological elements are measured or observed, they must be

recorded on the same media, such as agricultural meteorological registers, diskettes, and the like, manually or automatically.

(a) The data, such as the daily register of observations and charts of recording instruments, should be carefully preserved as permanent records. They should be readily identifiable and include the place, date and time of each observation, and the units used.

(b) These basic data should be sent to analysis centres for operational uses, such as local agricultural weather forecasts, agricultural meteorological information services, plant protection treatment and irrigation guidance. Summaries (weekly, 10-day or monthly) of these data should be made regularly from the daily register of observations according to the user demand and then distributed to interested agencies and users.

(c) Observers need to record all measurements in compliance with rules for harmonization. This will ensure that the data are recorded in a standard format so that they can readily be transferred to data centres for automatic processing.

Scrutiny of data and acquisition of metadata

It is very important that all agricultural meteorological data be carefully scrutinized, both at the observing station and at regional or national centres, by means of subsequent automatic computer processing. All data should be identified immediately. To allow for future improvement and continuing accessibility, good metadata database formats are ASCII, SQL and XML, because they are independent of any presently available computing set-up.

Format of data

The basic data obtained from observing stations, whether specialized or not, are of interest to both scientists and agricultural users. A number of established formats and protocols are available for the exchange of data. A data format is a documented set of rules for the coding of data in a form for both visual and computer recognition. Large amounts of data are typically required for processing, analysis and dissemination. It is extremely important that data are in a format that is both easily accessible and user-friendly. This is particularly pertinent as more and more data become available in electronic format. Some types of software, such as NetCDF (network common data form), process data in a common form and disseminate them to more users. Since the NetCDF package is quite general, a wide variety of analysis and display applications can use it. The NetCDF software and documentation may be obtained from the NetCDF Website at http://www.unidata.ucar.edu/packages/netcdf/.

Catalogue of data

The data catalogues should include the following information:

(a) The geographical location of each observing site;

(b) The nature of the data obtained;

(c) The location where the data are stored;

(d) The file types (for instance, manuscript, charts of recording instruments, automated weather station data, punched cards, magnetic tape, scanned data, computerized digital data);

(e) The methods of obtaining the data.

DISTRIBUTION OF DATA

Requirements for research

In order to highlight the salient features of the influence of climatic factors on the growth and development of living things, scientists often have to process a large volume of basic data. These data might be supplied to scientists in the following forms:

(a) Reproductions of original documents (original records, charts of recording instruments) or periodic summaries;

(b) Datasets on a server or Website that is ready for processing into different categories, which can be read or viewed on a platform;

(c) Various kinds of satellite digital data and imagery on different regions and different times;

(d) Various basic databases, which can be viewed as reference for research.

Special requirements for agriculturists

Two aspects of the periodic distribution of agro-meteorological data to agricultural users may be considered:

(a) Raw or partially processed operational data supplied after only a short delay (rainfall, potential evapotranspiration, water balance or sums of temperature). These may be distributed by means of:

i. Periodic publications, twice weekly, weekly or at 10-day intervals;

ii. Telephone and note; i

iii. Special television programmes from a regional television station;

iv. Regional radio broadcasts;

v. Release on agricultural or weather Websites.

(b) Agro-meteorological or climatic summaries published weekly, every 10 days, monthly or annually, which contain agro-meteorological data (rainfall, temperatures above the ground, soil temperature and moisture content, potential evapotranspiration, sums of rainfall and temperature, abnormal rainfall and temperature, sunshine, global solar radiation, and so on).

Determining the requirements of users

The agro-meteorologist has a major responsibility to ensure that effective use of this information offers an opportunity to enhance agricultural efficiency or to assist agricultural decision-making. The information must be accessible, clear and relevant. It is crucial, however, for an agro-meteorological service to know who the specific users of information are. The user community ranges from global, national and provincial organizations and governments to agro-industries, farmers, agricultural consultants, and the agricultural research and technology development communities or private individuals.

The variety of agro-meteorological information requests emanates from this broad community. Therefore, the agro-meteorological service must distribute the information that is available and appropriate at the right time. Researchers invariably know exactly which agro-meteorological data they require for specific statistical analyses, modelling or other analytical studies.

Agro-meteorological information should be distributed to all users, including:

(a) Agricultural administrations;

(b) Research institutions and laboratories;

(c) Professional organizations;

(d) Private crop and weather services;

(e) Government agencies;

(f) Farmers, ranchers and foresters.

DATABASE MANAGEMENT

The management of weather and climate data for agricultural applications in the electronic age has become more efficient.

A wide variety of database choices are available to the agro-climatological user community. Thus, a database management system for agricultural applications should be comprehensive, bearing in mind the following considerations:

(a) Communication among climatologists, agro-meteorologists and agricultural extension personnel must be improved to establish an operational database;

(b) The outputs must be adapted for an operational database in order to support specific agro-meteorological applications at a national/ regional/global level;

(c) Applications must be linked to the Climate Applications Referral System (CARS) project, spatial interpolated databases and a Geographical Information System (GIS).

This process is even more complicated when data from several different datasets, such as climatic and agricultural data, are combined. Some software programs for database management, especially the software for climatic database management, provide convenient tools for agro-meteorological database management.

CLICOM Database Management System

CLICOM (CLImateCOMputing) refers to the WMO World Climate Data Programme Project, which is aimed at coordinating and assisting the implementation, maintenance and upgrading of automated climate data management procedures and systems in WMO Member countries (that is, the National Meteorological and Hydrological Services in these countries). The goal of CLICOM is the transfer of three main components of modern technology, namely, desktop computer hardware, database management software and training in climate data management.

Among the technical limitations, the list includes (WMO, 2000):

(a) The lack of flexibility to implement specific applications in the agricultural field and/or at a regional/global level;

(b) The lack of functionality in real-time operations;

(c) Few options for file import;

(d) The lack of transparent linkages to other applications;

(e) The risk of overlapping of many datasets;

(f) A non-standard georeferencing system;

(g) Storage of climate data without the corresponding station information;

(h) The possibility of easy modification of the data entry module, which may destroy existing data.

Geographical Information System (GIS)

A Geographical Information System (GIS) is a computer-assisted system for the acquisition, storage, analysis and display of observed data on spatial distribution.

Weather generators (WG)

Weather generators are widely used to generate synthetic weather data, which can be arbitrarily long for input into impact models, such as crop models and hydrological models that are used for assessing agro-climatic long-term risk and agro-meteorological analysis. Weather generators are also the tool used for developing future climate scenarios based on global climate model (GCM) simulations or subjectively introduced climate changes for climate change impact models.

The popular weather generators are, inter alia, WGEN (Richardson, 1984, 1985), SIMMETEO (Geng et al., 1986, 1988), and MARKSIM (Jones and Thornton, 1998, 2000). The software allows for three types of input to estimate parameters for the generator:

(a) Latitude and longitude;

(b) Latitude, longitude and elevation;

(c) Latitude, longitude, elevation and long-term monthly climate normal.

AGROMETEOROLOGICAL INFORMATION

The impacts of meteorological factors on crop growth and development are consecutive, although sometimes they do not emerge over a short time. The weather and climatological information should vary according to the kind of crop, its sensitivity to environmental factors, water requirements, and so on.

Certain statistics are important, such as sequences of consecutive days when maximum and minimum temperatures or the amount of precipitation exceed or are less than certain critical threshold values, and the average and extreme dates when these threshold values are reached. The following are some of the more frequent types of information that can be derived from the basic data:

(a) Air temperature

i. Temperature probabilities;

ii. Chilling hours

iii. Degree-days

iv. Hours or days above or below selected temperatures

v. Inter-diurnal variability

vi. Maximum and minimum temperature statistics

vii. Growing season statistics, that is, dates when threshold temperature values for the growth of various kinds of crops begin and end.

(b) Precipitation

i. Probability of a specified amount during a period

ii. Number of days with specified amounts of precipitation

iii. Probabilities of thundershowers

iv. Duration and amount of snow cover

v. Dates on which snow cover begins and ends

vi. Probability of extreme precipitation amounts.

(c) Wind

i. Wind rose;

ii. Maximum wind, average wind speed;

iii. Diurnal variation;

iv. Hours of wind less than selected speed.

(d) Sky cover, sunshine, radiation

i. Per cent possible sunshine;

ii. Number of clear, partly cloudy, cloudy days;

iii. Amounts of global and net radiation.

(e) Humidity

i. Probability of a specified relative humidity;

ii. Duration of a specified threshold of humidity.

(f) Free water evaporation

i. Total amount;

ii. Diurnal variation of evaporation;

iii. Relative dryness of air;

iv. Evapotranspiration.

(g) Dew

i. Duration and amount of dew;

ii. Diurnal variation of dew;

iii. Association of dew with vegetative wetting;

iv. Probability of dew formation based on the season.

(h) Soil temperature

i. Mean and standard deviation at standard depth;

ii. Depth of frost penetration;

iii. Probability of occurrence of specified temperatures at standard depths;

iv. Dates when threshold values of temperature (germination, vegetation) are reached.

(i) Frost;

i. Weather hazards or extreme events

ii. Cold wave;

iii. Hail;

iv. Heat wave;

v. Drought;

vi. Cyclones;

vii. Flood;

viii. Rare sunshine;

ix. Waterlogging

(j) Agro-meteorological observations

i. Soil moisture at regular depths

ii. Plant growth observations;

iii. Plant population;

iv. Phenological events;

v. Leaf area index;

vi. Above-ground biomass;

vii. Crop canopy temperature;

viii. Leaf temperature;

ix. Crop root length.

Forecast information

Operational weather information is defined as real time data that provide conditions of past weather (over the previous few days), present weather, as well as predicted weather. It is well known, however, that the forecast product deteriorates with time, so that the longer the forecast period, the less reliable the forecast.

Statistical methods of Agrometeorological Data Analysis

Some Methods of Climatological Analysis (WMO Technical Note No. 81), which contain advice generally appropriate and applicable to agricultural climatology. Statistical analyses play an important role in agro-meteorology, as they provide a means of interrelating series of data from diverse sources, namely biological data, soil and crop data, and atmospheric measurements.

One example of freely available software is INSTAT, which was developed with applications in agro-meteorology in mind. It is a general-purpose statistics package for PCs that was developed by the Statistical Service Centre of the University of Reading in the United Kingdom.

Series checks

Before selecting a series of values for statistical treatment, the series should be carefully examined for validity. The same checks should be applied to series of agro-meteorological data as to conventional climatological data; in particular, the series should be checked for homogeneity and, if necessary, gaps should be filled in. It is assumed that the individual values will have been carefully checked beforehand (for consistency and coherence) in accordance with section 4.3 of the Guide to Climatological Practices (WMO-No. 100).

Climatic scales

In agriculture, perhaps more than in most economic activities, all scales of climate need to be considered:

(a) For the purpose of meeting national and regional requirements, studies on a macroclimatic scale are useful and may be based mainly on data from synoptic stations. For some atmospheric parameters

with little spatial variation, for example, duration of sunshine over a week or 10-day period, such an analysis is found to be satisfactory;

(b) In order to plan the activities of an agricultural undertaking, or group of undertakings, it is essential, however, to change over to the mesoclimatic or topoclimatic scale, in other words, to take into account local geomorphological features and to use data from an observational network with a finer mesh. These complementary climatological series of data may be for much shorter periods than those used for macroclimatic analyses, provided that they can be related to some long reference series;

(c) For bioclimatic research, the physical environment should be studied at the level of the plant or animal, or the pathogenic colony itself. Obtaining information about radiation energy, moisture and chemical exchanges involves handling measurements on the much finer scale of microclimatology;

(d) For research on the impacts of a changing climate, past long-term historical and future climate scenarios should be used.

Reference periods

The length of the reference period for which the statistics are defined should be selected according to its suitability for each agricultural activity. Calendar periods of a month or a year are not, in general, suitable. It is often best either to use a reduced timescale or, alternatively, to combine several months in a way that will show the overall development of an agricultural activity. The following periods are thus suggested for reference purposes:

(a) Ten-day or weekly periods for operational statistical analyses, for instance, evapotranspiration, water balance, sums of temperature, frequency of occasions when a value exceeds or falls below a critical threshold value, and so forth. Data for the weekly period, which has the advantage of being universally adopted for all activities, are difficult to adjust for successive years, however;

(b) For certain agricultural activities, the periods should correspond to phenological stages or to the periods when certain operations are undertaken in crop cultivation. Thus, water balance, sums of temperature, sequences of days with precipitation or temperature below certain threshold values, and the like, could be analysed for:

i. The mean growing season;

ii. Periods corresponding to particularly critical phenological stages;

iii. Periods during which crop cultivation, plant protection treatment or preventive measures are found to be necessary.

These suggestions, of course, imply a thorough knowledge of the normal calendar of agricultural activities in an area.

The beginning of reference periods

In agricultural meteorology, it is best to choose starting points corresponding to the biological rhythms, since the arbitrary calendar periods (month, year) do not coincide with these. For example, in temperate zones, the starting point could be autumn (sowing of winter cereals) or spring (resumption of growth). In regions subject to monsoons or the seasonal movement of the inter-tropical convergence zone, it could be the onset of the rainy season. It could also be based on the evolution of a significant climatic factor considered to be

representative of a biological cycle that is difficult to assess directly, for example, the summation of temperatures exceeding a threshold temperature necessary for growth.

Analysis of the effects of weather

The climatic elements do not act independently on the biological life cycle of living things: an analytical study of their individual effects is often illusory. Handling them all simultaneously, however, requires considerable data and complex statistical treatment. It is often better to try to combine several factors into single agro-climatic indices, considered as complex parameters, which can be compared more easily with biological data.

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Practical-5: Critical analysis of rainfall and possible drought period in India, Effective rainfall and its calculation

INTRODUCTION

Statistics is the study of the collection, organization, analysis, interpretation and presentation of data. It deals with all aspects of data, including planning of data collection for experimental design. Statistics also deals with science of understanding uncertainty. Will it rain today? Given that it has not rained for several days, what is the probability that it might rain in the next week? How does a dam affect stream ? ow? What are the health risks due to drinking contaminated water? These are all questions that statistics might be able to help answer. Probability theory and mathematical statistics are applied to hydrology. Probability theory has been presented in a summarized form here with emphasis on its use in hydrology. The emphasis is on inferential rather than descriptive statistics of classical hydrologic applications.

The purpose of hydrological data processing software is not primarily hydrological analysis. However, various kinds of analysis are required for data validation and further analysis may be required for data presentation and reporting.

The types of processing considered are:

- checking data homogeneity
- computation of basic statistics
- annual exceedance rainfall series
- fitting of frequency distributions
- frequency and duration curves

Most of the hydrological analysis for purpose of validation will be carried out at the Divisional and State Data Processing Centers and for the final presentation and reporting at the State Data Processing Centers.

Checking data homogeneity

For statistical analysis rainfall data from a single series should ideally possess property of homogeneity - i.e. properties or characteristics of different portion of the data series do not vary significantly. Rainfall data for multiple series at neighbouring stations should ideally possess spatial homogeneity.

A test of homogeneity is required for validation purposes and there is a shared need for such tests with other climatic variables. Tests are therefore described in other Modules as follows:

- Secondary validation of rainfall data
  - A. Spatial homogeneity testing
  - B. Consistency tests using double mass curves
- Correcting and completing rainfall data
  - A. Adjusting rainfall data for long-term systematic shifts – double mass curves
- Secondary validation of climatic data
  - A. Single series tests of homogeneity, including trend analysis, mass curves, residual mass

curves, Student's and Wilcoxon W test on the difference of means and Wilcoxon-Mann-Whitney U test to investigate if the sample are from same population.

B. Multiple station validation including comparison plots, residual series, regression analysis and double mass curves.

Computation of basic statistics

Basic statistics are widely required for validation and reporting. The following are commonly used:

- arithmetic mean
- median - the median value of a ranked series Xi
- mode - the value of X which occurs with greatest frequency or the midlle
- value of the class with greatest frequency
- standard deviation - the root mean squared deviation Sx
- skewness and kurtosis

In addition empirical frequency distributions can be presented as a graphical representation of the number of data per class and as a cumulative frequency distribution. From these selected values of exceedence probability or non-exceedence probability can be extracted e.g. the daily rainfall which has been exceeded 1%, 5% or 10% of the time.

Presentation of Rainfall Data

A few commonly used methods of presentations of rainfall data that are useful in interpretation and analysis are given below.

Chronological chart

Presentation of daily, weekly, monthly or annual rainfall data shown either as dots or line joining the dots is known as Chronological chart. Chronological charts may be plotted with a moving mean. A moving mean may be used to damp out or smooth out the oscillations of some of the random variables such as precipitation, stream flow, etc. Fig. 5.1 shows the annual rainfall and average annual rainfall of India in bar chart. As seen from Fig. 8.1, maximum rainfall occurred in 2001 and minimum rainfall occurred in 1986.

(Source: http://www.sciencedirect.com/science/article/pii/S0378377412003058)

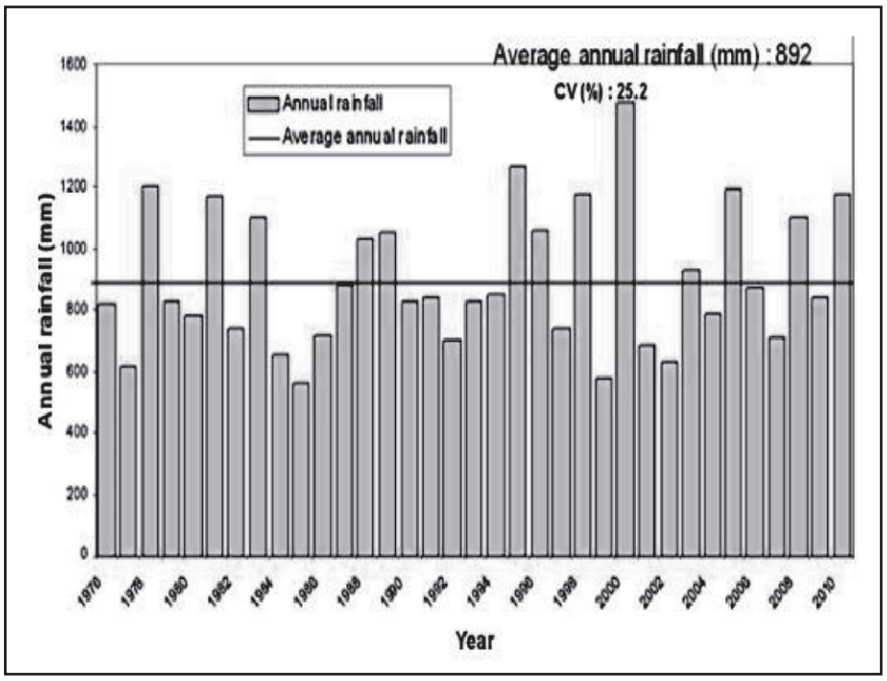

Fig. 5.1: Annual rainfall of India.

Mass Curve of Rainfall

The mass curve of rainfall is a plot of the accumulated precipitation against time, plotted in chronological order. Records of float type and weighing bucket type gauges are of this form. A typical mass curve of rainfall at a station during a storm is shown in Fig. 5.2

http://theconstructor.org/water-resources/analysis-presentation-of-rainfall-data/4493/)

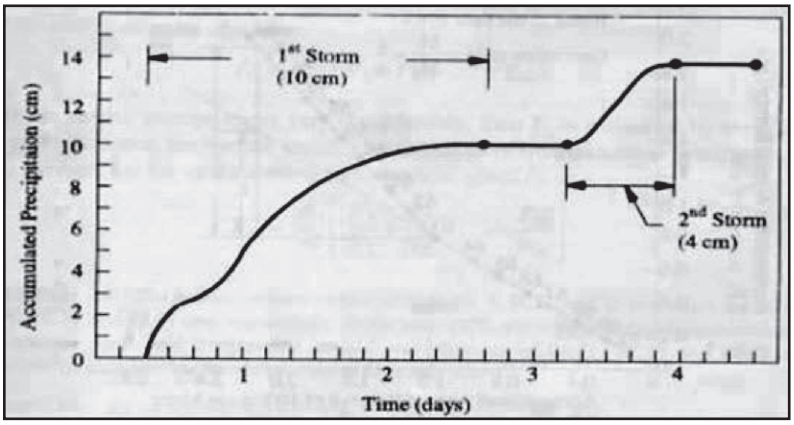

Fig. 5.2: Mass curve of Rainfall.

Double Mass Curve of Rainfall

The double mass curve technique, as illustrated in Fig. 5.3, is a reliable procedure for checking the consistency of a precipitation record. The technique compares long term annual or seasonal precipitation of a group of stations being evaluated. Some seasons of the year may have more inconsistencies than others. Therefore, seasonal analysis may provide better results than using total annual values. The accumulated annual or seasonal values for the comparison stations are plotted against the accumulated annual value for the evaluation station.

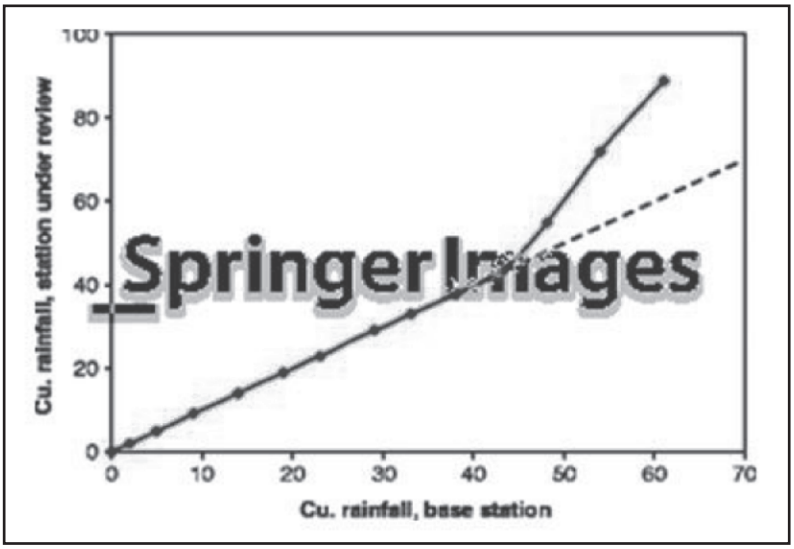

Fig. 5.3: Double Mass Curve of Rainfall.

(Source: http://www.springerimages.com/Images/Environment/1-10.1007_978-1-4419-6335-2_3-4)

Hyetograph

Hyetograph is a plot of the intensity of rainfall against the time interval, as illustrated in Fig. 5.4. The Hyetograph is derived from the mass curve and is usually represented as a bar chart. It is a very convenient way of representing the characterstics of a storm and is particularly important in the development of design storms to predict extreme floods. The area under a hyetograph represents the total precipitation received in the period. The time interval used depends upon the purpose. In urban-drainage problems small durations are used while in flood-flow computations in larger catchments the intervals are of about 6 h.

(Source:http://echo2.epfl.ch/VICAIRE/mod_1b/chapt_2/main.htm)

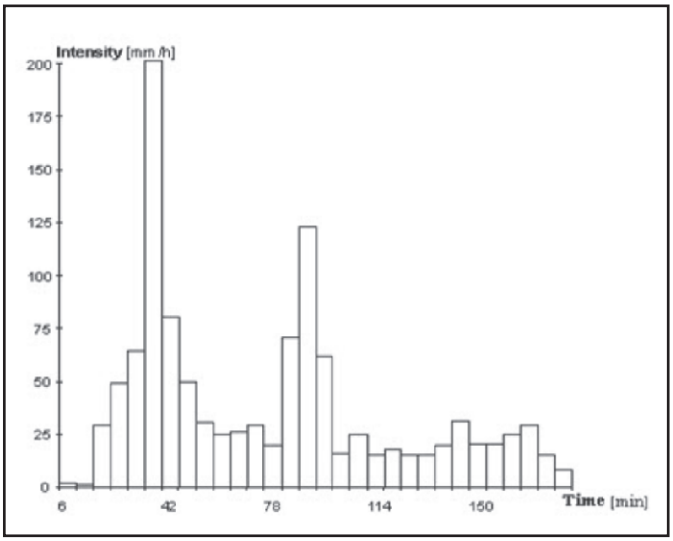

Fig. 5.4: Hyetograph.

Hydrograph

The term "Hydrograph" stands for the graphical representation of the instantaneous rate of discharge of a stream plotted with respect to time, as illustrated in Fig. 5.5. This is as a result of the physiographic and hydrometerological effect of the watershed. Hydrographs are graphs which show river discharge over a given period of time and show the response of a drainage basin and its river to a period of rainfall. A storm hydrograph shows how a river's discharge responds following a period of heavy rainfall. On a hydrograph, the flood is shown as a peak above the base (normal) flow of the river.

(Source:
http://web.cortland.edu/barclayj/hydrograph.jpg)

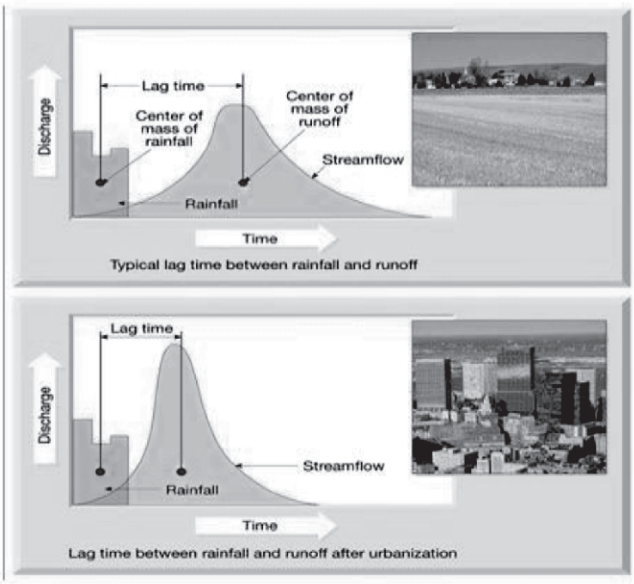

Fig. 5.5: Hydrograph.

Point Rainfall

The rainfall data measured at a place using a measuring device is known as point (or station) rainfall data. For small areas of less than 50 km2, point rainfall may be taken as the average depth over the area. In large areas, there will be a network of rain-gauge stations. Depending upon the need, data can be listed as daily, weekly, monthly, seasonal or annual values for various periods. Graphically these data are represented as plots of magnitude Vs chronological time in the form of a bar diagram. Such a plot, however, is not convenient for subsequent uses. Fig. 5.6 shows the monthly precipitation

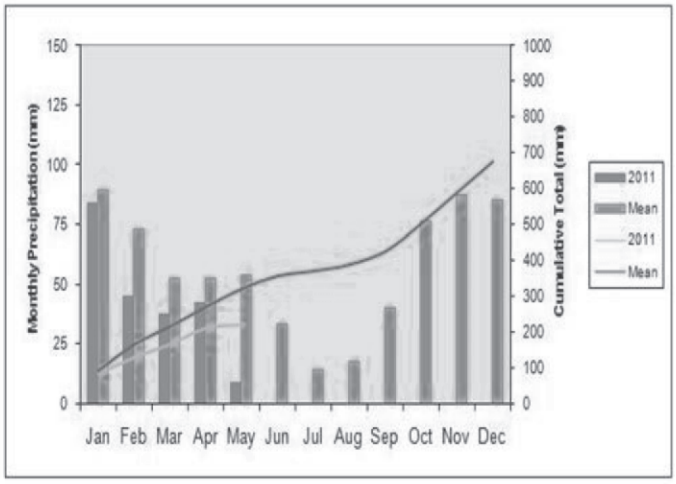

Fig. 5.6: Point Rainfall.

http://malvedos.wordpress.com/2011/07/19/may-2011-douro-insider/)

Mean Precipitation Over an Area:

To convert the point rainfall values at various stations in to an average value over a catchment the following three methods are used: i) arithmetical-mean method (ii) Thiessen-polygon method (iii) Isohyetel method.

(i) Arithmetical-Mean Method:

When the rainfall measured at various stations in a catchment show little variation, the average precipitation over the catchment area is taken as the arithmetic mean of the station values. Thus if $P_1, P_2, P_3 \ldots P_n$ are the rainfall values in a given period in N stations within a catchment, then the value of the mean precipitation over the catchment by the arithmitic-mean method is

$$\bar{P} = \frac{(P1+P2+P3+\ldots\ldots+Pn)}{N}$$

(ii) Thiessen Polygon Method

This method attempts to allow for non-uniform distribution of gauges by providing a weighting factor for each gauge, as illustrated in Fig. 8.7. The stations are plotted on a base map and are connected by straight lines. Perpendicular bisectors are drawn to the straight lines, joining adjacent stations to form polygons, known as Thiessen polygons. Each polygon area is assumed to receive uniform rainfall, as recorded by the raingauge station inside it, i.e., if P1, P2, P3, ...are the rainfalls at the individual stations, and A1, A2, A3, ... are the areas of the polygons surrounding these stations, (influence areas) respectively, the average depth of rainfall for the entire basin is given by:

$$\bar{P} = \frac{\sum_{i=1}^{M} P_i A_i}{A}$$

where ÓAi = A = total area of the basin.

(iii) The Isohyetal Method

In this method, the point rainfalls are plotted on a suitable base map and the lines of equal rainfall (isohyets) are drawn giving consideration to orographic effects and storm morphology. The average rainfall between the successive isohyets taken as the average of the two isohyetal values are weighted with the area between the isohyets, added up and divided by the total area which gives the average depth of rainfall over the entire basin

$$P_{ave} = \frac{\sum A_{1-2} P_{1-2}}{\sum A_{1-2}}$$

where A1–2 = area between the two successive isohyets P1 and P2

$$P_{1\text{-}2} = \frac{P_1 + P_2}{2}$$

$$\sum A_{1-2} = A = \text{total area of basin}$$

Intensity-Duration-Frequency Curve

The relationship between frequency, intensity and storm duration vary sufficiently from place to place and periodic revisions are desirable in each locality. The relationship between intensity-duration-frequency can be obtained from an analysis of rainfall records obtained at that location. The intensity of storm decreases with the increase in storm duration. Fig. 5.8 shows the intensity- duration curve over return period.

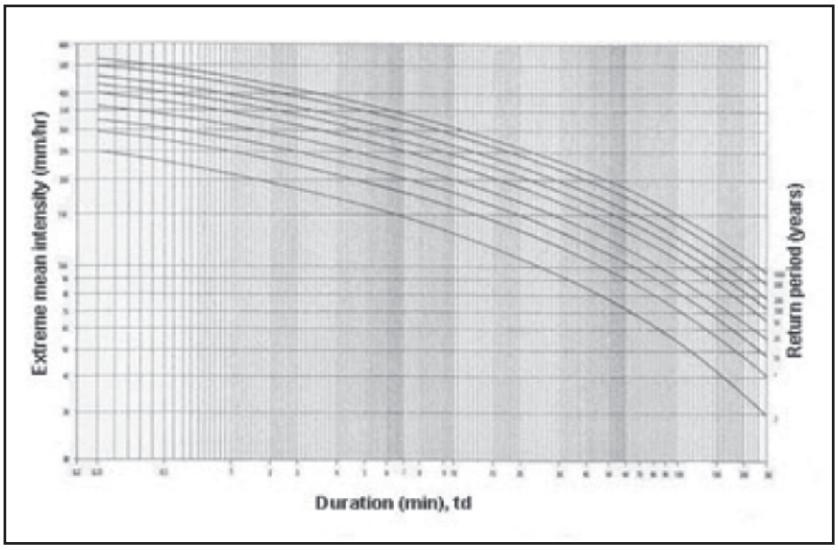

Fig.5.8: Intensity-duration-frequency curve

(Source: http://civcal.media.hku.hk/yuenlong/introduction/_idfcurve.htm)

Depth-Area-Duration Curve

A depth-area-duration curve express graphically the relation between a progressively decreasing average depth of rainfall over a progressively increasing area from the centre of the storm outward to its edge for a given duration of rainfall. It can be constructed from any isohyetal map of rainfall for the given duration. Such a curve can be constructed for the duration (usually 6 h, 12 h, 18 h, 24 h, and 36 h) as shown in Fig. 5.9.

(Source: http://www.springerimages.com/Images/Environment/1-10.1007_978-1-4419-6335-2_3-1)

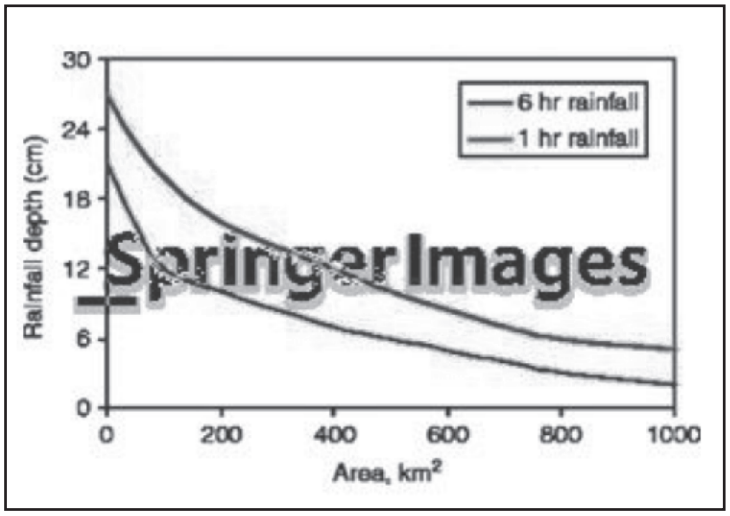

Fig.5.9: Depth-Area-duration curve

Simple Statistical Analysis

In the study of statistics we are basically concerned with the presentation and interpretation of chance outcomes that occur in a planned or scientific investigation. Hence, the statistician usually deals with either numerical data representing counts or measurements, or perhaps with categorical data that can be classified according to some criterion. We shall refer to any recording of information, whether it is numerical or categorical, as an observation. Statistical methods are those procedures that are used in the collection, presentation, analysis, and interpretation of data. These methods can be categorized as belonging to one of the two major areas called descriptive statistics and statistical inference.

Descriptive Statistics

Those methods concerned with collecting and describing a set of data so as to yield meaningful information. It provides information only about the collected data and in no way draws inferences or conclusions concerning a larger set of data.

Statistical Inference

Those methods are concerned with the analysis of a subset of data leading to predictions or inferences about the entire set of data.

Fundamental

1. Hydrological Process

Hydrological environment consists of water inputs, environment response and the output. This union of three in one-input, response, output-is described as the basic parts of a hydrologic system, while each of these parts represents a hydrologic process. Natural hydrologic processes are never deterministic but are a combination of various deterministic and stochastic processes.

2. Deterministic Process

These are the processes of hydrology that are the results of physical, chemical and biological deterministic laws. For example, a rating curve of the stage discharge relationship of a river cross section with a fixed bed is a unique function and is thus a deterministic relation giving the same discharge for the same stage at all times.

3. Stochastic Process

These are the processes of hydrology which are governed by the laws of chance such as precipitation, evaporation, and runoff. Stochastic models use random variables to represent processes with uncertainty and generate different results from one set of input data and parameter values when they run under "externally seen" identical conditions. A particular set of inputs will produce an output according to a statistical distribution. This allows some randomness or uncertainty in the possible outcome due to uncertainty in input variables, boundary conditions or model parameters. The application of flood frequency analysis in hydrologic design and operation of water resources systems are good examples of stochastic processes.

Mixed deterministic

Stochastic models can also be created by introducing stochastic error models to the deterministic model. For example, stochastic rainfall could be used as an input to a deterministic rainfall-runoff model or a deterministic model may be used to represent a stochastic system. It is important to stress that the term chance, random, probabilistic and stochastic are considered synonyms. They all refer to the phenomena subject to the laws of chance.

Practical-6: Studies on cultural practices for mitigating moisture stress. Characterization and delineation of model watershed

General recommendations

1. Selection of suitable crops and varieties

In vegetable crops like dolichos bean, cowpea, cluster bean, lima bean, chilli, drumstick, brinjal, okra are suitable for rain-fed cultivation. Among these, legume vegetables can be recommended for contingency crop-planning in an eventuality of late monsoon rains. Varieties having good root system and capacity to recoup after the alleviation of stress need to be selected. Depending upon situation, it is recommended to use short duration varieties.

2. Improved method of seedling production

Improved method of seedling production such as Protray grown seedling using coco peat, nylon net protection and bio-fertilizers/bio-pesticide inoculation at nursery stage has good potential for obtaining sturdy, uniform and healthy seedlings. These seedlings when transplanted in the main-field will establish better with less root damage and fare better in overcoming biotic and abiotic stresses particularly during water stress conditions.

3. Adoption of soil and moisture conservation techniques

Contour cultivation, contour trip cropping, mixed Cropping, tillage, mulching, zero tillage, are some of the agronomical measures for the in-situ soil moisture conservation. Mechanical measures like contour bunding, graded bunding, bench terracing, vertical mulching etc. also need to be followed for effective soil and moisture conservation in dry lands. Another technology for efficient utilization of runoff is water harvesting recycling. Rainwater harvesting includes collecting runoff water into dug out ponds or tanks in small depressions, gullies and into storage dams of earth or masonry structures. Rain water harvesting is possible in areas having rainfall as little as 500 to 800 mm. Depending on the rainfall and soil characteristics, 10-50 % of the runoff can be collected in farm pond. Surface run off thus collected in a farm pond can be used to provide protective irrigation in the period of prolonged dry spell or through micro irrigation techniques.

4. Enhancing soil organic matter content

Constant efforts must be made to improve the soil organic carbon. Incorporation of crop residues and farm yard manure to soil improves the organic matter status, improves soil structure and soil moisture storage capacity. Organic matter content of the soil can also be improved by fallowing alley cropping, green manuring, crop rotation and agro forestry. Vegetable being short duration crop and having faster growth phases, the available organic matter needs to be properly composted. Vermicomposting can be followed for quicker usage of available organic matter in the soil and improving the soil moisture holding capacity.

5. Application of foliar nutrition:

The foliar application of nutrients during water stress conditions helps in the better growth by quick absorption of nutrients. The spraying of K and Ca induces drought tolerance in vegetable crops. Spraying of micronutrients and secondary nutrients improves crop yields and quality.

6. Use of drip irrigation

Drip irrigation has proved its superiority over other conventional method of irrigation, in Horticulture due to precise and direct application of water in root zone. A considerable saving in water, increased growth, development and yields of fruits and vegetables and control of weeds, saving in labour under drip irrigation are the added advantages. Drip irrigation can be adopted in fruit crops and also to all vegetable crops including closed spaced crops like onions and beans. The saving in water is to the tune of 30-50 % depending on the crop and season. Generally inline drip laterals having emitting point spaced at 30cm distance and emitting at the rate of 2LPH is selected for vegetable crops. In crops like chilli, brinjal, cauliflower and okra paired row planting is practiced and one drip lateral is used for two crop rows.

7. Use of micro sprinkler irrigation

Depending upon situation and availability of water, this technology can be used for fruits and vegetable crops. The cost of initial establishment is lower compared to drip system. Further in summer the sprinkling of water helps in reducing the microclimate temperature and increasing the humidity, thereby improving the growth and yield of the crop. The water saved is to the tune of 20 to 30 per cent.

8. Moisture saving methods under limited water resource conditions:

The following methods may be adopted under limited water conditions to save water:

- **Water saving irrigation method**

  Under limited water situations, water-saving irrigation methods like alternate furrow irrigation or widely spaced furrow irrigation and drip irrigation systems can be adopted. Studies conducted on methods of irrigation in capsicum, tomato, okra and cauliflower indicated that adopting alternate-furrow irrigation and widely-spaced furrow irrigation saved 35 to 40 per cent of irrigation water without adversely affecting yield.

- **Mulching Practices in Vegetable Production**

  The technique of covering the soil with natural crop residues or plastic films for soil and water conservation is called mulching. Mulching can be practiced in fruits and vegetable crops using crop residues and other organic material available in the farm. Recently plastic mulches have come into use due to the inherent advantages of efficient moisture conservation, weed suppression and maintenance of soil structure. Wide variety of vegetables can be successfully grown using mulches. In addition to soil and water conservation, improved yield and quality, suppression of weed growth , mulches can improve the use efficiency of applied fertilizer nutrients and also use of reflective mulches are likely to minimize the incidence of virus diseases. For vegetable production generally polyethylene mulch film of 30micron thick and 1 to 1.2 m width is used. Generally raised bed with drip irrigation system is followed while laying the mulch film.

9. Wind breaks, hedges and intercropping:

To overcome the adverse effect of high temperature and dry winds, tall growing trees need to be planted all along the boundary of the farm. Inter cropping of vegetable crops of the area can be practiced in orchards during summer months. Maize/ Sorghum can be grown all along the border of the plot to mitigate the effect of desiccating winds.

10. Use of protected cultivation of vegetables

In peri-urban regions where climate does not favour year round production of crops in the open field, vegetable production can be taken up in protected environment. Protective structure is a facility to protect crop from biotic and abiotic constraints. Structures for protected cultivation include green houses, plastic/net houses and "tunnels". Commonly used protected structures are polyhouses and net or shade houses. Rain-shelter is a simple structure covered with polyethylene sheet which helps in producing the crops which are affected by excessive rainfall. The productivity of tomato, onions and melons are adversely affected in the event of high rainfall due to difficulty in managing the foliar diseases, lack of proper soil aeration and drainage and also depending on the nature of crop physical damage of the foliage and flower drop. Net house cultivation and shade net cultivation provide better microclimate especially during summer in minimizing the high temperature effect and improving the relative humidity. The productivity of tomato, French bean and capsicum can be improved during high temperature period by using net/shade net on the top.

11. Control of leaf miner and mite during high temperature stress

For management of leaf miner spray neem soap 4 grams / liter or triazophos at the rate 1.5 ml / l. To manage mites spray Abanectin 0.5 ml/l. Aphids may be observed in case of beans. Spray neem soap (1.0 %) or neem seed kernel extract (4.00 %).

NOTES

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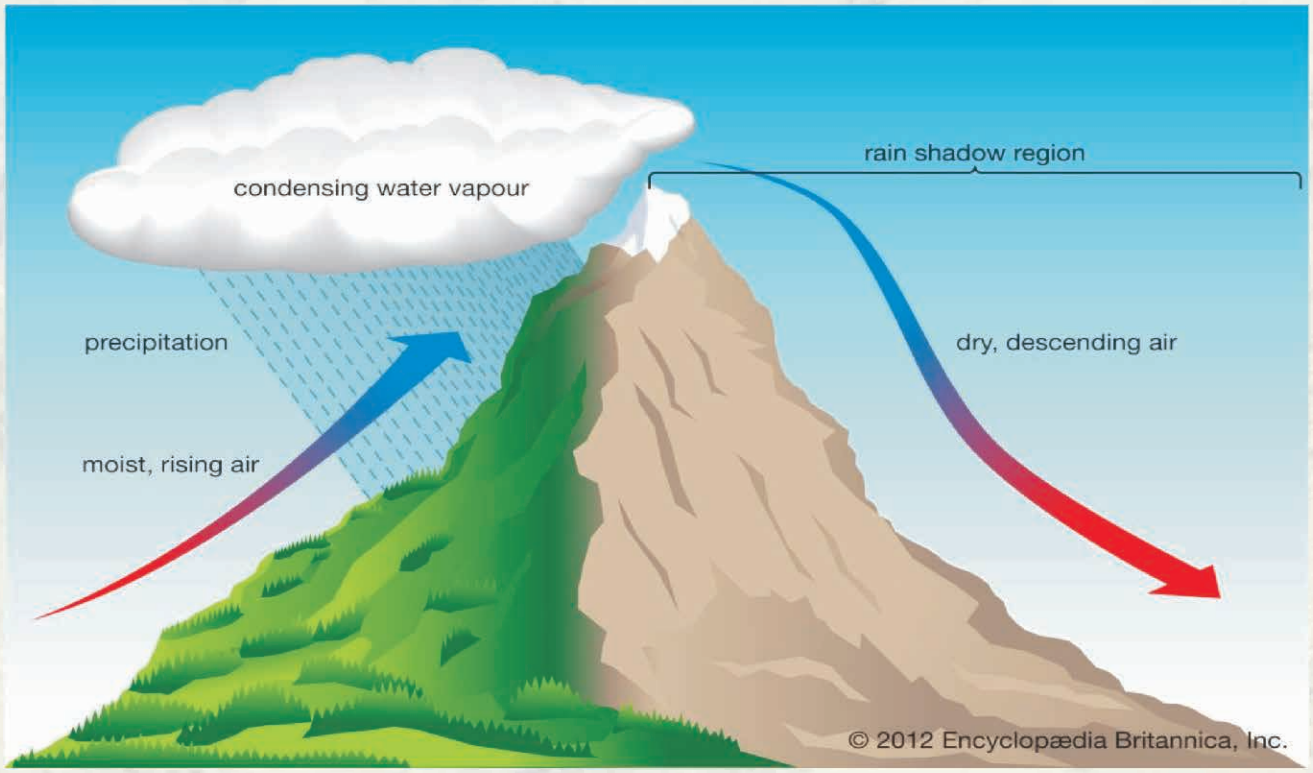
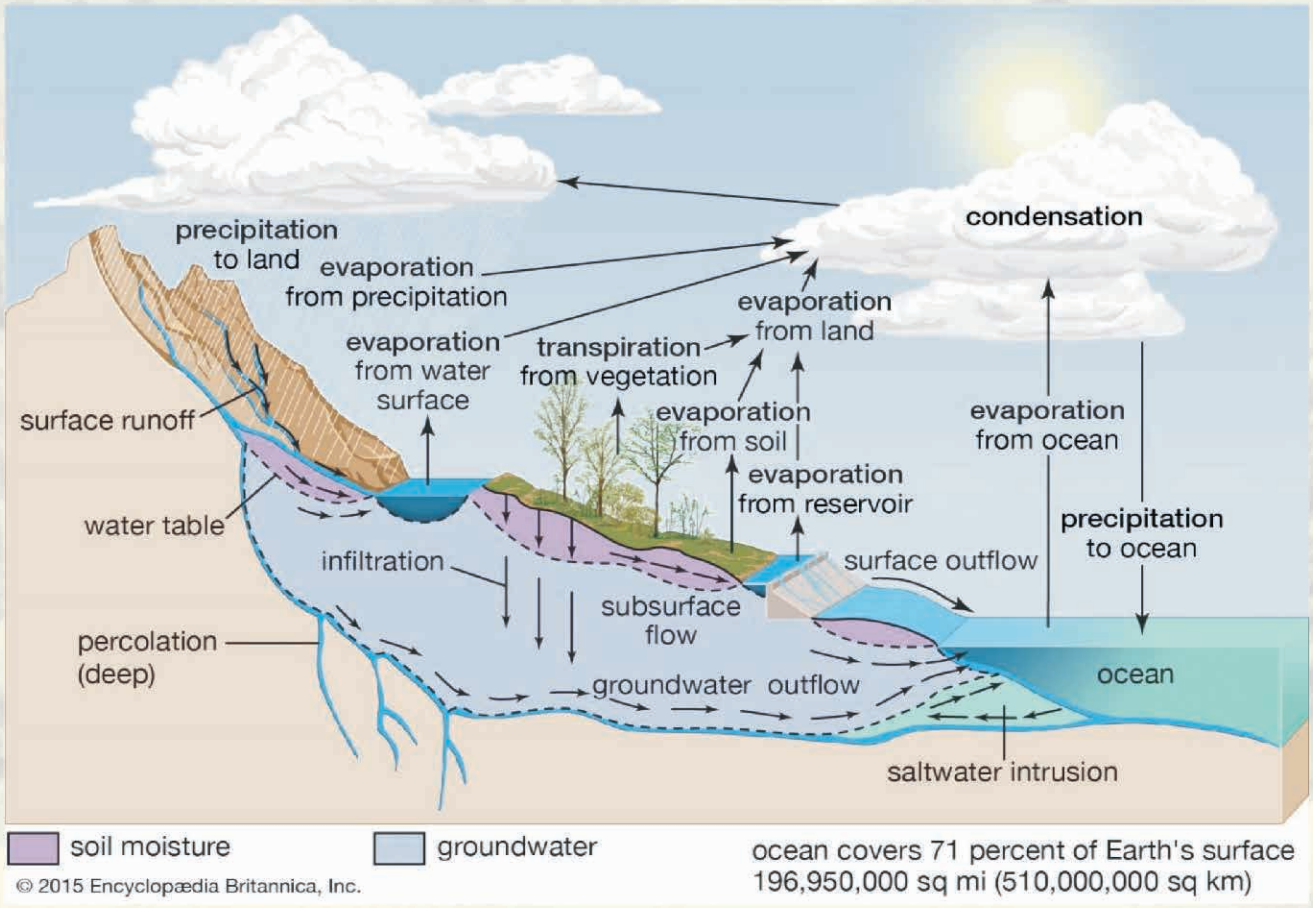


Orographic Precipitation



Hydrological Cycle

NAVSARI AGRICULTURAL UNIVERSITY

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NAVSARI AGRICULTURAL UNIVERSITY

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WAGHAI

Practical Manual

GPB-6.7 (1 + 1)

Crop Improvement-II (*Rabi*)





Prepared by

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Assistant Professor

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College of Agriculture
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Mankombu Sambasivan Swaminathan

(Born 7, August 1925)

He is an Indian genetics and administrator, known as **"Father of Green Revolution in India"** for his role in introducing and further developing high-yielding varieties of wheat in India. He is the founder of the MS Swaminathan Research Foundation.

He was director general of the ICAR (1972-1979). He also served as Director General of the International Rice Research institute (1982–88) and became president of the International Union for the Conservation of Nature and Natural Resources in 1988.

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Name: _____ **Roll No.:** _____

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:: FOREWORD ::

It gives me great pleasure to write the foreword of the Practical Manual of "Crop Improvement-II (*Rabi*) " prepared by Dr. Anita C. Solanke, Prof. P. A. Vavdiya and Prof. S.K. Jadav of the Department of Genetics and Plant Breeding. This is one of the most unique and fundamentals practical books available for fulfilling the requirements of the undergraduate students and has been prepared as per the latest syllabus prescribed by the ICAR. However, it is equally useful for the Post-graduate students, scholars, teachers and scientists working in the basic and applied aspects of Genetics and Plant breeding.

This manual entitled "Crop Improvement-II (*Rabi*)" A Practical Manual has been design for better understanding of basic aspect of breeding of various field crops, vegetable crops and some spice crops of *rabi* season. Plant breeding plays an important role in genetic improvement of crop plants in relation to their economic use for human being. I am sure that six semester students will be benefitted by this revised and updated manual.

I appreciate and congratulate *Dr. Anita C. Solanke, Prof. P. A. Vavdiya and Prof S. K. Jadav for their commendable efforts in bringing out this practical manual* for their efforts.

(J. J. Pastagia)

Preface

Crop improvement is one of the most urgent tasks in current plant breeding, as an enormous increase in demand for plant-derived products will rise in the near future due to the growing human population and the depletion of fossil resources. Practical manual on "Crop Improvement-II (*Rabi*)" is a fundamental book which highlights and makes the readers aware of the fundamental information about breeding of field, vegetable and some spice crops. This book has been especially designed keeping in view the latest syllabus prescribed by the ICAR as per the 5th dean committee recommendation for first semester undergraduate agriculture students.

However, it is equally useful for the post graduate students, research scholars, teachers and scientists working on the basic and applied aspects of Plant Breeding. The format of the exercises is appropriate for use as a workbook. It is hoped that this practical manual will be highly useful for the students in learning the fundamental information about breeding of various field and vegetable crops. The editors welcome suggestions from users, students as well as instructors/teachers for its future improvement.

A.C. Solanke
P. A. Vavdiya
S. K. Jadav

CERTIFICATE

Reg. No. : _____ **Batch no.: _____**

Roll No.: _____ **Uni. Seat No.: _____**

This is to certify that the practical exercises duly signed were performed in the subject of **Crop Improvement-II (*Rabi*)**, *Course No.* ***GPB 6.7 (1+1) [Crop Improvement -II]*** *as a part and partial requirement of the Course by Mr./Ms . _____*

Roll No. _____ of Six Semester class during academic year 20_____ .

The numbers of practical performed were _____ out of _____.

Course Teacher **Professor & Head**

External Examiner

:: INDEX ::

Exercise-1

WHEAT

Date :

- Wheat is the one of the leading cereal crops of the world.
- It is a major crop of the America, Canada, Europe and Asia.
- It ranks third in area and second in production among the cereals grown in India.
- The most important wheat producing states of India are Uttar Pradesh, Haryana, M. P., Punjab, Rajashthan, Maharashtra, Bihar and Gujarat.
- Wheat contains a substance called **gluten**, which make possible the production of loaf bread.
- This property is only present in wheat and to some extant in rye. Wheat is used to make bread, biscuits, pastry and semolina products. In India, it is mainly used for making *chapattis*.

1.	**Name of Crop**	**:**	Wheat
2.	**Botanical Name**	**:**	*Triticum aestivum* Bread Wheat (Irrigated) *Triticum durum* Durum Wheat Macroni Wheat (Irrigated or rainfed) *T.dicoccum* (Emmer or Khapli wheat)
3.	**Family**	**:**	Poaceae
4.	**Chromosome Number**	**:**	As per Table **1.1**
5.	**Center of Origin**	**:**	Diploid: Asia minor Tetraploid: Abyssinia, North Africas Hexaploid: Central Asia
6.	**Mode of pollination**	**:**	Self pollination (Chasmogamy)
7.	**Out crossing percentage**	**:**	< 1 per cent
8.	**Related species**	**:**	As per Table **1.1**

Polyploid:

An organism with more than two basic or monoploid sets of chromosome is called polyploid and such condition is known as polyploidy.

Autopolyploid:

Autopolyploids are polyploids with multiple chromosome sets derived **from the same species.**

Autopolyploids can arise naturally or can be produced artificially.

Allopolyploid:

Allopolyploids originated by combining complete chromosome sets **from two or more different species.**

In the F_1, hybrid, fertility can be restored by chromosome doubling.

Triticale is an example of an allopolyploid (six chromosome sets, allohexaploid, four from wheat **(*Triticum turgidum*)** and two from rye **(*Secale cereale*)).** *Amphidiploids* are a type of allopolyploids (they are tetraploid, containing the diploid chromosome sets of both parents).

Mode of origin of tetraploid and hexaplaoid wheat:

Tetraploid Wheat

Triticum monococcum **X** **Unknown**
2n= 14 (AA) ***(Aegilops spelltoides)***
2n=14 (BB)

↓

F_1 (AB) Diploid in nature

↓

Chromosome Doubling
2n= 4x=28 (AABB) Tetraploid
Triticum turgidum **–durum wheat)**

Hexaplaoid wheat

Triticum turgidum **X** ***T. tauchii***
2n= 28 (AABB) **2n= 14 (DD)**

↓

F1 (ABD)
2n=21

↓

2n= 6x= 42, AABBDD, Hexaploid
(Triticum aestivum)

Hexaploid Wheat

In nature, this wheat performs as diploid due to a mutation in 'ph' gene (dominant gene) on chromosome 5B, which inhibits pairing between homologous chromosomes

Table:1.1 Classification of wheat species as per ploidy level

Sr No.	Species	Chr No. (2n)	Genome Formula	Common Name
Diploid species (Natural group: Einkorn)				
1	*T. boeticum*	14	AA	Wild Einkorn
2	*T. monococcum*	14	AA	Einkorn
3	*Aegilops speltoids*	14	SS	-
4	*Triticum dichasians (Aegilops caudata)*	14	CC	-
5	*Triticum tauchii (Aegilops squarrosa)*	14	DD	-
6	*Triticum comosum (Aegilops comosa)*	14	MM	-
7	*Triticum umbellulatum (Aegilops umbellulata))*	14	UU	-
Tetraploid species: (Natural group: Emmer)				
1	*T. dicoccoides*	28	AABB	Wild Emmer
2	*T.dicoccum*	28	AABB	Emmer or Khapli
3	*T. durum*	28	AABB	Duram or Macaroni wheat
4	*T. turgidum*	28	AABB	Rivet wheat
5	*T. polonicum*	28	AABB	Polish wheat
6	*T. timpheevii*	28	AAGG	-
7	*T. araraticum*	28	AAGG	-
Hexaploid species (Natural group: Dinkel)				
1	*T. aestivum*	42	AABBDD	Bread wheat
2	*T. compactum*	42	AABBDD	Club wheat
3	*T. spelta*	42	AABBDD	Spelt wheat
4	*T. macha*	42	AABBDD	Macha wheat
5	*T. sphaerococcum*	42	AABBDD	Dwarf wheat
6	*T. vavilovi*	42	AABBDD	-
7	*T. zhukovskyi*	42	AAAAGG	-

Distribution of cultivated wheat species in India:

- There are three species of wheat namely, *Triticum aestivum, Triticum durum* and *T. dicoccum* grown on commercial basis in India.
- Out of total wheat area of the country, *Triticum aestivum* is grown on 90 to 95 % area, followed by *Triticum durum* 05 %. *T. dicoccum* is confined largely to the southern region mainly Karnataka and Southern Maharashtra.

Floral biology:

- The inflorescence of wheat called as Ear or head or spike.
- The Primary axis of spike is called as rachis which bears two opposite rows of lateral spikelets and single terminal spikelet and has zigzag appearance.
- Wheat inflorescence (spike) contains 13-23 spikelets. Inflorescence is a spike of spikelets, which are sessile. Each spikelet contains two subtending sterile bracts or glumes enclosing 2-7 florets born alternately on as short axis called as rachilla.
- Each floret consists of outer parianth called the ***lemma*** and thin two-keeled parianth called the ***palea.***
- These lemma and palea encloses two lodicules and sexual organs. The lemma covers the outer portion of the matured kernel and in the awn varieties it terminates in an awn.
- Sexual organs consist of 3 stamens and single pistil.
- Each stamen is made up of a filament and a yellow anther which produce about 1000-4000 pollen grains.
- Pistil consists of monocarpellary superior one ovary bearing two short styles bifurcated feathery stigmas.
- Florets at anthesis are forced open by the swelling of the lodicules. Stamens filaments elongate three times their original length in about 3 minutes and thus stamen exert quickly and expose the anthers.

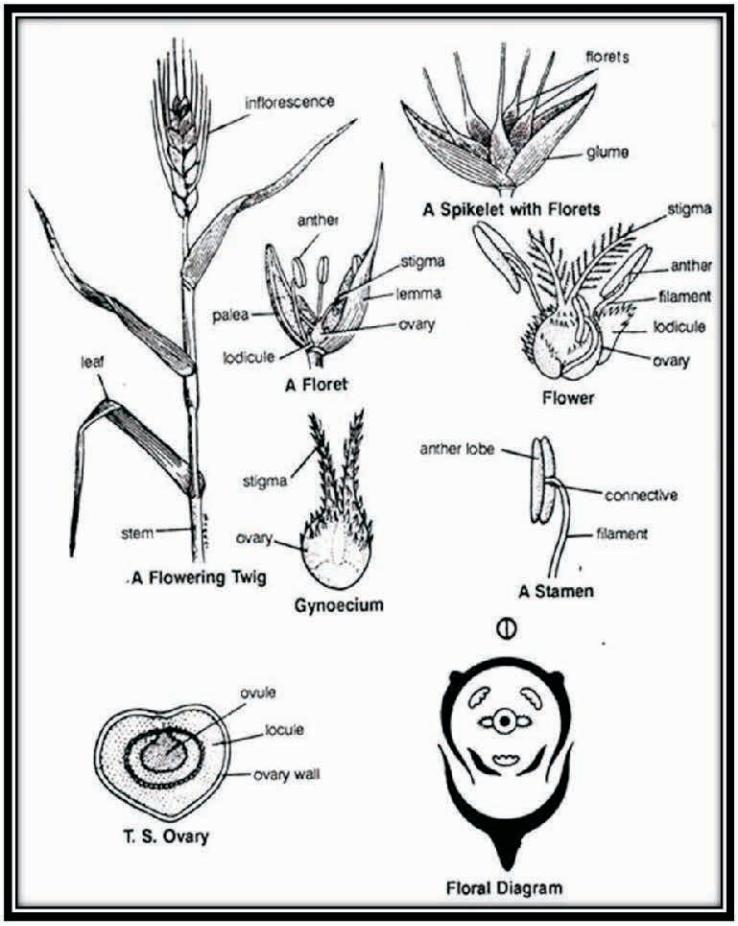


Figure 1.1: Floral structure of wheat

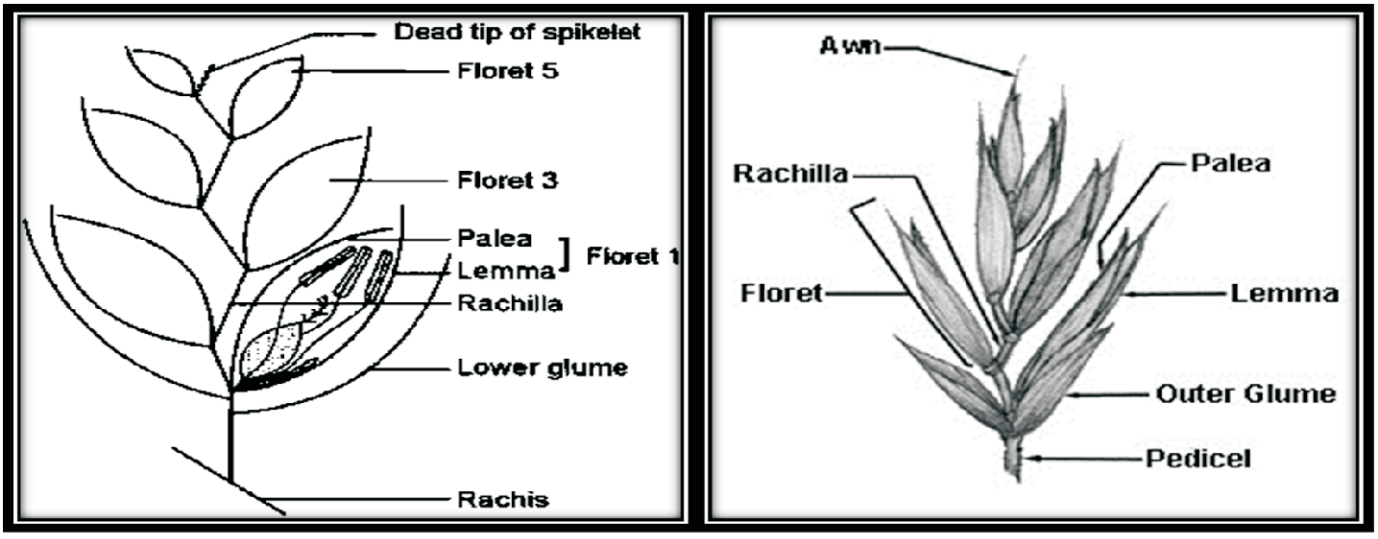


Figure 1.2: Spikelet of wheat

Anthesis

- Blooming starts several days after the wheat spike emerges. The flowers on the main stem (culm) bloom first and those on the tillers later, in order of the tiller formation.
- Flower maturity starts from the middle part of the spike and proceeds in both directions.
- Flowering continues throughout the day and takes 2-3 days for a spike to finish blooming
- The glumes normally open during the flowering process. The anthers protrude (emerge) from the glumes and part of the pollens shed outside the flowers.
- If the conditions are unfavourable for the opening of the glumes the anthers may shed their pollen without being extruded (emerged).
- Stigmas are receptive for 4 to 5 days under different condition but pollen is viable for 15 to 30 min.
- Pollen remains viable for a very short period, usually not more than 15-30 minutes. Therefore, fresh pollen is essential for obtaining good seed set when making crosses.

Selfing technique:

- The spike is to be covered with butter paper bag prior to flowering to avoid the crossing and then labelled it.

Emasculation technique:

- Select spike in which anthesis will occur one or two days later.
- Remove awns with the help of scissors in such a way that small portion of glume, lemma and palea is also cut. This will ease the removal of anthers.
- One fourth ($1_{/4}$) lower and upper florets are removed. Keep 16-20 spikelets only with the help of fine forceps, remove all three anthers in the evening or early morning. Take care that stigma should not be injured.

Crossing technique:

- Check the emasculated spike with a magnifying lance to ensure no anther left in the floret.
- Bagging and labelling is done.
- Pollination is done on the next morning or on the 2^{nd} day depending upon the weather condition and stigma receptivity.
- Select the spike for pollination from pollen parent and remove it from plant. Keep the spike in the sunlight for 10-15 minutes. Anthers will burst and pollen grains will be released.
- The pollen grains are dusted on all the sides of emasculated spike.
- Bag the pollinated spike and label it properly.

Breeding objectives:

(1) Higher yield

High yield depends on

a) The number of heads / unit area

b) The number of grains / head.

c) The average weight of grain

While breeding for high yielding varieties all the above three components must be looked into. Omitting any one of them may not yield results.

(2) Lodging Resistance

This is achieved after the identification of dwarfing gene in Japanese variety Norin 10.

Most of our dwarf wheats are two gene dwarfs. E.g. Sonara 63, sonara 64, kalyan sona.

Emphasis is now on triple gene dwarfs.

(3) Breeding for Quality:

a) Breeding for physical quality: The objective is to develop a variety with well accepted physical characteristics like colour vitreousness, texture/hardness, appearance, grain weight, test weight etc.

b) Breeding for chemical composition:

i. Starch composition: Modification of functionality of starch and amylase and amylopectin content as per desirable end product such as noodles, pasta, thickness, binding agents, bread etc. If the objective is to produce starch with no amylase, then breeding for waxy type wheat would be necessary

ii. Protein content: Wheat grain has a special significance of breeding for high protein and low protein for bread and biscuit purposes respectively and also for different end products.

iii. Nutritional quality: Wheat grains are deficient in lysine content. Efforts are needed to improve lysine as well as high protein content to improve nutritional quality of wheat.

iv. Breeding for market quality market quality: Includes physical characteristics, flour recovery milling quality, dough quality as well as gluten content useful for specific product.

(4) Disease resistance: Rust is the major disease. The black or stem rust, brown leaf rust and yellow or stripe rust are important ones. There are different races of rust. So while breeding for rust resistance horizontal resistance is to be looked into. Back cross method of breeding and development of multi lines are the methods.

(5) Insect resistant: The termites, aphids, armyworm, American pod borer and brown mite are the major pest of wheat which are mostly controlled by chemically.

(6) Early maturity

(7) Drought resistance

(8) Winter hardiness

Breeding Methods:

1. Introduction:

Semi dwarf wheat from Mexico, Sonara 63, Sonara 64, Mayo 64, Lerma Roja 64

2. Pure line selection:

Earlier varieties like P4, P6, P12 evolved at Pusa institute are result of pure line selection from local population.

3. Hybridization and selection

a) Inter varietal:

A number of successful derivatives were developed at IARI New Delhi and Punjab. However all these varieties were lodging and poor yielder when compared to other countries.

Introduced variety Sonara 63, Sonara 64 Mayo 64 and Lerma Roja 64 were utilised in our breeding programme and amber colour wheat varieties like Kalyan Sona, Safed Lerma, Sharbati Sonara were released, these are double gene dwarfs.

b) Inter specific crosses

To get Hessian fly resistance. So also for rust resistance.

c) Back cross method of breeding: Incorporated the genes for rust resistance in Indian wheat varieties through backcross which led to development of several near isogenic lines.

4. Hybrid wheat:

At Kansas Agri. Expt. Station USA male sterile lines were identified by crossing *T.timophevi x T. aestivum Bison variety. By repeated back crossing a male sterile line resembling* Bison was evolved. At present USA and Canada are doing work on this.

5. Mutation breeding

Dr. M. S. Swaminathan did extensive work on this with gamma rays. Sharbati, Sonara with increased protein content was evolved.

6. Development of multilines

Borlaug developed multilines against rust. MLKS 15 was developed at IARI. Multiline is a mixture of pure lines which are phenotypically similar but genotypically dissimilar. Each line is produced by separate back cross method of breeding. Each line having resistance against a particular race of a disease.

7. Biotechnology in wheat Improvement:

Biotechnological tools could be used for utilization of gametoclonal variation, genetic selection for biotic and abiotic stresses, gene transfer through embryo rescue, protoplast technology, somatic hybridization, and recombinant DNA technology. Somaclonal variation have been observed for plant height, size and shape of leaves, length of awns, fertility of spike, and size, shape and colour of seed. Callus, embryoids or haploid plant have been obtained from anther culture of *T. aestivum.*

8. Molecular Markers and wheat breeding:

Despite of low variability in wheat, extensive molecular maps have been prepared and as many as 36 traits have been tagged using molecular markers. The availability of large number of molecular markers in wheat suggests their use in intra-specific analysis, comparative analysis, gene introgression studies as well as marker assisted selection.

Ideotype Breeding:

- To cope up the ever increasing demand of wheat the approach for achieving quantum jump in the productivity is to restructure the wheat plant archetechure which can yield up to 8 tone/ ha.
- The Indian Agricultural Research Institute, New Delhi developed new plant type(NPT) of wheat utilizing a local germplasm and released wheat's genetic stocks, which have high 1000 grain weight, high grain number per strike, higher biomass, thick, broad, semi erect and dark green leaves, thick stem, plant height 85-100 cm and good root system.
- In this NPT genotype the negative correlation between grain weight and grain number per spike has been broken. These genotypes are also having post-anthesis mobilization of stem reserve to sink.

Research stations:

A. International:

International Maize and Wheat Improvement Center (CIMMYT), Mexico.

B. National:

- Directorate of Wheat Research (DWR), Karnal, Haryana.
- All India Coordinated Wheat Improvement Project (AICWIP) – Karnal (earlier New Delhi)

C. State level:

Main Wheat Research Station, SDAU, Vijapur, Gujarat.

Practical Achievements:

- The semi dwarf varieties has been developed by CIMMYT at **Me**xico which resulted in the green revolution.
- The Japanese line **Norin 10 has been utilized as source of dwarfing gene.**
- The productivity of dwarf variety is about two and half time more than the old tall variety and also they are lodging resistance and fertilizer

Improved varieties:

- ***Triticum aestivum* group:**
- Lok-1, GW-496, GW-503, GW-190, GW-173, GW-273, GW-322 and GW-366.
- ***Triticum durum* group:**
- GW-1, GW-2, Raj-1555, HI-8498 and GW-1139.

Exercise:

Q-1 **Define or explain the following terms:**

1. Lemma
2. Culm
3. Palea
4. Allopolyploid

Q-2 Justify the following sentence.

(i) Polyploid wheat performs as diploid

(ii) In wheat, fresh pollen is essential for obtaining good seed in crosses.

(iii) Explain the origin of diploid, tetraploid and hexaploid wheat in details.

Q-3 Which species is believed to be ancestor of all cultivated wheat?

Q-4 Write the quality parameters of wheat.

Q-5 Discuss the crossing technique in wheat crop in detail.

Q-6 Elucidate the important breeding objectives for wheat crop.

Q-7 Give the name of various research stations working for wheat improvement at state, national and international level.

Q-8 Write about the floral biology and draw the wheat opened spikelet and labelled it.

Q-9 Explain the emasculation technique in wheat crop in detail.

Exercise-2

CHICKPEA

Date :

- Chickpea is second most important pulse crop in India after pigeonpea.
- It is largest produced food legumes in South Asia and the third largest food legume globally, after common bean and field pea.
- India is the largest producer of chickpea in the world.
- The leading chickpea growing countries are India, Pakistan, Mexico, Turkey, Ethiopia and Burma.
- Chickpea is valued for its nutritive seeds with high protein content (20-22%). Chickpea is cooked and eaten as salads, cooked in stews, ground into flour called gram flour (*besan*) and used primarily in Indian dishes.
- Sprouted seeds are eaten as a vegetable or added to salads.
- Young plants eaten like spinach and green pods are eaten as roasted seeds.
- Chickpea plays important role in improving soil fertility by fixing the atmospheric nitrogen. Chickpea meet 80% of its nitrogen (N) requirement from symbiotic nitrogen fixation and can fix up to 140 kg N/ha.

1.	Name of Crop	:	Chickpea, gram, bengal gram, garbanzo bean, Indian pea, ceci bean
2.	Botanical Name	:	*Cicer arietinum* L.
3.	Family	:	Fabaceae
4.	Chromosome Number	:	2n = 16
5.	Centre of Origin	:	South eastern Turkey and northern Syria
6.	Mode of pollination	:	Self pollination
7.	Out crossing percentage	:	< 1%
8.	Related wild species	:	*C. bijugum, C. reticulatum, C. pinnatifidum, C. echinospermum C.judaicum, C.yamashitae,C.cuneatum*

Types of chickpea:

There are two main kinds of chickpea.

I. Desi (microsperma): It has small, darker seeds and a rough coat, cultivated mostly found in Mediterranean to central Asia. Desi types are generally smaller in stature with small leaflets and pods and posses predominantly pink colour flower.

II. Kabuli (macrosperma): It has cream or beige colored, larger seeds and a smoother coat, mainly found in the western Mediterranean region. Kabuli type are generally taller with has white flowers.

Flower Biology:

- Chickpea flowers are born on axillary on short jointed peduncles arising from the leaf axil and are situated opposite the leaves. They are white, pink, purple or blue in color.

- A chickpea flower has a single monocarpellary flower on each peduncle with five sepals, five petals (1 Standard +2 Wings +2 fused keels) and 10 stamens in diadelphous (9+1) condition.
- Ovary is ovate and covered by predominantly glandular hairs on its surface with 2, sometimes 4 ovuls.
- The style is linear, upturned and 3-4 mm long with a glabose stigma.
- Chickpea is predominantly a self-pollinated crop, perhaps, obligatory since pollination takes place at the hooded bud stage.
- Pollen is most viable when the flower is half opened, and pollination occurs 12 to 24 hrs before the flower is fully expanded.

Selfing Technique: Covering the flowers with paper bag.

Emasculation:

Emasculation is generally performed in the afternoon. The flowers in hooded bud stage are selected for emasculation.

Crossing technique:

- Pollination is carried out next day morning. The white bud stage is most suitable for crossing because at this stage, stigma is most receptive and pollen viability is high.
- However, crossing attempts involving either emasculation or no emasculation have given erratic results (23 to 98% hybrid seed) and this compounded by the low rate of natural seed set (18 to 52%) due to flower drops.

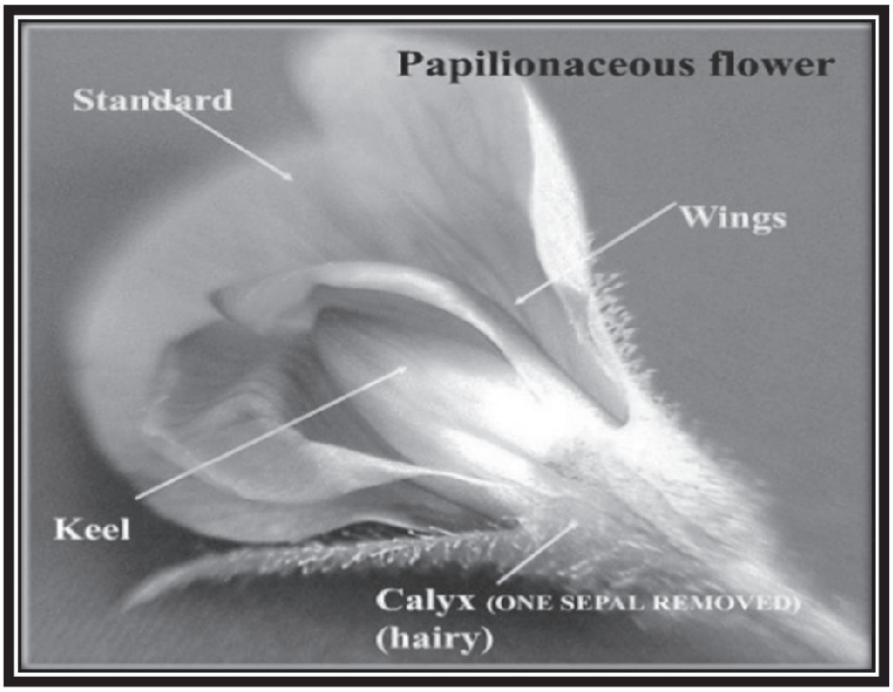


Figure 2.1: Flower of chickpea

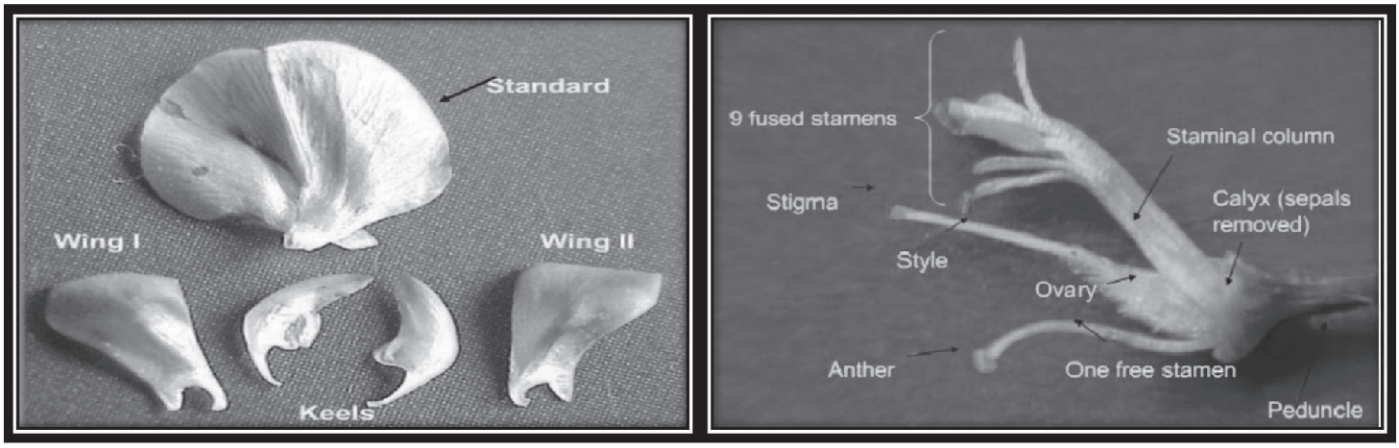


Figure 2.2: Corolla and reproductive organs of chickpea

Breeding objectives:

1. **High yield:** There is need for bringing a drastic change in the plant type of chickpea for bringing a breakthrough in chickpea
2. **Early maturity:** Short duration cultivars (90 to 120) escape terminal drought and heat stresses at critical pod development stages and enhance opportunities for inclusion of chickpea in different cropping systems.
3. **Increased biomass, Medium tall, erect and compact cultivars**
4. **Resistance to diseases and insect pests:** Fusarium wilt, dry root rots, ascochyta blight, botrytis gray mold, stunt, pod borer, root rot.
5. **Tolerance to stress environments** i.e. cold, heat, drought and saline and alkaline soil.
6. **Market preferred seed traits:** Mostly medium sized seed (16 to 22 g 100-seed^{-1}) usually with golden yellow seed coat colour of *desi* types are mostly preferred. Kabuli type having seed size >30 gm 100-seed^{-1} or diameter 8-9 mm are mostly preferred.
7. **Nutritional quality:** Breeding for high protein, methionine, beta-carotene, zinc, iron, linoleic acid, polyunsaturated fatty acids and dietary fibres content.

Breeding methods:

1. **Introduction:** introduction is cheap and a fast way of developing varieties, therefore suitable for countries with limited resources. G 109-1, a bruchid resistant line was selected from a Turkish variety introduced into India.
2. **Pure line selection:** The genetic variability present within landraces provides an opportunity of further selections and development of pure line. The notable varieties developed by this method include Annegeri, Chaffa, Jyoti, Ujjain 24, Warangal, CO 2, and Kripa.
3. **Hybridization:** Pedigree, bulk, single seed descent method (SSD) or different modification of this methods are used in handling segregating generations in chickpea. The varieties namely, JG 130, Vijay, Vishal, Pusa 391etc, are released by this method. Hybridization followed by Marker assisted selection proved to be helpful in indirect selection for the traits that are difficult or inconvenient to score directly (e.g. root traits or resistance to root knot nematodes).

4. **Mutation Breeding:** Mutation breeding is very useful in creating novel genetic variability. The varieties namely, Pusa 408 (Ajay), Pusa 413, WCG 2 (Surya) etc., are developed through this method.

5. **Transgenic technology:** Efficient regeneration protocols are now available for chickpea which have made it possible to introduce any desired gene from any source into chickpea.

Research stations:

A. **International:** International Crop Research Institute for Semi Arid Tropics (ICRISAT), Patancheru, Hyderabad, Andhra Pradesh

B. **National:** Indian Institute of Pulses Research (IIPR), Kanpur, Uttar Pradesh

C. **State:** Main Pulses Research Station, JAU, Junagadh, Gujarat

Exercise:

Q-1 Do as directed

(i) Draw the reproductive organs of chickpea and label it.

(ii) Describe the different types of chickpea.

(iii) Describe the floral biology of chickpea and draw reproductive organs.

(iv) Give breeding objectives of chickpea.

Q-2 Justify the following

Exercise-3

MUSTARD

Date :

- Mustard is important oil seed crop, grown in cool season sub tropics, higher elevations as winter crops.
- It is the second most important oilseed in the world as well as in India after groundnut.
- Seeds contain 40 – 45 % oil and 38-41 % protein.
- In Asia, it is mainly grown in China, India, Pakistan and Bangladesh.
- It is grown in as many as twenty three states in India.
- Indian mustard is a quantitatively photosensitive and basically temperate crop and requiring cool temperature, below 25°C (within agro-climatic conditions) during growth period. Therefore, this crop grown extensively in north eastern and central parts of our country. Mustard oil is considered to be oil that has low saturated fat as compared to other cooking oils.
- It basically consists of fatty acid, oleic acid, erucic acid and linoleic acid.
- It has antioxidant and cholesterol reducing properties. It is also loaded with essential vitamins.
- Though this oil is nutty tasting, it is good for heart and also has many other benefits.

1.	**Name of crop**	**:**	Mustard (Indian Mustard)
2.	**Botanical name**	**:**	*Brassica juncea* L.
3.	**Family**	**:**	Brassicaceae (Cruciferae)
4.	**Chromosome number**	**:**	2n = 36
5.	**Center of Origin**	**:**	Middle East, China
6.	**Mode of pollination**	**:**	Often Cross pollination
7.	**Out crossing percentage**	**:**	4 to 14%
8.	**Related/wild species**	**:**	*B. japonica, B. nigra* (2n=16), *B. oleracea* (2n=18), *B. carinata* (2n=34), *B. carica, B. napus* (2n=38), *B. compestris* (2n=20)

Constraints / causes for low yield potential in mustard:

1. Mustard is grown in unproductive marginal lands with low levels of inputs and aberrant weather conditions.
2. Continuous adaptation of the traditional package of practices.
3. Susceptibility to disease (white rust), pests (aphids) and frost.
4. Inadequate production and poor supply of quality seeds of improved varieties.
5. The unhealthy fluctuating marketing trends with poor support price.

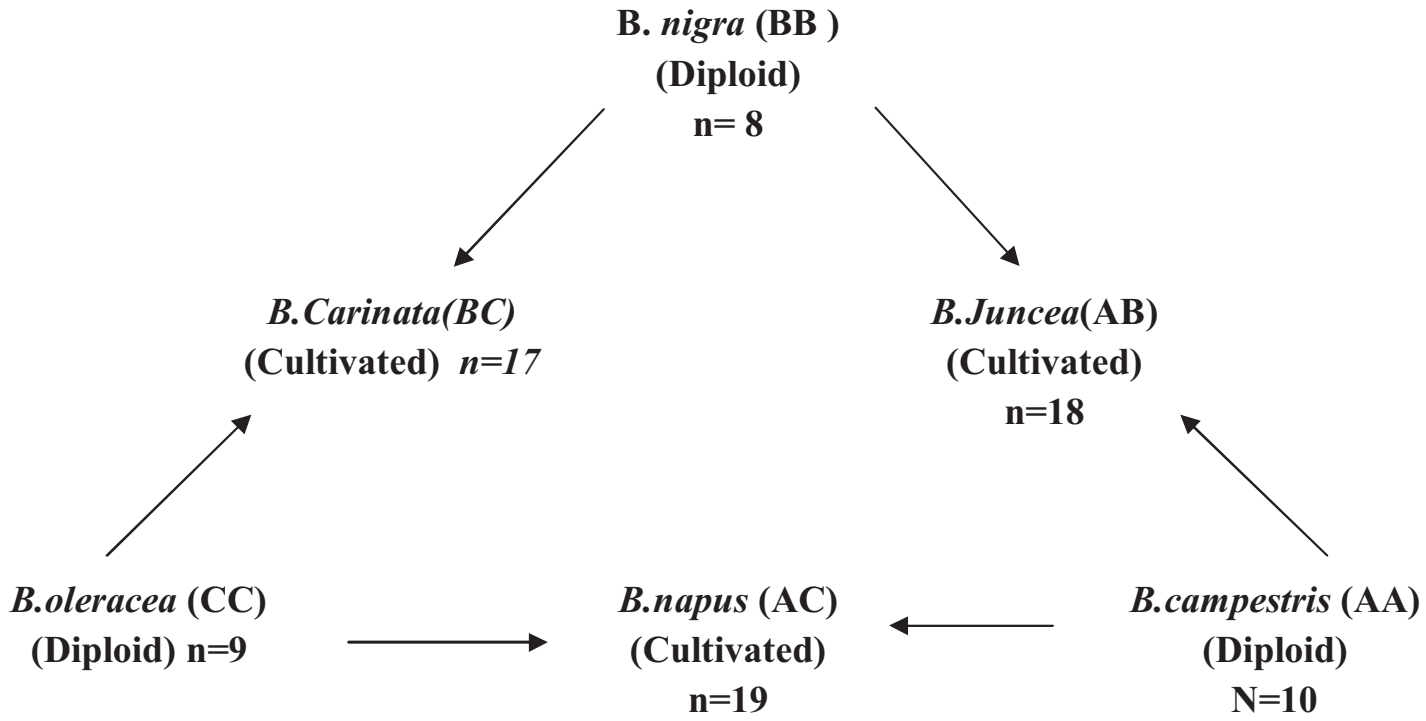
6. Poor water management and inadequate use of fertilizers.
7. Genetically, mustard crop has narrow genetic base.

Table: 3.1 cultivated species of rapeseed and mustard

Botanical name	Common name	2n	Genome
Rapeseed			
Brassica compestris (Syn. B. rapa)	Indian Rapeseed, toria, yellow sarson, Brown sarson	20	AA
Brassica napus	Rapeseed, ghobhi sarson	38	AACC
Mustard			
Brassica nigra	Black mustard	16	BB
Brassica juncea	Indian mustard, rai, raya, laha, brown mustard, oriental mustard	36	AABB
B. carinata	Abyssinian mustard, Ethiopian mustard, Karan rai	34	BBCC
Other related species			
Eruca sativa	Rocket, taramira, duan	22	EE

Brassica Triangle:

The genetical relationship between the oilseed brassicas are represented as follows.



Genetic origin of Indian mustard (Rai):

Brassica nigra (2n= 16 (BB)) x *Brassica campestris* (2n= 20 (AA))

↓

F_1

2n = 2x = 18 (AB)

(Chromosome doubling)

↓

Brassica juncea, 2n= 4x= 36 (AABB)

Allotetraploid or Amphidiploid

Floral Biology:

- The inflorescence is of *corymbose raceme* type.
- The flowering is indeterminate commencing from the base towards the tip of the main raceme.
- The buds flower within two hours after sun rise.
- The stigma is generally receptive three days before and after flower opens which mostly lead self pollination.
- In the bud stage, as flower opens and the time of dehiscing approaches, the inner whorls of the four anthers with longer filaments undergo a twist of 60^{o} to 180^{o} and result in extrorsely dehiscence in the case of self-incompatible types. The outer whorls of the two anthers with shorter filaments do not show this twist and dehisce introrsely.
- The dehiscence of all the anthers in self-compatible types is introrsely.
- Pollination is carried out by wind and mostly by honey bees (*Apis mellifera*).

1. Androecium:

- The stamens are six, four with long and two with short filaments (Tetradynamous). (Tetra - four, dynamis – strength): Out of six stamens, four inner stamens are long and two outer stamens are short.
- In the bud stage the immature stamens are always below the stigma. Just before the opening of the flower the four stamens, which have long filaments carry the anthers up to the stigma and the anthers are introse. (Anthers which have their face towards the pheriphery of the flower is called extrose anthers. When the face of anther lies towards centre of the flower, it is known as introse anther)

2. Gynoecium:

- The flower bears a hypogynous, syncarpous ovary (Syn – together or united, carpous – fruit or ovary), which is bicapellary with a very large number of ovules and parietal placentation.
- Before the flower opens, the style often increases in length. Generally, the stigma remains in flush with the opening of the tube formed by the corolla.

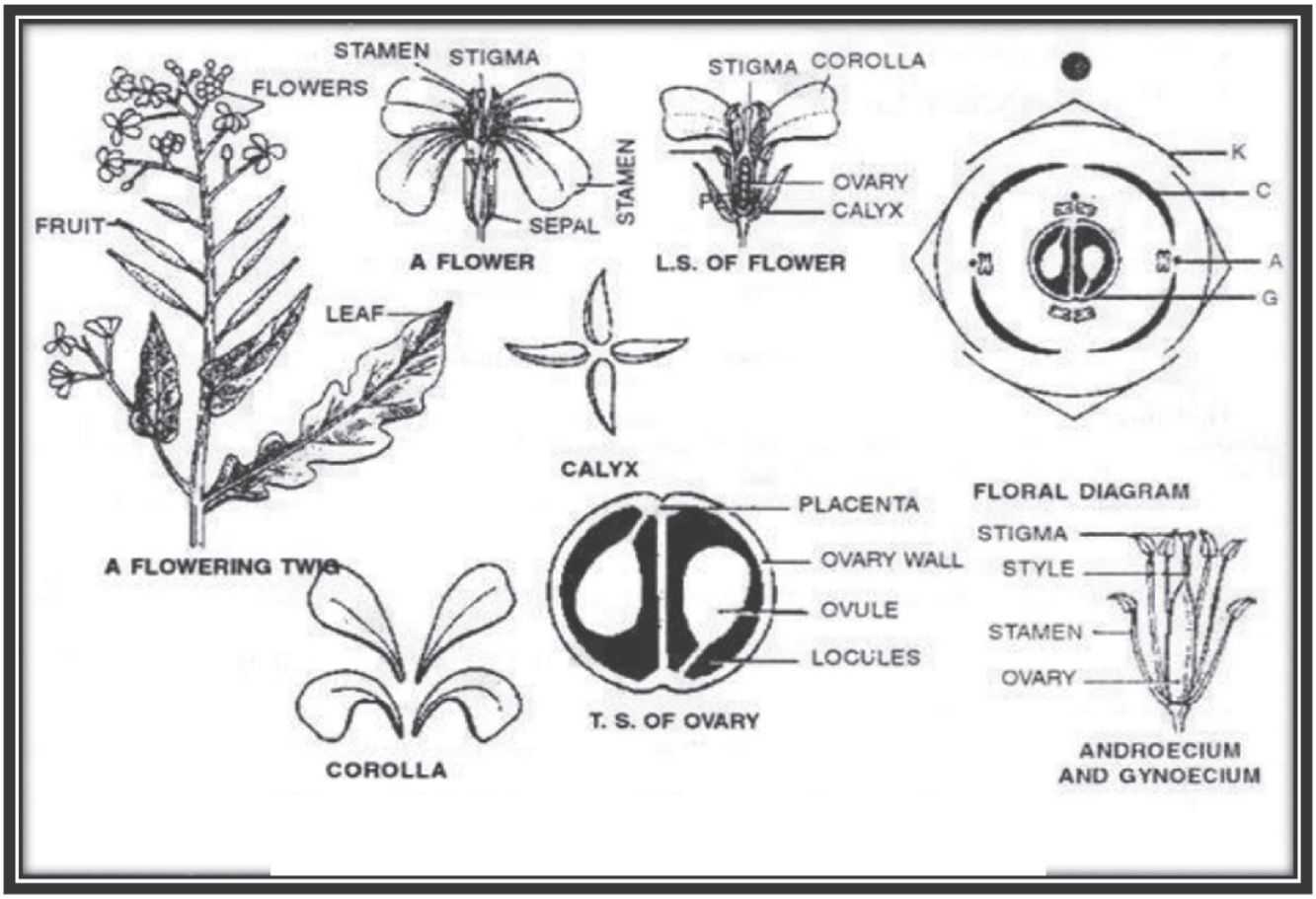


Figure 3.1: Floral structure and floral digram of a typical mustard crop

Anthesis:

- The flowers begin to open from 8.00 a.m. to 12.00 noon.
- The flowers continue to open till 3-4 days and on the 4th to 5th day, the petals and sepals are shed.
- As the flowers open, the anthers begin to dehisce from the apex downwards.
- At the time of dehiscence, the pollen liberating sides of the anthers, remain towards the stigma and slightly shaking of the flowers by wind etc. is sufficient to accomplish the transfer of pollen.
- Large numbers of bees visit the flowers soon after they open and certain amount of cross-pollination takes place.

Selfing technique: Selfing is carried out using muslin cloth bags effectively. Either the whole plant or a branch is bagged to ensure self pollination.

Emasculation:

- When the plant just commences its peak-bloom period, a lateral shoot without any fruit of the first or second order is chosen.
- About six to eight buds, likely to open on the following day or a after that, are left for emasculation and other are removed.
- The stamens are removed with help of fine forceps or with a pair of scissors.
- After removal of stamens, the opened buds are closed gently by rubbing the forceps along the sepals in an upward direction and cover the emasculated bud by muslin cloth or paper bag.

Crossing technique:

- Ripen anthers from fresh flower are collected in the morning (around 7 am) of the next day and placed under sun rays for dehiscence.
- Pollination is made by dusting pollens to stigma.
- After pollination the flowers are again bagged.

Breeding objectives:

1. **Higher seed yield per unit area:** By increased number of branch, pods per plant, seeds per pod and seed size. Further yield can be increased by increase in biomass, harvest index and maximum light penetration of crop canopy
2. **Early maturity:** Need to develop early maturing varieties for multiple cropping sequence with higher per day productivity.
3. **Resistance to biotic and abiotic stress:**
   - **Important Diseases:** Alternaria blight, white rust, powdery mildew, downy mildew collar Rot, white stem rot and wilt.
   - **Important Pest:** Aphids, saw fly, painted bug, leaf miner and Bihar hairy caterpiller- so far no resistance source identified.
   - **Abiotic stress:** Drought, salinity and frost resistance is needed to prevent yield losses. Winter hardiness is very important.
4. **Shattering resistance:** It is necessary to breed the varieties in which siliquae hold the seed for sufficient time after maturity.
5. **Higher oil content (45 per cent) and oil quality:**
   - Erucic acid and glucosinolate and fibre are the antinutritional factors in seed oil and seed meal (deoiled cake), respectively.
   - Glucosinolate is a group of compounds that give the characteristics flavor to vegetable and condiment. In meal, it is relatively high, therefore, restricted to use in cattle feed.
   - Low Erucic acid (<2 %) in seed oil and low glucosinolate (<30 µ moles glucosinolate/g) of deoiled cake and low fiber is designated as “Canola” (commonly known as triple low '000”) are considered as ideal for consumption as food and feed.
   - It necessary to develop varieties are having high oil content, high protein with higher quality, high crud fibre, low Erucic acid (<2 %) low glucosinolate (<10 µ moles glucosinolate/g) and low fiber.
   - High content of long chain fatty acid, erucic acid up to 50 per cent is desirable in oil, which is used as lubricant. But for the edible purpose it should be low.

- Linolenic acid should be reduced (<3%) as it very unstable and is easily oxidized to give unpleasant smelling substance in oil.

Breeding methods:

1. **Hybridization:** It is used to combine the desirable characteristics of two or more genotypes through inter-varietal or inter-specific crosses.
2. **Mass selection:** Mass selection is used to increase the frequency of desirable genotypes in population in both self-pollinated and cross-pollinated *Brassicas,* but there is no recombination among selected genotypes in case of self-pollinated *Brassicas*.
3. **Pure line selection:** Several successful varieties have been developed by using pure line selection in land races of yellow sarson, Indian-mustard, karan, rai and gobhi sarson.
4. **Bulk method:** This method can effectively use for improvement of those characters whose expression is depend on occurrence of favourable environment such as frost, drought, disease and pest.
5. **Pedigree selection:** It is the most commonly used selection method for cultivar development in self-pollinated *Brassicas.*
6. **Backcrossing:** This method is used to transfer a range of traits, such as low erucic acid, low glucosinolets, seed colour, disease resistance, male sterility and fertility restorer genes.
7. **Recurrent Selection:** This method is used in cross-pollinated *Brassicas* such as toria, brown sarson, black mustard and taramira for increasing seed yield and oil content by increasing frequency of desirable alleles through selection of superior recombinants.
8. **Development of synthetic and Composite varieties:** Synthetic and composite varieties are developed in self-incompatible and cross-pollinated *Brassicas* to exploit part of available heterosis.
9. **Hybrid breeding:** This method is used to exploit high heterosis for seed yield in hand bred F_1 obtained by employing CGMS system.
10. **Polyploidy breeding:** This method can be used widen the genetic base of digenomic species.
11. **Mutation breeding:** This method is generally used for rectification of a single deficiency or creation of a single desired characteristics in otherwise agronomically superior variety. The traits such as yellow seededness coupled with high oil content has been improved through induced mutation.
12. **Anther and microspore culture techniques**
13. **Re-synthesis of amphidiploids:** This technique could be used to widen the genetic base of natural amphidiploids
14. **Molecular breeding:** This technique has following uses:
    - Molecular markers can be used to identify somatic hybrids, cybrids, somaclones and cytoplasmic lines in oilseed *Brassicas*.
    - Identification of genes responsible for specific traits such as high erucic acid.
    - Genetic modification through genetic engineering technique e.g. Barnase-Barstar reproductive system which induced male sterility and fertility restoration.

Procedure of hybrid seed production of mustard

Principle of hybrid seed production:

Cytoplasmic Genetic Male Sterility (CGMS) system is used for commertial hybrid seed production of mustard. The male sterile line (A line) contains sterile cytoplasm and recessive genes for fertility restoration. This is maintained by a male fertile counterpart (line B) which also contains recessive genes, but has fertile cytoplasm.

For production of hybrid seed male sterile line (A line) is crossed with a fertility restoring line (R line) which has the dominant genes for fertility restoration, but may have either sterile or fertile cytoplasm. The restorer line (R line) should nick well with 'A' line to produce F_1 hybrid seed.

1. Production of male sterile line ('A'line) Seed:

- **Isolation Requirements:** Seed fields must be isolated from other brassica field and same line increase fields not conforming to varietal purity requirements of certification at least by 200 meters.
- **Planting Ratio:** The proportion of female line (A line) and male line (B line) should be 4:2. In order to have pollen pressure two-four border rows of B-line all around the field may be grown.
- **Roguing:** The off-type plants distinguishable on the basis of morphological characteristics should be removed before flowering. The seed crop should be sown in wide rows (30 cm) to permit rouging.
- **Harvesting:** The B-line should be harvested just after flowering period is over and prior to harvest of female rows to avoid contamination.

2. Production of maintainer line (B-line) and restorer line (R-line) seed:

- The B-line and R-line are self-fertile and may be multiply by open-pollination in an isolated field having isolation distance 200 m.
- Spacing: Row to row distance 42-45 cm.

3. Production of hybrid sunflower seed:

- **Isolation requirements-** Seed fields must be isolated at least by 200 meters from the fields of other brassica and same hybrid seed production not conforming to varietal purity requirements of certification.
- **Planting ratio:** The proportion of female parent (A line): male line (R line) should be kept at 3:1. However, the first two border rows on either side may be sown with the male parent seed to suplly enough pollen.
- **Roguing:** The off-type plants distinguishable on the basis of morphological characteristics should be removed before flowering. Remove objectionable weed plant (Satyanashi)
- **Spacing:** Row to row: 30cm and plant to plant: 20 cm
- **Seed rate:** A line 1.88 kg per ha.
  R line 0.88 kg per ha.
- **Harvesting:** Male lines are harvested before female line when siliqua are mature and attain yellow colour.

Research stations:

A. National:

National Research Centre for Rape Seed and Mustard (NRCRM), Sewar, Bharatpur, Rajasthan

B. State level:

Main Mustard Research Station, Sardarkrushinagar Dantiwada Agricultural University, Sardarkrushinagar, Gujarat

Achievements:

- Gujarat Mustard-1 (GM 1)
- Gujarat Mustard-2 (GM 2)
- Gujarat Mustard – 3 (GM 3)

- Gujarat Dantiwada Mustard – 4 (GDM 4)
- Varuna , Pusa Jay Kisan (Developed by somaclonal variation, IARI, New Delhi)

Exercise:

Q-1 Do as directed

(i) Describe the floral biology of mustard and draw L.S. of flower.

(ii) Give breeding objectives of mustard.

(iii) Discuss the crossing technique in mustard crop in detail.

(iv) Explain the emasculation technique in mustard crop in detail.

(v) Give the genetic origin of Indian mustard.

(vi) Explain the brassica triangle.

Q-2 Explain detail procedure of hybrid seed production in mustard

Exercise-4

SUNFLOWER

Date :

- Sunflower is one of the important oilseed crops grown in India.
- Its genetic name 'Helianthus' is derived from the Greek word 'halio' meaning 'sun' and `anthos' meaning 'flower'.
- It is a crop of the temperate region, it has spread to all the continents of the world like Russia, Bulgeria, Romania, Canada and USA.
- In India, it is extensively grown in Maharashtra, Karnataka, Tamil Nadu and Andhra Pradesh.
- Its seed contains 40-42 per cent edible oil with low cholesterol content.
- The oil is also suited for soap making and for preparation of a number of other allied products.
- The oil cake contains 40-44 per cent protein.
- Sunflower meal is used as a bird and animal feed.
- Sunflower oil is considered relatively good quality oil in comparision to most other vegetables oil because of its light colour, bland flavour, high smoke point, high level of oleic acid and absence of linolenic acid.
- The unsaturated fatty acids, oleic and lenoleic comprises about 90% of total.

1.	**Name of crop**	**:**	Sunflower
2.	**Botanical name**	**:**	*Helianthus annus* L.
3.	**Family**	**:**	Asteraceae
4.	**Chromosome number**	**:**	2n = 34
5.	**Center of Origin**	**:**	Central America
6.	**Mode of pollination**	**:**	Cross pollination (protandry)
7.	**Out crossing percentage**	**:**	> 90%
8.	**Related/wild species**	**:**	*H. agrestis, H. angustifolius, H. anomalus, H. argophyllus, H. arizonensis, H. atrorubens, H. bolanderi, H. californicus, H. petiolaris*

Floral biology:

- The disc-shaped head called capitulum (diameter varies from 6 to 75 cm) is borne terminally on the main stem and branches.
- The capitulum consist of an outer whorl of showey and generally yellow ray florets which are normally sterile, having rudimentary pistil and vestigial style and stigma, but no anther.
- The main function of ray florets is to attract honeybees and pollination.

- Flowers over the reminder of the discoidal head are called disk florets (number varies from 700 t0 3000) which are perfect flowers and epigynous in nature.
- The corolla of each floret has 5 fused petals except at the tip. Inside the corolla tube, 5 fused anthers form as second tube which encloses style which termites distally in a bilobed stigma curls outward above the anther tube.
- Flowering starts from the periphery to the centre of the capitulum.
- Suflower is protoandrous in nature and there is 10 to 12 hrs difference in maturation of male and female elements.
- Honeybees play an important role in cross-pollination.

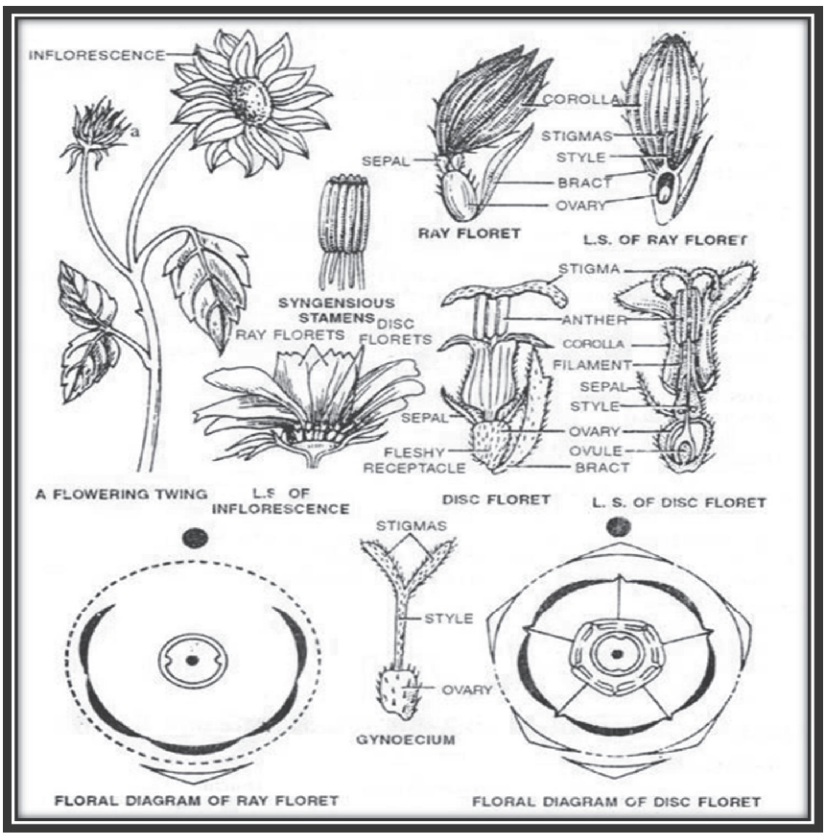


Figure 4.1: Floral structure of sunflower

Selfing technique: Covering the capitulum with muslin cloth bag.

Breeding objectives:

1. **Higher yield:** Higher diameter of capitulum, higher number of disc floret and high test weight contribute towards higher yield.
2. **Early maturity:** Suitable for dry land and in spring situation.
3. **Lodging resistance and dwarf type**
4. **Breeding varieties with high oil content:** Complex character yield and oil content are negatively correlated, to increase oil content the shell must be thin. Breeding for high oleic acid and linoleic acid and low chlorogenic acid

5. **Breeding for self fertile lines:** Protoandry and self-incompatability mechanism operates in sunflower. Hence hand pollination is necessary. To avoid this self fertile lines should be evolved.
6. **Resistance to biotic and abiotic stress:**
    - **Disease:** Alterneria blight, rust and downy mildew.
    - **Abiotic stress:** Drought and salinity tolerance.
7. **Resistance to bird damage**

Breeding Methods:

1. **Hybridization**
2. **Mass selection:** This method is used to eliminate plants with undesirable traits and maintaining the varietal population.
3. **Pustovoit's method of reserves:** This method is a form of recurrent selection method also popularly known as varietal renovation method. This method has been successfully used for developing open-pollinated varieties.
4. **Development of synthetic and composite varieties**
5. **Backcross method**
6. **Mutation Breeding:** A wide range of variability for oil content, fatty acid composition, morphological characteristics, test weight, hull content and flowering has been reported in mutants.
7. **Molecular breeding:** this includes:
    - Genetic transformation of disease resistance
    - Gene tagging for high oleic production
    - Molecular characterization of sunflower species and domestic cultivars

Heterosis Breeding:

- Hybrid cultivars have distinct advantages over open pollinated varieties in form of production stability, response to high-input, high self fertility, uniformity in growth and maturity.
- CGMS system is used for commercial hybrid seed production in sunflower.

Procedure of hybrid seed production in sunflower

Principle of hybrid seed production:

Hybrid sunflower is produced by using cytoplasmic male sterility and genetic fertility restoration system. The male sterile line (A line) contains sterile cytoplasm and recessive genes for fertility restoration. This is maintained by a male fertile counterpart (line B) which also contains recessive genes, but has fertile cytoplasm.

For production of hybrid seed male sterile line (A line) is crossed with a fertility restoring line (R line) which has the dominant genes for fertility restoration, but may have either sterile or fertile cytoplasm. The restorer line (R line) should nick well with 'A' line to produce F_1 hybrid seed.

1. **Production of male sterile line ('A'line) Seed:**
    - **Isolation Requirements:** Seed fields must be isolated from other sunflower field, same line increase fields not conforming to varietal purity requirements of certification and wild sunflower species at least by 600 meters.
    - **Planting Ratio:** The proportion of female line (A line) and male line (B line) should be 3:1. However, the first two border rows on either side may be sown with the male line (B line) seed to ensure enough pollen supply.

- **Seed rate:** A line : 7.5 kg/ha and
  B line : 2.5 kg/ha
- **Roguing:** The male-fertile plants in the female parent lines should be removed each day during the entire flowering period. This is best done in the morning hours before the bees have removed the pollen.
- **Supplementary pollination:** For supplementary pollination (Hand pollination) the palm is first gently rubbed on the male parent flowers and then on the stigmas of the female line to transfer the pollen.
- **Harvesting:** The male parent rows should be harvested prior to harvest of female rows to avoid contamination. No male parent heads should be left intermingled with the female parent rows.

2. Production of maintainer line (B line) and restorer line (R line) seed:

The seed is produced in an isolated field having isolation distance 600 m

3. Production of hybrid sunflower seed:

- **Isolation requirements :** Seed fields must be isolated atleast by 400 meters from the fields of other varieties, commercial hybrid of the same variety, fields of same hybrid seed production not conforming to varietal purity requirements of certification.
- **Planting ratio:** The proportion of female parent (A line): male line (R line) should be kept at 3:1. However, the first two border rows on either side may be sown with the male parent seed to suplly enough pollen.
- **Seed rate:** A line 7.5 kg per ha.
  R line 2.5 kg per ha.

Other practices are the same as described for the A line seed production.

Achievements:

a) Improved varieties: Modern, Surya, TNAU SUF 7, GAU-SUF-1, EC-68413, EC-68414, EC-68415 and EC-69874

b) Hybrid varieties: BSH-1, KBSH-1, KBSH-11

Research stations:

a) National: Directorate of Oilseed Research, Hyderabad

b) State: Main Oilseeds Research Station, JAU, Amreli, Gujarat.

Exercise:

Q-1 Do as directed

(i) Describe the floral biology of sunflower and draw L.S. of disc floret.

(ii) Define capitulum, ray florets and disc florets

(iii) Give the breeding objectives of sunflower.

(iv) Justify that sunflower is highly cross-pollinated crop.

Q-2 Explain detail procedure of hybrid seed production in sunflower

Exercise-5

POTATO

Date :

- Potato (*Solanum tuberosum* L.) is the most important non-grain food crop in the world, ranking 4th in terms of total food production rice wheat and maize.
- It is grown in around 150 countries spread across both temperate and tropical regions and at elevations from sea level to 4,000 m.
- More than half of the potato production takes place in developing countries including India, and over one billion people have potato as their staple diet.
- Nutritionally, potatoes are second only to soybean for amount of protein/ha, with the major storage protein being patatin, one of the most nutritionally balanced plant proteins known.
- The lysine content of potato complements cereal based diets that are deficient in this amino acid.
- A single 150g tuber provides up to 45% of recommended daily allowance (RDA) for vitamin C, 10% vitamin B6, 8% niacin, 6% folate as well as significant amounts of other essential mineral nutrients required.
- Diversified uses of potato covers fresh food, processed products, animal food, seed and raw material for industries (mainly starch as raw material for alcohol, dextrin an glucose).

1.	**Name of crop**	**:**	Potato
2.	**Botanical name**	**:**	*Solanum tuberosum* L.
3.	**Family**	**:**	Solanaceae
4.	**Chromosome number**	**:**	2n =4x=48
5.	**Center of Origin**	**:**	South America
6.	**Mode of pollination**	**:**	Self-pollination
7.	**Out crossing percentage**	**:**	1 to 20%
8.	**Wild species**	**:**	*S. acaule, S. megistacrolobum, S. berthaultii, S. tarijense, S. neocardenasii, S. violaceimarmoratum, S. colombianum, S. commersonii, S. chacoense*

Table 5.1: Cultivated potato species with their chromosome number and ploidy level

Solanum species	Chromosome number	Ploidy level
S. ajanhuiri *S. goniocalyx* *S. phureja* *S. stenotomum*	2n = 2x = 24	Diploid
S. chaucha *S. juzepczukii*	2n = 3x = 36	Triploid
S. tuberosum ssp. tuberosum *S. tuberosum ssp. andigena*	2n = 4x = 48	Tetraploid
S. curtilobum	2n = 5x = 60	Pentaploid

Floral Biology:

- The inflorescence of the potato is cymose and may be simple or compound.
- The potato flowers are bisexual and possess all the four essential whorls.
- Calyx is composed of five sepals united at the base to form bell shaped structure below the carolla.
- The corolla consists of petals joined at the base and forms a short tube with a flat five-lobed surface. The colour of corolla may be white, light blue, blue, red, or purple with different combinations and intensities. The colour of the corolla is valuable trait in distinguishing different varieties.
- Androecium consists of five stamens. The stamens are composed of anther and filament joined to the corolla tube. Anthers are fused in a conical structure or spread loosely enclosing the pistil. The colour of anther varies from light yellow to deep orange. Pollens dehiscence is through the pores.
- Two carpels fuse to form as syncarpous, bilocular, superior ovary with long style and stigma with 2 lobes.
- Flowers in the cultivated potato open mostly in early morning.
- Germination of the pollen is completed after 30 minutes and the ovary is fertilized within 12 hours. Cross pollination is most often accomplished by bumblebees.
- The mature fruit is a green berry with axial plancentation.The cultivated tetraploid potato species (*S. tuberosum sub* spp. *tuberosum* and *S. tuberosum sub* spp. *andigena*) are photoperiodically long day plants and require long days and short nights for their flowering, but more than 90 per cent of the potato growing area in India is in plains and in *rabi* season (October planting) when the day lengths are shorter. Therefore, the flowering does not take place in the plains.

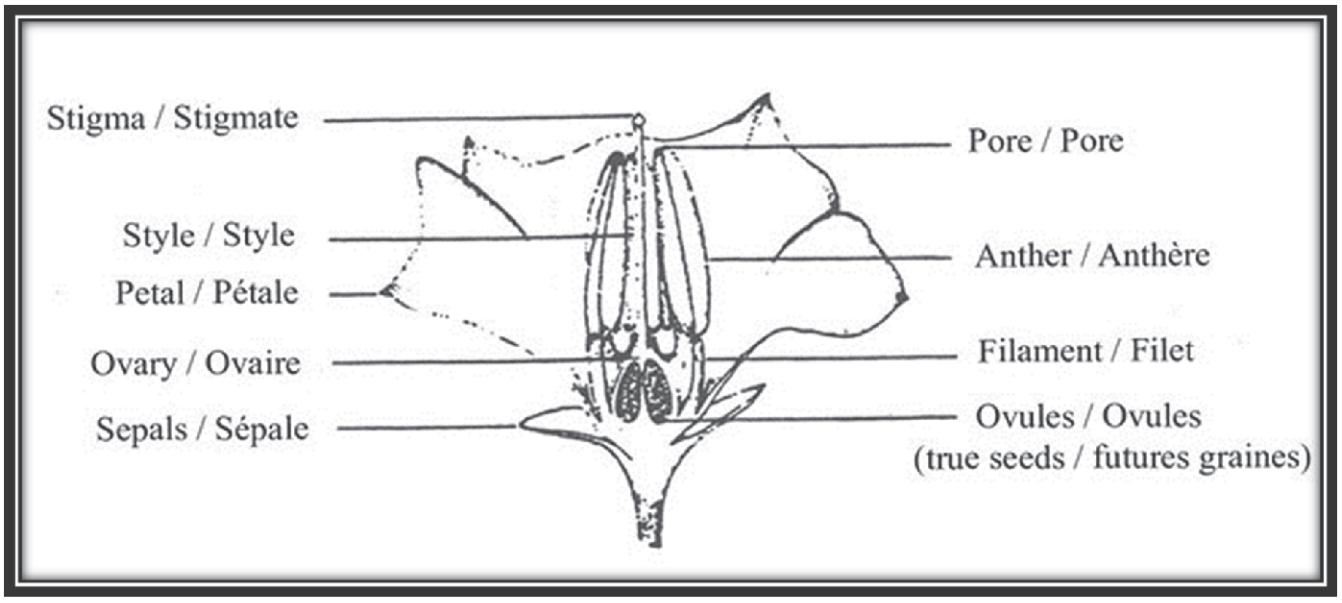


Figure 5.1: Floral structure of potato flower

Emasculation:

- In female parents about 4-5 flower buds per branch are retained by removing very small and old flowers as well as formed berries.
- In the process of emasculation, anthers, petals and half portion of sepals is removed from the unopened fresh flower buds. Care is taken to injure stigma during the course of emasculation.

Crossing technique:

I. Pollen collection:

- Flowers from male parents are collected in the evening preceding the day of pollination.
- Freshly opened flowers with anthers that are about to shed pollens or large sized bud, which would open next day should be collected and spread on a sheet of paper placed on the table at room temperature.
- Stigma and petals are removed from the male flowers, so that pollen does not stick to these while pollen extraction.
- Next day morning, anthers are separated and pollens are extracted shacking anthers in nylon tea sieve.
- The can be stored in a refrigerator at 6-8^{o} C for future.

II. Pollination:

- Each receptive stigma is pollinated by dipping the tip of stigma in pollen.
- Repeated pollination of receptive stigma twice or thrice at interval of 8 hrs is known to produce higher percentage of berries per flower bunch and more seed per berry.
- The pollinated bud is tagged with label with information like cross details, number of buds pollinated and date of pollination is noted in the hybridization register.

Breeding Objectives:

1. **Breeding for high yield:** Yield of tubers decided by number of tubers, tuber size and distribution of tuber.
2. **Breeding for Early maturing varieties**
3. **Photoperiod insensitivity**
4. **Breeding for varieties having better morphology of tuber:** Varieties should produce attractive, medium sized, shallow eyed, white, yellow or red skinned tubers, less physical injuries with good keeping quality. The round shaped tubers of 45-80 mm diameter are preferred for making chips. For French fries, the oblong or long (more than 75 mm in length) tubers are desired.
5. **Breeding for high nutritional quality:** Varieties should have high vitamin C and protein content, low glycoalkaloid content.
6. **Breeding for high processing quality:** For preparation of good quality fried products (chips or French fries) or dehydrated products (flakes, flour, powder, etc) tubers should have low reducing sugars (<0.1%), low phenol content (<0.02%) and high dry matter content (>20%).
7. **Resistance to biotic and abiotic stresses:**
    - **Biotic stresses:** Resistance to late blight, early blight, charcoal rot, wart, common scab, bacterial wilt, soft rot, viral diseases (potato virus X and potato virus Y), nematodes, root knot nematode, aphids, potato tubeworm.
    - **Abiotic stresses:** Resistance/tolerance to heat, drought, frost, soil salinity.

Breeding methods:

1. **Introduction:** Magnum, Bonum and Cragis Defiance.
2. **Hybridization and clonal selection:** Hybridization relates to production of inter-varietal and inter–specific hybrid progeny of the parents identified on the basis of desirable attributes. Potato being a vegetatively propagated crop, it offers a unique privilege of fixation hybrid vigour of hybrid progeny.
3. **Backcross Method:** The genes for disease resistance or other specific traits which are simply inherited can be transferred through back cross method.
4. **Mutation Breeding**
5. **Embryo culture:** The *in-vitro* culture of immature embryos in potato allows the rescue of plants from

distant crosses. It therefore facilitates use of diverse gene pool for potato improvement. Embryo rescue may be applied both in the first inter-specific cross and/or in the first backcross.

6. **Anther culture for haploid production:** The production of haploid in large numbers enables construction of homozygous pure lines after diploidization.
7. **Somaclonal variation:** In potato, somaclonal variation has been reported in plants regenerated from protoplasts, stem explants, leaf disc and other somatic tissues.
8. **Somatic hybridization:** Advances in protoplast fusion technology have made somatic hybridization techniques of more immediate value for potato breeding of potato breeding. The combination of breeding at dihaploid level with somatic hybridization offers new opportunities for introducing novel characters into potato, and of synthesizing superior tetraploid potato clones.
9. **Marker assisted selection (MAS) and gene pyramiding:** MAS can be used for incorporating vertical as well as horizontal resistance for various diseases as well as improvement of quantitative traits like early maturity and vigour.

True potato seed (TPS) technology:

One of the constraints for potato production in India and developing countries is the inadequate supply of healthy seed tubers at an affordable cost. This problem could be overcome to some extent by using True Potato Seed (TPS). This concept was first realized to commercial crop in India by Dr. S. Ramanujam, the first Director of the Central Potato Research Institute in early fifties. The main advantages of the TPS method are as follows:

1. The requirement of TPS in small quantity and diversion of tubers meant for seed towards human consumption.
2. Freedom of TPS crop from viral disease common in seed tuber crops.
3. Elimination of storage losses in seed tubers.

Achievments:

I. Varieties grown in India:-Kufri Pushkar, Kufri Shailja, Kufri Surya, Kufri Khyati, Kufri Himsona, Kufri Girdhari.

II. Indian varieties grown in other countries: Kufri Chandramukhi, Kufri jyoti, Kufri Sindhuri, I-1039 cv. Montanosa.

Research stations:

a) International level: International Potato Centre (CIP), Lima, Peru

b) National level: Central Potato Research Institute, Shimla, Himachal Pradesh

c) State level: Potato Research Station, SDAU, Deesa, Gujarat.

Exercise:

Q-1 Do as directed

(i) Describe the floral biology of potato and draw the floral structure of potato.
(ii) Define cymose.
(iii) Give the breeding objectives of potato.
(iv) Explain the emasculation technique in potato crop in detail.
(v) Give crossing technique in potato crop in detail.
(vi) Justify that in India, flowering does not take place in the plains.

Q-2 Explain the TPS technology in potato.

Exercise-6

LUCERNE

Date :

- Lucerne is known as "Queen of forage crops".
- It is cultivated as an important forage crop in many countries around the world.
- It is most productive and nutritious forage crop, grown for hay, silage and pasture.
- The sub-species *sativa* of Lucerne is mostly cultivated.
- Lucerne has ability to fix environmental nitrogen.

1.	**Name of crop**	:	Lucerne or Alfalfa
2.	**Botanical Name**	:	*Medicago sativa* L.
3.	**Family**	:	Fabaceae
4.	**Chromosome Number**	:	2n =4x=32 (autotetraploid)
5.	**Centre of Origin**	:	South West Africa
6.	**Mode of pollination**	:	Cross pollination (Self-incompatibility)
7.	**Out crossing percentage**	:	80 to 100%
8.	**Wild species**		*Medicago caerulea* (2n=16) (**Progenitor of *Medicago sativa* L.)** *Medicago falcate* (2n=16,32) (Cold-resistant) *Medicago arborea* L. (2n=32) *Medicago prostrata* (2n=32)

Floral Biology:

- The flowers are typical pea shaped and purple in colour. Flowers develops in dense clusters of 20-30 flowers at the tip of the branches.
- Flower consist of calyx 5 united, corolla 5 – (standard 1, wings 2, keels 2 free),
- Androcium consist of 10 stamens in 9+1diadulphos (9+1) condition form a staminal column
- Gynoecium is superior and monocarpellary.
- The petals are partially joined and encloses the stamens and pistil.
- In lucerne bees are the most important insect pollinators.

Tripping:

- Pollen is dispersed by an explosive action commonly known as tripping.
- When the keel petal is pressed by the weight of the bees, the stamens and stigma are snapped upward and came out free of keel just like a spring action. The insect is struck by the staminal column and a mass of pollen is carried by it.
- The tripped flower cannot be fertilized again

Figure 6.1: Flowered branches of lucerne crop

Selfing technique: Selfing is done with the help of bagging the flowers or covering the whole plant under wire cage. Some bees can be kept inside the cage to carry out the tripping of flowers to have better seed set.

Emasculation:

- Mostly emasculation is not needed due to self sterility.
- However, lucerne can be successfully emasculated by first clipping the standards from plants in full bloom, then tripping the flowers to expose the stigmatic column, next immersing the inflorescence in 57% ethyl alcohol for 10 seconds and finally rinsing off the alcohol by transferring to a beaker of water for a few seconds.

Crossing technique:

- Pollinate the emasculated flower with pollen of interest.
- In second method, grow the male and female parents nearly or in different pot and then tied in one wire cage. Keep bees inside the cage. Harvest seeds from both the parents.

Breeding Objectives:

1. Forage yield: Vigorous tall growing plants, better tillering having quick regeneration potentialities after cutting.
2. High nutritive value, good palatability and better digestibility.
3. Lower saponins content (anti-nutritional factor)
4. Earliness: Varieties early in 50 % flowering give higher per day productions of forage yield.
5. Seed yield: A good balance between the seed and forage yield is required.
6. Amenable for multi-cut
7. Succulent plant stature with

8. Abiotic stress: Tolerance to cold, drought and salinity.
9. Disease and Insect resistance.

Breeding Methods:

1. **Introduction:** Ladakh strain was introduced in USA from North India in 1970.
2. **Mass selection**: Grimm 451
3. **Recurrent selection**
4. **Hybridization and selection**
5. **Synthetics and composites**
6. **Heterosis breeding:** Hybrid Forace -400
7. **Top cross**
8. **Polycross method:** In forage crops for the development of multiplant synthetic.
   - This is adopted to develop a multiplant synthetic in vegetatively propagated forage crops.
   - The first step is collect a number of desirable plants and form a source nursery. From the nursery twenty five to fifty superior plants are selected and grown in isolated nursery. Random cross pollination takes place in the isolation.
   - The seeds are harvested and grown as progeny rows. Then the best ones are selected and clonally propagated.
   - These selected clones are again raised in isolation for random crossing and a synthetic is established.
9. **Genetic transformation:** Roundup ready alfalfa (glyphosate (herbicide) resistance variety developed in California)

Achievements:

Varieties: GAUL-1, GAUL-2 **Anand Lucerne-3, Anand Lucerne-4, Chetak, Sirsa-9 and CO 1.**

Research stations:

A. **National: ICAR-Indian Grassland and Fodder Research Institute, Jhansi, UP**

B. **State level:** Main Forage Research Station, AAU, Anand.

Exercise:

Q-1 Give breeding objectives of lucerne.

Q-2 Explain the emasculation technique in lucerne crop in detail.

Q-3 Explain crossing technique in lucerne crop.

Q-4 What is tripping? Explain its mechanism in detail

Q-5 Describe the floral biology of lucerne

Q-6 Give different forage research stations at national as well as state level.

Exercise-7

SUGARCANE

Date :

The word sugarcane is derived from Sanskrit word 'sharkara' meaning sugar. It includes 3 cultivated species like *S. officinarum*, *S. barberi* and *S. sineese*. Sugarcane is an important sugar crop in all the countries of tropical Asia. Sugarcane is grown in more than 110 countries. The world's largest producer of sugarcane is Brazil, followed by India, China, Thailand, Pakistan, Mexico, Columbia, Australia, America and Philippines. The sugar industry is the second largest agro-based industry in India in terms of economic gains and employment potential. The states having substantial sugarcane area in India are, Utter Pradesh, Maharashtra, Haryana, Andhra Pradesh, Tamil Nadu, Karnataka, Bihar and Punjab.

Sugarcane products include table sugar, falernum, molasses and ethanol. The bagasse that remains after sugarcane crushing may be may be burned to provide heat and electricity. Because of its high cellulose content, serve as raw material for making paper and cardboard. In Brazil, ethanol extracted from sugarcane is blend with petrol for running vehicle.

1.	**Name of crop**	:	Sugarcane
2.	**Botanical Name**	:	*Sachharum officinarum* L.
3.	**Family**	:	Poaceae
4.	**Chromosome Number**	:	2n = 80
5.	**Centre of Origin**	:	New Guinea and North India
6.	**Mode of pollination**	:	Cross pollination (protogyny)
7.	**Out crossing percentage**	:	42-50 %

It includes three cultivated and two wild species as below:

Wild Species:

1. ***Saccharum spontaneum*** (2n=40 – 128)

- A perennial grass, free tillering, often with rhizomes.
- *Saccharum spontaneum* having the smallest chromosome numbers and they are found in North India, probably the centre of origin.
- *Saccharum spontaneum* is the probable progenitor of *S. barberi* and *S. sinense*.
- It is widely used in breeding programmes as a source of vigour, hardiness and disease resistance.

2. ***Saccharum robustum*** (2n=60-194)

- It is perennial, vigorous but highly susceptible to mosaic virus and leaf scale.
- *S. robustum* is the progenitor of *S. officinarum* with which it is inter fertile.
- It has very limited use in the breeding programme.

Cultivated species:

3. ***Saccharum officinarum*** (2n=80)

- *S. officinarum* is a chewing cane also known as noble cane. The term Noble was given by Dutch scientists John.
- The canes of this species have thick stem, soft rind, low fibre, high sugar content and high cane yield. The noble canes are susceptible to most of the diseases.

4. ***Saccharum barberi*** (2n=82-124)

- S.barberi is short medium to slender in thickness, with high fibre content, medium sucrose content and poor yielder.

5. ***Saccharum sinense*** (2n=116, 118)

- Chinese cane.
- They are tall vigorous, slender with high fibre content and poor juice quality.

Origin of cultivated species:

(I) Noble cane: *Saccharum officinarum:*

- *S. officinarum* is also known as noble cane.
- The canes of this species have thick stem, soft rind, low fibre, high sugar content, high cane yield, and resistance to smut.
- *S. officinarum* originated from *S. robustum* in New Guinea.
- ***S. robustum***

  S. officianarum **(New Guinea)**
- It migrated from its centre of origin to other places and was modified by natural hybridization.

(II) The Indian cane: *S. sinense* and *S. barberi*

- This might have originated by natural hybridization between *Saccharum officinarum* and *Saccharum spontaneum.*
- ***S. officinarum X S. spontaneum***

  ↓ *Mutation, selection, hybridization*

  S. barberi and S. sinense (North India).

Sugarcane is highly heterozygous due to high chromosome number and complex ploidy levels (due to hybridization of several genomes).

Floral biology:-

Photoperiod is an important factor for flowering in sugarcane. It flowers all the year round at equator, where day length is constant for 12 hours. Warm nights, humid conditions and high rainfall favours flowering, white cool weather and high altitude where the day length varies affecting the flowering.

- The inflorescence / panicle is just like arrow shape hence it is called arrow, contains flowers about 10,000 to 50, 000 individual spikelets.

- The flowers are in pair, one sessile (without petiole) and one pedicellate (with petiole). The sessile spikelet flowers before the pedicellate spikelet.
- The stamens are three and stigma is feathery and bifurcated.
- The flowers open in the morning between 5 and 6 a.m. About 7 to 14 days are required for an arrow to complete the flowering.
- The flowers show a wide range of fertility, ranging from male sterility to high pollen fertility. Generally, the flowers are protogyny in nature.
- A mature sugarcane seeds consists of the mature dry fruit (caryopsis), glumes, callus hairs, anthers and stigma which are extremely small in size, often poorly developed and invisible with sticky hairs called fluff. Fluff is the entire flower panicle without the main flower axis and larger lateral axes used for breeding programme.

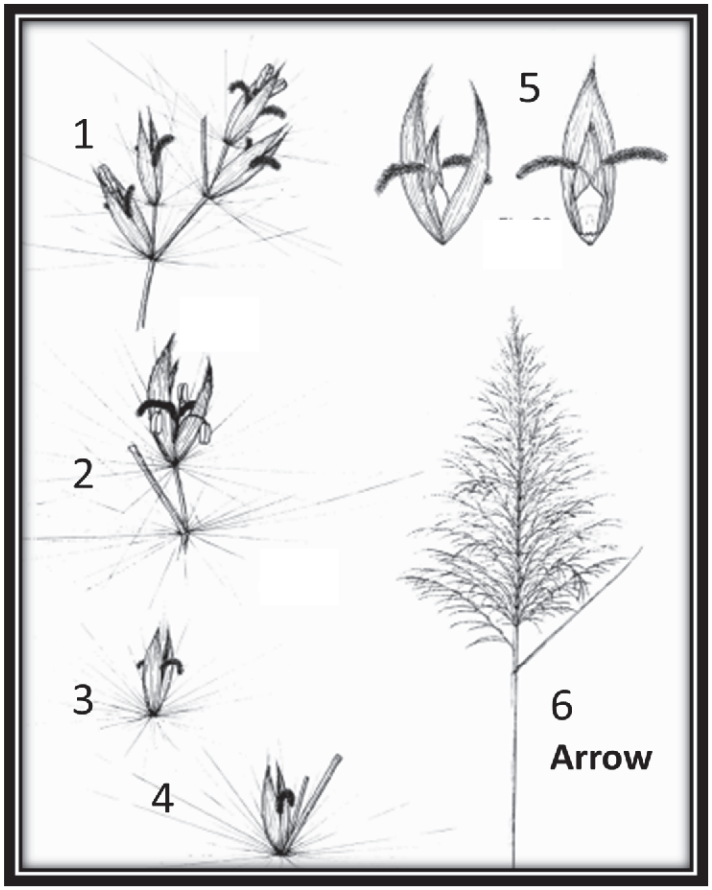


Figure 7.1: Diagram of matured inflorescence of sugarcane showing developmental stages of maturing spikelet

Self technique:-

The arrows of sugarcane are covered in a lantern (A bamboo frame work or cage like structure which covered a muslin cloth bag or a polyethylene) before anthesis to ensure selfing.

Crossing technique:-

- Due to small and large number of flowers on arrows and tall plant height emasculation is not practicable.
- The female parent is selected on the basis of protogyny, male sterility or late pollen shading.

The crossing is attempted by any of the following three methods:

1. The male and female parent is planted closely. The male and female arrows are enclosed in a single lantern.
2. The arrows from male parent are cut-off and cut end of arrow is kept in weak sulphur dioxide solution (arrow can be kept alive) and then these arrows are dusted on female arrows.

3. Marocotting procedure (technique):-

This procedure was first used India and now it is adopted by several countries. The procedure in which a plastic sleeve containing a growth medium is secured about 2 and 3 nodes above the base of the stalk to induce rooting is called marcotting. In this technique, healthy female clones are selected.

a. Just prior to flowering, a polyethylene strip containing a mixture of moist potting soil is wrapped around a bud of the sugarcane stalk about two nodes above the ground level.

b. Roots will develop on the stalk within 10 day where the bud has been marcotted.

c. The cane is cut below the rooted portion and taken to the crossing area, where they are transplanted in a big plots containing soil.

d. Clusters of such 3-4 female arrows are usually kept in a lantern and pollination is carried out either by enclosing male and female arrows under same lantern or by dusting the pollen.

Flowering is undesirable in commercial canes:-

1. Plant stops growing and matures rapidly after the appearance of the flowering stalk.
2. Reduction in cane and sugar yield as the food is diverted towards growing inflorescence.
3. Sugarcane stalk becomes hollow.

Breeding objectives:

1. Higher cane yield
2. High sucrose content
3. Early to full season maturity
4. Resistance to lodging
5. Resistance to abiotic stresses (frost, drought and water logging)
6. Resistance to diseases and pests
7. Breeding for quality:- (1) Sugar content of juice (2) Quality of juice and (3) Milliability

Millability:

It refers to the characteristics of the canes that make it possible to Recover the sucrose from the stalk by normal methods of extraction.

Desirable characteristics for good Milliability:

a. Moderate hardness of rind (bark)

b. Good length of fibers

c. Long internodes

d. Low-fiber: sucrose ratio

e. Good fiber quality for paper making

Sugarcane varieties:

Popular varieties:

Co 62175, Co 419, CoC 671, Co 6806, Co 8338, Co 86032, Co 99004 etc.

Improved varieties:

CoN 91132 (Guj. Sugarcane-1), CoN 85134 (Guj. Sugarcane-2), CoN 95132 (Guj. Sugarcane-3), CoN 03131 (Guj. Sugarcane-4), CoN 5071 (Guj. Sugarcane-5), CoN 5072 (Guj. Sugarcane-6), CoN 04131 (Guj. Navsari Sugarcane-7), CoN 7072 (Guj. Navsari Sugarcane-8).

Research stations:

A. National: 1. Sugarcane Breeding Institute (SBI), Coimbatore, Tamil Nadu.

2. Indian Institute of Sugarcane Research, Lucknow, Uttar Pradesh.

B. State level: Sugarcane Research Station, JAU, Kodinar, Gujarat.

Exercise:

Q-1 Define / Explain following:

(1) Noble cane (2) Arrow (3) Sessile flower (4) Fluff

(5) Lantern (6) Pedicellate flower (7) Marcotting (8) Milliability

Q-2 Justify the following

(i) Sugarcane is highly heterozygous crop.

(ii) The maintenance or conservation of hybrid vigour is easy in sugarcane.

(iii) Photoperiod is an important factor for flowering in sugarcane.

(iv) Flowering is undesirable in commercial production of sugarcane.

(v) Crossing programme of sugarcane is carried out at Coimbatore.

(vi) Emasculation is not practicable in sugarcane.

Q-3 Do as Directed:

(i) Which country is the largest producer of sugarcane in the world?

(ii) Write the various important products of sugarcane.

(iii) Which sugarcane product is blend with petrol for running vehicle?

(iv) Write the cultivated and wild species of sugarcane.

(v) Enlist the desirable characteristics of sugarcane for good millability

(vi) State the name of various research stations working for sugarcane improvement at state, national and international level.

(vi) How selfing is done sugarcane?

Q-4 Write the genetic origin of cultivated sugarcane species.

Q-5 Mention the breeding objectives of sugarcane.

Q-6 Write about the floral biology of sugarcane and draw the fully matured floret.

Q-7 Discuss the crossing technique in sugarcane crop in detail.

Q-8 Brief out the marcotting technique in sugarcane.

Exercise-8

TOMATO

Date :

- Tomato is one of the most important vegetable crops grown throughout the world. The leading tomato growing countries in the world are the USA, Several European countries, Japan and China.
- China is the major producer of tomato followed by US, Turkey, India and Italy.
- World acreage of tomato is more than 3 million hectares. In India tomato is grown in about 6.0 lakh hactares.
- It is a rich source of vitamins and minerals. Tomatoes are consumed as fresh and in processed form.

1.	**Name of crop**	**:**	Tomato
2.	**Botanical name**	**:**	*Solanum lycopersicon* Formerly *Lycopersicon esculentum*
3.	**Family**	**:**	Solanaceae
4.	**Chromosome number**	**:**	2n =2x=24
5.	**Center of Origin**	**:**	Peru, Equador and Bolivia
6.	**Mode of pollination**	**:**	Self-pollination
7.	**Out crossing percentage**	**:**	1 to 10 %
8.	**Related/wild species**	**:**	*L. cheesmanii, L. parviflorum, L.chmielewskii, L. pennellii, L. hirsutum, L. chilense, L. peruvianum*

Flower Biology:

- Tomato flowers are bisexual, consist of united sepals at base.
- Corolla is bright yellow in color and gamopetalous,
- Androcium consist of 5 stamans with small filaments and large anthers and form a solid cone enclosing the pistil. Anther dehiscence is introrsely longitudinal.
- Gynocium consist of superior, bicarpellary and syncarpous overy, with single style and bilobed stigma.
- Anthisis starts in morning from 6.00 hrs and continuous till late morning (maximum between 7.00 to 9.00 hrs.

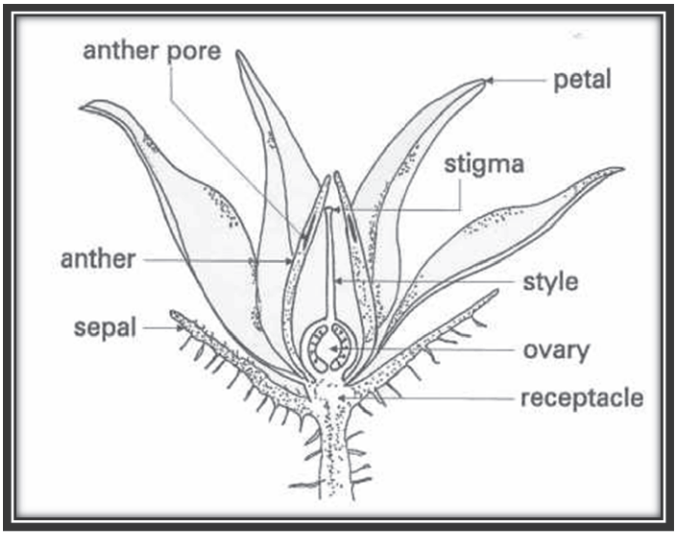


Figure 8.1: Flower structure of tomato crop

- Stigma receptivity is from 16-18 hours before anthesis and 5 to 6 days after the anthesis
- Pollen remains viable from 2 to 5 days (18-25 °C).

Selfing technique: For selfing covers the flower with butter paper bag.

Emasculation:

- Emasculation is usually done in afternoon one day prior to anthesis/flower opening, when anthers and corolla are beginning to change from light to dark yellow. The stigma is fully receptive at this stage allowing for pollination even immediately after emasculation.
- Anthers are removed as a group with or without the surrounding corolla, by inserting forecep between the sepals to grip the base of the anthers and/or petals which are then removed by a firm but steady pull.

Crossing technique:

- Next day forenoon, pollen are collected on the tip of forcep by slitting the forcep inside the anthers of mature flowers and then be lightly applied to the stigmatic surface and should be visible as a white covering.
- Forcep should be sterilized by dipping in alcohol or methylated spirit after each pollination.
- Protection of pollinated flowers by wrapping with cotton or small pollination bags is essential.

Breeding objective:

1. **High fruit yield**
2. **Earliness**
3. **Fruit yield:**
    - Large round fruit with adequate firmness and shelf life, uniform fruit size-shape, red colour and freedom from external blemishes or abnormalities for fresh market.
    - Large fruit size, high fruit quality and continuous production for home garden tomatoes.
    - Deep, uniformly red coloured tomatoes, pH below 4.4, high total soluble solids (4.5-7%) and high alcohol insoluble solids (AIS) in processing tomatoes.
4. **Indeterminate cultivars for greenhouse production**
5. **Resistance to diseases:** Fusarium wilt, verticillium wilt, late blight, early blight, septoria leaf spot, anthracnose, bacterial wilt, bacterial canker, tomato yellow leaf curl virus/tomato leaf curl virus, Root knot nematode
6. **Resistance to insect:** Fruit borer, whitefly,
7. **Resistance to abiotic stresses:** cold set varieties, hot set varieties, drought tolerance, salt tolerance, low temperature, germination and growth, chilling injury tolerance, herbicide tolerance.

Breeding Methods:

1. Introduction
2. Pureline selection
3. Pedigree method
4. Single seed descent method
5. Backcross method

6. Mutation breeding: Tilling and Eco-tilling (reverse genetics)

7. Heterosis breeding

8. Biotechnological methods

- Use of molecular markers for marker assisted selection
- Genetic transformation

Achievements:

Varieties:

GNTom-6, Pusa Ruby, Pusa Early Dwarf, HS 101, CO3, KS2, Punjab Chhuhara, Roma, Pant Bahar, Gujarat Tomato-3 and Gujarat Tomato-6

Hybrids: Pusa Hybrid 1, Pusa Hybrid 2

Research stations:

A. **International:** Asian Vegetable Research and Development Center (AVRDC), Shanhua, Taiwan

B. **National:** Indian Institute of Vegetable Research (IIVR), Varanasi, Uttar Pradesh

C. **State level:** Vegetable Research Station, JAU, Junagadh

Exercise:

Q-1 Do as directed

(i) Describe the floral biology of tomato and draw the flower structure of tomato.

(ii) Give breeding objectives of tomato.

(iii) Give different research centres of tomato at international, national and state level.

(iv) Enlist the different related/wild species of tomato

Q-2 Explain the emasculation technique in tomato crop in detail.

Q-3 Explain crossing technique in tomato crop.

Exercise-9

BRINJAL

Date :

- The brinjal also knows as "Egg plant".
- Brinjal, tomato and pepper are the member of the nightshade family.
- It is a mainly grown in plains and is available more or less throughout the year.
- In India brinjal is cultivated throughout the country and liked by both poor and rich.
- It is primarily used as cooked vegetable and popular for the preparation of various dishes in different regions of the country.
- It is rich source of vitamin A and B. It has also medicinal value in *Ayurveda*.

1.	**Name of crop**	**:**	Brinjal, Egg plant, Guinea squash
2.	**Botanical Name**	**:**	*Solanum melongena* L.
3.	**Family**	**:**	Solanaceae
4.	**Chromosome Number**	**:**	2n =2x= 24
5.	**Center of Origin**	**:**	Central Asia
6.	**Mode of pollination**	**:**	Often cross pollination
7.	**Out crossing percentage**	**:**	30-40%
8.	**Related wild species**	**:**	*S. insanum, S. incanum*

Botanical varieties under the species *S. melongena:*

Sr. No	Variety Group	Fruit shape / Plant type
1.	*S. melongena var. esculentum*	Round or egg shape fruit
2.	*S. melongena var. sopentium*	Long and cylindrical shape fruit
3.	*S. melongena var. depressum*	Dwarf type plant

Floral biology:-

- The flower is bisexual and it contains stamens that dehisce at the same time when the stigma is receptive, thus, self pollination is the rule. However, upto 30-40 % cross-pollination is also reported.
- Inflorescence is often solitary but sometimes it constitutes a cluster of 2-5 flowers. Flower is complete, actinomorphic and hermaphrodite.
- Calyx is five lobbed, gamosepalous and persistence, it forms a cup like structure at the base.
- Corolla is five lobbed gamopetalous (characterizing a corolla with partially or wholly fused petals) with margin of lobes incurved.

- Anthers are cone shaped, free and with apical dehiscence
- Anthers start dehiscence from 7.30 a.m. to 11.00 a.m.
- Ovary is hypogenous (having asuperior ovary and other floral organs attached bwelow the gynoecium on the receptacle), bicarpellary, syncarpous (gynoecium has multiple carpels "fused" into a single structure) and with basal placentation.
- Stigma receptivity is highest during anthesis i.e. flower opening. The receptivity of stigma can be observed from its plump and shiny appearance which gradually becomes brown with the loss of receptivity.
- Stigma becomes receptive until about four days from flower opening.

Types of flowers depending upon the length of the style.

a) Long style with big sized ovary.

b) Medium styled with medium rudimentary ovary which do not produce fruits.

c) Pseudo- short styled with rudimentary ovary which do not produce fruits.

d) True short styled with very rudimentary ovary which do not Produce fruits.

Selfing technique:-

For effective and cent per cent selfing, entire plant or branches of plants are covered with muslin cloth bags.

Emasculation:-

- A healthy long styled, well developed bud from the central portion of the plant is selected.
- The bud is opened gently with the help of fine pointed forceps one or two days before the opening of the bud and all the five anthers are carefully removed.

Crossing techniques:-

- Freshly dehiscing anthers are picked up and are slit vertically with fine needle to get sufficient pollen at the tip of the needle.
- Collected pollens are applied on stigma of emasculated flower.
- Pollinated flowers are labelled and covered with small pollination bag.

Breeding objectives:-

1. Higher yield
2. Earliness
3. Fruit shape, size and colour as per consumer preference
4. Low portion of seed
5. Soft flesh
6. Lower solanine content
7. Upright sturdy plant free from lodging

8. Resistance to bacterial wilt, phomopsis blight, little leaf, root knot nematode, shoot and fruit borer and jassids.

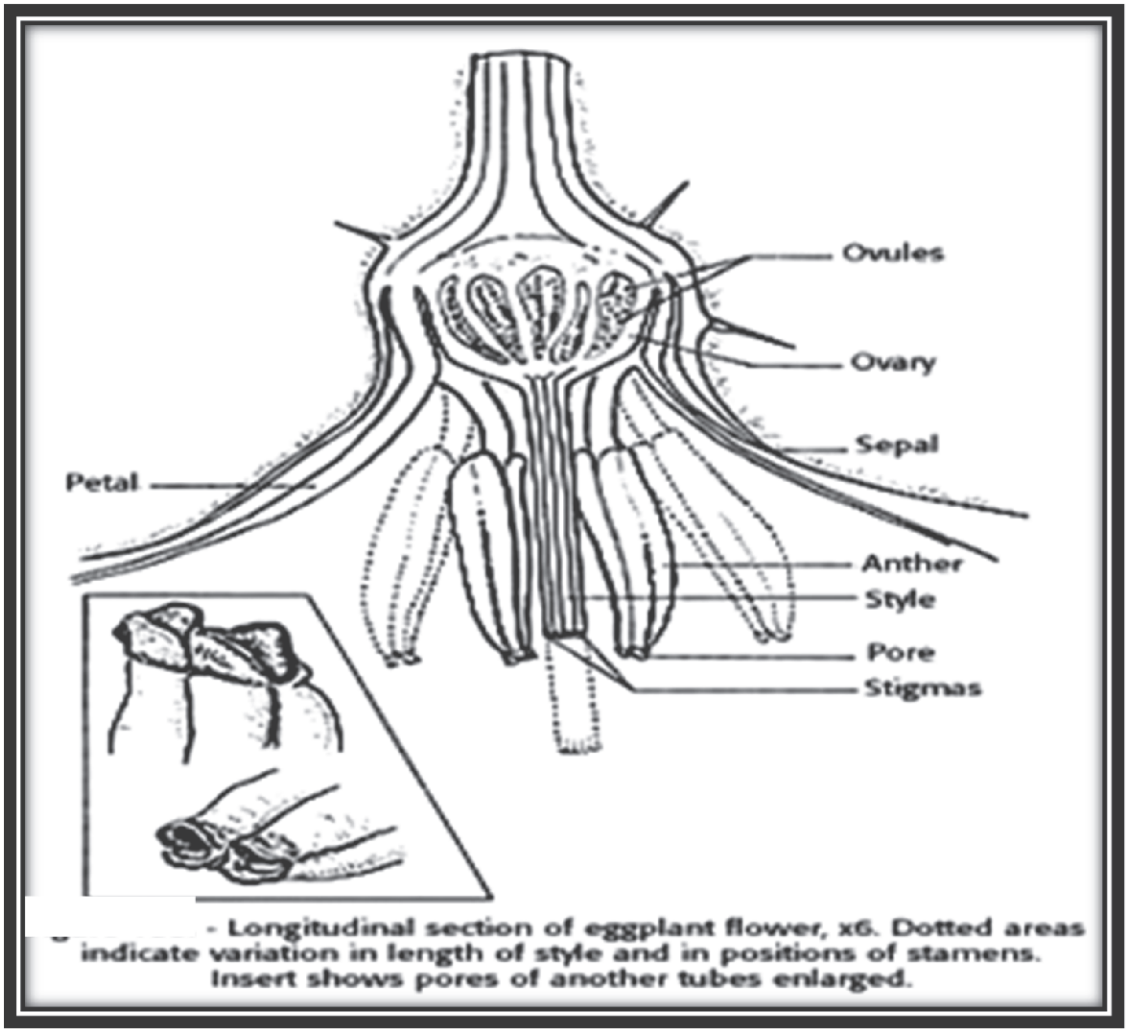


Figure 9.1: Flower structure of brinjal crop

Breeding Methods:

1. Introduction
2. Pureline selection
3. Pedigree method
4. Bulk method
5. Single seed descent method
6. Combination of bulk and pedigree method
7. Backcross method
8. Mutation breeding:
9. Heterosis breeding

10. Biotechnological methods:

- Tissue culture- Anther culture, somaclonal variation and somatic hybridization
- Use of molecular markers for molecular mapping and marker assisted selection
- Genetic transformation

Research station:-

A. International:- Asian Vegetable Research and Development Centre (AVRDC), Shanhua, Taiwan.

B. National:- Indian Institute of Vegetable Research (IIVR), Varansi, UP

C. State level:- Vegetable Research Station, JAU, Junagadh, Gujarat.

Improved varieties:-

GNRB-1 PLR-1, KS-224, Junagadh Ravaiya, DBSR-91, Gujarat Brinjal Oblong -1, JBGR-1, GJB-2, GJB-3, Pusa Purple long, Pusa Purple Cluster, Pusa Purple Round, Pusa kanti and Pusa Bhairav and Junagadh Brinjal Green Round-1

Hybrid varieties: - Gujarat Brinjal Hybrid-1 and Gujarat Brinjal Hybrid-2.

Exercise:

Q-1 Justify the following

(i) In brinjal, short or medium styled bud is not selected for crossing.

(ii) Long styled buds are selected for crossing in brinjal.

(iii) Normally self pollination is the rule in brinjal.

Q-2 Do as Directed:

(i) Give the botanical varieties of *S.melongene* with their features.

(ii) Which vegetables are the members of nightshade family?

(iii) Describe the types of flowers in brinjal depending upon the length of the style.

(iv) Mention the breeding objectives of egg plant.

(v) Write about the floral biology of brinjal and draw the flower structure of brinjal.

Exercise-10

CHILLI

Date :

- Chillies are also called as pungent pepper, grown all over the world except in colder climates.
- It is a constituent of many foods, add flavour, colour, vitamin C and pungency to world food basket.
- Top chilli growing countries are India, China, Turkey, Nigeria, Mexico, Spain, USA, Indonesia, Korea, Bangladesh, Pakistan and Thailand.
- Red chilli contains high amounts of vitamin-C and carotene (provitamin A).
- Yellow and especially green chilli contains a considerably lower amount of both substances.
- In addition, peppers are a good source of vitamin B complex and Vitamin B_6 in particular.
- They are very high in potassium, magnesium and iron.

1.	**Name of crop**	**:**	Chilli
2.	**Botanical name**	**:**	*Capsicum annuum*
3.	**Family**	**:**	Solanaceae
4.	**Chromosome number**	**:**	2n = 2x = 24
5.	**Center of Origin**	**:**	As per table
6.	**Mode of pollination**	**:**	Often cross pollination
7.	**Out crossing percentage**	**:**	Up to 80%
8.	**Related/wild species**	**:**	*C. eximum, C. cardenasii*

Different cultivated species of chilli

Sr. No	Botanical Name	Centre of origin	Plant description
1.	*C. annuum*	Mexico	White flowers, blue to purple anthers, a toothed calyx and typically single-fruited nodes with the possible exception of an occasional double flowered axil in a lower main fork.
2.	*C. chinense*	Amazonia	White or greenish white flowers, blue anthers, a constricted, toothed calyx and typically form one to three fruits per nodes.
3.	*C. frutescens*	Amazonia	Greenish flowers, a non-toothed, non-constricted calyx that encloses the fruit base, blue anthers and mostly single fruited nodes but with a few double flowered nodes on each plant.
4.	*C. pendulum*	Peru and Bolivia	White flowers with the yellow corolla throat spots, yellow anthers, and the long, curved, characteristically pendant fruits pedicels and leaf petioles.
5.	*C. pubescens*	Peru and Bolivia	Larger, showy purple flowers, soft pubescens leaves, yellow orange fruits, and black seeds are unique.

Floral Biology:

- Flowers are small, solitary in leaf axils or 2 - 3 or more together at the tip of branches and long pedicelled. Pedicels are erect, noding at the tip, light green shortly pubescent, terete and 1.5 to 2.5 cm long and pentamerous.
- Calyx is minute, companulate, minutely abstrusely 5-toothed or sub truncate, yellowish green, glabrous and not or hardy enlarged under the fruit.
- Corolla is gamopetalous, patent, flat, yellowish or greyish white deeply 5-partite and 0.5 to 1.0 cm in diameter.
- Stamens are five and erect. Anthers are bronze-green in colour.
- The pistil comprises an overy of 2-3 carpels that is 2-5 mm long and 1.5-5 mm in diameter with capitate stigma.

Selfing technique: To ensure cent percent selfing branch or entire plant are covered with muslin cloth bags, net or cotton bag after removal of open flowers and already set pods.

Emasculation:

- Flowers are emasculate in bud stage just prior to anther dehiscence.
- Emasculation is beginning with removal of petals from the flowers. Then carefully remove anthers with the help of forceps or needle without damaging the pistil.
- If more than two flowers are present at a node, only one flower is kept and others are snipped off to reduce competition for food and space.
- Mark emasculated flower with a clip for easy location the next day on the next day.
- Stigma receptivity to pollen is highest on the day of anthesis.

Crossing technique:

- Crosses can be made any time during the day but morning hours are preferable.
- Pollen for crossing can be obtained at any time of day, with the most abundant and viable pollen coming from freshly dehisced anthers. Freshly dehisced anthers can be picked from the male parents and used to make the pollination. Stigma receptivity to pollen is highest on the day of anthesis.

Breeding objectives:

1. Higher green fruit yield

2. Earliness

3. Desirable fruit shape and size (long fruits in chilli), segmentwise fruit shape, size, wrinkleness, fruit colour, seed content and pungency in Indian context.

4. High oleoresin content

5. Breeding for superior fruit quality: (i) Pleasing flavor (ii) High sugar-acid ratio (iii) High pigment content and vitamin C (iv) High capsaicin ($C_{18}H_{27}NO_3$, a fat soluble, flavorless, odourless and colourless compound)

6. Resistance to diseases like common leaf-curl virus, fruit rot, cercospora leaf spot, powdery mildew, bacterial leaf spot, phytophthora root rot, root knot etc.
7. Resistance/tolarance to insects like thrips, mites, aphid and fruit borer
8. Resistance/tolarance to abiotic stresses (heat, water stress, salinity)
9. Rejuvenation ability after winter in hot-pepper in north India

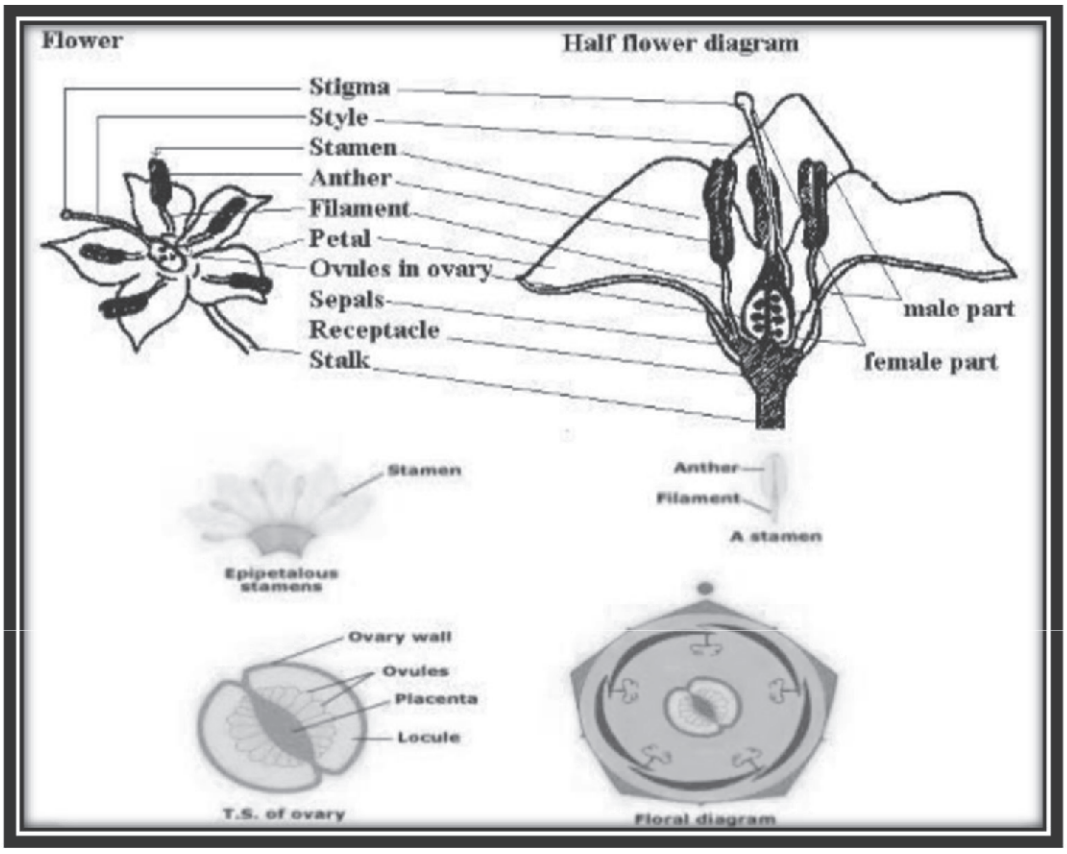


Figure 10.1: Floral structure of chilli

Breeding Methods:

1. Introduction
2. Mass selection
3. Pureline selection
4. Pedigree method
5. Single seed descent method
6. Backcross method
7. Mutation breeding
8. Heterosis breeding

9. Biotechnological methods

- Use of molecular markers for marker assisted selection
- Genetic transformation

Achievements:

Varieties:

Hemlata, Bhagyalakshmi, Andhra jyoti, Pusa jwala, CO 2, Pant C-1, Punjab Lal, pusa Sada Bahar

Research stations:

A. International: Asian Vegetable Research and Development Center (AVRDC), Shanhua, Taiwan

B. National: Indian Institute of Vegetable Research (IIVR), Varanasi, Uttar Pradesh

C. State level: Vegetable Research Station, JAU, Junagadh

Exercise:

Q-1 Do as directed

(i) Describe the floral biology of chilli and draw the half flower diagram of chilli.

(ii) Give breeding objectives of chilli.

(iii) Enlist different cultivated species of chilli.

(iv) Enlist the different related/wild species of chilli.

Q-2 Explain the emasculation technique in chilli crop in detail.

Q-3 Explain crossing technique in chilli crop.

Exercise-11
ONION

Date :

- Onion is one of the oldest vegetables grown throughout the world.
- A global review of major vegetables show that onion ranks second after tomato in area.
- The leading onion growing countries are China, India, USA, USSR, Japan, Spain, Brazil, Italy, Egypt and Pakistan.
- In India, it is grown in Maharashtra, Gujarat, Andhra Pradesh, Bihar, Karnataka, Madhya Pradesh, Orissa, Tamil Nadu and Uttar Pradesh.
- Onions are used in a large number of recipes and preparations spanning almost the totality of the world's cultures.
- They are now available in fresh, frozen, canned, pickled, powdered, chopped and dehydrated forms.
- Onions can also be used, usually chopped or sliced, in almost every type of food, including cooked foods and fresh salads and as a spicy garnish.

1.	**Name of crop**	**:**	Onion
2.	**Botanical name**	**:**	*Allium cepa*
3.	**Family**	**:**	Alliaceae
4.	**Chromosome number**	**:**	2n =2x=16
5.	**Center of Origin**	**:**	Central Asia (Pakistan, Iran)
6.	**Mode of pollination**	**:**	Cross-pollination (Protoandry)
7.	**Out crossing percentage**	**:**	95 to 100%
8.	**Related/wild species**	**:**	*A. vavilovii, A. galanthum*

Two types of onions commercially grown in India:

1. **Common onion (*Allium cepa* var. *cepa*):** This is most important in commercial trade. Bulbs are large, normally single and plants reproduce through seeds.
2. **Multiplier onion (*Allium cepa* var. *aggregatum*):** This produces bulbs of smaller size and they are several in numbers to form an aggregated cluster. Propagation is usually vegetative via daughter bulbs.

Floral Biology:

- The flowering structure is called an umbel forms aggregate of small inflorescences (cymes) of 5 to 10 flowers, which open in a definite order and to last for 2 or more weeks.
- The individuals flower contains 6 stamens, 3 carpels, united into one pistil and 6 perianth segments. The pistil contains 3 locules each of which has 2 ovules.
- The flower is protoandrus. Anthers shed pollen over a period of 3-4 days prior to stigma becomes receptive leading to cross-pollination.

Bolting: When a onion plant produces a flower stolk is called as bolting.

Selfing technique: In onion, selfing beyond S2-S3 generation is very difficult due to high inbreeding depression. Mostly selfing is done by sib-mating (rubbing umbels against each other) in cages or three ring muslin cloth bags are used for selfing.

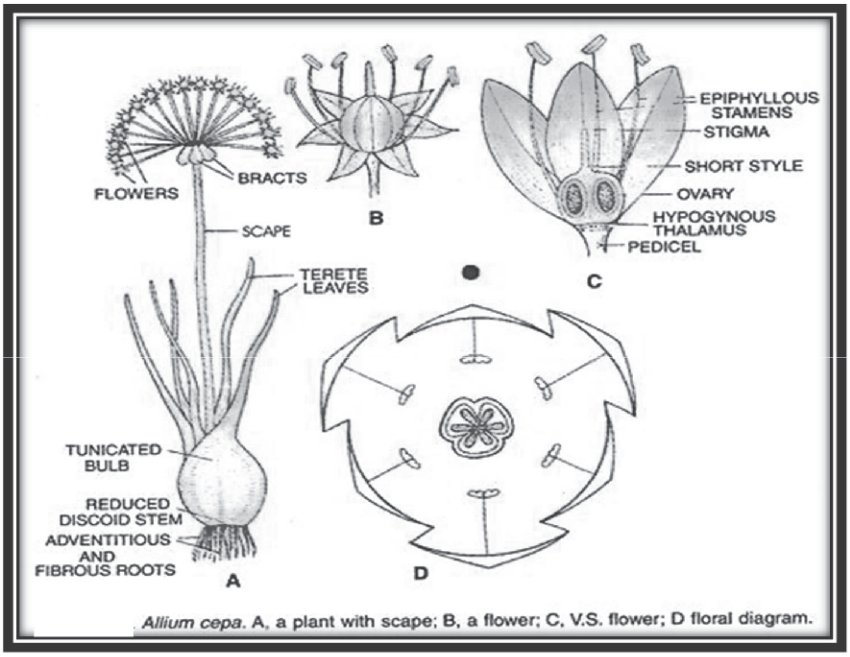


Figure 11.1: Plant and floral structure of onion

Emasculation:

- As soon as few buds in an umbel open, the whole umbel of the female parent is bagged in a muslin cloth bag. The flowers are removed daily for a few days until the peak flowering has reached after which buds are emasculated as they open.
- When sufficient buds have been emasculated, the remaining young flower buds are removed.

Crossing Technique:

- The umbel of pollen parent covered by a muslin cloth bag is cut off and its stalk placed in a glass bottle filled with water.
- This bottle is fastened to a bamboo/wooden stake and fixed in soil close to the female parent. Female parent umbel (emasculated one) and the pollen parent umbels are now enclosed in the same common bag.
- For few days in the morning, the male umbel is gently rubbed over the emasculated umbel to ensure pollen shedding and cross-pollination.
- A few common houseflies can also be introduced into the bag for pollen transfer.

Breeding objectives:

1. Higher bulb yield
2. Early maturity
3. Self-topping habit and more bulb storage life (self life)
4. High total soluble solid content
5. Breeding varieties for dehydration purpose

6. Resistance to diseases (Purple blotch, basal rot, Stemphyllium blight, bacterial storage rot, downy mildew)
7. Resistance to insect pests (thrips and jassids)
8. Resistance to abiotic stresses (moisture stress, high temperature, salinity, alkalinity)
9. Bulb quality:

- Bulb size, shape and colour, bulb weight, bulb pungency, bulb firmness dormancy etc.
- Dormancy is important for longer storage.
- High TSS (14%) is important for dehydration industry producing chips and powder.
- The amount of s-alkyl cysteine sulfoxide preculsors and the enzyme allinase contribute to the yield of sulphur compound that constitute the pungency of the onion bulbs.
- Single centred bulbs especially for fresh market.

10. Bolting resistant varieties specially for september-October planting.

Method of reproduction onion:

(1) Bulb to seed: It requires two seasons. In first seasons bulbs are obtained from seeds and in the next season these bulbs are planted and seed are harvested at the end of the second season.

(2) Seed to seed (Bolting): In this method only one season is required to produce seed. Seeds are planted in nursery and seedlings are transplanted. In onion occasional bolting (appearance of flowering) occurs and if allowed to mature, these flowers will bear seeds taking food material from developing bulb under the soil surface.

Breeding Methods:

1. **Introduction:** Early Grano is an introduction into India. In long-day types, Brown Spanish was also a successful introduction.
2. **Mass selection:** Common in cross-pollinated crops. Most of the onion varieties in India have been developed by mass selection.
3. **Pedigree method**
4. **Backcross method**
5. **Selfing and massing:** Suggested by Jones and Mann (1963). This method is very good for improvement in a crop, where inbreeding depression is common. Improvement in cultivar can be effected by selfing followed by massing. The procedure is as follows.

- **First year (bulb crop):** Select 100 best bulbs of desired type.
- **Second year (seed crop):** Grow selected bulbs, self one or more umbels per plant to initiate a separate line each.
- **Third year (bulb crop):** Grow the progenies of each inbred line separately. Discard the poor performing lines during the growing season, at harvest or in storage. Select at least 25 best lines and keep 15-20 bulbs of each for selfing and open pollination for next year.
- **Fourth year (seed crop):** Self pollinate 1-2 umbels in each plant and allow others to open pollinate. Mass open pollinated seed and increase for large-scale production for more than two generations to avoid much inbreeding depression.

- **Fifth year (bulb crop):** Grow the selfed progenies separately. Select again the best 25 lines and 15-20 bulbs of each lines as above in the third year.
- **Sixth year (seed crop):** Composite and plant bulbs of all selections in a field or in a cage for free open pollination in between the unrelated lines. The open pollinated seed can be massed and increased as foundation seed.

6. **Hybridization:** Used when we want to introduce characters from other varieties.
   - **Intervarietal :** Very common
   - **Interspecific :** Very rare
7. **Heterosis breeding:** The F_1 hybrids are high yielding with uniformity in bulb size, the two most desired characters.
8. **Biotechnology:**
   - Production of double haploids
   - Marker assisted selection

Procedure of hybrid seed Production in onion

Principle of hybrid seed production:

In onion, hybrid seed production is based on Cytoplasmic Male Sterility system (CMS) involving A, B, and C or R lines which have following genetic constitution.

A line = S msms

B line = N msms

C line = N MsMs or N Msms or N msms or S MsMs or S Msms

Maintenance of Parental lines:

I. A line: A line is maintained by crossing with male fertile non-restorer B line. The A and B lines are generally planted in the same cage. Equal number of bulbs of the A and B lines are usually planted in separate row in the cage. Once anthesis starts, each plant checked carefully for fertile pollen production. It is essential to rough out any pollen –fertile plants from the A line. A maturity, seed is harvested from A line. On large scale seed increase, A line is produced by planting A and B lines in alternate rows by keeping isolation distance not less than 3 km between two pollen-fertile lines.

II. B line: Line is maintained by selfing or sib-mating. Rogue out any pollen-sterile plant from B line planted in the cage for maintenance of A-line. Harvest of seed from B line separately.

III. C line: Line is maintained by selfing or sib-mating by planting in a net cage in isolation. Rogue out the off-type plant from C line. On large scale seed increase, C line is planted in isolation by keeping 3 km distance from other fertile onion line.

Production of hybrid seed:

- The hybrid seed is produced in open in an isolated field. Carefully selected bulbs of A line and C line are planted in alternate rows in the ratio of 4:1 or 8:2 or 12 :2.
- The bulbs are generally planted in rows 50 to 100 cm apart to facilitate cultural operations.
- The flowering of A and C lines must synchronize and which can be achieved by:
  i. Adjustment of storage temperature (warmer storage temperature within the range of 0-12^{o}C causes earlier flowering).
  ii. Adjustment of planting dates (early planting causes earlier flowering)

- In large fields, 3-4 beehives/0.40 ha are placed to ensure large population of honey bees for cross-pollination.
- Daily rouging of pollen shedding plants and other off type plants in A line in the morning before dehiscence of anthers is essential. Roguing should be done at bulb stage as well as at the time of flowering.
- The isolation distance from other onion fields should be at least 2 km.
- Bulb to seed method is used in hybrid seed production.

Seed harvesting:

- Seed maturity takes approximately 30-50 days after anthesis, depending on cultivar.
- Harvest the crop when 5-10 % capsule shows black seeds. Male plants (C line) are harvested or destroyed before the female is harvested to avoid contamination. After harvest, the umbels can be dried by sun drying, drying on racks in sheds or in bins with forced war air. The threshed seed is dried to <12% moisture and store at <8% moisture.

Seed Yield: Hybrid seed yields 100-500 kg/ha

Achievements:

Improved varieties:

- *Kharif*: Agrifound Dark Red, N-53, Agrifound White, Phule Safed, Gujarat Junagadh Red Onion- 11, CO 5
- *Rabi*: Agrifound Light Red, Pilipatti, Talaja Red, Arka Niketan, Gujarat White Onion-1, Gujarat Junagadh White Onion- 3, Agrifound White.

Hybrid varieties: Arka Lalima and Arka Niketan

Research stations:

A. International: Asian Vegetable Research and Development Center (AVRDC), Shanhua, Taiwan

B. National: ICAR-Directorate of Onion and Garlic Research, Rajgurunagar, Pune, Maharashtra

C. State level: Vegetable Research Station, JAU, Junagadh

Exercise:

Q-1	Do as directed
(i)	Give the breeding objectives of onion.
(ii)	Which are the wild species of onion?
(iii)	Explain crossing technique in onion crop.
(iv)	How selfing is done in onion crop?
(v)	Give the emasculation technique in onion crop.
(vi)	Define bolting.
(vii)	Give different types of onion commercially grown in India.
Q-2	Describe the floral biology of onion and draw the V.S. of lower of onion.
Q-3	Describe the different method of reproduction in onion.
Q-4	Explain detail procedure of hybrid seed production in onion.
Q-5	Give in detail the steps involved in selfing and massing method.

Exercise-12

GARLIC

Date :

- Garlic has long been recognized all over the world as valuable condiments for foods and as a popular folk remedy or medicine for various ailments and physiological disorders.
- It has also insecticidal, fungicidal and bactericidal properties.
- India is a larger producer of garlic and grown throughout the country.
- Garlic is a good source of amino acids and protein.
- Garlic contains amino acid allin and the enzyme allinase convert allin into allicin.
- Pungency is due to Diallyl disulphide (60%) and Allylpropyl disulphide (20%).
- This crop is another foreign earner of India.

1.	**Name of crop**	**:**	Garlic
2.	**Botanical name**	**:**	*Allium sativum* L.
3.	**Family**	**:**	Amaryllidaceae
4.	**Chromosome number**	**:**	2n =2x=16
5.	**Center of Origin**	**:**	Central Asia
6.	**Mode of pollination**	**:**	Cross-pollination
8.	**Related/wild species**	**:**	*A. lingicuspis, A. vineale*

Garlic flowers:

- The flowers are placed at the end of a stalk rising directly from the bulb, grouped together in a globular head, or umbel, with an enclosing leaf-like structure called spathae, and among them are small bulbils.
- Garlic flowers, though pretty, were rarely picked as ornament because of their strong odour.
- Garlic plants are sexually sterile and only propagates through bulblets or cloves.
- Garlic plants are obligate opomictics or there is presence of absolute apomixes in garlic.

Garlic bulbs: The garlic bulbs consist of 6-35 smaller bulblet is called “cloves”.

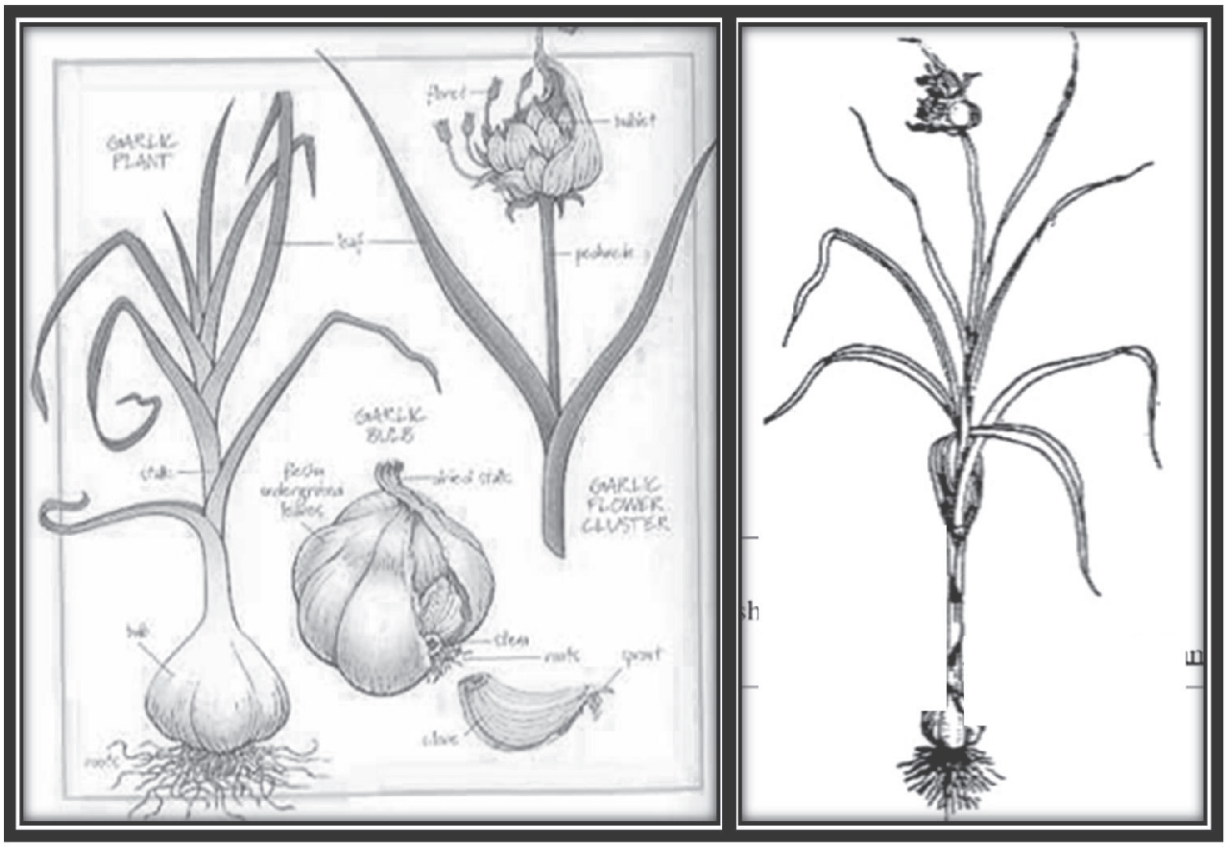


Figure 12.1: Plant, flower and bulb structure of garlic

Breeding objective:

1. Higher yield
2. Larger bulb size
3. Bulb quality: White colour, high pungency and compact cloves
4. Resistance to disease: Mosaic, purple blotch and *stemphylium* blight
5. Resistance to insect-pest: Mite aphid and thrips
6. Longer storage life

Breeding Methods: In garlic, exclusion of sexuality is a major handicap. However, following methods are used in garlic breeding.

1. Mass selection
2. Clonal selection
3. Mutation breeding
4. Tissue culture: Somaclonal variation

Achievements:

Varieties: Gujarat Garlic-4, Gujarat Junagadh Garlic-5, Yamuna safed, Agrifound white, G-282, Agrifound parvati, Bhima Omlkare, Bhima purple, Pant Rohit, Madrasi, Ooty-1

Research stations:

A. International: Asian Vegetable Research and Development Center (AVRDC), Shanhua, Taiwan

B. National: ICAR-Directorate of Onion and Garlic Research, Rajgurunagar, Pune, Maharashtra

C. State level: Vegetable Research Station, JAU, Junagadh

Exercise:

Q-1 Do as directed

(i) Explain the features of garlic flower

(ii) Enlist breeding objectives of garlic.

(iii) Enlist the different related/wild species of garlic

(iv) Give the name of compound responsible for pungency in garlic.

(v) Draw the flower structure of garlic

(vi) Define clove

Exercise-13

CUMIN

Date :

- Cumin seed is one of the most important condiments and it is one of the earliest known minor spices used by mankind.
- The typical pleasant aroma which the seeds possess is due to its volatile oil content varies from 2.5 to 5.6 per cent. Cuminol or the cuminaldehyde is the principal constituent of the volatile oil.
- The seed of cumin also content 14.3 to 24.0 per cent ether extract, 17.7 per cent protein, 35.5 per cent carbohydrate and 7.7 per cent ash. They are also rich in vitamins, particularly, B_1, B_2, A and C.
- The cumin seeds form an essential ingredient of all mixed spices and curry powders for flavouring vegetables, pickles, sausages, cheese and for seasoning bread, cakes and biscuits.
- It is also used in perfumery and for flavouring liquors and cordials.
- Seed are also used in Aurvedic medicine prescribed for stomach-ache and dyspepsia, diarrhoea and hoarseness of voice.
- The seeds have diuretic, carminative, stimulant, astringent and emmenagogue properties which make them useful for medicinal preparations.

1.	**Name of crop**	**:**	Cumin
2.	**Botanical name**	**:**	*Cuminum cyminum* L.
3.	**Family**	**:**	Apiaceae Synonym: Umbelliferae
4.	**Chromosome number**	**:**	2n =2x=14
5.	**Center of Origin**	**:**	Egypt and Syria, Turkestan and the Eastern Mediterranean region.
6.	**Mode of pollination**	**:**	Cross-pollination (Protoandry)
7.	**Out crossing percentage**	**:**	80 to 100%

Floral Biology:

- Flowers, small and borne in compound umbels about 2 to 3 cm across.
- Calyx is five-toothed gamosepalous.
- Corolla consists of five pink-coloured but sometimes white-coloured petals united at base.
- Androecium consists of five stamens; anthers mature earlier than the stigma becomes receptive (protoandry).

- Gynoecium has two carpels with syncarpous inferior ovary, stigma persisting as distinct stylopodium.
- The commonly known cumin seed is a schizocarpic fruit-each mericarp with concave inner and convex outer surface, contains a single seed embedded in the endosperm.
- Cross pollination mediated through bees is the rule.

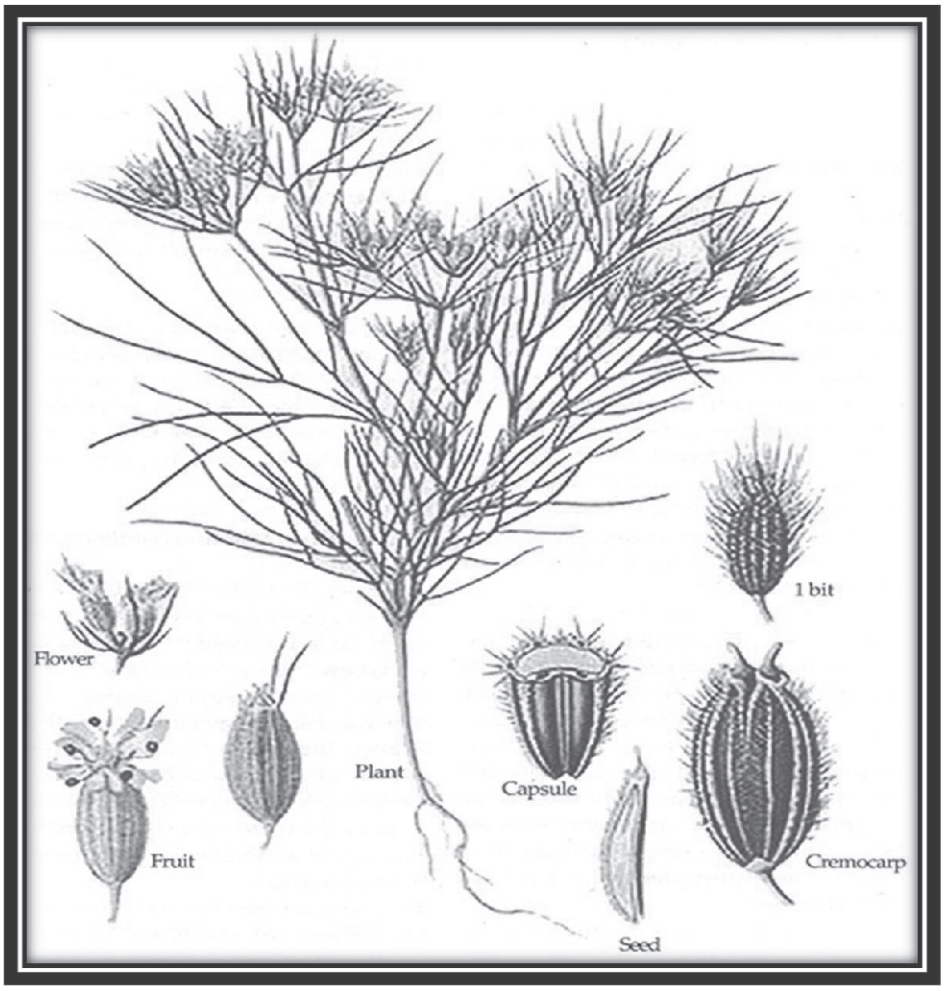


Figure 13.1: Floral and fruit structure of cumin crop

Selfing technique: Selfing is done with sib-mating in enclose chambers (cages) of muslin cloth bags.

Breeding Objectives:

1. **High seed yield:** High number of umbels per plant, umbellates per umbels, seeds per umbellate, primary and secondary branches per plant are contribute towards high seed yield
2. **Resistance to biotic and abiotic stresses:**
   - The most important diseases in cumin cultivation are**:** wilt, blight and powdery mildew and aphids
   - Abiotic (cold, drought, salinity) stresses

Breeding Methods:

Cumin is a cross pollinated crop, and bees often help in pollination. The flowers being small and slender, artificial pollination is rather difficult and varieties are developed by sib- mating in enclosed chambers. Most of the varieties that are available today are selections. In Morocco, an individual selection of plants from the local collections was used to produce improved varieties. Hybridization is also done by growing parents in common cage hybrids are obtained by a chance. Following are the main methods of breeding in cumin.

1. Selection

2. Hybridization

3. Mutation breeding

4. Tissue culture: Somaclonal variations

Achievements:

Varieties: GC-1, GC-2, GC-3, GC-4, S-404, MC 43, Vijapur, UC 198, RZ-19, RZ-209

Research stations:

a) **National level:** ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan

b) **State level:** Seed Spices Research Station, SDAU, Jagudan

Exercise:

Q-1 Do as directed

(i) Describe the floral biology of cumin and draw the floret of cumin.

(ii) Give different seed spices research stations at national as well as state level.

(iii) Give the breeding objectives of cumin.

(iv) Which is the principle compound of volatile oil in cumin?

Exercise-14

CORIANDER

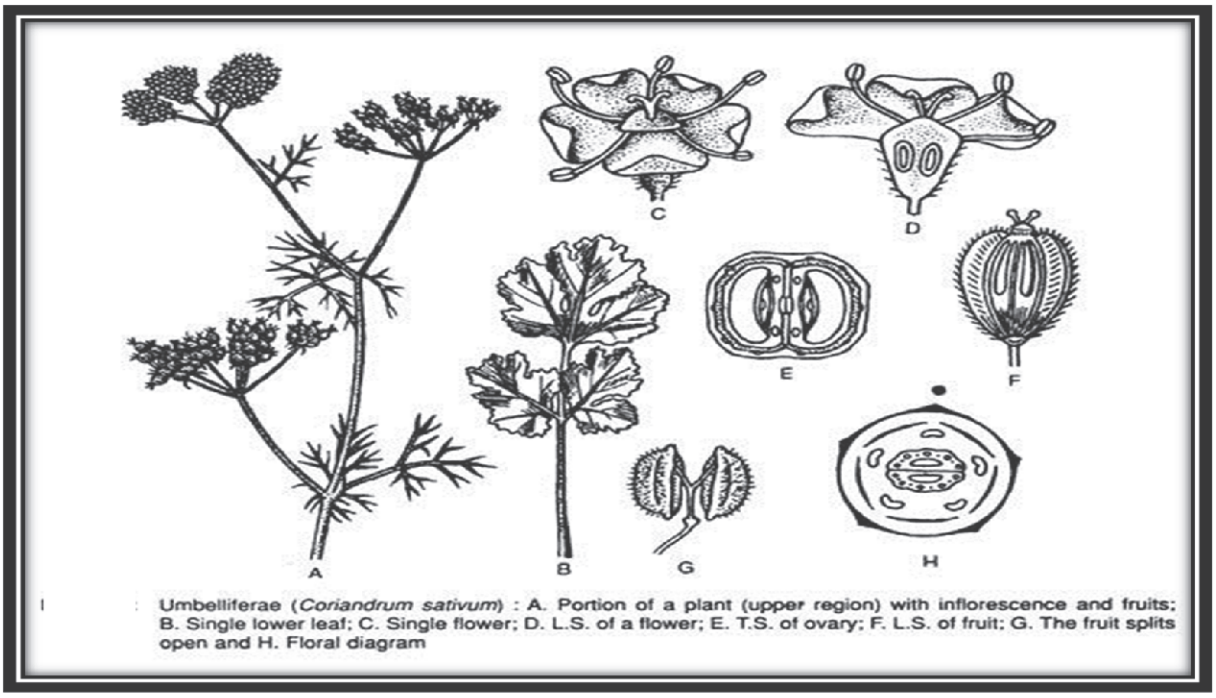
Date :

- Coriander is mainly cultivated for its fruits and leaves, which have a fragrant odour and pleasant aromatic taste.
- It is cultivated in Morocco, Russia, Bulgaria, Mexico, USA, Argentina, China, Romania, Italy, Japan, Hungary, Poland, Czechoslovakia, Guatemala and India.
- The odour and the taste are due to an essential oil, containing of hydrocarbons and oxygenated compounds.
- The oil content ranges from 0.10% to 1.00% in the dry seeds which is volatile in nature. Besides the essential oil, the seed contains 19 to 21 % fatty oil, which is used for the preparation of soaps of pleasant odour and good lathering property. Whole or ground fruits are a major ingredient of curry powder
- About 5% oleoresin may be extracted from seed.

1.	**Name of crop**	**:**	Coriander
2.	**Botanical name**	**:**	*Coriandrum sativum* L.
3.	**Family**	**:**	Apiaceae Synonym: Umbelliferae
4.	**Chromosome number**	**:**	2n =2x=22
5.	**Center of Origin**	**:**	Mediterranean region.
6.	**Mode of pollination**	**:**	Cross-pollination (protoandry & andro-monoecious)
7.	**Out crossing percentage**	**:**	50 to 60%
8.	**Related/wild species**	**:**	*Coriandrum tordylium*

Floral Biology:

- Flowers small and borne in compound umbels, about 4.0 cm across;
- Calyx-gamosepalous, green and 5-toothed;
- Corolla with 5 white or pink-coloured petals of unequal size;
- Androecium:- Stamens 5 with spreading filaments.
- Hermaphrodite or staminate flowers may occur in the same umbel. Hermophrodiate flowers are present at periphery while unisexual flowers are present innerside.
- Gynoeciums: Two carpel with syncarpous inferior ovary.
- The schizocarp fruit consist of two mericarps, inner surface of which is concave and outer convex.



Umbelliferae (*Coriandrum sativum*) : A. Portion of a plant (upper region) with inflorescence and fruits; B. Single lower leaf; C. Single flower; D. L.S. of a flower; E. T.S. of ovary; F. L.S. of fruit; G. The fruit splits open and H. Floral diagram

Figure 14.1: Floral structure of coriander crop

Selfing technique: Selfing is done with sib-mating in chambers (cages) of muslin cloths.

Anthesis:

- First umbel unfolds after 66-76 day from the date of sowing, while the last umbel on the same plant unfolds 96-102 days after sowing.
- First sign of anthesis is indicated by the appearance of cracks at the top the buds in the sepals which proceed downwards.
- Cracking of the florets starts in the afternoon around 14.00 hrs. The following day ending 21 to 22 hours after the first sign of cracking of sepals, the process of unfolding of petals exposing the stigma is completed by 11.30 hrs and 13.30 hrs in most of the florets.
- Dehiscence of anthers starts 30 to 40 minutes of unfolding of the flower and is completed is about 20-25 minutes.
- With the increase in maximum temperatures dehiscence is hastened and is completed in short period.
- Stigma is normally shiny and healthy about 6 hours after anthesis and remains so up to 6-7 hours.

Emasculation:

- Florets ready for anthesis were found most suitable for emasculation.
- As the florets are small and delicate in nature, binocular loupe (2.5x) is used for emasculation.
- Emasculation either in the previous day evening (15:00 to 18:00 h) or in morning (07:00 to 08:00 h) was found suitable. However, dew was an obstruction during the morning hours.
- The emasculated florets were bagged immediately after emasculation.

Crossing technique:

- Fresh pollens are collected from just opened florets. The pollination is carried out on the 3rd day of emasculation.
- Repeat pollination on 3rd and 4th day of emasculation was found better than one time pollination.
- Pollen remains viable for two days in the field condition and three weeks at 25°C in incubator

Breeding objectives:

1. **High seed yield:** High number of umbels per plant, umbellates per umbels, seeds per umbellate, primary and secondary branches per plant are contribute towards high yield
2. **High number of leaves**
3. **High essential oil content**
4. **Varieties adaptable for different agro – climatic regions.**
5. **Biotic and abiotic stress resistance:**
    - **Biotic stress:** Resistance to wilt, powdery mildew and stem gall and aphids
    - **Abiotic stress:** Resistance to frost, cold, drought, salinity

Breeding Methods:

1. Selection
2. Hybridization
3. Mutation breeding
4. Tissue culture: Somaclonal variations

Achievements:

Varieties: Ajmer Coriander-1, Ajmer Coriander-2, GC-1, GC-2, AGCr-1, RCr-41, RCr-20, RCr-435, RCr-436, CS-2 (Sindhu), CO-1, CO-2, Pant Haritima and Hisar Sugandh

Research stations:

a) **National level:** ICAR-National Research Centre on Seed Spices, Ajmer, Rajasthan

b) **State level:** Seed Spices Research Station, SDAU, Jagudan

Exercise:

Q-1 Do as directed

(i) Give different seed spices research stations at national as well as state level.

(ii) Give the breeding objectives of coriander.

(iii) Explain crossing technique in coriander crop.

(iv) Give the emasculation technique in coriander crop.

Q-2 Describe the floral biology of coriander and draw the L.S. of floret of coriander.

Q-3 Give in detail process of anthesis in coriander

Exercise-15

MAINTENANCE BREEDING OF DIFFERENT *RABI* CROPS

Date :

Maintenance Breeding:

a) Objective: Maintenance of genetic purity of a variety

b) Principle: Maintenance breeding refers to the process to maintain uniform expression of all the distinguishable traits of a variety year after year without any genetic drift. It requires negative selection i.e., the plant progeny which deviates in expression has to be rejected but there is no positive selection for performance.

- Maintenance breeding is adopted to maintain genetic purity, quality and health of the variety. It produces true to the type, healthy and quality seed sowing material to produce Breeder seed for exploitation of the variety to enhance production and extend the life of the variety.
- It maintains a population in an organized and systematic way to retain the relationship of small quantity of Nucleus seed with that originally selected by the concerned plant breeder.

Maintenance of nucleus and breeder seed

Self pollinated crops

- Maintenance of newly released variety
- Maintenance of established variety

Cross pollinated crops

- Maintenance of newly released variety
- Maintenance of established variety

The nucleus or breeder seed should be produced in such a manner that it strictly satisfy the genetic purity and identify the quality of seeds. It should subsequently maintain the quality of foundation and certified seed produced / multiplied from it.

A. Maintenance of Nucleus and Breeder seed in self pollinated crops:

- The variety of self-pollinated crops should be completely homogenous (uniform).
- However, in practice some amount of variation may occur during seed production cycle due to natural crossing.
- Therefore, purification of such variety during maintenance of nucleus/breeder seed is necessary.
- The methods of maintaining nucleus/breeder seed can be divided in two groups.
  1. Maintenance of newly released variety
  2. Maintenance of established variety.

1.1 Maintenance of nucleus seed of newly released variety:

- Harrington (1952) outlined the procedure for maintenance of nucleus seed of newly released variety as under.

a) Sampling of the variety to obtain nucleus seed

b) Table examination of the samples

c) Location and seeding of nucleus seed

d) Inspection of two rows plot and removal of off types

e) Harvesting, threshing and seed treatment of nucleus seed

a) Sampling of the variety to obtain nucleus seed

- The selected plants or lines which are highly promising in yield trials or breeding nurseries should be sampled for seed purification.
- Maximum fifteen such promising line at a research station should be sampled in one year.
- Approximately 200 plants from the central rows should be selected.
- To avoid shattering of the seeds, these plants should be pulled 4 to 5 days before the grains are fully mature.
- To prevent breakage or loss, these plants should be tied in a bundle and wrapped in a cloth or paper.
- Store properly these bundles till final yield results are available. Discard any of these bundle found inferior in yield and quality based on the results.

b) Table examination of the samples

- The two hundred plants of each sample should be threshed separately, clean the seeds and examine in piles on the table.
- Discard the pile found off type, diseased or not uniform.
- The seed of these selected two hundred plants is called nucleus seed, which is to be sown in a variety purification nursery.

c) Location and seeding of nucleus seed

- Each nucleus seed should be grown on clean fertile land at the research farm in the region or area for which it is to be released.
- The land to be used for sowing the nucleus seed must not had the same crop sown in the previous year.
- The 200 progenies of a nucleus should be sown in 50 double rows plots in four series.
- To facilitate examination of rows during different growth stage the plot to plot distance should be at least 45 cm.
- It should be isolated properly to prevent contamination by natural crossing.

d) Inspection of two rows plot and removal of off types

- From seedling stage up to maturity, the plot should be examined critically.
- Differences in early plant growth, rate of growth, time of heading, plant height, head characters and disease reaction should be observed if any plot differs from the average in such traits, it should be removed.
- From flowering to maturity, roguing should be done based upon ear-head characters.

e) Harvesting and threshing of nucleus

- Each plot of the nucleus should be harvested separately, tied in bundle with proper labeling.
- Thresh the bundle individually, clean the seeds taking care that it should not get mixed with seeds of another plot.
- The seeds should be treated with fungicide and insecticide, bagged and labeled properly and stored as "Breeder's stock seed".

1.2 Maintenance of Breeder seed of newly released variety

- Breeder's stock seed obtained from nucleus should be sown on clean fertile land.
- The land to be used for sowing should not have a crop of the same kind grown in the previous year.
- The land requirement varies with the crop. e.g. In case of wheat about 1.2 ha. while, in case of transplanted paddy the land requirement is 3 hectare.
- The seed should be properly isolated as per the seed certification standard.
- The field should be produced at research farm of university and in the area or region for which the variety has been bred.
- The sowing should be done in rows keeping sufficient spacing between rows so as to permit examination of plants for mixtures or off type.
- Roguing should be critically done before flowering i.e. during growth period and after flowering i.e. during reproductive stage.
- Harvesting, threshing, drying, cleaning, bagging and labeling should be carried out with most care to avoid contamination.
- A portion of breeder seed should be retained by the plant breeder to multiply the stock with 100 % genetic purity.

2.1 Maintenance of Breeder seed of established variety:

- The breeder seed of established variety can be maintained by two ways.

  i. By raising the crop in isolation : The breeder seed of established variety can be maintained by growing it in isolated plots and by rigorous roguing during various stages of crop growth by observing plant characters.

  ii. By Bulk selection : In this method 2000 to 2500 plants representing typical plants characters of the variety are selected, harvested and threshed, separately.

- The seeds from each selected plant are examined by table examination making piles of the individual plant and if seeds of any pile found off type or dissimilar than it is discarded.
- The remaining piles are bulked to constitute the breeder seed.
- How long a particular method should be used depends on the rate of deterioration in a variety either through natural crossing or mutation or mechanical mixture.
- If enough care is taken while production, we can maintain the genetic purity for several generations.
- Carry over seed : A portion of breeder seed retained by the plant breeder for continuation of a variety is called carry over seed. The breeder must retain enough quantity of seeds to safeguard against the loss of variety if there is complete failure during the foundation seed multiplication phase.

B. Methods of maintaining nucleus and breeder seed in cross pollinated crop:

- Maintenance of variety of cross pollinated crops is complicated because it involves the maintenance of parental material and the method of breeding the variety.

1. Maintenance of nucleus seed of inbred lines

- It involves self pollination, sib pollination or combination of both the procedures.
- Generally, sibbing (mating between the siblings) is preferred because it does not reduce the vigour excessively. However, if a change in breeding behavior is observed then selfing should be used as a means of stabilizing the inbred lines.
- Alternate selfing and sibbing is generally practiced to maintain the parent material.
- The individual ear head obtained through selfing or sibbing is carefully examined and those appearing off type or inferior in any characters like texture, color, seed size, seed shape, and shape and size of ear head are discarded.
- The remaining ear heads are then threshed separately and are planted in ear to row method or all ear heads of an inbred are bulked for increase in the next season.
- Seed multiplication is carried out in isolation.
- Roguing is carried out at different growth stages.
- Harvesting is done at physiological maturity. Generally, ear to row line (Progeny rows) is harvested, separately.
- Threshing or shelling is carried out in bulk or individually and then composited by examining the seeds.

2. Maintenance of breeder seed of inbred lines:

- The breeder's stock obtained from nucleus seed is planted in an isolated field.
- Attention is paid to land, isolation, roguing, harvesting, shelling and drying so as to maintain maximum possible genetic purity.

3. Maintenance of breeder seed of established variety:

- The breeder seed of established variety can be maintained in two ways :
    1. By raising the crop in isolation and roguing the off types thoroughly at various stages of crop growth right from sowing to maturity.
    2. By mass selection: The crop is grown under isolation and roguing is carried out at different growth stages.
- At maturity 2000 to 2500 true to type plants are selected.
- The selected plants are harvested separately and after careful examination they are bulked to constitute the breeder seed.

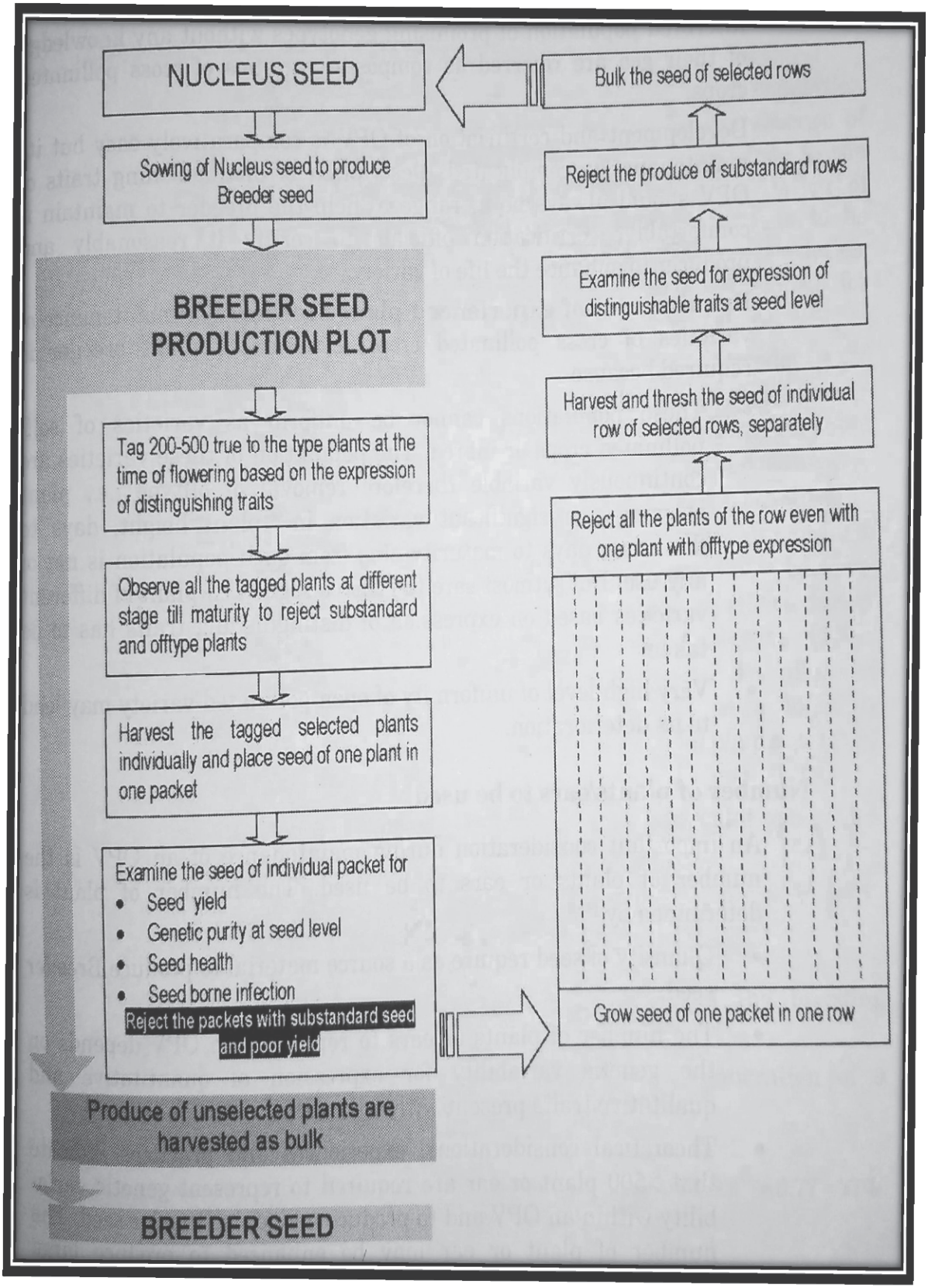


Figure 15.1: Maintenance breeding of self-pollinated crop

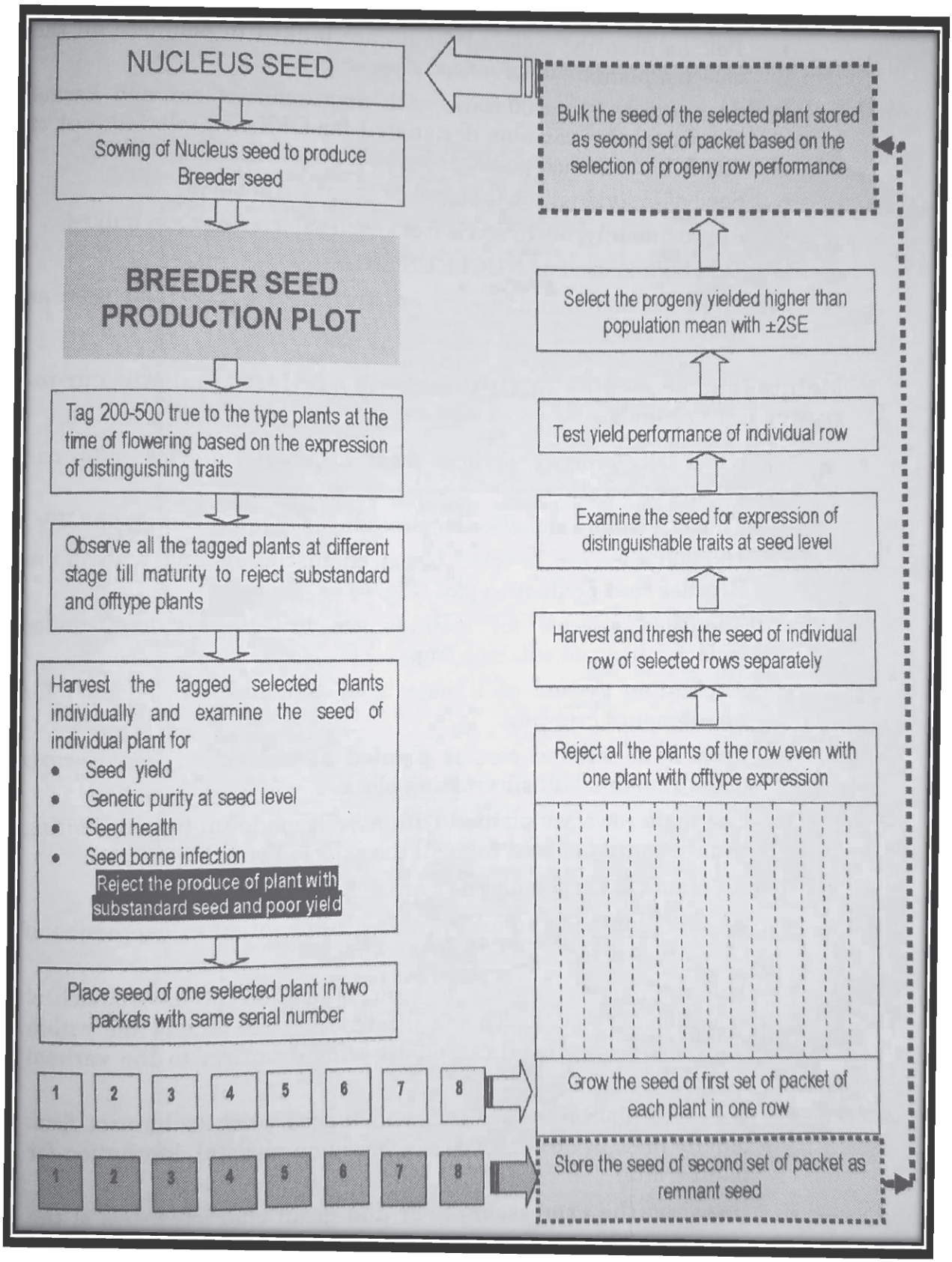


Figure 15.2 Maintenance breeding of cross-pollinated crop

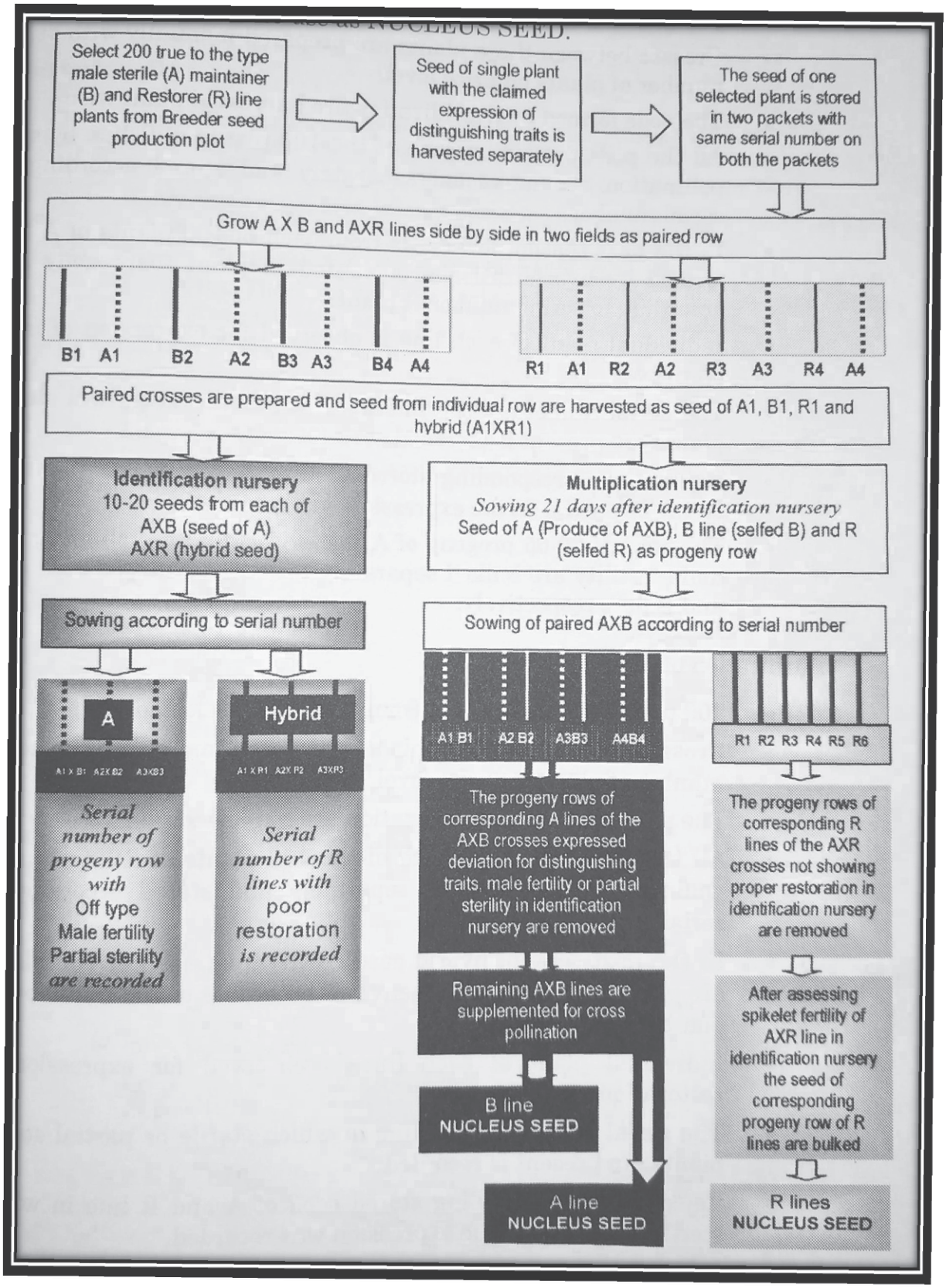


Figure 15.3 Parental line maintenance of hybrid rice

Exercise:

Q-1 Do as directed

(i) Give the objective and principle of maintenance breeding.

(ii) Explain the procedure of maintenance of nucleus seed of newly released variety of self-pollinated crop.

(iii) Explain the procedure of maintenance of breeder seed of newly released variety of self-pollinated crop.

(iv) Give the procedure of maintenance of breeder seed of established variety of self-pollinated crop.

(v) Write the method of maintenance of nucleus seed of inbred line of cross-pollinated crop

(vi) Write the method of maintenance of breeder seed of inbred line of cross-pollinated crop

(vii) Give the procedure of maintenance of breeder seed of established variety of cross-pollinated crop.

Exercise-16

Date :

1. VISIT TO VARIETAL/HYBRID SEED PRODUCTION PLOT

Q.1 Where did you visit a seed production plot?

Q.2 Name the crop in which seed production was taken up by the farmer/organizer.

Q.3 What are the criteria for selection of a site for production plot?

Q.4 Write the Name of variety/hybrid and its parentage details.

Q.5 What was the isolation distance and planting ratio kept?

Q.6 What were the important stages of rouging in this seed production plot?

Q.7 Write the following agronomical details of seed production plot?

1. Date of sowing:

2. Spacing : a) Row to row:
   b) Plant to plant:

3. Fertilizer: a) Basal:
   b) Top dressing:

4. Number of irrigation:

5. Number of weeding

Q.8 What was the expected yield of hybrid/ variety seed production?

2. VISIT TO AICRP PLOT

Norman Ernest Borlaug (1914-2009)

He was an American agronomist, known as "Father of Green Revolution". He won Nobel Peace Prize (1970) for his contributions towards peace through increasing food supply.

Tiruvadi Sambasiva Venkataraman (1884-1963) was an Indian botanist, agronomist and plant geneticist who specialised in the study and hybridisation of sugarcane. He transferred thick stem and high sugar contents from tropical noble cane (Saccharum officinarum) to North Indian canes (Saccharum barberi).This process is known as Noblization of sugarcane.

Nagaharu U (1898 -1959) The triangle of U is a theory about the evolution and relationships among members of the plant genus Brassica.

Dr. B. P. Pal (1906-1989)

He was the first Director of Indian Council of Agricultural Research. He was one of the foremost scientists in Wheat genetics and breeding.

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